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Influences of cement asphalt emulsified mortar construction on track slab geometry status

Tao Wang, Shaoliang Wu, Hengqiong Jia, Zhao Wei, Haiyan Li, Piyan Shao, Shanqing Peng and Yi Shi
China Academy of Railway Sciences Corporation Limited, Metals and Chemistry Research Institute, Beijing, China

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Abstract

Purpose – The construction of cement asphalt (CA) emulsified mortar can obviously disturb the slab status after the fine adjustment. To decrease or eliminate the influence of CA mortar grouting on track slab geometry status, the effects of grouting funnel, slab pressing method, mortar expansion ratio, seepage ratio and grouting area on China Railway Track System Type (CRTS I) track slab geometry status were discussed in this paper.

Design/methodology/approach – Combined with engineering practice, this paper studied the expansion law of filling layer mortar, the liquid level height of the filling funnel, the pressure plate device and the amount of exudation water and systematically analyzed the influence of filling layer mortar construction on the state of track slab. Relevant precautions and countermeasures were put forward.

Findings – The results showed that the track slab floating values of four corners were different with the CA mortar grouting and the track slab corner near CA mortar grouting hole had the maximum floating values. The anti-floating effect of "7" shaped slab pressing device was more efficient than fixed-joint angle iron, and the slab floating value could be further decreased by increasing the amount of "7" shaped slab pressing devices. After CA mortar grouting, the track slab floating pattern had a close correlation with the expansion rate and water seepage rate of CA mortar over time and the expansion and water seepage rate of the mortar were faster when the temperature was high. Furthermore, the use of strip CA mortar filling under the rail bearing platform on both sides could effectively reduce the float under the track slab, and it could also save mortar consumption and reduce costs.

Originality/value – This study plays an important role in controlling the floating values, CA mortar dosage and the building cost of projects by grouting CA mortar at two flanks of filling space. The research results have guiding significance for the design and construction of China's CRTS I, CRTS II and CRTS III track slab.

Keywords Ballastless track, Track slab, CA mortar, Geometry status

Paper type Research paper

1. Introduction

China Railway Track System Type I (CRTS I) ballastless track has been widely used in Chinese high-speed railway owing to its simple structure, convenient construction and low maintenance (Shigeru, Hideyuki, & Masao, 1998; Katsuoshi, 2001; Jia, Wei, Wu, & Li, 2013; He, Long, Xie, & Liu, 2012). The cement asphalt (CA) mortar, which was poured into the filling space (about 40–60 mm thick) between the track slab and concrete roadbed, was an important filling material of CRTS I ballastless track. Fine adjustment of slab was a key step in

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controlling the elevation and smoothness of railway (Murata, 2003; Zeng, Xie, & Deng, 2012a; Zeng, Xie, & Deng, 2012b; Wang, 2013; Song, Zeng, Xie, Long, & Ma, 2020). Theoretically, there was no need to use a height-adjusting gasket under the rail correct orbital condition as it was just the final geometry state of slab after fine adjustment (Department of science & technology of China railway ministry, 2008; Fu, Xie, & Niu, 2016; Wang, Jia, & Li, 2016). However, according to the engineering practice, uneven rail-bearing surface of one slab and stagger step between two slabs occur frequently after CA mortar grouting, which lead to lift up or gap between slabs, will finally affect the smoothness of the rail (Coenraad, 2003; Wang, Liu, & Hu, 2010; Zeng, Xie, & Deng, 2016; Deng, Ye, Yuan, & Wang, 2016).

CA mortar grouting construction has significant impact on the status of the slab after fine adjustment (MOON, LEE, & LEE, 2009; He, Long, & Xie, 2009; Tian, Deng, Huang, & Liao, 2010; Xie, Fu, & Zheng, 2014; Kumar & Ramamurthy, 2015). During this construction process, behaviors that may disturb the geometry status of track slabs are forbidden, such as tread or put heavy stuff above the slab. In most cases, slab pressing device, which can lock the slab, is employed as a main method to prevent slab floating. However, these methods cannot eliminate the impact to the fine adjustment. Meanwhile, technical requirement does not include using slab pressing device (Department of science & technology of China railway ministry, 2008). As shown in Figure 1, we can determine the fullness of mortar and then decide the dosage of it by judging the floating level of supporting bolt. Interim technical requirements and practical operation indicate that the construction of CA mortar grouting will affect the geometry status of track slab, but the influencing factors are not discussed in detail.

