The Research of Capacity Control Standard in Bridge Transition Section Subgrade Based on Measured Dynamic Stress

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Abstract. The dynamic stress in existing bridge transition section of often bigger than ordinary roadbed due to its stiffness irregularity, so using the ordinary subgrade bearing standard as bridge transition section standard is inappropriate. Based on the measured dynamic stress in Xin-feng river bridge transition section, related standard for raising speed and Boussinesq's answer for stress in subgrade, Evd value and bearing standard in transition section subgrade are derived. Research shows that, Evd value control standard is not than 55MPa(fine-grained soil)and not less than 40MPa (coarse-grained soil). The bearing capacity control standard is not less than 210kPa for surface layer of subgrade and 180kPa for bottom layer of subgrade, which are 30kPa bigger than ordinary subgrade. The research provides a standard basis for reinforcement in existing railway bridge transition section.

Introduction

As a newly-built high-speed railway, The Railway Ministry of China has published *the interim provision for new building passenger railway of 200-250km/h*, which provides strict rules for the dynamic deformation modulus(E_{vd} value), foundation coefficient(K_{30} Value) and subgrade compaction coefficient(K value). But for the existing railway to speed up to 200km/h, there is not based standard for bridge transition section subgrade, and current implementation of the standards developed in accordance with the ordinary subgrade of new railway, so it is necessary to discuss the control standards of bridge transition section subgrade in existing railway.

The requirements of static and dynamic load on surface layer of subgrade

Load calculated by theory static load and measured dynamic load superposition method, and the measured dynamic load is tested in Xin-feng River bridge transition section.

The static stress on the surface layer of subgrade produced by track and ballast. According to the book "*subgrade engineering*", track and ballast load calculated as static load. According to the standard, when the class I railway is heavy track, the thickness of ballast is 50cm, ballast severe is 20 kN/m^{3}, and track weight is 0.6kN/m, sleeper length is 2.6m, the track and ballast load is 72.2kN/m. Therefore, the conversion static stress on the surface of subgrade is generated to 19.8kPa, and then rounded up to 20kPa.

The measured dynamic loading size and capacity requirements. The dynamic stress test results on subgrade at Xin-feng river bridge transition section on Ning-qi Existing railway shows in table 1. The tested dynamic stress is very big due to serious ballast capsule. The maximum dynamic stress is 204kPa and average dynamic stress is 115.64kPa.

Table.1 The dynamic stress test results at Xin-feng river bridge transition section

Transition section name	Large mileage side				Small mileage side	
Press box No.	2151	2168	2118	2194	2187	2154
The distance from the abutment /m	4.55	8.45	12.35	16.25	5.85	13.65

The maximum dynamic stress /kPa	85	85.13	115.41	52.32	151.48	204.55

According to the dynamic stress test result at Xin-feng river bridge transition section, it can be seen track irregularities had huge impact on the subgrade surface and produced big dynamic stress, which is bigger than the dynamic stress calculated by theory, this is also the reason ballast capsule.

Due to the conversion ratio of dynamic to static stress, the subgrade's dynamic strength is about 60% of the static strength. According to the experimental results, the average dynamic stress at transition section is 115.6kPa, corresponding to the demand for static strength of 192.7kPa. Considering the static load generated by the track and ballast bed, the subgrade static strength requirement is 192.7+20=212.7kPa, rounded up to 210kPa.

The discussion of E_{vd} value control standard for subgrade surface. In the *railway subgrade design standard* (TB10001-2005)[2], foundation coefficient (K_{30}) is the comprehensive index for subgrade strength testing and deformation. According to the studies of Datong-Qinhuangdao line, the corresponding relation between foundation coefficient (K_{30} value) and bearing capacity shows as follow[3]:

$$[\sigma_0] = 0.24K_{30} + 0.015 \qquad (1)$$

In the formula(1), the unit of $[\sigma_0]$ is MPa and the unit of K_{30} is MPa/cm.

Foundation coefficient(K_{30}) is the most direct method to detect subgrade on existing railway, but it is more difficult to test K_{30} on the subgrade on existing railway, so it is rarely used and replaced by E_{vd}. According to Wang C G's research, the conversion formula between K_{30} and E_{vd} is $K_{30}=3.45\times E_{vd}+0.1$[4], then the following formula can be gotten:

$$E_{vd} = \frac{(K_{30} + 0.1)}{3.45} \qquad (2)$$

In the formula(2), unit of E_{vd} is MPa and the unit of K_{30} is MPa/cm.

