Research on Application of Pavement Quality Indicator and Infrared Thermal Camera in Asphalt Pavement Process Control in China

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ABSTRACT: Based on the results from the investigation and research of some testing roads in China with new technical detecting devices such as Pavement Quality Indicator(PQI) and Infrared Thermal Camera(ITC), the research summarizes the results of the experiments in asphalt pavement paving and compacting, offers a practical asphalt pavement construction quality process control method to guide asphalt pavement construction in China. Research and analysis of combining using of PQI and ITC figures out the asphalt pavement segregation positions, finds out the relationship between different compaction ways, offers a practical method to judge the arrangement of construction machines and the number of compacting, minimizes the segregation and also decreases the construction cost. Temperature segregation on asphalt pavement could be effectively detected by ITC and PQI. So, segregation could easily be revealed by detecting the temperature difference, especially comparing with using Mixture Transfer Vehicle(MTV) and not. Detecting the compacted test pavement section with calibrated PQI shows higher accuracy to the density of asphalt layer. The relativity to the results from core drilling can be above 90%. This means it can replace the traditional testing method. It is helpful for the research on variabilities of asphalt compaction, void volume, gradation and asphalt-aggregate ratio. It is also helpful for obtaining experiment foundation for the achieving of asphalt pavement quality process control. Besides, it provides a higher accuracy in compaction testing and paving segregation monitoring and evaluating. These construction technologies secure a good condition for construction and minimize the early damages as well.

KEY WORDS: Asphalt pavement, process control, pavement quality indicator, infrared thermal camera.

1 INTRODUCTION

Controlling the density of hot mix asphalt (HMA) during the construction of asphalt pavements is an important factor that can directly affect the quality and the long-term performance of the pavements. A process that can provide accurate, expedient and cost effective monitoring the density of HMA during the construction is very important. The coring process traditionally used for obtaining asphalt pavement density is time-consuming, costly, and destructive to new pavements. The drawbacks mentioned above for using the coring method have handicapped the monitoring of asphalt pavement density during the construction and to a certain degree contributed to the poor asphalt pavement performance and the long-term durability problems in many asphalt pavements in China. Currently the used of PQI in China is very limited, primarily in the state of exploratory and research. The use of PQI for monitory asphalt pavement density during the construction is very limited. There are several reasons that have contributed to that. One of the reasons is the lack of reliable field data of using PQI for measuring HMA density in China.

Seggregation is also a key problem in HMA construction. It is always ignored and hard to detect. Using ITC can solve this question successfully. As a new detect technical equipment it is gradully accepting for engineers.

This paper presents several research studies especially for collecting HMA density data measured using PQI and that from the coring process in several asphalt pavement construction project in China. Analyses of these data as summarized in this paper have confirmed that the viability of using PQI for measuring HMA density in the field as a means for asphalt pavement compaction quality control. Analyses of ITC data have revealed it can be used to judge and evaluate the seggregation area.

This paper is organized as follows. A brief description of PQI and ITC are first presented. The use of PQI for comparison with that from the core density are presented to establish the accuracy and reliability of using PQI in China. Two case studies of using PQI for monitoring asphalt mat compaction density are presented to demonstrate the potential benefits of using PQI for QA asphalt pavement construction. One case study of using ITC for judging and evaluating the seggregation area by comparing with using HMA transfer vehicle and w/o. Finally, conclusions are presented.

2 ABOUT PQI AND ITC

PQI and ITC were invented firstly in the United States and some researchers have taken the lead in research. The article published based on PQI and ITC are few in China.The density of HMA in asphalt pavements is directly proportional to the measured dielectric constant of the material. The density is measured by the response of the PQI's electrical sensing field to change in electrical impedance of the material matrix, as shown in Figure 1 and Figure 2. The composite dielectric constant of a HMA includes the aggregates, asphalt binder and the air trapped in the voids of HMA. Since the dielectric constant of air is much lower than that of the other constituent materials in a HMA, therefore, as compaction action densities the HMA combined dielectric constant increases because the percentage of air voids in the HMA decreases. The embedded computer in the PQI converts the field signals into the density readings.

To obtain accurate HMA density readings the PQI must be calibrated at each job site by taking the PQI readings on the asphalt mat and compared with the density results obtained from the core samples taken from the same locations.