According to engineering practice (Wang, Liu, Wang, & Hu, 2008; Wu, Li, Shao, Wang, & Jia, 2012; Zeng *et al.*, 2012a, b; Shao *et al.*, 2013), this paper systematically analyzed influencing factors such as expansion of mortar in filling area, the height of liquid level in grouting funnel, slab pressing device as well as water seepage ratio on geometry status of slab. The results could offer some favorable solutions for design and construction of CRTS I, CRTS II and CRTS III ballastless track slab.

2. Experiment

2.1 Materials and synthesis

(1) Emulsified asphalt: exclusive cation slow-crack emulsified asphalt of CRTS I mortar with 60% solid content; (2) dry mixture: exclusive dry mixture for CRTS I mortar with less than 30% of solid particle less than 0.075 mm; (3) latex: TD-08 polymer emulsion; (4) defoamer: silicon; (5) air entraining agent: rosin.

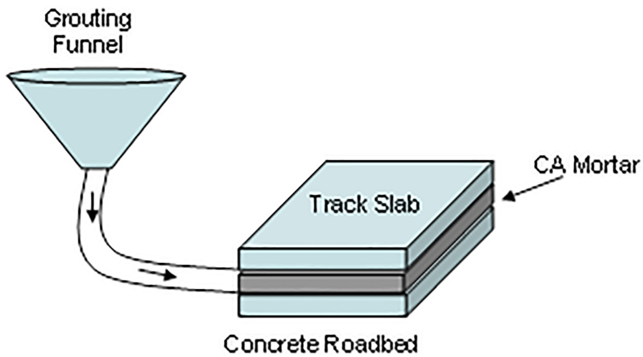

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Figure 1.
Grouting construction of CA mortar in construction practice

Mix proportion dry mixture: emulsified asphalt: latex: water: defoamer: air entraining agent = 3: 1.29: 0.11: 0.067: 0.0004: 0.004. Density of dry mixture: 1,103 kg/m^3.

NFLG (Fujian South Highway Machinery Co., Ltd) Mortar Mixer was used to prepare CA mortar. All materials were quantified automatically, and the mixing process parameters can be controlled by a pre-defined program. The mixing technic was as follows: (1) mixing water, emulsified asphalt, latex and defoamer under rotation speed of 30 r/min; (2) adding dry mixture under rotation speed of 80 r/min; (3) adding air entraining agent under the high speed rotation of 120 r/min to rotate 120 s; (4) mixing the compound under rotation speed of 30 r/min for 30 s and then complete the preparation of CA mortar.

2.2 Experimental procedure

The expansion rate of mortar was examined according to the basis of technical requirement that carried out by Department of science & technology of China railway ministry (2008).

The geometry of track slab surface was measured by dial gauges which were located at four corners of track slab.

Seepage ratio of CA Mortar under slab was tested by using two steel plates that measure 600 mm × 800 mm× 50 mm, are clamped by bolt. After the grouting bag fully filled with mortar, it was tilted with a small angle for the sake of water flowing and weighed by electronic balance. Seepage ratio equals to seepage loss divided by the total weight of mortar.

3. Results and analysis

The geometry status of track slab was mainly determined by the construction of mortar layer after fine adjustment. The influence of mortar grouting on geometry status of track slab was analyzed through the study of the liquid level height of filling funnel, the slab-pressing method, the expansion pattern of mortar, the amount of water seepage ratio and the filling area under the plate.

3.1 Geometry status of track slab after grouting

The slab pressing device, mostly "7" shape, was used to prevent slightly floating of track slab after grouting, however, it was not used in construction of CRTS I mortar in earlier stage. During construction process, the height of grouting funnel was fixed at 100 cm and dial gauge was used to measure floating elevation, as shown in Figure 2 (zero point shows the elevation right after fine adjustment finished).

