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Research on Transition of Road Bed of Wuhan-Guangzhou Passenger Line and Bridge

Bo-Soon Kang* and Yang Jun**

Abstract

High speed railway challenge the design, construction and maintaining of traditional railway, many traditional design concepts have been changed. Transition of railway and bridge has two main problems. one is that different lines have different ability of resisting distortion in area of trial load, which was known that problem of smooth transition of stiffness, the other is that differential settlement between artificial structure and earth structure cause bending of railway. The two problems have effect on train moving. The principle of processing transition of railway and bridge is same in world, but it is difficult to find relationship between design standard of transition, vehicle performance, line standard, design speed and so on form documentation and data reports. Based on mechanics, the paper analyzed dynamic performance of transition of high speed railway, studied various rough elements which is effective to train moving, built mathematical model of interaction of train and transition of high speed railway and developed numerical simulation software. In various different work conditions, we did great quantity of numerical simulation, comprehensive analysis and performance analysis.

Keywords : *Railway development, High speed railway, Road bed, Transition of railway and bridge*

1. Introduction

The world's railway industry since its creation to the last century, 50 years, has been in a major development. Subsequently, due to the challenges of the aviation industry and highways, railway growth has been slowing the pace of development. To 1964, the world's first high-speed railway - Japan, the Tokaido Shinkansen was completed and put into operation, with its speed, transport can be large, save energy, to ensure safety on time, less pollution and other people in the world won the favor of the comprehensive advantages [1], which greatly improved the world's interested countries to develop high-speed railway, so that the railway industry, when there is a thriving Period. Following the Tokaido Shinkansen, the Japanese have successively built Sanyo, Tohoku, Joetsu and Hokuriku Shinkansen; the French TGV high-speed train in 1981, with 260 km/h top speed into the formal operations; Italy's tilting train 1988 are connected to the Milan and Rome; the German ICE train high-tech official opening in June 1991; built in 1991, Madrid, Spain - Sevilla high-speed rail.So far, the world's highest speed at 200 km/h over 4000 km new high-speed rail has been more than 200 km per hour if we include the line, the world's total mileage to run more than 10000 km. Although these lines is only about the world's railway mileage of 1% of the total business, but it bears a larger portion of the passenger has the workload of the country. For example: Japan has built Tokaido, Sanyo, Tohoku, Joetsu Shinkansen a total of four long-1835 km, about Japan’s railway mileage of 9% of total business, to carry out railway passenger turnover of 30%; France's south-east line and the Atlantic Ocean Line total length 745 km mileage of railways in operation in France only 2%, TGV train has assumed the railway passenger turnover of 55.8%. Therefore, the high-speed railway has become the general trend of the world's railway development, has also become a national and regional development and transportation of the strategic goals. Europe plans to be completed by 2010, the total size of more than 24,000 km of high-speed railway, including the

* Department of Civil and Geotechnical Engineering of Pai chai University, Korea, Republic
E-mail: bskang@pcu.ac.kr
**Department of Civil and Geotechnical Engineering of Pai chai University, Korea, Republic
E-mail: yjcc2008@hotmail.com

construction of 9000 km per hour at 250~300 km and above the new line, transformation 15000 km per hour is about 200 km of the existing lines; Japan planning new routes will be extended to 6900 km; South Korea are under construction in Seoul - Pusan High Speed Line (411 km); United States plans to build in this century Houston, Dallas, San Antonio, the triangle between the high-speed network; Canada, Brazil, India and China's Taiwan Province will also be planned or have already started the construction of high-speed railway. Mainland China High-Speed Rail - Beijing-Shenyang Railway has been completed quickly and is ready to pre-operational. The first high-speed railway - the Beijing-Shanghai high-speed railway will also be built in early in this century.

