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Research on the Influence of Train Formation on the vibration Stress of Railway Subgrade in Seasonally Frozen Region

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Abstract: In order to research the characteristics of subgrade vibration response under train vibration load, the finite element method is used to establish a three-dimensional numerical model of railway subgrade vibration response. Through numerical calculation, the vibration response of roadbed in different freezing periods and train formation is analyzed, and the influence of train formation in different seasons on dynamic stress, acceleration amplitude-frequency characteristics and amplitude attenuation law of roadbed is deeply studied. The results show that: (1) affected by the superposition of vibration, the dynamic stress amplitude and acceleration amplitude of the train both increase significantly with the increase of train number in each frequency band; (2) the amplitude of acceleration at the surface of the foundation bed is affected by the frozen state of the subgrade, and the amplitude of acceleration at different freezing periods at the bottom of the foundation bed is basically the same. The dynamic stress effective value in the freezing period is greater than that in the normal period, and the dynamic stress effective value in the spring thawing period is the smallest. The results provide theoretical basis for the permanent deformation of railway subgrade caused by train load in seasonal frozen soil area.

1. Introduction

Railway lines are widely distributed in seasonally frozen region in China, and the strategy of high speed and heavy load is being implemented. Due to the frequent occurrence of roadbed diseases in seasonally frozen region, the vibration stability of subgrade under running trains has increasingly become a focus of engineering and academic research. The research methods for the vibration response of roadbed caused by train operation can be generally summarized as analytical method, empirical prediction model and numerical simulation[1]. Sheng[2], Dieterman et al. [3], Hirokazu et al. [4] respectively studied the vibration response characteristics of foundation under different load types. Kaynia et al. [5] simplified train load into a concentrated load, simplified track, track bed and foundation bed into beam on horizontal layered foundation, taking into account the nonlinear characteristics of foundation soil and the influence of train speed on subgrade displacement. Wang changjing et al. [6] found that the dynamic stress generated in the roadbed when the train passed by
was a cyclic stress mainly composed of compressive stress by analyzing the variation law of dynamic stress distribution in the roadbed, but this method did not consider the non-linearity of the foundation soil either. Hendry et al. [7] simplified the train into a series of point loads moving at a certain speed by adopting the winkle foundation model, simulated the train with the method proposed by Hall[8], and compared the calculated results with the field measured results.

In this paper, the finite element method is adopted to establish the three dimensional numerical model for railway subgrade vibration response. Through numerical calculation, the vibration response of roadbed in different freezing periods and train formation is analyzed, and the influence of train formation in different seasons on dynamic stress amplitude-frequency characteristics and amplitude attenuation law of roadbed is deeply studied. The results provide theoretical basis for the stability of railway subgrade caused by train load in seasonal frozen soil area.

2. Numerical modeling

2.1 Computational section selection
In this paper, section K124+118 of the Harbin-Man zhouli railway in typical deep seasonal permafrost area was selected to establish a calculation model. Section selection and geometric size mean temperature field were identical, and the site profile was detailed in paper [9].

![Section scheme of the railway subgrade(unit: m).](image)

In order to analyze the influence of seasonal changes on the vibration response of railway subgrade, the modeling in this paper is carried out for typical spring melt period, freezing period and unfrozen period respectively. The temperature field distribution of the central section of subgrade on January 15, 2010 (freezing period), May 15 (spring thaw period) and October 15 (normal period) was taken as the temperature field distribution, and the cloud diagram of the temperature field distribution was detailed in paper [9]. Combined with the existing meteorological data of Daqing region and the calculation results of the temperature field of Harbin-Man zhouli railway subgrade, the maximum freezing depth in the freezing period is 2m, that is, the frozen soil layer state of seasonal freezing-thawing layer 1 and seasonal freezing-thawing layer 2 is shown in the figure. In the spring thawing period, the frozen layer and thawing layer were both 1m, in which the seasonal freeze-thaw layer 1 was the thawing layer and the seasonal freeze-thaw layer 2 was the frozen layer. In normal period, both seasonal freezing-thawing layer 1 and seasonal freezing-thawing layer 2 are non-frozen layers for calculation, as shown in figure 1 for details.
3. Train formation influences vibration response

Using the load program compiled by the research group, five different train forms were obtained through calculation, with the running speed of 140km/h train load, and the calculation model was input. The amplitude-frequency characteristics of dynamic stress and attenuation law in depth direction, amplitude-frequency characteristics of acceleration and attenuation law in horizontal direction were analyzed.

3.1 Dynamic stress amplitude frequency effect

Under different train formation conditions, the effective value of vertical dynamic stress decays rapidly with the increase of depth. Figure 3 shows the effective value of vertical dynamic stress decays along the depth curve of different train formation conditions. Figure 4 shows 1/3 octave spectrum of vertical dynamic stress of different train formation at P4. As can be seen from the figure, dynamic stress of different train formation has five obvious frequency bands: 1~2Hz, 2~10Hz, 10~30Hz, 30~100Hz and 100~150Hz. Affected by the superposition of vibration, the dynamic stress amplitude of trains in each frequency band is 1 passenger car locomotive (NJ2)+10 carriages (YZ25) is greater than that of other vehicles, and the amplitude of other trains in each frequency band is not different.
Figure 3. Attenuation curve of dynamic stress on subgrade with different formation of trains.

Figure 4. 1/3 octave center frequency spectrum of dynamic stress with different formation of trains (point P4).

Under the superposition of vibration, with the increase of the number of train formation, the peak value of vibration acceleration induced by multi-excitation points increases slightly. The effective value of dynamic stress in freezing period is larger than that in normal period, and the effective value of dynamic stress in spring thawing period is the smallest. The relationship between the dynamic stress effective values of the base bed surface and the base bed bottom points in different freeze-thaw states and train formation is shown in figure 5.

Figure 5. Relationship between dynamic stress effective value of subgrade and train formation in different freezing period

4. Conclusion

In this paper, a three-dimensional numerical model of railway subgrade vibration response is established by using finite element method. The vibration response of railway subgrade in different freezing periods and train formation is analyzed by numerical calculation. The influence of train formation in different seasons on dynamic stress, acceleration amplitude-frequency characteristics and amplitude attenuation law of railway subgrade is studied in depth. The research results show that:

(1) Under different train formation conditions, the effective value of vertical dynamic stress decays rapidly with the increase of depth.

(2) The dynamic stress of different train formation has five obvious frequency bands: 1~2Hz, 2~10Hz, 10~30Hz, 30~100Hz and 100~150Hz. Affected by the superposition of vibration, the dynamic stress amplitude of the train increase significantly with the increase of train number in each frequency band.
(3) The effective value of dynamic stress in freezing period is larger than that in normal period, and the effective value of dynamic stress in spring thawing period is the smallest.

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