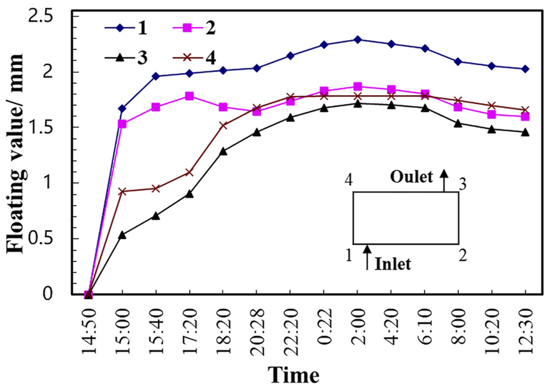

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Figure 2. The geometry Status of track slab over time after grouting

As shown in Figure 2, the floating values of all four corners of the track slab elevate rapidly, and they rise slowly to the highest point of about 1.5 mm to 2.3 mm within 10 h. Then, the floating values of all four corners of the track slab decrease slowly and then keep constant at approximately 1.3 mm and 2 mm after 21 h. According to the above results, the elevations of four corners have different values, the corner near inlet has the highest elevation, which may be related to the different pressure at the four corners and the high liquid pressure in the funnel at the inlet.

3.2 Grouting funnel

CA mortar grouting that used funnel with the advantage of reducing waste and controlling the speed more easily, and it was one of the most important steps in site construction. Different mortar liquid level will generate different liquid pressure as well as different floating pressure. However, there still no relevant technical requirements for liquid level in grouting funnel.

The maximum floating force on the slab, which caused by liquid level of mortar, can be obtained from the following equation: $P = \rho * g * h$, where ρ stands for the density of mortar, g represents the gravitational acceleration (9.8 N/Kg) and h represents the height of the track slab. The floating force can be calculated by pressure and area of track slab. For density of fresh mortar was 1.64×10^3 kg/m^3 and the area of P4962 track slab was 11.91 m^2, when liquid level changes by 10 cm, the floating force exerting on track slab changes by 19.14 kN.

China in the early days of constructing the CRTS I track slab, there was no standards for grouting funnel, which lead to its height gradually increased with the time. During the early constructions, the minimum distance between the bottom of funnel and concrete roadbed was 50 cm. When the distance increased from 50 cm to 90 cm, the grouting time decreased from 10 min to 3–4 min. The filling pressure of CA mortar can be converted into floating force of the track slab according to the principle of liquid pressure and by controlling the level height of the mortar in the funnel from 80 to 120 cm, as shown in Figure 3.

Figure 3 showed that the floating force generated in mortar with the height of grouting funnel increased. The floating force exerting on track slab increased 19.14 kN as per 10 cm increased in the height of funnel. When funnel height, which taken its bottom as basis, ranges from 50 cm to 90 cm, the floating force was 153.12 kN–229.68 kN, it means the equivalent pressing weight that preventing the track slab from floating should be 15.6 T–23.4 T. Hence, we can optimize the installation of slab pressing device by using torque wrench, which can unify pressing forces on four corners and prevent uniform floating.

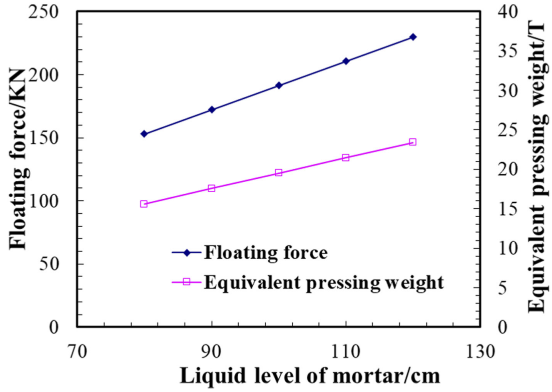

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Figure 3.
Floating force and equivalent pressing weight caused by mortar liquid level

3.3 Slab pressing method

After fine adjustment of the slab, three pairs of "7" shaped slab pressing device were usually installed on two sides of a track slab to avoid floating. Meanwhile, using angle steel at hoisting hole to connect the slab and the concrete roadbed or adding slab pressing device at the inlet can prevent the track slab from floating. The height of grouting funnel was fixed at 100 cm, and dial gauge was used to evaluate the floating value with different methods. All relevant results were shown in Figures 4–6.

As shown in Figure 4, when the slab and concrete roadbed clamped together by angle iron, the average floating value at four corners was 2.07 mm after grouting. And then, the average floating values of four corners were increased to 2.38 mm, significantly exceeding the allowable standard (1.5 mm) after squeezing the mortar at the inlet. The largest floating height of inlet corner was about 3.5 mm, which was more than twice of the allowable value. Therefore, it can be found that using angle steel at four hoisting holes cannot efficiently prevented track slab from floating.