2. High-speed Trains and Road and Bridge Transition Section Mechanical Analysis Model of the Interaction

2.1 Road and Bridge Transition Section Mechanical Analysis Model Interaction

In the railway system, a variety of mutual relations, the interaction between vehicles and the track is the most basic, but also the most important issue. Vehicles driven on the track, in essence, is a dynamic process, simply. Is a moving mass system with an infinitely long continuous supporting structure of the dynamic interaction between the. As the lines are not smooth and the surface of wheel and rail geometry defects and other reasons, and mutual movement between the wheel-rail force, up to pass to the locomotives and rolling stock to pass down to the track structure. Vibrations caused by their own, and these vibrations and mutually coupled to form a more complex vibration patterns of the vehicles and track adverse effects, and sometimes [2] even endanger road safety. For comprehensive analysis of the train passing through the transition section of the track when the vehicle and track dynamic effects, grasp the variation of the transition section to find a reasonable design parameters, must be reasonable and dynamic analysis mode

2.2 Locomotive Model

Vehicle speed V as a simulation running on the lines of the multi-body dynamic system, the rigid body are as follows:

Body, the former bogie, bogie, after the first round of the right, the second ballot, the third round of the right, the fourth round of the relationship between the various rigid-body connection as shown in Fig. 1, consider the vertical vibration, the vibration differential equation which D'Alembert principle can be obtained:

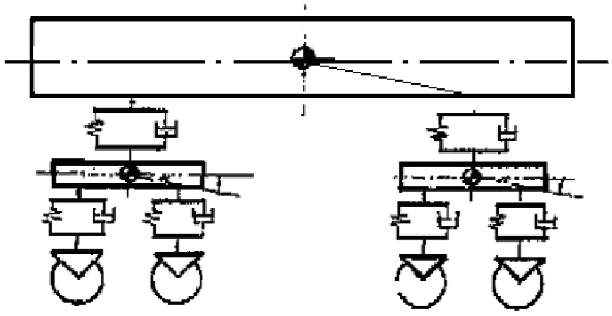

Fig. 1 Schematic diagram of the rigid connection between

(1) The Rise and Fall of body movement

$$M_o\ddot{Z}_c+2Crz\dot{Z}_c+2K_{rz}Z_c-C_{rz}\dot{Z}_{rc}-K_{rz}Z_c-K_{rz}Z_{rc}=0 \quad (1)$$

(2)The Rise and Fall of movement before the bogie

$$M_o\ddot{Z}_{rc}+(C_{rz}+2C_{rz})\dot{Z}_c-C_{rz}\dot{Z}_{rc}-(K_{rz}Z_c-2K_{rz}Z_c)-K_{rz}Z_c=0 \quad (2)$$

$$-C_{rz}\dot{Z}_{rc}-K_{rz}Z_c-K_{rz}Z_c-K_{rz}Z_c-C_{rz}l_r\dot{\varphi}_c-K_{rz}l_r\varphi_c=0 \quad (3)$$

(3) The Rise and Fall of movement after the bogie

$$M_o\ddot{Z}_{rc}+(C_{rz}+2C_{rz})\dot{Z}_{rc}-C_{rz}\dot{Z}_{rc}+(K_{rz}Z_c+2K_{rz}Z_c)-K_{rz}Z_c$$

$$-C_{rz}\dot{Z}_{rc}-K_{rz}Z_c-K_{rz}Z_c-K_{rz}Z_c-C_{rz}l_r\varphi_c-K_{rz}l_r\varphi_c=0 \quad (4)$$

(4) The body nod Sports

$$J_c\ddot{\varphi}_c+2C_{rz}l_a^2\ddot{\varphi}_c+2K_{rz}l_a^2\varphi_c-C_{rz}l_rZ_{rc}+C_{rz}l_rZ_{rc}$$

$$-K_{rz}l_rZ_{cr}+K_{rz}l_rZ_{ct}=0 \quad (5)$$

(5) The former bogie frame nod Sports

$$J_c\ddot{\varphi}_{cz}+2C_{rz}l_a^2\ddot{\varphi}_c+2K_{rz}l_a^2\varphi_c-C_{rz}l_rZ_{rc}+C_{rz}l_rZ_{rc}$$

$$-K_{rz}l_rZ_{cr}+K_{rz}l_rZ_{ct}=0 \quad (6)$$

(6) motion after the bogie frame nod

$$J_c\ddot{\varphi}_{cz}+2C_{rz}l_a^2\ddot{\varphi}_c+2K_{rz}l_a^2\varphi_c-C_{rz}l_r\dot{Z}_{rc}+C_{rz}\vec{l}_r\dot{Z}_{rc}$$

$$-K_{rz}l_rZ_{cr}+K_{rz}l_rZ_{ct}=0 \quad (7)$$

2.3 Road Line Model

Based on “various sleeper rail extension depends on the vertical bearing on the track bed and the embankment,” the fact that the track structure supported by a continuous elastic beams and three-point Euler (rail - sleeper - ballast bed) discrete linear oscillator connected to simulate the rail line, Rail used as a continuous point-supported beam of infinite length, in the X = Xi (i = 1,2, ... n) at a linear har-

