Dynamic Characteristic of Subgrade in Da-Qin Heavy Haul Railway

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Abstract
According to dynamic test on the subgrade in Da-Qin heavy haul railway, study the relationship among the dynamic characteristic of subgrade, the speed of train, the locality of subgrade and the depth of subgrade. Analyze the longitudinal distributive regularity of dynamic characteristic in heavy haul railway subgrade and the depth direction distributive regularity of its, providing references for the device and maintenance of heavy haul railway in our country. With the increasing distance from bridge, dynamic stress of the surface layer of subgrade bed decreases with undulatory property; The dynamic stress of No.3 and No.5 emerging local maximum on the mileage of k13+700 illustrates the defect of subgrade here and the decreasing bearing capacity, which needs maintenance timely for the security of train; Compare with static load, the dynamic load of train has bigger influence on the status of line, and influences the subgrade-bridge transition section more obvious; Dynamic stress is attenuated very fast with the depth of subgrade; The load of train influences subgrade bed primary; Dynamic stress of subgrade-bridge transition section is bigger than that of others, and they approximates each other gradually as depth increases ; The dynamic stress numerical value of experiment in the three points is reasonable; With the train passing, the dynamic displacement of subgrade emerges the law of periodic fluctuation which increases as the speed of train increases. The speed of train influences the dynamic displacement of subgrade-bridge transition section more than that of other location.

Key words: Da-Qin Heavy Haul Railway, Subgrade-bridge Transition Section, Subgrade, Dynamic Stress, Dynamic Displacement

1. INTRODUCTION
Da-Qin heavy haul railway is a major route for the western coal transportation in our country, undertake tremendous coal transportation mission. With the economic development of our country, the transportation mission is increasing annually. During 2010, the freight volume of Da-Qin heavy haul railway is four hundred million, which is 4 times for the design freight volume, and the railway line is faced with serious ordeal. Subgrade is the basis of track, which should have the peculiarity of high strength, high rigidity, stability and durability. The subgrade-bridge transition section should have higher standard than other location. Japan(Sunaga and Makoto,1990)studies the relationship between dynamic stress of subgrade and settlement by means of field test. Germany(Leykauf, Gunther, Mattner and Lothar,1990) study the subgrade with different rigidity by means of wheel load experiment. Xinwen Cao(Cao and Cai, 1996) deems dynamic stress in direct proportion to axle load, with the speed of train increases, the dynamic stress of subgrade and vibration accelerated speed increases. Xianmin Li and so on(Li and Wang, 2004)deems if the subgrade of subgrade-bridge transition section is filling ultrahigh, the dynamic stress decreases with the speed increases of train. Chengbiao Cai and so on(Cai, Zhai and Zhao, 2001) deems differential settlement of foundation have influence on dynamic stress of subgrade-bridge transition section conspicuously. There are many studies on passenger transport line,speed-increase line and normal line, but few field test and theoretical study on the dynamic characteristic of subgrade-bridge transition section on heavy haul railway. This paper which studies the dynamic characteristic of subgrade-bridge transition section on heavy haul railway by means of field test and theoretical study based on a national 863 item. Designation of the national 863 item is the study on static and dynamic force test, continuous test, actual time test and state assessment technology. The study of this paper can provide theoretical foundation for add transport volume, increase the speed of train, state assessment of state assessment subgrade and the design of new heavy haul railway.

2. TEST SCHEME AND ARRANGEMENT OF TEST POINT
The dynamic characteristic of subgrade is a key factor influencing the subgrade status, for example: dynamic stress, elasticplastic deformation, accelerated speed and so on. This paper studies the variation rule of dynamic stress and dynamic displacement on heavy haul railway subgrade, which can be influence by many factors, such as: axle-load of train, speed, direction, construction of track, characteristic of subgrade padding and so on. This paper studies the dynamic characteristic of subgrade with different speed of train, different location and depth of subgrade.
This paper selects three typical subgrade location of subgrade-bridge transition section on Da-Qin heavy haul railway. The mileages of them are K13+700, K266+314 and K266+414 respective. The subgrade location with mileage of K13+700 is located in DaTong which has cold and dryness climate, earthquake intensity is VII and VIII. The earth's surface is new loess, 1m thickness; the grade of padding is B. The grade of soil below the surface is C, which is the main source of subgrade coring, the expansion rate of the filling is 8.5~11.8%. The subgrade location with mileage of K266+314 and K266+414 are located in ChaWu, BeiJing, which have much annual rainfall, high underground water level, soft soil and high embankment. The subgrade location with mileage of K266+314 is close to bridge abutment, which belongs to subgrade-bridge transition section. The subgrade location with mileage of K266+414 is far from the bridge abutment, which belongs to main track subgrade.

The grouping-mode of test train is test train as follows: HXD2 electric locomotive is the traction, adopts the scheme of 1+1 (one HXD2 locomotive, one hundred and five C80B freight train, one HXD2 locomotive, one hundred and five C80B freight train, one intelligent controlled train tail), the traction weight is 20 thousands ton in total. The traction power of HXD2 electric locomotive is 9600 kW, and its axle load is 23t; the axle load of C80B freight train is 25t.