Figures 5 and 6 indicated that when track slab and concrete roadbed clamped together by "7" shaped slab pressing device, the four corners also float after grouting. There was a further float of the slab with an average of 1.54 mm after squeezing. The floating height of corner that near the inlet and with single slab pressing device was 1.97 mm, which was higher than all other corners. The floating height of the inlet corner that with two slab pressing device were 1.56 mm, meanwhile, the average float of the slab rose to 1.46 mm.

3.4 Expansion ratio

The expansion ratio of CA mortar was 1–3%, representing the expansive percentage of one cubic meter mortar. When the loading area was certain, free expansive height was only determined by the thickness of mortar. The height of mortar layer under the track slab was usually 5 cm, as well as the maximum expansive height was usually 1.5 mm. Taking the weight of track slab, pressing force and seepage into account, the mortar had no significant effect on the height of track slab when the filling space was fully filled. The expansion behavior of mortar was measured under different environment conditions, and corresponding results were shown in Figures 7 and 8.

Figures 7 and 8 indicated that the change of mortar volume was strongly depended on environmental temperature over time. The mortar expansion ratio increased rapidly for two hours, and then it increased slowly, finally the mortar expansion ratio declined slightly and kept at a stable level under sunlight. In addition, the rapid expansion stage would last for five hours, and then the expansion rate decreased and became stable at midnight as the presence of sunlight. The reason for this phenomenon was that the gas generation rate of aluminum powder had a positive correlation with ambient temperature as sunlight offered heat to mortar. Meanwhile, comparing Figures 7 and 8 to Figure 4, it can be concluded that the expansion pattern of mortar was similar with the floating pattern of track slab.

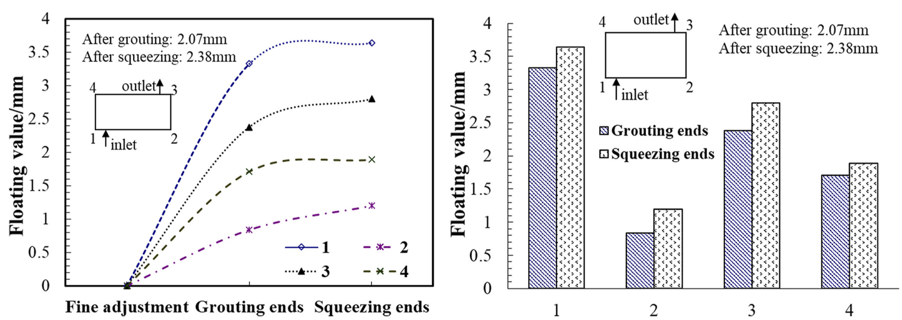

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Figure 4. Floating value of four corner clamped by angle steel after grouting

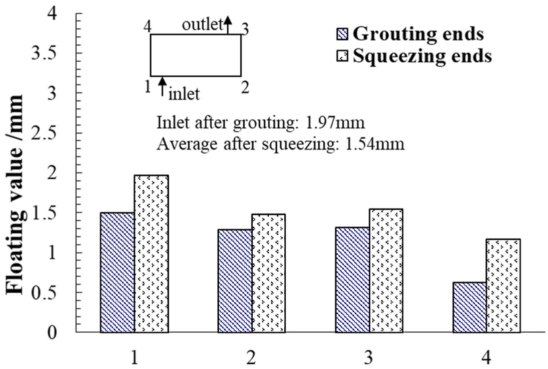

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Figure 5.
One 7-shaped device at the inlet

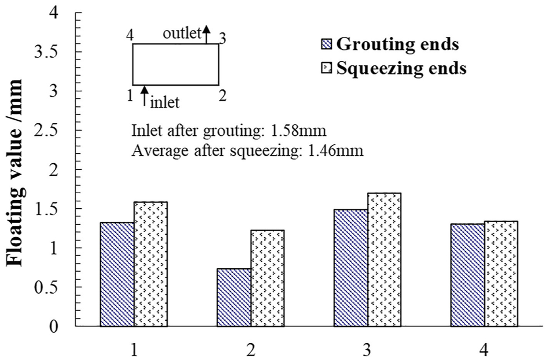

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Figure 6.
Two 7-shaped device at the inlet

