Research on the Deformation Behaviour of the Track Interlayer Structure during the Deviation Correction of the Offset Ballastless Track

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Abstract. In view of the problem that the large deviation of the ballastless track structure affects the smoothness of the line due to the complex geological environment, in order to realize the deviation correction and repair of the offset ballastless track within the skylight time to restore the smoothness of the line, we researched the technology and process of ballastless track structure deviation correction and repair based on polymer chemical debonding, and the deformation and evolution behavior of the ballastless track interlayer structure during deviation correction and repair. The results show that by polymer chemical debonding and lifting technology, it ensure that the track structure is completely separated from the cement graded gravel layer, and significantly reduce the adhesion and friction between the base plate and the surface of the foundation bed, which creates conditions for the successful implementation of deviation correction. By the step-by-step loading and synchronous push control, the track slab and support layer are uniformly stressed and deformed synchronously. There is no track structure cracking loss, interlayer bonding failure or dislocation damage. The engineering tests show that the developed deviation correction technology can ensure the deviation correction and repair of the offset ballastless track structure without damaging the ballastless track structure.

Keywords. Ballastless track, offset, push, deviation correction, strain.

1. Introduction
At present, the ballastless track in China's high-speed railway line is mainly divided into CRTS I, CRTS II and CRTS III. The main structural forms include asphalt mortar or concrete, which is very different from the traditional railway [1]. The ballastless track has the characteristics of long operation cycle, good stability, high safety and less maintenance work [2]. High-speed railways mostly use ballastless tracks. From top to bottom, the ballastless track structure of the subgrade section consists of steel rails, pads, track bed slabs, base slabs, bed surface layer, bed bottom layer, and embankment body. The track bed slab and base slab are reinforced concrete structure, and the surface of the bed is filled with cement graded gravel [3]. Due to the complex geological environment, the ballastless track structure of individual road base sections may have a certain horizontal shift phenomenon [4], and
then, large track lateral irregularities are produced, which has a certain impact on normal driving, at the same time accelerate the deformation and failure of each component of the track [5-8].

Aiming at the above-mentioned ballastless track line offset problem, it is necessary to use the skylight time to perform lateral push deviation correction and repair on the offset ballastless track structure to restore the smoothness of the track structure [9-12]. Because the ballastless track is a layered structure feature, when realizing deviation correction and repair, it results to deformation of the track structure of each layer. It is a key difficulty that the coordinated and synchronized deformation of the track structure of each layer and the track structure does not produce interlayer adhesion failure or dislocation damage.

Relying on the research and development project (2017G002-D) of China State Railway Group Co., Ltd, in view of the structural characteristics of ballastless tracks and the construction conditions of operating railways, China Academy of Railway Sciences had developed a suitable treatment technology for lateral deviation of ballastless track structures, and proposed a construction technology and supporting tooling for lateral offset correction based on chemical debonding, mechanical lifting debonding, and air cushion lifting debonding for skylight operations by theoretical analysis, structural design, material development, tooling development, experimental verification, engineering practice and other research work. And we ensured that under a certain amount of deviation correction, the ballastless track structure was reasonably stressed without being damaged or cracked, and each layer was synchronously deformed without slippage, thereby ensuring that the deviation correction effect meets the line smoothness requirements. Therefore, this article focused on the key technical programmes for ballastless track structure deviation correction and repair based on polymer chemical debonding, and emphatically introduced the deformation evolution behavior of the ballastless track interlayer structure during the deviation correction and repair, in order to provide reference and technical support for the repair of similar deviation disease of the high-speed ballastless track.

2. Deviation Corrective and Repair Method

(1) The friction factor between the base plate and the cemented graded crushed stone has a greater impact on the deviation correction reaction force. For the sections that need to be corrected and rectified, first we used high-pressure grouting technology to inject a high-polymer chemical debonding agent with fast expansion performance between the base plate and the graded gravel on the surface of the foundation bed. When the debonding agent was solidified from a liquid to a hardened body, the reaction was fast (5s-10s) and accompanied by volume expansion, which generated a large expansion stress during the expansion process. In this way, it can smoothly lift the ballastless track structure, and it means that the bonding and restraint between the bottom of the support layer and the graded crushed stone were separated and released, and then the air cushion lifting method was used to lift the track structure to further reduce the friction between layers, and then implement correction.

(2) According to different ballastless track structures and on-site working conditions, the reaction wall installed on the adjacent line or on this line can be used as the reaction force support to correct deviation.

(3) According to the duration of construction operation, the deviation should be reasonably segmented and corrected several times. The pushing amount of each correction unit is controlled from the maximum offset in the middle to the two sides.

(4) When correcting the deviation of track structure, the displacement sensor, total station, leveling instrument and other instruments should be used to monitor the midline displacement and elevation change of ballastless track structure in real time.