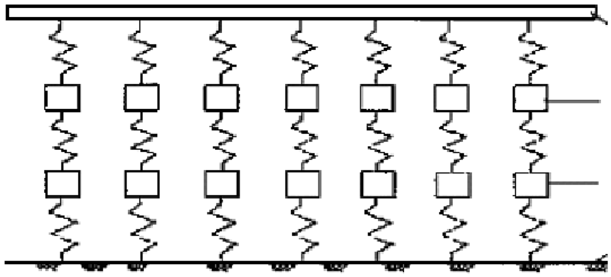

Fig. 2 Connection between track structure

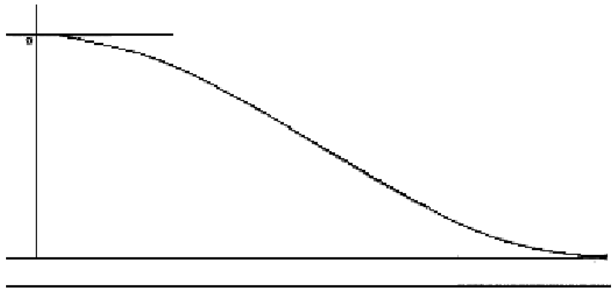

Fig. 3 Schematic diagram of the entire route

monic oscillator, connected with the three adjacent points of support from the (Xi +1- Xi) that the sleeper spacing, the connection relationship shown in Fig. 2. At this time, the system equations of motion can be expressed as:

First layer of rail Second-tier sleeper Third level track bed The fourth layer of subgrade

$$Ely^{(4)}(x,t)+py(x,t) = \sum_{i=1}^{n} P_i(t)\delta(x-x_1)+\sum_{i=1}^{n} G_i(t)\delta(x-x_1) \quad (8)$$

$$m_{1i}y_{ti}(t)+k_{11}[y_{11}(t)-y(x,t)]-k_{12}[y_{11}(t)-y(x,t)] = 0 \quad (9)$$

$$m_{1i}y_{ti}(t)+k_{11}y_{11}(t)+k_{12}[y_{11}(t)-y(x,t)] = 0 \quad (10)$$

And there:

$$P(t) = k_{12}[y_{11}(t)-y(x,t)] \qquad (i=1,2,\ldots\ldots n) \quad (11)$$

Where: EI,ρ- Bending stiffness of beam, respectively, per unit length of quality; y (x, t)-- Vertical displacement of the beam; $y_{1t}(t)$-- I, a sleeper displacement; $y_{2t}(t)$-- I, a track bed displacement; m_{1i},m_{1i}--- Were I, a sleeper, ballast quality; k_{1i},k_{1i},k_{1i}-- I, respectively, a sleeper, ballast, subgrade stiffness; $G_i(t)$-- Acting on the wheels on the rail contact force, j=1,2,3,4;

The $\delta(x-xi)$ is the Dirac function, Its dimension is the L^{-1}o Here that the partial derivative of demand on the coordinates, Denotes the partial derivative of demand on time.

2.4 Transition Section is Set

To consider the actual line conditions, there can be no sharp chine rails, track transition section two simulation curves. Where: A differential settlement on behalf of the foundation, L on behalf of the length of transition section. The entire circuit as shown in Fig. 3

$$y = \frac{A}{2}\left[cos\left(\frac{\pi}{L}x\right)-1\right] \quad (12)$$

2.5 Interaction Between

Vehicle and track interaction point is the point of contact between wheel and rail can be seen, the relationship between vehicles and track all the problems rooted in the wheel-rail contact point between the forces. Therefore, the wheel-rail contact mechanics model is coupled vehicle system and track system a crucial element [3]. In the vertical, using the Hertz elastic contact theory describing the vertical force

Table 1 Basic Parameters of Quasi-high Speed Double-decker Bus (Modified 209HS Bogie)