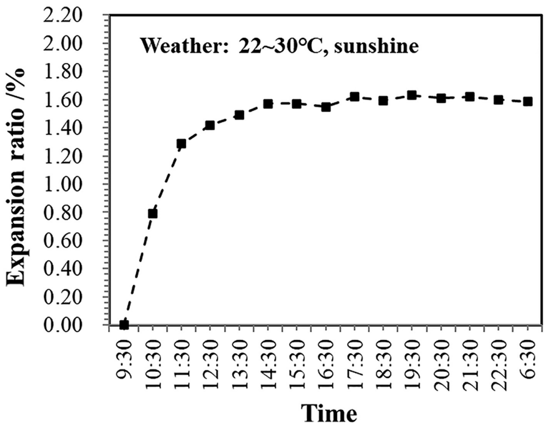

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Figure 7.
Expanding ratio of mortar under sunlight, 22–30°C

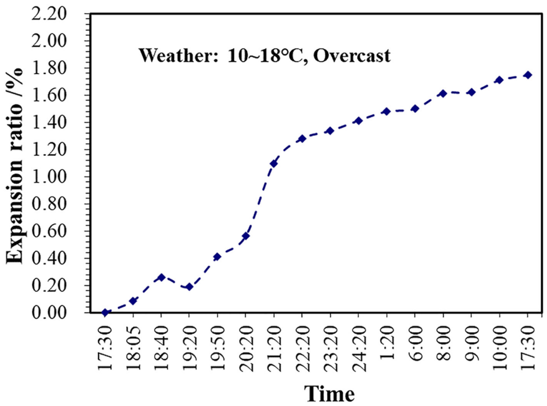

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Figure 8.
Expanding ratio of mortar in shady place, 10–18℃

3.5 Water seepage ratio

The fresh CA mortar of CTRS I type ballastless track was relatively stable, which did not bleed water in its sealed and static state. According to engineering practice, it is found that grouting bag will seepage some water around its periphery because of its water pressure at the inlet and expansion pressure from its inside (Wang *et al.*, 2016). The volume of mortar will shrink, and it also can neutralize some floating and change the microstructure of hardened mortar. The 600 mm × 800 mm × 50 mm grouting bags were made and placed between two small steel slabs, which used to simulate the slab and further to measure its variation of water seepage ratio. The seepage ratio of CA mortar was measured under different environmental temperature and the corresponding results were shown in Figures 9–11.

Figures 9–11 showed that the seepage ratio of mortar between small slabs strongly depended on the environmental temperature. The seepage ratio increased rapidly at the first step for about four hours with the increase of temperature on a sunny day, and then it increased slowly over the following eight hours and finally reached the peak and became stable. On the contrary, the seepage rate slowed down with the decrease of temperature in a cloudy day. During the night time when the temperature cooled down to 10℃, the seepage continued to increase for over 15 h and then became stable. Under different environment, the variation pattern of seepage rate of CA mortar was similar with the expansion and floating, because the setting and hardening process of mortar strongly depended on environmental temperature. The higher the temperature was, the faster the hardening was, which meant the shorter time of expansion and seepage. Besides, after grouting, the variation pattern of slab elevation mainly depended on the interaction between expansion and seepage of the mortar in the filling space.

Figures 9–11 also indicated that seepage ratio of this experiment was around 4%. If we took this value as the seepage ratio of mortar, the volume of the mortar should decrease by 4%, which was much higher than its factual expansion. The reason was that when the small size steel slab was under pressure, the water easily bled from surrounding, however, the track slab in engineering practice was much larger, so only a few water near the surface could exude. As a result, the seepage ratio was too small to counteract the floating, which was contrary to the experimental value in engineering practice. Besides, the periphery color of mortar was lighter than center, when the slab was removed from the hardened mortar, which indicated that periphery of the mortar had less moisture content. For instance, when the track slab was removed after three days, the width of periphery with light color was 20 cm.

