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Study on Mechanized Construction of Highway Asphalt Concrete Pavement

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ABSTRACT: This research analyzed that the traditional asphalt concrete pavement construction existed lots of defects and deficiencies, which brought many problems to use and maintenance of the completed asphalt pavement, and caused a waste of lots of money and human power. On the basis of analyzing and studying the current construction technology, it proposed a new construction technology and model, and analyzed the stand-alone operation law of the cluster in the new technology; meanwhile, it studied optimal configuration, quality control, and field test of the cluster. On the basis of making the most of the various countries' sturdy on transfer vehicles (MTV), according to the whole asphalt concrete pavement mechanized construction process, this paper systematically studied each process of the whole mechanized construction technology, proposed a new mechanized construction technology based on transfer vehicles (MTV), and made a test research of its actual application in material segregation, temperature segregation and pavement evenness three aspects, proving that the technology is feasible in China, and has a certain practical significance and theoretical significance for the whole asphalt concrete pavement mechanized construction.

KEYWORDS: Engineering machinery; Construction technology; Test research; Transfer vehicle; Asphalt concrete pavement.

INTRODUCTION

The designed service life of the asphalt concrete pavement is generally several years, but the actual service life is only about 10 years. Therefore, the asphalt concrete pavement needs to be overhauled once every 10-15 years. The asphalt concrete pavement mechanized construction process is a dynamic change process with relatively high technology content, and strict requirement for each process. But in the process of asphalt pavement construction, many bad results will also be caused for a variety of reasons, making the asphalt pavement produce some early pavement damage phenomena, such as cracking, rutting, pitting, looseness, water damage, oiling, subsidence and bump at bridge-head (top of culvert), surface function attenuation, etc., which will influence the service life and effect of the asphalt pavement to a great extent [1-3]. The main reason for these results is backward in construction equipment management and construction technology. Those experience and method in low-level pavement construction may be easily introduced to the highway pavement construction and management during the construction process, which will cause many bad results, and consequently bring some hidden danger to use of the pavement. The study of the various countries shows that the key to causing these problems is material segregation and temperature segregation existing in the construction process. No proper solving of these problems not only will influence the construction quality and engineering cost of the asphalt pavement, but also will bring extremely high costs to use and maintenance of the asphalt pavement in the future [4-6].

ANALYSIS OF CURRENT CONSTRUCTION TECHNOLOGY

The current asphalt concrete pavement construction technology mainly includes production, transportation, and paving of asphalt mixture and compaction of paving course, and the mechanical equipment corresponding to them are respectively asphalt mixing plant, dump truck, asphalt paver, road roller. It can be seen from Figure 1 that after all preparation work is done, firstly the asphalt mixing plant will produce the asphalt mixture, and the dump truck will transport the mixed asphalt mixture to the paving site, and directly discharge it in the hopper of asphalt paver, then the paver will carry on paving according to the parameters set in advance, and when the asphalt mixture paved has a proper temperature, the compaction machinery will carry on roller-compaction in different stages. The problems existing in the construction process include mixture material segregation, temperature segregation, stand-alone

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performance and technology application, mechanized collaborative operation, etc. No proper solving of these problems will influence the pavement construction quality [7,8].

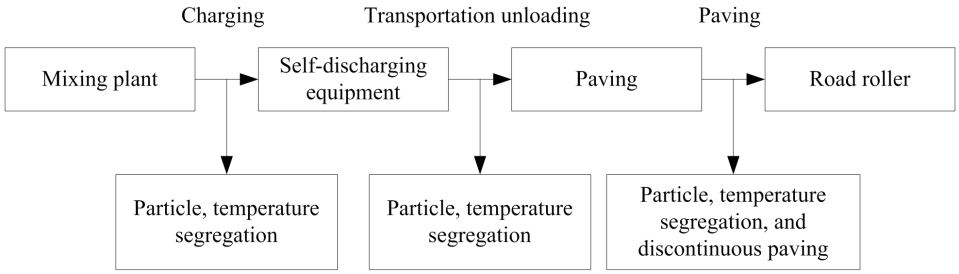

Figure 1. Current asphalt concrete pavement construction technology process.