Parameter names and symbols		Value	Units
Body mass	Mc	42800	Kg
Quality Framework	Mt	15260	Kg
Wheel of quality	Mw	2670	Kg
Body mass nod	Jc	1.255159 × 106	Kg·m2
Quality Framework nod	Jt	1.3665 × 104	Kg·m2
A series of suspension stiffness	Ks1	3.74 × 106	N/m
2Department of suspension damping	Cs1	1.20 × 105	Ns/m
A series of suspension stiffness	Ks2	2.3 × 106	N/m
2 Department of suspension damping	Cs2	2.4 × 105	Ns/m
Vehicle fixed distance of a half	Lc	4.5	M
Fixed wheelbase of the semi -	Lt	1.45	M
Wheel radius	R	0.625	M

Table 2 SS8 Basic Parameters of Locomotive

Parameter names and symbols		Value	Units
Body mass	Mc	42800	Kg
Quality Framework	Mt	3086	Kg
Wheel of quality	Mw	1675	Kg
Body mass nod	Jc	2.999 × 106	Kg·m2
Quality Framework nod	Jt	4.37 × 103	Kg·m2
A series of suspension stiffness	Ks1	2.58 × 106	N/m
2Department of suspension damping	Cs1	3.0 × 105	Ns/m
A series of suspension stiffness	Ks2	9.6 × 105	N/m
2 Department of suspension damping	Cs2	1.4 × 105	Ns/m
Vehicle fixed distance of a half	Lc	9.25	M
Fixed wheelbase of the semi -	Lt	1.2	M
Wheel radius	R	0.4575	M

between wheel and rail to study the inside of wheel-rail contact force to the G (t) of the commonly used formula is:.

$$G(t) = \left[\frac{1}{W}\Delta\gamma(t)\right]^{3/2} \quad (13)$$

Where: W - wheel-rail contact constant; ΔY(t)- wheel-rail traffic between the elastic compression.

For the tapered tread wheels

$$W = 4.57R - 0.149 \times 10^{-8} \text{ (m/N2/3)} \quad (14)$$

Where: R - Wheel radius (m).

Suppose vehicle operation, the wheel-rail does not occur from the wheels as a static amount of 0, this point, the wheel-rail capacity between the elastic compression:

$$\Delta Y(t) = Yj(t) - y(Xj, t) \quad (15)$$

Where, Yj (t) is t times the first j-bit dynamic vertical wheel displacement, y (Xj, t) is t times the corresponding j-position the wheel at the rail vertical dynamic displacement, obviously, ΔY(t) > 0, Accordingly, the wheel-rail contact stress as follows:

$$\delta(t) = S[G(t)]^{1/3} \quad (16)$$

$$S = 2.49R - 0.25 \times 10^{7} \text{(N2/3/m2)} \quad \text{(Tapered tread wheels)} \quad (17)$$

2.6 Bridge Dynamic Performance Calculation Parameters of Transition Section

In the analysis of train and track dynamics of the system characteristics of transition section, the selection of SS8 locomotive traction quasi-high speed double-decker bus (a dynamic three drag) as well as China's orbit basic parameters of trunk.

2.7 Road and Bridge Over Band Dynamic Performance Computing Program

In the study of dynamic properties of track transition section, to consider the impact of changes following factors:

(1) from the foundation (or reclamation) subsidence caused by the track deformation.

(2) differential settlement (A) take 5 cm, 10 cm, 15 cm.

(3) speed (V) take 80,160,200 km/h.

(4) to consider the directions of traffic from low stiffness to high stiffness orbit, and from high to low stiffness of the track two kinds of stiffness.

(5) The transition section length (L) taken 10 m, 20 m, 30 m.

Comprehensive consideration of these factors, take the formula set out in Table 3.

Track transition section dynamic performance computing program

2.8 Dynamic Performance Evaluation of Road and Bridge Transition Section Contents

In order to complete analysis and evaluation of train passing through the transition section of the track when the dynamic performance of the system, special select the following evaluation components:

(1) wheel-rail vertical force Fwr (kN)

(2) The fulcrum of rail pressure Fr (kN)

(3) The subgrade bed surface stress δr (Mpa)

(4) rail acceleration ar (m/s2)

(5) sleeper acceleration as (m/s2)

(6) The track bed acceleration ab (m/s2)

(7) body acceleration av (m/s2)

(8) the amount of wheel suspension yw (mm)