The temperature segregation is liable and common to happen in the HMA construction. It must be tested with temperature devices such as ITC because of hard finding for nake-eyes. ITC is a popular inspection equipment well using in HMA temperature segregation diagnosis and evaluation. It can be used in alliance with MTV for non-contact measurement by some develped countries. But researchs on ITC are not deeply done in China these years.

Figure1: Exterior appearance of PQI

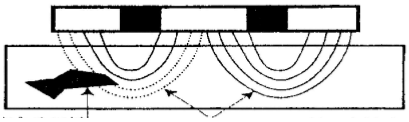

Figure 2: Principle for PQI detecting

Figure 3: Infrared thermal camera

3 COMPARISON AND CALIBRATION OF PQI

The following asphalt paving projects was selected as the test sites in order to demonstrate the applicability, accuracy and advantage of using PQI for measuring the density of compacted hot mix asphalt mixes (HMA) during the asphalt paving operations.

The test section was on the expressway between Bozhou and Fuyang in Anhui Province. The pavement structure for this motorway consists of 3 layers of HMA, 4 cm of SMA-13mm (SBS), 6 cm of AC-20mm (SBS) and 6 cm of AC-20mm, and 35 cm of cement treated semi-rigid base and 20 cm of cement-stabilized soubise. The test section was on the middle asphalt layer. A total of 51 sampling points were selected on different lanes with some on the shoulders where the surfaces exhibited apparent segregation and with large exposed coarse aggregates on the surface. The purpose of this investigation was to assess the ability and accuracy for PQI to determine the HMA density on this type of asphalt pavement surface. The results are presented in Figure 4.

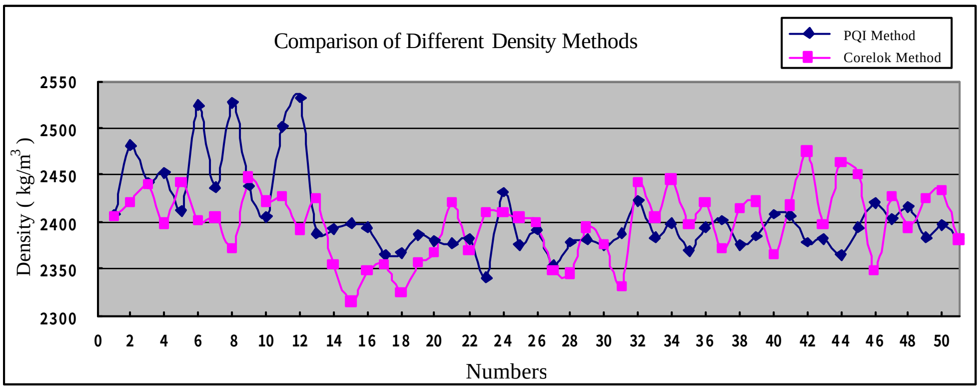

Figure 4: Comparison of PQI and core density

It is important to point out that among the first 12 measuring points the PQI density readings were based on the calibration from a non-segregated smooth asphalt pavement surface. This resulted in erratic PQI density readings among these 12 measuring points. This was done intentionally to find out the effect of using improper calibration for PQI on the accuracy of determining the HMA density. The PQI was then re-calibrated on the segregated surface. The remaining PQI density readings (point #13 to #51) were then performed after the re-calibration. The errors between the PQI density readings with that of the core density data was much lower among these measuring points. The percentage error between the PQI density readings and that of the core density data for the first 12 points was 2.43%; while that for the last 39 points was 1.44%. These pointed out the importance of proper calibration on the accuracy of the PQI density measurements.

4 PQI FOR MONITORING PAVEMENT CONSTRUCTION

Although the advantages of monitoring asphalt pavement compaction efforts for obtaining optimum compaction results and improving the construction efficiency have been recognized, often it was not practical to implement such practice with the traditional method for measuring the HMA mat density by the coring process. Use of nuclear density gage could do this, but is still cumbersome. PQI offers many advantages for providing real-time monitoring of HMA compaction in the field. It is lightweight and easy to transport and accurate readings can be obtained in 3 to 5 seconds that make it feasible for the operator to take the mat density readings following each pass and get out of the way of the roller prior to the next pass. As mentioned before, being containing non-nuclear source means no licensing requirements and no safety concerns. All these make it practical for using PQI to do this type of work practically and cost effectively. The following 2 field investigations were carried out to demonstrate the potential use and the benefits of using PQI in monitoring the asphalt compaction operations. This was a part of the research efforts in assessing the potential use of PQI for the QA control of asphalt pavement construction in China.

