Static Strain Analysis of CRTS I Bi-Block Ballastless Track

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Abstract. In this paper, relying on the National Engineering Laboratory of High-Speed Railway Construction Technology, a full-scale model of the double-block ballastless track structure is established, and the strain analysis of the layered track structure under different static loads is carried out, which has a certain practical significance for the design and maintenance of the high-speed railway ballastless track in our country. Research conclusion: (1) Under the action of static load, the sleeper directly under the rail is under compression; the four corners of the sleeper are tensile strain; (2) The strain at each measuring point on the surface of the track slab around the sleeper is compressive strain; the edge of the top surface of the track slab is compressive strain; The longitudinal strain at the bottom of the side of the track slab is tensile strain; (3) Under static load, the longitudinal strain measurement point on the top surface of the base plate is tensile strain at a distance of two sleepers from the static load position; the longitudinal strain at the bottom of the side of the base plate is tensile strain.

Keywords. CRTS I bi-block ballastless track, static load, strain analysis.

1. Introduction

CRTS I bi-block ballastless track has obvious layered structure, for decreasing step by step a system of structure stiffness [1]. The sleepers are double-block sleepers connected by steel truss. Sleeper using reinforced truss will strengthen the connection with ballast slab, improving the structural integrity. Ballast slab adopts double reinforcement. But CRTS I bi-block ballastless track is in situ for the whole during, therefore the track structure is no prestressing. Its compression damping effect should be studied further confirmation.

By the finite element software, beam-slab-slab models of double-block ballastless track on bridge and subgrade are established separately to simulate the effect of stress and strain under static load on subgrade and bridge, while the analysis of sleeper force and deformation is ignored [2].

Taking the low vibration track in the middle-south channel tunnel as the research object, through the full-scale model static load test, Wu and Li [3] studies the mechanical properties of a single bearing block under the vertical load. However, they only do the statics analysis and don’t take into account the dynamics [4].

Based on the National Engineering Laboratory of High-Speed Railway Construction Technology at Central South University, static load test is carried out on the solid scale model of CRTS I bi-block ballastless track to explore the distribution law of maximum principal stress of double-block ballastless track.

2. Static Load Test Results and Analysis
2.1. General Situation of Test
Through the static load test of short rail, the track geometric shape retention capacity and load distribution law under vertical load are determined [5]. Through static load test, the stress of bi-block sleeper, surrounding stress of double block sleeper, concrete stress of track slab surface and concrete stress of supporting layer surface are analysed [6, 7]. The specific layout of strain gauge measuring points is shown in figure 1.

When loading, load uniformly to 130 kN at a speed of 1~2 kN/s. Record loading time and measurement data in integer multiples of 20 kN, 40 kN, 60 kN, 80 kN, 100 kN, 110 kN, 115 kN, 120 kN, 125 kN, 130 kN. Repeat the measurement 3 times.

![Strain gauge layout of double-block track structure](image)

(a) Top view of measuring point layout of track slab
(b) Side view of measuring point layout of track slab
(c) Site layout drawing of strain gauge

Figure 1. Strain gauge layout of double-block track structure.

2.2. Strain and Analysis of Double-Piece Sleeper, Track Bed Slab and Base Plate
(1) A total of 6 strain gauges are arranged in the bi-block sleeper [8]. The specific arrangement is shown in figure 2. Draw the strain of each measuring point under each static load into a graph, as shown in figure 3.

It can be seen from the above figure that the strain gauge located directly under the rail is compressed, and the compressive stress increases linearly between -0.0773 με~0.3343 με; the strain gauges located at the four corners of the sleeper are under tension, and the tensile strain is 0.1461. It increases linearly between 0.1461 με~1.3552 με, and the linear slopes of the strain measuring points on both sides of the same position are basically the same; the compressive strain of the sleeper under the rail is smaller than the tensile strain of the four corners of the sleeper.
Figure 2. Arrangement of two-piece sleeper strain gauges.

Figure 3. Strain variation pattern of each measuring point of sleeper under different static load.

(2) The track slab is arranged with 23 strain gauges. The specific layout is shown in figure 4. Draw the strain at each measuring point of the track bed slab around the sleeper under each static load, as shown in figure 5.

Figure 4. Strain gauge layout of double-piece track bed plate.

Figure 5. Strain variation pattern of each measuring point of track slab around sleeper under different static load.

Each measuring point on the surface of the track slab around the sleeper is compressive strain; at the corners where the sleeper and the track slab are in contact, the compressive strain is large and increases rapidly, with a range of \(-0.4196 \mu\varepsilon\) to \(-2.5633 \mu\varepsilon\); The compressive strain increases slowly in the range of \(-0.0741 \mu\varepsilon\) to \(-1.3354 \mu\varepsilon\), which is close to the horizontal and longitudinal centerline of the sleeper.