ANALYSIS OF NEW CONSTRUCTION TECHNOLOGY

In the construction of asphalt concrete pavement, assume that the asphalt pavement can be considered as high-quality as long as these conditions can be met: ① Ensure the quality of raw materials; ② Ensure that the asphalt mixing plant can produce qualified asphalt mixture and meet the work requirements of the paver; ③ Ensure that the asphalt mixture can be timely transported to the paving site, without causing or rarely causing material segregation and temperature segregation; ④ Ensure that the paver has a constant-speed, stable and continuous work; ⑤ Carry on the compaction according to the specified compaction temperature and compaction way. A large quantity of tests and construction experience also shows that in the whole asphalt concrete pavement construction process, a high-quality pavement can be obtained as long as the above conditions can be met or basically met. But how to meet these conditions, the various countries have made many researches. One of the most effective way is to add an asphalt mixture transfer device [9,10] in the paving process, which means that the mixture transported by the dump truck is firstly discharged in the transfer device hopper, then the transfer device will supply materials to the paver hopper after the secondary mixing to ensure the paver has a continuous and stable work. The specific technological process is shown in Figure 2. It can be seen from Figure 2 that after all preparation work is done, the first is to produce the asphalt mixture, then the dump truck will transport the mixed asphalt mixture to the paving site, firstly discharge it in the hopper of asphalt concrete transfer vehicle, and supply materials in the paver hopper after the secondary mixing of the asphalt mixture transfer vehicle. After that, the paver will carry on paving according to the parameters set in advance, and the asphalt pavement paved will be conducted with the roller-compaction by the compaction machinery in different stages when its temperature declines to a suitable compaction range.

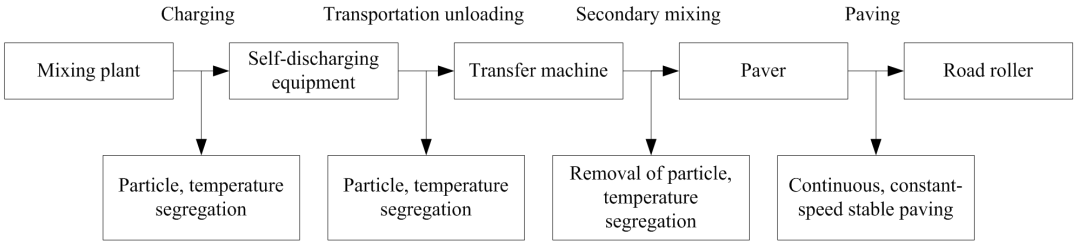

Figure 2. Process of new technology of asphalt concrete pavement mechanized construction.

A set of process, namely the asphalt mixture transfer process is added in the asphalt concrete pavement mechanized construction, which is mainly used to carry on the secondary mixing of asphalt mixture to reduce the material segregation and temperature segregation, meanwhile to ensure the paver has a continuous, stable and constant-speed work, thus to ensure a high-quality asphalt concrete pavement can be paved [11,12].

NEW TECHNOLOGY APPLICATION RESEARCH

In the middle or late December, 2013, LH25 transfer vehicle independently developed by SANY HEAVY INDUSTRY CO., LTD. was put into trial use on Changjin Highway of Jiangxi Province. In the whole construction process, the double paver trapezoidal operation method was adopted, with use of the transfer vehicle on one side and

no use on the other side to make a contrast test. The author made a test research in material segregation, temperature segregation and pavement evenness three aspects.

Mechanical Configuration Method

(1) Number and operating speed of paver

$$Q = \frac{60 \cdot V \cdot D \cdot W \cdot T}{100 \times C}$$

For senior highways, the paving length of a paver shall not exceed 8m, but when it is less than 6.5m, the performance may be better. If the paving width exceeds 8m, two pavers of the same model shall be adopted. In addition, the operating speed of paving machinery shall not be high or too low. That's because when the paving velocity is too low, the capacity of the paver to overcome the running resistance will become weak, while when the paving velocity is too high, with the problems in the dumper cohesion, the paver will have difficulty in continuous operation. Refer to the following formula (1) for the production capacity of the mixing plant calculated thereby:

$$Q = \frac{60 \cdot V \cdot D \cdot W \cdot T}{100 \times C} \tag{1}$$

Where:

V -Paving velocity, m/min;

D -Mixture density, t/m³;

W -Paving width, m;

T -Paving thickness, cm;

C -Paver efficiency coefficient, (0.8-0.9);

Q -Paver productivity, t/h;

$Q' = K \cdot Q$

Q is the paver productivity, and refer to the following formula for the productivity Q' of the mixing plant calculated thereby:

$Q' = K \cdot Q$

(2) Number configuration of transport vehicle

$$n = \alpha \frac{t_1 + t_2 + t_3}{T}$$

The mixture mixed by the mixing plant shall be timely transported to the site. Therefore, in order not to influence the quality of the mixture, the engineering shall be configured with a reasonable number of transport vehicles. For the the requirement of continuous production, the transport vehicle n shall be calculated according to the following formula (2):

$$n = \alpha \frac{t_1 + t_2 + t_3}{T} \tag{2}$$

Where:

t_1 -Heavy load transport time, min;

t_2 -No-load transport time, min;

t_3 -Discharging and storing time, min;

α -Storing coefficient, taking 1.1-1.2;

T -Time required for mixing of a whole vehicle of mixture, min;

Q' -Production capacity of the mixing plant, t/h;

G_0 -Vehicle loading capacity, t;

(3) Road roller number matching

$$K = \frac{(E \times V)}{(S \times B/2)} \times n + 1$$

Compaction is the last process for construction of senior highway asphalt concrete pavement, and is also a key step to ensure the construction quality. The insufficient compaction will cause large voidage, while the excess compaction will make the pavement voidage become too small, or will cause the mineral aggregate crushing, make the pavement appear the instability phenomenon, and influence the pavement strength and stability. Therefore, refer to the following formula (3) for the number of road roller:

$$K = \frac{(E \times V)}{(S \times B/2)} \times n + 1 \quad (3)$$

Where:

K -Necessary number of road roller;

n -Required compaction times, taking full-width back and forth compaction as one time;

S -Speed of road roller, m/min;

V -Velocity of paver, m/min;

E -Road width, m;

B -Effective width of road roller, when it is steel wheel, B is 2/3 of the wheel width; when it is rubber wheel, B is 1/2 of the wheel width; when it is vibratory wheel, B is the wheel width subtracted by 0.2m.

4.2 Reduction of material segregation

(1) Sampling method

Through the sampling of left, middle, right three points of front, rear hoppers of the asphalt mixture transfer vehicle, the extraction and screening shall be made to measure its grading, and compare it with the designed standard grading, thus to understand the segregation condition of the asphalt mixture discharged from the transport truck and the secondary mixing of the transfer vehicle and its role in improving the gradational segregation of the asphalt mixture. As the mixture in the front hopper of the transfer vehicle is directly discharged from the truck, it can reflect the grading condition of the mixture discharged from the truck to the paver hopper.

The left, middle, right three points of the paving of two pavers (after the paving, before the compaction) shall be respectively sampled. The sampling is to directly dig into the bottom of this layer with a shovel, namely sampling along the entire thickness, then to make the extraction and screening, and evaluate the segregation condition of the asphalt mixture paved by the paver.

(2) Contrast test of grading of the mixture in the front, rear hoppers of the transfer vehicle

As shown in Figure 3 and Figure 4 (in Figure 3 and Figure 4, "Sany Transfer" represents the transfer vehicle of SANY HEAVY INDUSTRY CO., LTD.; "Front" means the front hopper, and "Rear" means the rear hopper): The distribution of the asphalt mixture discharged from the dumper to the transfer vehicle exists a big segregation. Two outermost grading curves in Figure 3 are all the grading curve for the mixture directly discharged from the truck. The grading curve of the mixture of three different positions shows that the mixture discharged from the truck exists a certain segregation, finer in the middle part and coarser in the two sides. Through the comparison of Figure 3 and Figure 4, it can be seen that before being mixed by the transfer vehicle, the grading curve of the mixture of three different positions has a big degree of deviation. For example, the range of the grading curve with the screen size of 4.75, 9.5, 13.2, 16mm is respectively 10.85%, 19.88%, 18.59%, 11.56%, while the degree of deviation for the grading curve of the asphalt mixture after the secondary mixing of transfer vehicle decreases significantly, and the corresponding range is respectively 6.85%, 6.04%, 4.01%, 3.21%. This shows that there is an obvious improvement of grading of the asphalt mixture after the secondary mixing of transfer vehicle, and the biggest improvement degree is 16.67%, making the asphalt mixture have a better evenness. The average range before transfer is 6.11%, and the average range after transfer is 3.52%.