4.1 Case I

The main objective of this field investigation was to evaluate the use of PQI to monitor the degree of compaction of asphalt mats. The test section was on Bo-Fu Motorway in Anhui Province, the same one described in Section 3. The pavement structure for this motorway consists of 3 layers of HMA, 4 cm of SMA-13mm (SBS), 6 cm of AC-20mm (SBS) and 6 cm of AC-20mm, and 35 cm of cement treated semi-rigid base and 20 cm of cement-stabilized soubise. The monitoring of the compaction effort report in this section was for paving and compaction of the second HMA layer. The test section consists of 5 measuring points, each 5 meters apart along the paving direction.

The compaction process consisted of a total of 9 passes using 4 different types of rollers. DD-110 and XD-120 were steel rollers while YL20A and YL26 were rubber tired rollers. This represents the typical equipment and the rolling process for compacting asphalt pavements in China

Breakdown Rolling: 1 pass using a DD-110 Roller with weak vibrating action when moving forward in the first half rolling pass and then changes to strong vibrating action in the return pass.

Intermediate Rolling: 2 pass using a XD-120 Roller with strong vibrating action, 2 pass of kneading compaction with YL20A and YL26 Rollers, 1 pass of static rolling with a DD-110 Roller, 2 pass of kneading compaction with YL20A and YL26 Roller.

Finishing Rolling: 1 pass of finishing rolling with a DD-110 Roller.

The HMA laydown temperature should not be lower than 160 ℃, and the finishing rolling should be completed before the temperature in the mat fell below 90 ℃. Another requirement was that the maximum temperature in the HMA should not exceed 195℃, or the mix should be abandoned.

The mat density at each of the 5 measuring point after each pass of the roller and the density behind the paver and before the breakdown rolling (0 pass) were measured by PQI and the results are summarized in Table 1 and Figure 5.

Table 1: Density and Compaction Passes of Samples （g/cm^3）

pass / point	0 pass	1st pass	2nd pass	3rd pass	4th pass	5th pass	6th pass	7th pass	8th pass	9th pass
1	2.221	2.32	2.373	2.386	2.40	2.401	2.391	2.37	2.379	2.405
2	2.241	2.33	2.373	2.388	2.40	2.397	2.391	2.37	2.386	2.414
3	2.268	2.33	2.360	2.398	2.40	2.402	2.376	2.37	2.390	2.401
4	2.249	2.30	2.359	2.393	2.40	2.392	2.395	2.37	2.401	2.407
5	2.233	2.30	2.357	2.365	2.39	2.390	2.398	2.37	2.398	2.384

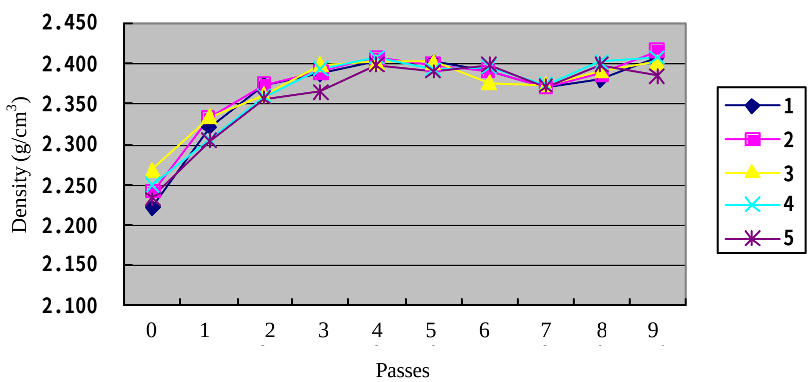

Figure 5: Density and compaction passes of samples

The HMA densities from all 5 measuring points as shown in Table 1 and Figure 5 indicated that the density results measured by PQI at these 5 locations were all very consistent. The trends of density versus rolling pass shown in Figure 5 can be divided into the following 4 stages:

(1) Densification stage: During the first 3 rolling passes, including the breakdown rolling and 2 intermediate rolling using the steel roller with strong vibrating actions, caused the mat density to increase rapidly.

(2) Achieve maximum density: The mat density reached the maximum after pass #4 with the application of one kneading compaction using the rubber tired rollers.

(3) Decline mat density: The kneading compaction using the rubber tired roller in pass #5 and the compaction in pass #6 using the static steel roller had caused the mat density to decrease.

(4) Increase mat density again: The additional kneading compaction in pass #7 and pass #8 and the finishing rolling in pass #9 caused the mat density to increase again to the same density reached at stage 2.