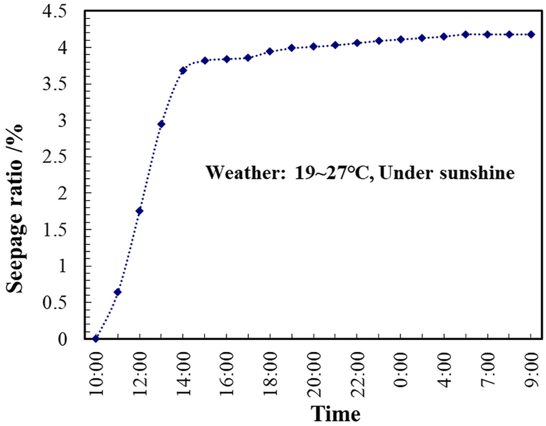

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Figure 9.
Seepage ratio under 19–27℃

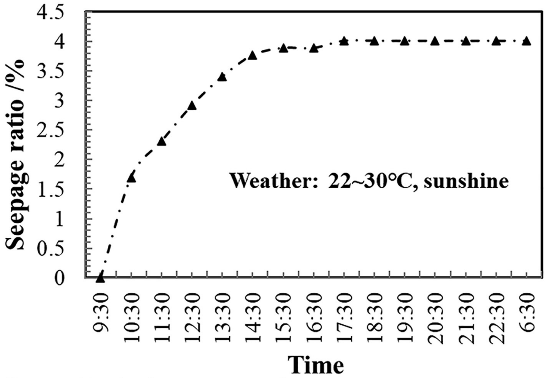

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Figure 10.
Seepage ratio under 22–30℃

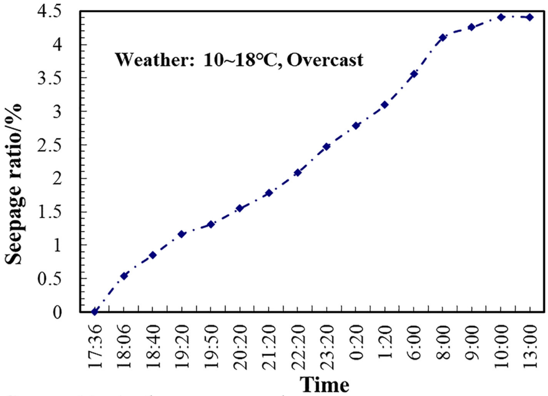

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Figure 11.
Seepage ratio under 10–18℃

In the actual project, the seepage water after pouring CA mortar was sampled, and the seepage was sampled every 15 min, the seepage sample was dried naturally and the solid content was calculated after weighing the residue. The residue was dissolved with trichloroethylene and the soluble component (such as asphalt component) was analyzed. The test results were shown in Figures 12 and 13.

Figure 12 showed that after mortar pouring, the solid content in the seepage water gradually decreased with the extension of time, and it was slowed down after 15 min, then it was stabilized after 30 min. The actual engineering seepage on site began to be turbid and clear in the late stage, which also showed that the early solid composition of the seepage was large and the final solid content was about 3%, including the crystal weight of the inorganic salts in the natural drying process in the seepage. Figure 13 showed that the asphalt content in the seepage water gradually decreased with time and stabilized in the later stage. In addition, without considering the weight of the inorganic salts crystallized into solids in the seepage, assuming that the 3% solid content was all exudate, combined with the soluble matter content and the water seepage area of 20 cm as above mentioned, even if the mortar truck single pot stirring minimum 0.15 m^3 as the base, the total exudation solid content was only about 0.15%. If each piece of 0.6 m^3 as the base, the solid content was only 0.375‰, converted into asphalt, cement, sand and so on, its single component leachate was lower, far lower than the mortar truck measurement deviation of 1% requirements. Therefore, the influence of exudate on mortar composition can be ignored.

3.6 Grouting area

The CA mortar of CRTS I track plays an important role in supporting rail bed. By reference to the frame slab, two strip grouting bag are placed under two flanks of the supporting rail bed to reduce the required liquid pressure. To study the effect of grouting area on the floating height, same track slab, slab pressing device and grouting funnel were used in experiment. The height of grouting funnel was fixed at 100 cm, and the results were shown in Figures 14 and 15.

Figures 14 and 15 indicated that under the same operating condition, grouting at two sides could decrease the floating height significantly that compared with grouting in whole space, as we can see when grouting at two sides, the average value of slab was only 0.17 mm. With same facilities such as same grouting funnels and appropriate height, we can control the floating height within 1 mm, which meets the requirement of current standard. Using strip grouting bag could save grouting time and lower the liquid pressure at inlet, which was more convenient to control the elevation of track slab. Meanwhile, it can save the amount of mortar to save the cost.