This test adopts the technology of automatic data gathering and wireless transmission, which is received by mainframe in laboratory, realizing the long-distance automatic monitoring long-term to the monitoring point.

2.1. Dynamic Stress Test Scheme and Arrangement of Test Point

This dynamic stress test use TFL-TY-PXX soil pressure box, which can show the temperature of instrument and temperature compensation Automatic, can improve the veracity and reliability of monitoring data.

The test point of DaTong in the mileage of K13+700 layouts 7 soil pressure box, serial number is from NO.1 to NO.7 successively, which are located at the contact surface between surface layer of subgrade bed and railway ballast, under the head of rail bearing. The distance between These soil pressure box and the back of bridge abutment Are 3m, 5m, 7m, 9m, 11m, 13m, 15m respectively. As shown in fig1.

The test point of ChaWu in the mileages of K266+314 and K266+414 laid outs 9 soil pressures box respectively, and have the same arrangement form. As shown in fig.2. The depth of these soil pressure box are 0m, 0.2m, 0.5m, 0.7m, 1m, 2m, 3m, 4m, 6m respectively.
2. Dynamic Displacement Test Scheme and Arrangement of Test point

The test point of ChaWu in the mileages of K266+314 and K266+414 layouts 2 dynamic displacement test point, and have the same arrangement form. As shown in Fig.2 the depth of baseline road is 8m. Its diameter is 200mm, thickness is 6mm, and fixed by concrete in the base 1m. So this paper deems the baseline pole cannot be influenced by vibrating load of train. Dynamic displacement test points lie under the head of rail bearing, which have LED light source internally installed. A dynamic displacement detector lies on the top of baseline road, which can precise measure and record the vibration condition of LED light source in the dynamic displacement test point, and can gain the dynamic displacement of subgrade.

3. ANALYSIS OF TEST RESULT

3.1. Analysis of Dynamic Stress Test Result in DaTong

The dynamic stress peak value variation with different speed, 5km/h, 60 km/h, 70 km/h, 80 km/h respectively, longitudinal along the line are shown in Fig.3. According to the Fig.3 can draw conclusions as follows:

(1) As the distance increases away from bridge abutment, the dynamic stress of subgrade foundation bed surface has the rule of decreasing volatility. The max value of dynamic stress in test point 1 is 51.3 kPa, and that of test point 7 is 36.3kPa. The rigidity of abutment is larger than that of subgrade-bridge transition section subgrade. When the heavy haul train pass subgrade-bridge transition section subgrade, there are stress concentration phenomenon and the dynamic stress largen, which can accelerate the settlement of transition section subgrade. The settlement can lead to more serious phenomenon of stress concentration, so the vicious circles come into being. In order to reduce the damage of transition section subgrade, the rigidity of transition section subgrade should be enhanced. Concrete rubble with large rigidity can be used in the transition section subgrade with less-than 150m. this rigidity short subgrade can mitigate the rigidity difference between subgrade and bridge abutment, mitigate the phenomenon of stress concentration, and settle the damage of transition section subgrade radically (Zhang Quan and Luo Qiang, 2006);

(2) The dynamic stress of test point 3 and test point 5 emergence maximum value, which illustrates the carrying capacity of subgrade is poor and has the phenomenon of stress concentration. The two test points should be maintained in time, or the damage may influence the security of railway operation.

The dynamic stress peak value variation with different speed, 5km/h, 60 km/h, 70 km/h, 80 km/h respectively, are shown in Fig.4. According to the Fig.4, this paper can draw conclusions as follows:

(1) With the speed of train increases, the dynamic stress of transition section subgrade increase corresponding. (2) For the same change value of speed, the dynamic stress change value near the bridge abutment is bigger than that of other site. Variation curve of the former is steeper than that of the latter.

Dynamic stress change value of test point 1 is 14.8kPa, and that of test point 7 is 7kPa. Therefore, the dynamic condition of train has more influence on the status of line than that of static state. The dynamic load has obvious influence on the transition section subgrade, so the dynamic index of transition section subgrade should be intensified.

**Figure 3.** The dynamic stress value variation curve of subgrade surface longitudinal along the line

**Figure 4.** The dynamic stress value variation curve of subgrade surface with different speed
3.2. Analysis of Dynamic Stress Test Result in ChaWu

The dynamic stress value variation curves with different depth on the test point of K266+314 and K266+414 are shown in fig.5. According to the fig.5 this paper can draw conclusions as follows: (1) Dynamic stress decays quickly with the depth of subgrade increase. In the mileage of K266+314, the dynamic stress of surface layer of subgrade bed is 55.6 kPa; the dynamic stress in the depth of 0.7m is 40.3 kPa, which is 72.5% of that on surface layer of subgrade bed; the dynamic stress in the depth of 2m is 21.3 kPa, which is 38.3% of that on surface layer of subgrade bed; the dynamic stress in the depth of 3m is 15.6 kPa, which is 28.1% of that on surface layer of subgrade bed. (2) The dynamic stress of transition section subgrade is larger than that of main track. With the depth increases, the variations trend of them tend to the same one.