(5) After completing the deviation correction and repair, the track structure was completely filled with polymer slurry, so it restored the interface bonding between the ballastless track base plate and the graded gravel layer on the surface of the foundation bed. Dynamic indicators such as train safety and track structure stability were monitored to evaluate whether the dynamic performance of the ballastless track in the turnout area met the safety and stability requirements of the D-Series High-Speed Train when passing at a speed of 300 km/h.
3. Structural Deformation Evolution Behavior between Deviation Correction Layers

In the test of ballastless track structure lateral pushing deviation correction, we employed these methods: the jack pressure gauge was used to monitor the synchronous grading pushing of each jack, and the total station and the cable displacement sensor were used to measure the lateral correction amount of the corresponding position of each jack during the step-by-step loading and pushing, and the strain test system automatically collected the Strain-time curve of each measuring point. The synchronous strain on the left side of the track plate and the support layer tested under the stepwise loading control was shown in figure 1, and the synchronous strain on the right side of the track plate and the support layer was shown in figure 2.

It can be shown from figures 1-2 that during the stepwise increase of the jacking force from zero, the change trend of the concrete strain curve of the track slab is basically the same as the support layer on the same side of the track structure. The whole show synchronous deformation, but there are certain differences in local strain and it is mainly manifested that the strain of the support layer at the same position is less than the strain of the track plate. After analysis, it is believed that the structure of the track slab and the support layer are different. The former is a reinforced concrete structure, and the latter is a plain concrete structure. This determines that the rigidity of the track slab in the plane is greater than that of the supporting layer. According to the test data, the maximum tensile and compressive strains of the track structure are less than the ultimate strain of the track structure concrete. It can be seen that the local strain inconsistency between the track plate and the support layer caused by complicated factors is not enough to cause the relative displacement of the track plate and the support layer. During the pushing process, there is no sign of loss of adhesion or misalignment between the track plate and the support layer.

![Figure 1. Synchronous strain curve on the left side of the track under stepwise loading control.](image1)

![Figure 2. Synchronous strain curve on the right side of the track under stepwise loading control.](image2)

4. Deviation Correction Implementation Effect

The ballastless track deviation correction technology researched and developed by the China Academy of Railway Sciences was carried out to a test section of a subgrade ballastless track. The alignment comparison before and after deviation correction was shown in figure 3. From the comparison of alignment, it can be known that the deviation correction of the ballastless track structure achieves the
expected deviation correction effect, therefore, the offset disease is eliminated, and the smoothness of the ballastless track is effectively restored.

Figure 3. Comparison of line shapes before and after deviation correction.

5. Conclusions
The main conclusions of this article as following:

(1) The use of high polymer chemical debonding agent with fast expansion performance, which can quickly expand after being injected into the base plate to smoothly lift the ballastless track structure, significantly reduced the adhesion between the base plate and the surface of the foundation bed, and ensured the separation of track structure from the high cement content graded gravel layer. The air-cushion lifting method was used to lift the track structure, which further reduced the friction between layers and creates conditions for the successful implementation of the ballastless track structure deviation correction.

(2) Through the support layer and track plate synchronous lateral push and deviation correction, the track slab and the support layer of ballastless track were basically uniformly stressed and deformed synchronously without causing track structure cracking loss or interlayer bonding failure or dislocation damage.

Acknowledgements
This work was supported by the National China State Railway Group Co., Ltd Scientific Research and Development Subject (Grant number K2019G010).

References
[1] Wang Q X 2019 Application research on structural disease and maintenance technology of ballastless track in high speed railway Technology Innovation and Application 16 167-168.
[2] Li J W 2019 Research on life-cycle maintenance measures for ballastless track structure of high-speed railway China Southern Agricultural Machinery 1 242.
[3] Zhen X G 2020 Rapid replacement technology of ballastless track structure components in high speed railway Science and Technology Innovation Herald 13 37-39.
[4] Kai Y W and Cai X 2017 Analysis of lateral offset of ballastless turnout structure and its disease treatment Railway Engineering 3 129-133.
[5] Chen G, Zuo H F and Zhai W 2001 Influences of track irregularities on lateral random vibration responses of vehicle and track system Journal of Nanjing University of Aeronautics & Astronautics 3 227-232.
[6] Cai X, Guo L, Hou B and Ren C 2016 Influence of ballastless track complex irregularities on high-speed train Journal of Beijing Jiaotong University 1 12-19.
[7] Wang Q Y, Zhang J S and Meng F 2012 Study on track-subgrade model of high-speed railway and dynamical loading Journal of the China Railway Society 12 90-95.
[8] Lin Y S, Li X Z and Qiang S Z 2005 Studies on runability of train excited by the irregularity of track on the high-speed railway bridge Journal of the China Railway Society 6 4-5.
[9] Weng X H 2017 Research on deviation correction technology of CRTSII slab ballastless track for high speed railway Railway Investigation and Surveying 1 6-9.

[10] Liu J, Zheng X G, Li S M, Yang D J, Liu X H, Pan Y J, Zeng Z, Cheng G Z and Dong Q X 2018 Research and application of deviation correction and repair techniques for crossover turnout ballastless track structure based on high-polymer chemical desorption and air cushion lifting Railway Engineering 1 70-74.

[11] Xing X M 2016 Research on new technology of lifting and correcting deviation of ballastless track of high-speed railway Railway Construction Technology 4 107-109.

[12] Li Q H 2017 Research on deviation correction technology of ballastless track structure in lanxin passenger train Railway Construction Technology 2 82-85.