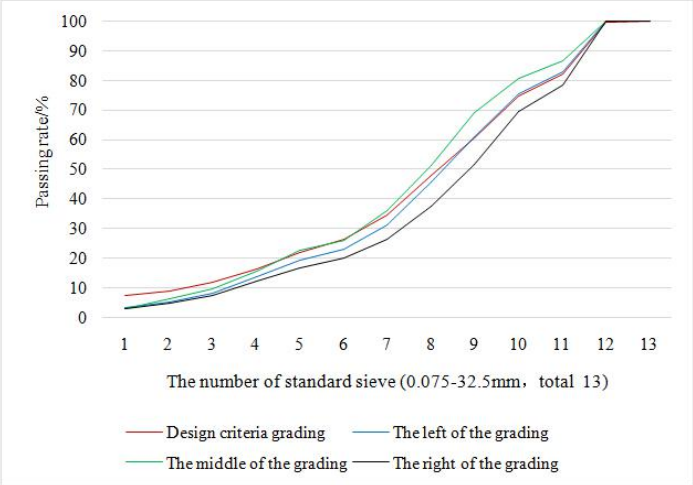

Figure 3. Grading of the mixture in the front hopper of the transfer vehicle.

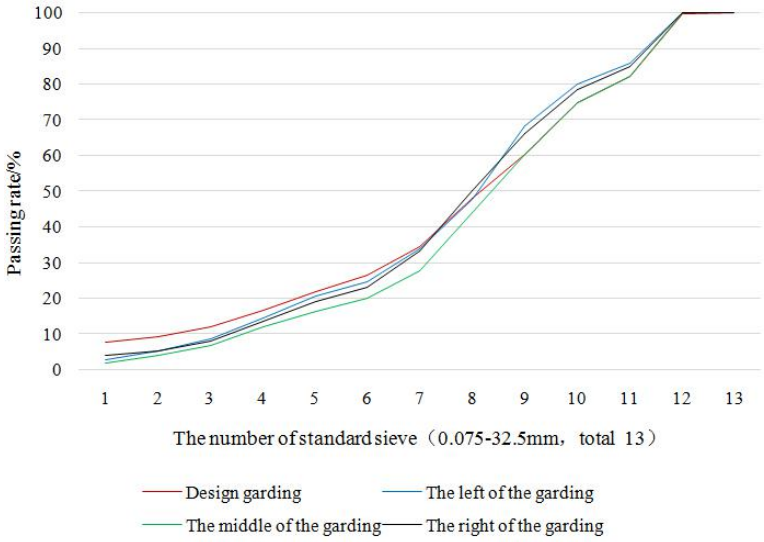

Figure 4. Grading of the mixture mixed by the transfer vehicle.

(3) Contrast test of grading of the asphalt mixture with using and no using of the transfer vehicle for paving

Through the comparison of grading of the pavement mixture paved by different paving operation modes in Figure 5 and Figure 6 (in Figure 5 and Figure 6, "ABG" and "Sany" respectively represent ABG company and the pavement paved by the transfer vehicle paver that is produced by SANY HEAVY INDUSTRY CO., LTD.), it can be seen that

when the transfer vehicle is not adopted, the grading between the pavement mixture within a certain range of both sides of the paver and the mixture of middle area has a big difference. The mixture of both sides is coarser than that of middle area, while the evenness of the asphalt mixture paved by the paver after the transfer vehicle is adopted is obviously superior to the paving effect without adopting the transfer vehicle for paving. The average range of grading of the pavement mixture without adopting the transfer vehicle for paving is 7.42%, while the average range of grading of the pavement mixture paved by adopting the transfer vehicle is 3.38%.

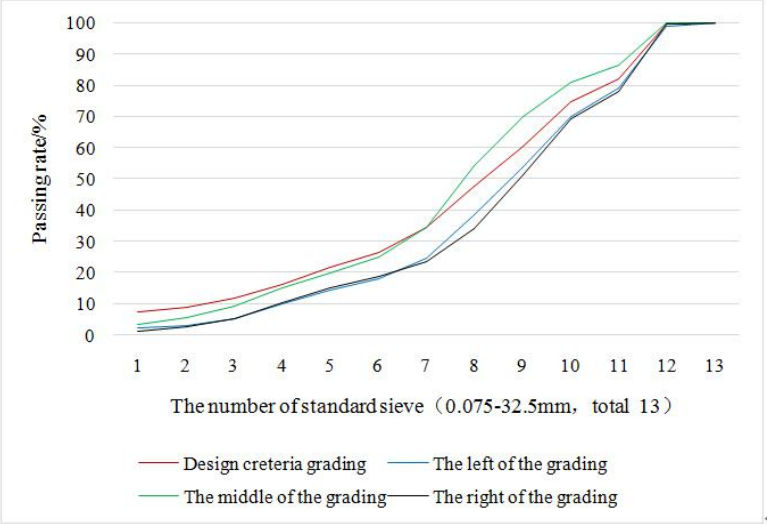

Figure 5. Grading of the pavement mixture without adopting the transfer vehicle for paving.