Train load spread to deep with the form of impetus wave, which is influenced by damping effect of soil and diffusion of soil pressure. With the depth increases, dynamic stress will attenuation quickly.

It can thus be seen, the main influenced portion of subgrade by train load is foundation bed, so the intensity and rigidity of subgrade foundation bed should be intensified during the process of design and operation on heavy haul railway.

The dynamic stress value variation curves with different speed on the test point of K266+314 and K266+414 are shown in fig.6. According to the fig.6, the dynamic stress of subgrade with different depth increases with the speed of train increases. The speed of train has the most influence on the surface layer of subgrade bed. As the depth increased, the influence generated by speed of train on the dynamic stress is decreasing gradually; the dynamic stress variation value of the surface layer of subgrade bed is 18.9kPa, and the dynamic stress variation value of 6m depth is 2.2kPa, which is few influenced by speed of train.

According to the regulation of Handbook of Railway Working System-Track: the dynamic stress of existing railway line surface of subgrade foundation bed should be not more than 0.15MPa, and the dynamic stress of new railway line surface of subgrade foundation bed should be not more than 0.13MPa. Therefore, the dynamic stress of the three test points reach the standard all.

![Figure 5. The dynamic stress value variation curve with different depth of subgrade](image)

![Figure 6. The dynamic stress value variation curve with different speed of train](image)

3.3. Analysis of Dynamic Displacement Test Result

The dynamic displacement variation curve with different speed on the foundation bed surface in K266+314, 60 km/h, 70 km/h, 80 km/h respectively, are shown in fig.7 fig.8 fig.9 respectively. According to the three figures, this paper can draw conclusions as follows: (1) Subgrade dynamic displacement appears the regularity of periodic fluctuation with the train passing through; the dynamic displacement amplitude consistent to different carriages with the same speed. (2) As the speed of train increasing, the dynamic displacement of subgrade increases corresponding. The dynamic displacement of subgrade is 0.112mm with the speed of 60km/h and 0.269mm with the speed of 80km/h.

The dynamic displacement amplitude curve with different speed on the foundation bed surface in K266+314 and K266+414 are shown in fig.10, according to the fig.10 this paper can draw conclusions as follows: (1) The dynamic displacement of transition section subgrade is larger than that of main track; the dynamic displacement max amplitude of subgrade in K266+314 is 0.269mm, the dynamic displacement max amplitude of subgrade in K266+414 is 0.203mm. (2) The speed of train has relatively great influence on the dynamic displacement of transition section subgrade; the dynamic displacement variety value is 0.157mm on the
foundation bed surface in K266+314, and the dynamic displacement variety value is 0.12mm on the foundation bed surface in K266+414.

According to relevant criterion of China, the maximum vertical displacement of the foundation bed surface w=2mm; for the railway of 200km/h, the maximum dynamic displacement of the foundation bed surface should be controlled less than 2.5mm. Thus it can be seen, the maximum dynamic displacement of foundation bed surface in the three test points can meet the demand all.

**Figure 7.** The dynamic displacement variation curve with the speed of 60km/h

**Figure 8.** The dynamic displacement variation curve with the speed of 70km/h

**Figure 9.** The dynamic displacement variation curve with the speed of 80km/h

**Figure 10.** The dynamic displacement amplitude curve with different speed on surface of foundation bed
4. CONCLUSIONS

According to the field test on the three typical test points, this paper can draw conclusions as follows:

(1) The dynamic stress of subgrade near the back of bridge abutment is bigger than that far from it. As the distance increases away from bridge abutment, the dynamic stress of subgrade foundation bed surface has the rule of decreasing volatility.

(2) The dynamic stress of test point 3 and test point 5 emerges maximum value, which illustrates the carrying capacity of subgrade is poor and has the phenomenon of stress concentration. The two test points should be maintained in time, or the damage may influence the security of railway operation.

(3) The dynamic condition of train has more influence on the status of line than that of static state. The dynamic load has obvious influence on the transition section subgrade, so the dynamic index of transition section subgrade should be intensified.

(4) Dynamic stress decays quickly with the depth of subgrade increase. The dynamic stress of transition section subgrade is larger than that of main track. With the depth increases, the variation trends of them tend to the same one. The main influenced portion of subgrade by train load is foundation bed, so the intensity and rigidity of subgrade foundation bed should be intensified during the process of design and operation on heavy haul railway.

(5) Subgrade dynamic displacement appears the regularity of periodic fluctuation with the train passing through; the dynamic displacement amplitude consistent to different carriages with the same speed. The dynamic displacement of transition section subgrade is larger than that of main track. The speed of train has relatively great influence on the dynamic displacement of transition section subgrade.

In order to maintain a fine operation state of subgrade, study the dynamic characteristic of subgrade only is not enough, we should study the interaction among the overall system of train, track and subgrade. It needs a scientific and reasonable structural style of railway and operation scheme of train to improve the operation state of subgrade.

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