Draw graphs of the longitudinal, transverse and sleeper centerline strains of each measuring point under each static load, as shown in figures 6-8.
Figure 6. Longitudinal strain change pattern of each measuring point on the edge of the track bed

Figure 7. The law of lateral strain change at each measuring point on the edge of the track bed under different static loads

Figure 8. Strain variation pattern of the center line of the track bed sleeper under different static load forces

For longitudinal strain measurement point on the edge of the top surface of the track bed, the longitudinal strain directly below the static load application point is the compressive strain, which gradually increases between -0.0563 με~0.5093 με; at the one sleeper distance and two sleeper distances from the static load application position, the longitudinal strain is tensile strain, and the magnitude gradually increases between 0.0239 με~0.2466 με.

The longitudinal strain measured at the bottom of the side of track slab was tensile strain below the static load point, which directly increased gradually from 0.1189 to 0.8615. The longitudinal strain at the distance of 2 sleepers and 1 sleeper from the static loading position was compressive strain, which increased gradually from -0.1119 με~0.3920 με.

The transverse strain at the edge of the top surface of the track bed was measured. The transverse strain just below the static loading point was tensile strain, which increased gradually from 0.0260 με to 0.1612 με. The transverse strain at the distance of one sleeper and two sleepers under static load increased gradually from -0.0007 με~0.0636 με.

The vertical strain measured at the bottom side of the trackbed plate was compressive strain, which increased gradually from -0.1757 με~1.0923 με.

The transverse strain at the center line of the sleeper on the top of the track slab was measured. The transverse strain just below the static load point was compressive strain, which increased gradually...
from -0.1683 με ~ -1.4005 με. The transverse strain between one sleeper and two sleepers at static loading position was tensile strain, which increased gradually from 0.0732 με - 0.6713 με.

(3) For strain analysis of the base plate, a total of 6 strain gauges are arranged on the side and top surface of the base plate at the position of the drop axis and two adjacent sleepers in the longitudinal direction. The specific layout is shown in figure 9.

Draw the strain of each measuring point under the action of each static load into a graph, as shown in figure 10.

For the longitudinal strain measuring point on the top surface of the base plate, the longitudinal strain at two sleeper distances from the static load point is tensile strain, and the magnitude is gradually increased between 0.0579 με~0.4394 με; the static load point is one sleeper distance and static load point, the longitudinal strain is compressive strain, and the magnitude of compressive strain gradually increases between -0.0078 με~ -0.2732 με.

For the longitudinal strain measuring point at the bottom of the side of the base plate, the longitudinal strain directly below the static load point is tensile strain, and the magnitude is gradually increased between 0.0107 με~0.0736 με; for the static load point the distance between 1 sleeper and 2 sleepers, longitudinal strain is compressive strain, and its size gradually increases between -0.0015 με ~ -0.0573 με.

3. Conclusion
(1) Under static load, the bi-block ballastless track structure is located at the sleeper measuring point directly below the rail. The strain gauges are under compression during loading. With the increase in load, the compression strain has a linear increase; Tensile strain is at each corner, and with the increase of load, the tensile strain of each measuring point has a linear increase, and the linear slope is basically the same.
(2) The strain at each measuring point on the surface of the track slab around the sleeper is compressive strain. With the increase of load, the tensile strain at each measuring point gradually increases; the longitudinal strain measuring point at the edge of the top surface of the track slab is at the point of static load. The longitudinal strain directly below is compressive strain, and the longitudinal strain at one sleeper distance and two sleeper distances from the static load position is tensile strain; the longitudinal strain measuring point at the bottom of the side of the track slab is tensile strain directly below the static load point. At two sleeper distances and one sleeper distance from the static load position, the longitudinal strain is compressive strain. With the gradual increase of the static load force, the strain gradually increases; the transverse strain measurement point on the top edge of the track slab is applied in the static load, where the transverse strain is tensile strain, and at one sleeper distance and two sleeper distances from the static load position, the transverse strain here is compressive strain; the vertical strain measuring point at the bottom of the side of the track slab is the compressive strain, and with the gradual increase of the static load, the magnitude of the strain is gradually increasing; the transverse strain measuring point on the center line of the sleeper on the top surface of the track slab, the transverse strain is the compressive strain directly below the static load. The lateral strain at the distance between one sleeper and two sleepers at the acting position is tensile strain.

(3) Under static load, the longitudinal strain measuring point on the top surface of the base plate is tensile strain at a distance of two sleepers from the static load position. With the increase of static load, the tensile strain is $0.0579 \mu \epsilon - 0.4394 \mu \epsilon$. When the static load is one sleeper distance and the static load is applied, the longitudinal strain is the compressive strain. As the static load increases, the compressive strain increases between $-0.0078 \mu \epsilon - 0.2732 \mu \epsilon$; the bottom of the base plate is longitudinal. At the strain measuring point, the longitudinal strain directly below the point is tensile strain. As the static load increases, the tensile strain increases between $0.0107 \mu \epsilon - 0.0736 \mu \epsilon$; at a distance of 1 sleeper and 2 sleepers away from the static load, the longitudinal strain is compressive strain. With the gradual increase of static load, the magnitude of compressive strain increases between $-0.0015 \mu \epsilon - 0.0573 \mu \epsilon$.

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