This is very interesting in that according to the results shown in Table 1 and Figure 5, the traditional rolling process employed by China asphalt paving contractors was inefficient. According to the results shown in this study, pass #5, 6, 7, and 8 were not needed. Only pass #2, #3, and #4 were required for the intermediate rolling and could immediately followed with the finishing rolling (pass #9). This would save nearly 40% to 50% of the compaction efforts. This would be particularly significant in light of the fact that full width paving (7 m or wider paving width) is the most common practice in the asphalt paving operation in China. By reducing the number of rolling pass from 9 to 5 for the full width paving would significantly improve the compaction efficient and that would result in improving the overall paving efficient and the quality of the pavement.

Obviously these results were only from one study. More studies along this line to cover different HMA types, different thicknesses and using different compaction equipment and different rolling processes will be needed to further confirm and validated the results. However, the availability of PQI with its lightweight, easy to handle and rapid density reading capability has mdke such types of studies practical.

4.2 Case II

Segregation of HMA during the paving operation is quite common in China. This would lead to poor pavement performance and affecting the long-term durability. Some transportation agencies have required paving contractors to use material transfer vehicles (MTV) in the paving train to mitigate the potential segregate problem. The purpose of this study was to assess the effect of with and without using MTV on the effect of reducing HMA segregation by measuring the compacted asphalt mats using PQI. The test section was on Bo-Fu Motorway in Anhui Province and the pavement structure for this motorway consists of 3 layers of HMA, 4 cm of SMA-13mm (SBS), 6 cm of AC-20mm (SBS) and 6 cm of AC-20mm, and 35 cm of cement treated semi-rigid base and 20 cm of cement-stabilized soubise. The investigation report in this section was during the paving and compaction of second HMA layer.

The PQI density measurements were conducted at four locations, two (at K16+350 and K16+300) with the conventional paving operations without using MTV and the other two (at K15+400 and K15+310) in which MTV was used in the paving operation. At each location PQI density measurements were conducted at ten randomly selected measuring points immediately after the finishing rolling. The results are presented in Table 2 and Figure 6.

Table 2: Comparison HMA density with and without using MTV(kg/m^3)

No.	Sta.	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#	Avg.	Standard Deviation
No MTV	K16+350	2460	2524	2354	2417	2359	2381	2525	2413	2377	2394	2420	2.60 %
No MTV	K16+300	2389	2527	2382	2399	2419	2447	2375	2430	2340	2276	2398	2.77 %
Use MTV	K15+400	2407	2411	2388	2437	2426	2413	2409	2441	2415	2444	2419	0.73 %
Use MTV	K15+310	2446	2443	2441	2460	2392	2459	2440	2414	2431	2377	2430	1.74 %

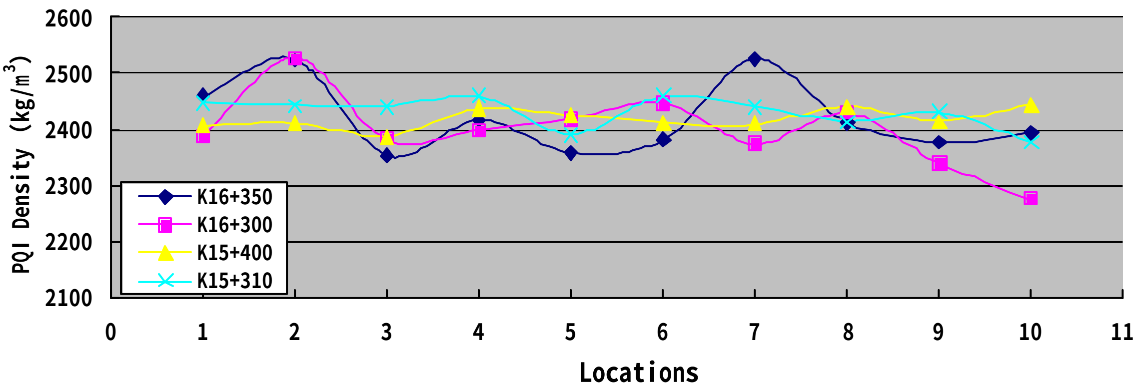

Figure 6: Comparison HMA density with and without using MTV(kg/m^3)

The results show that with using the MTV the mat densities were much more uniform with standard deviations of 0.73% and 1.14% over the mean densities of 2419 and 2430 kg/m^3 for K15+400 and K15+310 respectively; while for the 2 locations without using MTV, the standard deviations were 2.60% and 2.77% over the mean densities of 2420 and 2398 kg/m^3 respectively for K16+350 and K16+300 sections. This clearly showed that use of MTV can indeed reduce the segregation of HMA during the paving operation. Again, the use of PQI has made this investigation practical.