Formula (3) can be drawn from formula(1) and formula(2).

$$E_{vd} = \frac{\dfrac{[\sigma_0] - 0.015}{0.24} \times 100 + 0.1}{3.45} \qquad (3)$$

The conversion ratio of dynamic to static stress is 0.6 in literature[1] and is 0.67 in literature[5], then 0.6 ratio is taken considering safety. The maximum dynamic stress is 204kPa according to the test in Xin-feng river bridge transition section, so its equivalent static load is 340kPa, and total static stress is 360kPa, so E_{vd} requirements is 41.7MPa according to the formula(3).

Recommended control standard for E_{vd} value. According to *the interim provision for new building passenger railway of 200-250km/h*, the dynamic deformation modulus(E_{vd}) requirement for subgrade surface layer is 55MPa, and 40MPa for subgrade bottom layer.

According to the calculation, the tested dynamic stress and related standard, transition section suffered dynamic stress is mainly controlled by the locomotive, and the E_{vd} requirement in standard is 55MPa, which is bigger than the calculation's 41.7MPa. Considering transition section subgrade's requirement is greater than ordinary subgrade, and most tested E_{vd} value on Ning-Qi existing railway can meet the E_{vd} demand, so the recommended standard is 55MPa. Exploration is easy to disturbed and can not get real Evd values when the surface of subgrade is coarse sand, the Evd value often lower than real Evd value. Considering coarse sand has the stability characteristics, 45MPa standard is recommended and the minimum value is not less than 41.7MPa.

The foundation bearing capacity requirement of each layer based on Boussinesq solution

Under vehicle uniaxial loads, the simply dynamic stress distribution on the surface of subgrade shows as Fig.1. The dynamic stress distribution along transverse direction is a rectangular, which width is equal to the supporting layer. The dynamic stress distribution along longitudinal direction is triangular, and the maximum stress position is corresponding to the load position[6].
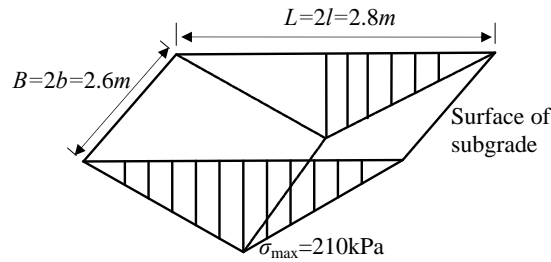
Fig.1 dynamic load distribution diagram

According to the Boussinesq's solution, the foundation bearing capacity requirements calculation of each layer is shown in table1, in which the maximum dynamic stress is taken as average tested stress(115kPa).

Table.1 The stress calculation for each layer of subgrade

Depth/m	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4
Dynamic stress attenuation coefficient	1	0.911	0.726	0.715	0.487	0.395	0.322	0.266	0.218
Total static stress/kPa	210	191.3	152.6	150.3	102.3	82.9	67.5	55.4	45.9
self weight stress of subgrade/kPa	0	5.4	10.8	16.2	21.6	27	32.4	37.8	43.2
Total stress/kPa	210	196.7	163.4	166.5	123.9	109.9	99.9	93.2	89.1

According to table.1, the bearing capacity of subgrade surface layer(0-60) requirement should be not less than 210kPa. When the depth is greater than 1.5m, the bearing capacity requirement is less than 100kPa, and less then the requirement in railway standard(150kPa). But the low bearing capacity represents the compressibility increases, which can cause excessive settlement of transition section subgrade and is forbidden in the area. So the recommend bearing capacity requirement is not less than 166.5kPa(the max value of bottom layer of subgrade), rounded up to 170kPa.

Conclusions

Due to the particularity of the transition section on existing railway, the transition section subject to dynamic stress is much larger than ordinary subgrade, so it takes improved soil as the surface layer of subgrade. Bridge transition section subgrade capacity requirement greater than ordinary subgrade, according to the railway standard and relational calculation some conclusions can be drawn as follows:

1)The E_{vd} control standard is 55MPa while the transition section filler is fine-grained soil or improved soil. While filler is coarse-grained soil, due to easy to disturbance and its self-stability, so the E_{vd} control standard is 40MPa.

2) If using bearing capacity as control standard, the bearing capacity will not less than 210kPa for surface layer of subgrade in transition section, and not less than 170kPa for the bottom of subgrade.

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