Repair Method for Ballasted Track by Composite Filling Material Consisting of Water Glass and Polymer

Takahisa NAKAMURA

Researcher,

Track Structures & Geotechnology Laboratory, Track Technology Division

Katsumi MURAMOTO, Dr.Eng.

Senior Researcher,

Track Structures & Geotechnology Laboratory, Track Technology Division

When ballasted tracks include a high-mix ratio of fine particles, track irregularities tend to increase soon after track maintenance performed by tamping because the density change of the ballast is large, and such work impairs the density of the ballast. Therefore, in this study, we developed a method to fill gaps under sleepers with a filling material for the realignment of tracks without impairing the density of the existing ballast. The authors also performed testing to confirm the validity of the method. The results confirmed that this technique is an effective approach for the repair of ballasted tracks.

Keywords: repairing method for ballasted tracks, method of filling gaps under sleepers, filling material, field test construction

1. Introduction

Track maintenance is generally performed by tamping using a tie tamper on ballasted tracks when track irregularity grew after a periodical track measurement in that track irregularity occurs by cyclic loading for trains. The foregoing repairing method is to perform the realignment of tracks by pushing ballast into the ballast under sleepers.

When ballasted tracks include a low-mix ratio of fine particles, the initial settlement after track repair by tamping is less because the density change in the ballast is lower. However, when ballasted tracks have a high-mix ratio of fine particles, the density change in the ballast is large, and the initial settlement is also large, consequently, track irregularities increases soon after track repair by tamping. In other words, when ballasted tracks have a high-mix ratio of fine particles, track repair by tamping is ineffective without ballast renewal.

Therefore, the authors are currently under development of a repairing method by a composite filling material consisting of water glass and polymer to repair ballasted tracks including a high-mix ratio of fine particles. Under this technique, gaps under sleepers are filled with a filling material by air pressure so that ballasted tracks can be repaired without impairing the density of the existing ballast (Fig. 1). It also leads to reduced maintenance costs, as it enables effective repair for ballasted tracks without ballast renewal.

Fig. 1 Example of filling method under sleeper

The stone blower technique, which has been put to practical use in U.K., is a ballasted track repair method with the same approach as this technique.

In this study, the authors performed direct shear test to evaluate the strength properties of this composite filling material. Furthermore, the in-situ test was performed due to confirm the effect of this method.

2. Development of filling material

2.1 Outline of composite filling material consisting of water glass and polymer

In a previous study, the authors found that a material used to fill gaps under sleepers requires fluidity resistance and shear strength. The former is needed to resist water flow that occurs by pumping action of loose sleepers, while the latter is needed to support train load. To meet these requirements, the authors developed a composite filling material consisting of water glass and polymer. Specifically, it consists of a granular filling material (mixed silica sand, water glass and organic acid) and polyvinyl alcohol water (polymer) as shown in Figs. 2 and 3. The granular filling material reacts with the polymer under the sleepers, thereby generating a composite filling material. The silica sand, formed by crushing quartzite, has a high level of hardness. Water glass is generally applied in civil engineering work for soil

Fig. 2 Granular filling material and polymer

Fig. 3 Composite filling material

improvement, and organic acid is used as a food additive. In addition, the polymer is recognized as a biodegradable soil improvement material, meaning that it imposes a lower environmental load.

2.2 Strength properties of composite filling material consisting of water glass and polymer

The authors performed direct shear test to evaluate the strength properties of this composite filling material using a direct shear test device (Fig. 4). The size of specimen was 40 mm in height and 60 mm in diameter. Table 1 shows the test conditions. The soil samples included both the composite filling material and saturated silica sand for comparison. The confining pressure was set both in the case of a railway load equivalent (5 kPa) and a train load equivalent (100 kPa: when an axel load 160 kN acts on rail) for each soil sample.

Figure 5 shows the relationship between confining pressure and shear strength. Here, the maximum shear strength occurring in the ballast is approximately 66 kPa (the dotted lines in the figure) when a train load equivalent acts on it. Silica sand shows sufficient shear strength when a train load equivalent is applied, but the shear strength is only 15 kPa when a train load equivalent doesn't act on it. Silica sand therefore has a level of shear strength that can support train loads for a short period, but it is possible that granular material will flow out due to the pumping action of loose sleepers when a train

Table 1 Test conditions

Test case	Soil sample	Confining pressure
1	Composite filling material	5 kPa
2	Saturated silica sand	100 kPa

Fig. 4 Direct shear test device

Fig. 5 Direct shear test results

load equivalent doesn't act on it, and there are puddles on the surface of the ballast. Conversely, this composite filling material has sufficient shear strength when a train load equivalent acts on it; furthermore, the shear strength is approximately 60 kPa when a train load equivalent doesn't act on it. This is because this composite filling material has both the shear strength of silica sand and the cohesion of a composite gel consisting of water glass and polymer.

The above results confirmed that this composite filling material has sufficient fluidity resistance to withstand water flow occurring by pumping action of loose sleepers as well as adequate shear strength to support train loads.