5 ITC FOR JUDGING SEGGREGATION AREA

The test section was also on Anhui province. To compare with two cases, one is using MTV and the other without. The temperature filed can be analysis after paver closed mixture peck. Contrasting with two conditions: firstly there is only one paver and secondly a pair pavers, to ascertain the effects and sample test point consecutively, it is easy to find that the segregation rate is positive correlation to the temperature fluctuation.

The test section was on the expressway between Chuzhou and Nanjing in Anhui Province. The whole length is 85km. The pavement structure for this motorway consists of 3 layers of HMA, 4 cm of AC-13mm (SBS), 6 cm of AC-20I mm (SBS) and 6 cm of AC-25mm, and 35 cm of cement treated semi-rigid base and 20 cm of cement-stabilized soubise. The test section was on the middle asphalt layer. A total of 300m section was used MTV and the other 300m was not.

Table 3: Content of test

	Contents	Method
Paving Process (w/ & w/o MTV)	After close the mixture peck	With ITC

To consider the differences between two technics, one is use transfer vehicle, the other is not. With ITC detecting the field , it is easy to judge the effect as figure 7 shown.

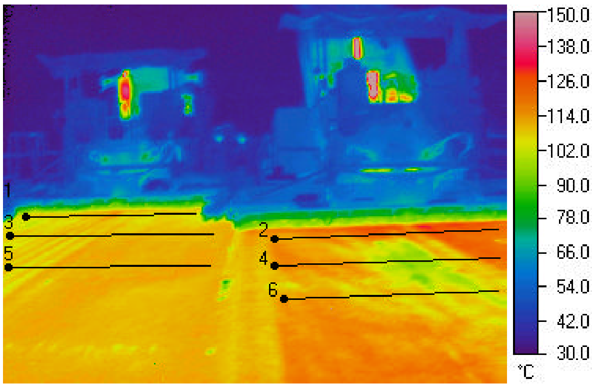

Figure 7: The temperature distributing field on terraced paving (Left: w/ MTV. Right: w/o MTV)

From Figure 7, the picture indicate that the temperature distributions are easily detected, the biggest difference of temperature can reach 15～25℃ if there is no transfer vehicle, but it can be reduced to 5～10℃ for using transfer vehicle. It is clearly that using ITC can help finding the seggregation areas and locating them directly. So ITC could be used in asphalt pavement quality process control.

6 CONCLUSIONS

Controlling density of HMA during the construction of asphalt pavements is an important factor that can directly affect quality and long-term performance of asphalt pavements. The PQI provides an attractive alternative for monitoring asphalt pavement density in the field and ITC gives a effective solution for judging and evaluating the seggregation area during the construction. This is particularly appealing to the asphalt paving industry in China as the potential exposure to radiation hazards for using the nuclear density gages has deterred the asphalt pavement construction industry from using nuclear density gages and that leaves the coring process to be the only alternative, which is time-consuming, costly, and destructive to new pavements. The following conclusions can be drawn from this research study.

(1) The differences between the density readings from the PQI and that from the core samples were very small, within 2.0% difference.

(2) It is important that PQI should be pre-calibrated on asphalt mat with similar characteristics to that where the density is to be measured. In the study presented in this paper for measuring the density of a moderately segregated asphalt pavement, it was found that pre-calibration of PQI on the same segregated mat and that on a non-segregated smooth asphalt mat resulted in significant difference on percentage error in the density measurements, 1.44%

and 2.43% respectively, when compared with the core densities.

(3) PQI offers many advantages for providing real-time monitoring of HMA compaction in the field due to its lightweight and ease for transporting and can rapidly obtained density readings. These features make PQI practical for QA control of asphalt pavement construction in China. In one of the study presented in the paper, the number of passes for achieving the desired compaction in an asphalt project could be reduced from 9 to 5 passes. This would significantly improve the compaction efficient.

(4) It is easy to judge and evaluate the seggregation area with ITC. There are some seggregations unavoidable by traditional technics. ITC can make seggregation area visualize and help managers to adopt a measure to avoid the seggregation.

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