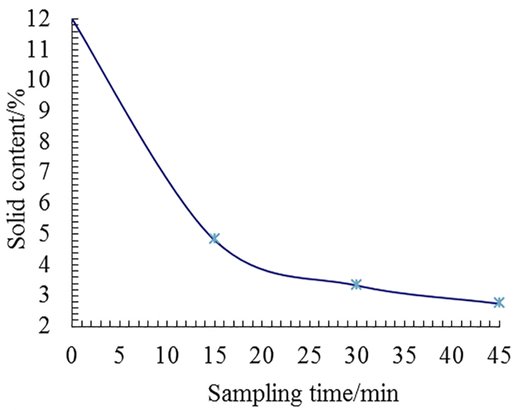

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Figure 12. Solid content of seepage water

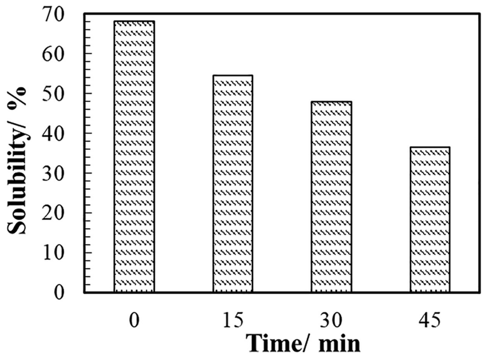

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Figure 13.
Solubility of solid in seepage water

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Figure 14.
Grouting at two flanks

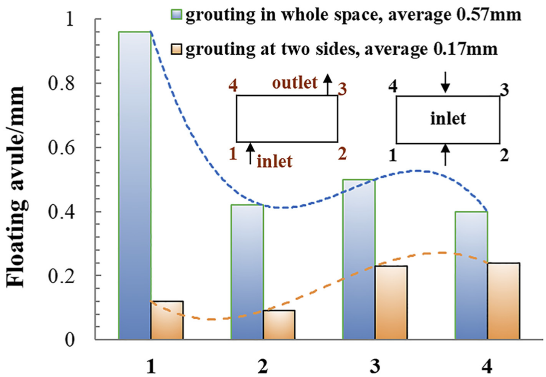

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Figure 15.
Grouting area and floating height

4. Conclusions

We have studied the influence of grouting mortar on geometry status of slab such as the liquid level in funnel, slab pressing method, mortar expansion pattern, seepage ratio and filling area. The following conclusions can be drawn:

(1) The use of slab pressing device still cannot avoid the floating of the track slab caused by CA mortar grouting. With the injection of CA mortar, the track slab floats up significantly, and then the CA mortar extrudes the track slab to the highest point after the end of perfusion. In addition, with the hydration of the CA mortar, the height of the condensed track slab decreases slightly until it finally tends to stable.

(2) The floating force that caused by mortar liquid level exerting on track slab increases with the height of grouting funnel. Per 10 cm increase of liquid level leads to the increase of the floating force of 19.14 kN. When using general grouting funnel, the equivalent press weight that preventing the track slab from floating should be 15.6 T–23.4 T.

(3) "7" shape and angle steel slab pressing device can decrease float values of the four corners after grouting, while "7" shaped slab pressing device is more effective. The increase of the slab pressing device number can make further efforts in against floating. After compacting the CA mortar under the track slab, the track slab will have a future float with the highest elevation of the inlet angle.

(4) The expansion ratio and seepage ratio of CA mortar strongly depend on environmental temperature. Under high temperature, mortar expansion and seepage increase rapidly to the highest point and then become stable, which is familiar with the floating pattern of track slab. Under low temperature, the expansion stage of mortar is extended and the seepage rate of mortar is slowed down, but seepage ratio keeps constant.

(5) The water seepage rate of the small slab has a "size effect", and its value is much higher than the water seepage rate of the mortar under the plate. The solid content in the seepage water gradually decreases with the extension of time, and it tends to stabilize after 30 min. When converted into a single raw material, the amount of seepage is minimal and the impact on the composition of mortar can be completely ignored.

(6) Strip grouting bag at two sides can reduce grouting time and liquid pressure at inlet, making it easier to control the floating elevation. Meanwhile, it can save the amount of mortar as well as the cost.

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Corresponding author
Shaoliang Wu can be contacted at: wushliang@sina.com

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