Table 3 Basic Parameters of Line

Parameter names and symbols			
Elastic modulus of rail	E	2.059×1011	N/m2
The quality of rail unit of length	ρ	60.64	Kg
Cross-section moment of inertia of rail	I	3.217×10-5	m4
Sleeper Quality	M1	160	Kg
Sleeper spacing	Ls	0.6	m
Cushion stiffness under rail	K1	6×107	N/m
Ballast stiffness	K2	7.058×107	N/m
Road-bed density	γ	1.75×103	Kg/m3
Road-bed thickness	H	0.35	m
Subgrade stiffness	K3	2.427×108	N/m

* In the table values corresponding to a rail

Table 4 Track Transition Section Dynamic Performance Computing Program

Formula		Differential settlement(cm)	Driving directions	Speed (km / h)	Transition Section Length (m)	Calculation of the content
Number	Objective					
1~5	Initial track	5			0	Rail deformation curve
6	Deformation analyse	10 15			20	
7~10	The directions of traffic impact analysis	5	High→low Low→high	160	0 20	Fwwr, fr, ar, as, av, ab, yw, δf
11~13	Effectof driving speed	5	High→low	160	0 20	Fwwr, fr, ar, as, ab aw, δf
14~22	Track transition lengths impact analysis	5 10 15	High→low	160	10 20 30	Fwwr, fr, ar, as, ab, aw, δf
23~24	Track stiffness differential driving directions 10 times the impact analysis	0	Low→high			Fwwr, fr av, δr
25~27	Track stiffness difference 10 times the length of transition section of the track impact analysis	0	Low→high	160	10 20 30	Fwwr, fr av, δr

3. Track Settlement Mutation Analysis of Dynamic Characteristics of the Lot and Transitional Paragraphs Setting

In front of the establishment of the kinetic model used to calculate the settlement from the foundation (or long-term landfill settlement) arising from the initial deformation of rail.

Figs. 4~6 for the settlement difference 5 cm, 10 cm, 15 cm and without a transition section, the rail deformation curve. Calculation of the scope of the foundation before the 100 sleeper no settlement, the first 100 sleepers were beyond the scope of the settlement of the foundation of 5 cm, 10 cm, 15 cm. The figure the distance between

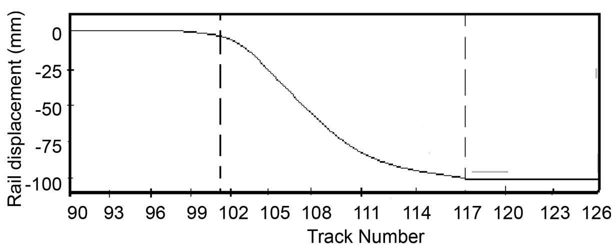

Fig. 4 Differential settlement caused by rail deformation curve (differential settlement 5 cm)

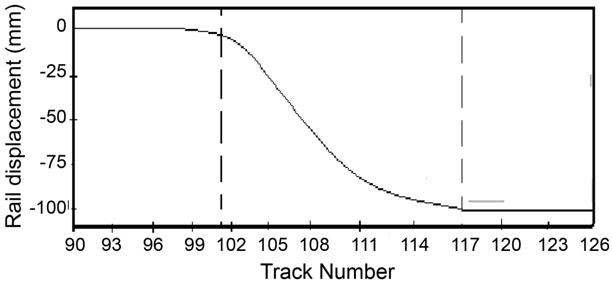

Fig. 5 Differential settlement caused by rail deformation curve (differential settlement 10 cm)

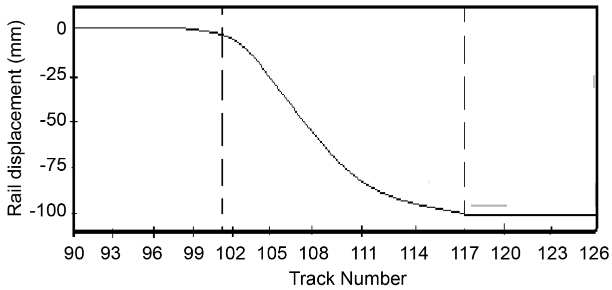

Fig. 6 Differential settlement caused by rail deformation curve (differential settlement 15 cm)

the two dotted lines for differential settlement in the low stiffness of the track on the sphere of influence [4].

4. Influence of Driving Directions

Fig. 7~Fig. 8 shows the stiffness under rail-based difference of 10 times, different directions of traffic on vehicle and track the impact dynamics of the system. From Fig. 27, Fig. 28 can be seen that the track stiffness differential movement of the wheel-rail force of probably about 10%, not too great. However, the impact of acceleration on the body is larger.