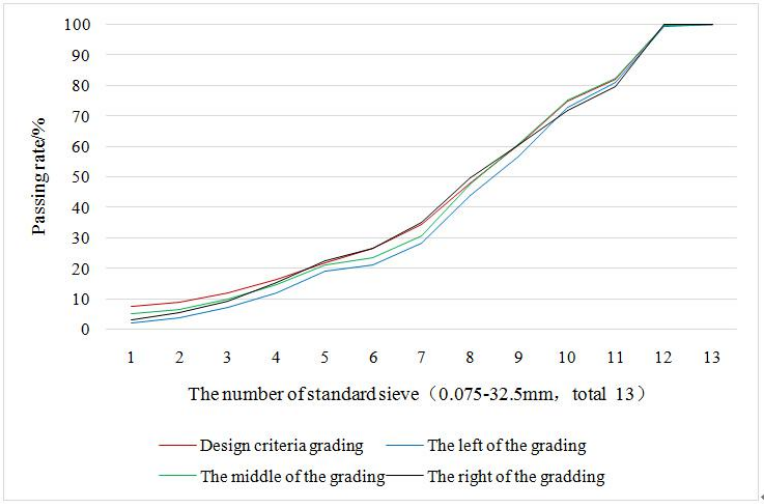

Figure 6. Grading of the pavement mixture by adopting the transfer vehicle for paving.

Temperature Segregation

(1) Sampling method

The test points for temperature uniformity in the auger conveyor of the paver are shown in Figure 7.

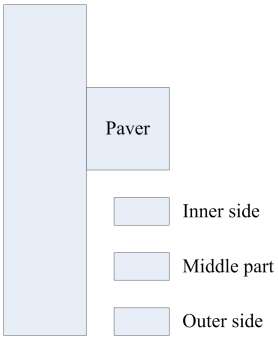

Figure 7. Test points for temperature uniformity of the paver auger conveyor.

The paving surface temperature uniformity test method is shown in Figure 8, with 7 temperature test points set in the width of 6m and with the time interval of 1min.

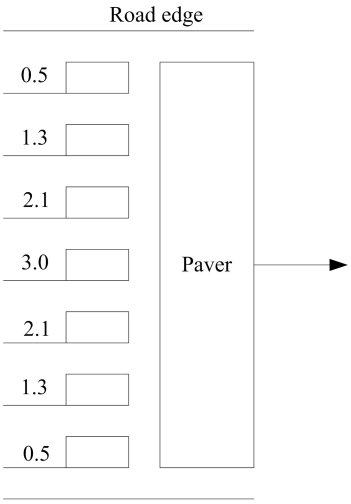

Figure 8. Paving belt surface temperature uniformity test points per meter.

(3) Contrast test of temperature uniformity in the paver auger conveyor with using and no using of the transfer vehicle

When no transfer vehicle is adopted, the temperature distribution in the paver auger conveyor is shown in the Table 1, and when the transfer vehicle is adopted, the temperature distribution in the paver auger conveyor is shown in the Table 2. From Table 1 and Table 2, it can be seen that when the transfer vehicle is adopted, the temperature distribution in the paver auger conveyor is relatively uniform, and with the time change, the asphalt mixture is even, stable, basically removing the temperature segregation phenomenon. When no transfer vehicle is adopted, the temperature in the paver auger conveyor is extremely different and nonuniform, presenting a periodical change with the time change, and a large fluctuation range. Sometimes, the temperature difference may reach 15℃. This phenomenon is similar with the test results of the paving belt surface temperature.