3. Development of a construction device

The authors developed the two kinds of construction method and devices to fill the gap under a sleeper with granular filling material that consists of silica sands,

(a) Long nozzle method

(b) Air-gun method

Fig. 6 Construction devices

Fig. 7 Construction by driving long nozzle method

water glass and organic acid. One is the long nozzle method (Fig. 6(a)), and the other is the air-gun method (Fig. 6(b)).

With the long nozzle method, a long nozzle is inserted under the sleeper end, and granular filling material is transferred from the device's tank to gaps under sleepers by air pressure. Furthermore, we produced the type of device to drive long nozzle which is given the strength driving in ballast with an electric breaker (Fig.7). Thereby, this method is possibly adaptable in the spot where there is no sufficient gaps under sleepers. The time required for filling work with the long-nozzle method is short, and the finish precision is high. However, it is necessary to remove ballast from the ballast shoulder.

Conversely, with the air-gun method, a nozzle is inserted from the side of the sleepers, and the granular filling material is transferred to the gap from an exclusive bottle by an air jet. The construction in the air gun method can be performed simply because construction device is small, and little ballast is removed. However, the approach requires improvement in terms of finish precision.

4. In-situ test construction

The authors carried out in-situ test construction with this repairing method by a composite filling material consisting of water glass and polymer for ballasted tracks near a level crossing on JR Central's Iida line (Fig. 8). The rail type is 50 kgN at this construction section, and the PC sleepers are type-3 at the origin and wood at the end from a rail joint. The annual passing tonnage is approximately 250 million tons, and the line is a single line. Although mud pumping does not occur at this construction section, joint depression becomes routine due to the difficulty of track maintenance adjacent to the level crossing.

This construction section is a of a track length of ten sleepers (Fig. 9), and the construction was carried out with the long-nozzle method in places where there was a sufficient track raising height. Conversely, the drive long-nozzle method was carried out in places where the track raising height was insufficient near the level crossing for the origin. Here, the track raising height was slightly less near the level crossing because the rail level is confined by the precast-prestressed crossing. Accordingly, it was not possible to carry out the construction regarding three sleepers located closely adjacent to the

Fig. 8 In-situ test construction section

Fig. 9 Positioning sleepers and construction spot

Fig. 10 Construction process

Fig. 11 Construction by long nozzle method

Fig. 12 Pouring the polymer

level crossing. The time taken for filling work with the long-nozzle method is approximately five minutes per sleeper, and the work was carried out while allowing trains to pass through one after another during the construction. Figure 10 shows a construction process for this method, and Figs. 11 and 12 show the construction work. The construction process is as follows:

- ① Measure a rail level of this construction section, and draw up the plan line of rail level for setting up the track raising height.
The authors drew up the plan line that the rail level of rail joint was 5mm higher than the rail level of level crossing according to the measure result. Here a rail settlement of rail joint is largest in this section.
- ② Remove the ballast shoulder of a sleeper end in the construction section, and secure the insert route of the long nozzle.
- ③ Set up the jack near the rail joint, and upload a jack up to a plan line.
- ④ Pour a half polymer to around a sleeper, and start to fill granular filling material.
- ⑤ Pour another half polymer after completion of filling work, and allow it react with granular filling ma-

Fig. 13 Restored irregularity of longitudinal level (This repairing method)

Fig. 14 Restored irregularity of longitudinal level (Repairing method by tie tamper)

Fig. 15 Change of growth of track irregularity

terial under the sleeper.

Figure 13 shows a change of restored track irregularity of longitudinal level about right and left rail for this section concerning after this construction. For comparison, Figure 14 also shows the change in the restored track irregularity of longitudinal level after repair of the ballasted track by a tie tamper for the same section. Track irregularity occurred at a sleeper adjacent to the level crossing in the case of track repair by a tie tamper. However, the construction section in the case of this method has maintained track irregularity almost as same as that of level crossing. On the contrary, in the case of track

repair by a tie tamper, the entire construction section had a distribution shape indicating that track settlement occurred because the degree of track rising height in the case of track repair that of a tie tamper was less than by this approach, furthermore, a track irregularity returned original track condition in four months ago after track repair by a tie tamper.

Figure 15 shows a change of growth of track irregularity per one month near the level crossing. A growth of track irregularity by this method is 1/3 less than that of a tie tamper. Therefore, it was confirmed that this approach is effective for repairing ballasted tracks.

5. Conclusions

The results of in-situ field testing confirmed that this method was effective for repairing ballasted tracks including a high-mix ratio of fine particles. In future work, the authors plan to fundamentally improve the air-gun

device construction method and incorporate easier and more effective repair for ballasted tracks in practical use.

Acknowledgment

This study was supported by JR Central's Shinshiro Track Maintenance Depot. The authors would like to express their sincere appreciation for the cooperation received.

References

- [1] NAKAMURA, T., MURAMOTO, K., and MITACHI, T., "Development of a repairing method for ballasted track by filling composite gel consisting of water glass and polymer," *RTRI report*, Vol. 23, No.10, PP.23-28, 2009 (in Japanese).