The main reason is the bending stiffness of rail itself, so that track surface does not appear bent, while in the wheel load under the action of vertical displacement of track surface makes major changes in the body have a greater acceleration. In addition, from Fig. 7, and Fig. 8 also shows the train tracks from low stiffness to high stiffness of track, rail bending stress change more dramatic fulcrum rail pressure is greater. This is also a larger side of the track stiffness before the few sleeper easily cause damage.

5. Conclusion

Through the establishment of the train and the track transition section of the unified model of dynamic analysis to develop numerical simulation software, on different

Wheel-rail force (MPa) The train tracks from a high stiffness - low stiffness track

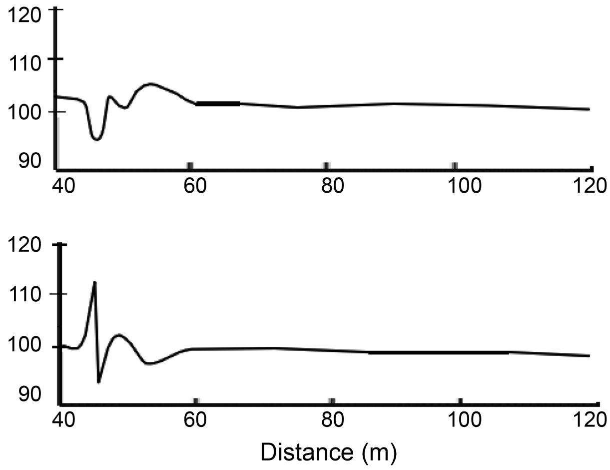

Fig. 7 Traveling in the direction of the wheel-rail force effects (stiffness 10 times worse, without transition section)

Rail acceleration (m/s2) The train tracks from a high stiffness - low stiffness track

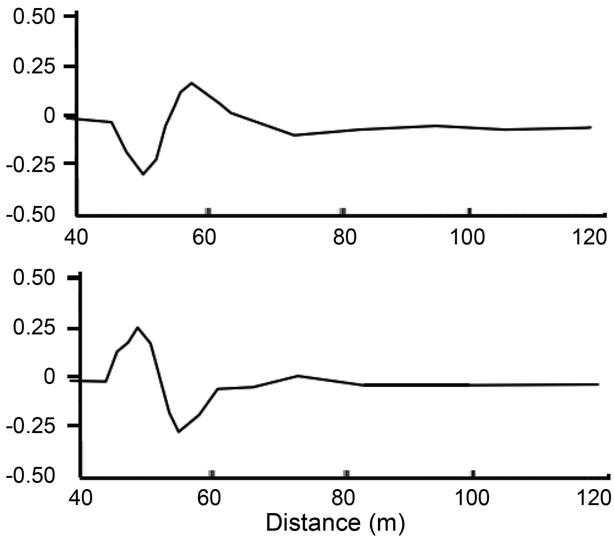

Fig. 8 Traveling in the direction of the body acceleration effects (stiffness 10 times worse, without transition section)

foundation under rail tracks connecting with the typical aspects of road and bridge transition section of the dynamic performance on a variety of different conditions to carry out a large number of computer simulation, comprehensive analysis and performance evaluation.

The main points will now be summarized as follows:

5.1 The Initial Deformation of Rail Curve

Because the road, are two significant differences in the nature of the project structures would inevitably produce a post-construction differential settlement. Therefore, there is a big rail and identified on the initial deformation, only difference with the settlement related to the orbit of transition section in the past dynamics analysis model, assuming that the track corner approach is biased conservative. The model proposed in this paper is more realistic.

5.2 Driving Directions

Without setting the case of transition section, the train out of the bridge than the bridge into the more dangerous. If installing a transition section is little difference between the two dynamical effect.

5.3 Driving Speed

Speed of the train and the track transition section of the dynamic role of the significant influence. The higher the speed, power, the larger the role. When the settlement difference of 5 cm, the potential for the SS8 traction high-speed trains, the speed 160 km/h, the body has reached the limit of acceleration.

Finally, the need to point out is that this paper on the transition section of the track is only theory and methodological in nature, the existence of a wide variety of practical engineering transition section of the track structure, and in different operating conditions (normal line, speed lines, heavy lines, high-speed lines) and dynamic properties and optimize the design parameters have yet to be in the next stage in-depth study.

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