Table 1. Paver edge temperature (no transfer vehicle) (℃)

Time	Inner side	Middle part	Outer side	Range	Time	Inner side	Middle part	Outer side	Range
15:53	141	130	144	13	16:14	143	135	143	8
15:54	156	161	153	8	16:15	150	139	142	11
15:57	162	162	155	7	16:16	160	153	143	17
16:00	158	155	159	4	16:18	156	159	155	4
16:02	161	148	154	13	16:20	159	155	147	12

16:09	154	145	145	9	16:22	156	150	154	6
16:11	155	155	137	15	16:24	153	159	156	6
16:12	130	142	141	11	16:26	157	151	154	6
16:13	138	148	133	15	16:28	159	156	153	6

Table 2. Paver edge temperature (with transfer vehicle) (℃)

Time	Inner side	Middle part	Outer side	Range	Time	Inner side	Middle part	Outer side	Range
17:02	154	148	249	6	17:11	150	147	151	4
17:03	146	150	148	4	17:12	148	149	150	2
17:04	150	151	149	2	17:13	151	152	152	1
17:05	154	150	150	4	17:14	154	158	156	4
17:06	154	153	154	1	17:15	150	155	157	7
17:07	154	156	150	6	17:16	158	152	153	5
17:08	154	154	155	1	17:17	153	158	158	5
17:09	151	149	150	2	17:18	159	158	157	2
17:10	152	153	148	5	17:19	154	155	156	2

(3) Contrast test of temperature uniformity of the paving belt surface with using and no using of the transfer vehicle

When no transfer vehicle is adopted, the temperature distribution of the paving belt surface is shown in Table 3, and when the transfer vehicle is adopted, the temperature distribution of the paving belt surface is shown in Table 4. It can be seen from the measured data that when the transfer vehicle is adopted, the temperature distribution of the paving belt surface is relatively uniform. On one hand, the temperature is uniform, stable with the time change; on the other hand, the temperature along different paving widths at the same time is also relatively uniform, with a small difference. The test results of the infrared spectrum instrument of Chang'an University on the site also show that its paving surface temperature is uniform, basically removing the temperature segregation phenomenon. When no transfer vehicle is adopted, the paving surface temperature is extremely different, and nonuniform. On one hand, the temperature has a big fluctuation, and sometimes it may approximate to 23°C. The mixture with low temperature is mainly from the hopper edge, and frequently taking back the hopper causes the periodic local low-temperature area. On the other hand, the temperature along different paving widths at the same moment also has a big difference.

Table 3. Paving surface temperature (℃) (no transfer vehicle)

Time	Position					Time	Position				
12.19	0.5m	1.3m	2.1m	3.0m	Range	12.19	0.5m	1.3m	2.1m	3.0m	Range
9:26	144	139	143	135	9	9:33	144	146	148	138	10
9:27	149	147	147	145	4	9:34	145	138	145	137	8
9:28	146	142	136	134	12	9:35	137	140	144	143	7
9:29	145	143	128	138	7	9:36	141	126	136	135	15
9:30	147	137	135	137	12	9:37	135	112	119	134	23
9:31	142	136	144	135	8						

Table 4. Paving surface temperature (℃) (with transfer vehicle)

Time	Position					Time	Position				
12.18	0.5m	1.3m	2.1m	3.0m	Range	12.18	0.5m	1.3m	2.1m	3.0m	Range
11:32	138	139	137	138	2	11:45	141	142	143	142	2
11:33	137	142	136	137	6	11:46	143	143	142	141	2

11:34	143	144	139	137	7	11:47	143	143	143	140	3
11:35	145	144	148	140	8	11:48	142	143	143	141	2
11:36	145	145	146	140	6	11:49	142	142	142	140	2
11:37	145	144	145	143	2	11:50	141	143	143	142	2
11:38	143	144	147	144	3	11:51	141	142	144	141	3
11:39	142	145	147	142	5	11:52	142	140	143	139	4
11:40	145	146	142	141	5	11:53	143	141	142	140	3
11:41	146	146	144	143	3	11:54	143	141	142	139	4
11:42	147	147	148	144	4	11:55	142	141	140	140	2
11:43	144	142	146	144	4	11:56	142	141	140	140	2
11:44	141	143	145	143	4						

CONCLUSION

(1) This paper proposed a new technology of adding the asphalt mixture transfer vehicle in the traditional asphalt concrete pavement construction on the basis of analyzing the deficiencies of the traditional asphalt pavement construction. The use of the asphalt mixture transfer vehicle can effectively reduce the asphalt mixture segregation, temperature segregation and improve the evenness of asphalt pavement.

(2) The new technology proposed for construction of the asphalt concrete pavement intelligent cluster is the asphalt mixture transfer vehicle + double paver trapezoidal operation method, which is feasible in the actual construction.

(3) The construction technology model of the asphalt concrete pavement intelligent cluster is composed of asphalt mixture temperature change model, cluster optimal configuration model and cluster construction technology control model.

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