International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Heat and Technology
Vol. 43, No. 2, April, 2025, pp. 741-750
Journal homepage: http://iieta.org/journals/ijht

Thermal and Rheological Properties Tracking of Asphalt Binder in Flexible Pavement Using Smartphone Thermography Method: A Case Study

Abdulhaq Hadi Abdali

Department of Highway and Transportation Engineering, College of Engineering, Mustansiriyah University, Baghdad 10244, Iraq

Corresponding Author Email: abdulhaq1969@uomustansiriyah.edu.iq

https://doi.org/10.18280/ijht.430233

Received: 5 February 2025
Revised: 26 March 2025
Accepted: 9 April 2025
Available online: 30 April 2025

Keywords:
asphalt binder viscosity, asphalt mixture plant, infrared thermal imaging, thermal changes

ABSTRACT

The process of collecting field temperature observations of the asphalt mixture plant is conducted using a portable camera connected to a smartphone using infrared thermal imaging techniques within the spectral range from 5.6 to 20 micrometers at a 1.0 m imaging distance. The field observations are validated from infrared thermal imaging. The temperatures have been measured and analyzed so as to be correlated to the source of emission and the extent of its change during the stages of implementing the asphalt mixture paving process. The study was applied to the streets of the Badour Baghdad residential complex. FLIR ONE is a miniature thermal imaging camera compatible with a smartphone, and it is used to measure and evaluate the effect of temperature changes on the surface of the tiling layer and to determine the location of the highest and lowest temperatures within the imaging area. Transporting the asphalt mixture from the factory to the work site is an important stage in the deterioration of its temperatures. This process causes repeated changes in the properties of the asphalt binder and possible acceleration. There is a large discrepancy between the paving surface and its bottom, which generates large changes in the viscosity of the asphalt binder used within the thickness of one layer. The thermal survey concluded that it increased was concentrated at the asphalt tank, rotary kiln, and mixer, where it reached 165℃, and decreased during paving and tiling to reach less than 100℃. This difference significantly changes the efficiency of the asphalt binder.

1. INTRODUCTION

The asphalt mixture passes through multiple stages, and changing conditions require focusing on the design process and considering these changes. An appropriate mechanism should be determined and developed for selecting materials and conducting tests to ensure the preservation of the properties of the produced mixture and avoid failure. As is known, the asphalt mixture consists of aggregates in multiple grades to ensure stability and stability of the mixture and to prepare the mixture to resist different weather and traffic conditions. This process requires the presence of a binder with acceptable specifications to bind the aggregates to achieve the required stability. Asphalt is the basic binder for this mixture, separately or with the other additional materials that assist in improving the bond strength and keep the mixture stable for the longest possible period, which represents the life of the asphalt mixture or the service life of the paving.

Temperature plays a pivotal and major role in determining the strength of this bond because the asphalt bond needs heat within certain ranges to work on good bonding between the aggregates, as a drop in temperature below the specified range hardens this bond, and thus cracks may occur as the load is applied and break it [1]. Vice versa, when the temperature increases, it loses its important properties and causes disintegration or dispersion of the components of the mixture as a result of the loss of the basic bond between them. The initial stage of the production of the asphalt mixture includes selecting the appropriate materials from the specific location since the temperature plays an important role in determining the appropriate asphalt binder of the site being selected by determining the efficiency of the performance of the aforementioned link within the clear variation of temperatures in the implementation area [2]. Following this stage, the important task begins by increasing the temperature degree of the components of the asphalt mixture to temperatures that achieve the desired bond. Then, mixing them with another temperature ensures achieving homogeneity and mixing between them to achieve the best coverage of the aggregate to ensure stability and stability. In building the mixture, the process of preparing it as a construction site is then conducted by achieving the required density and maintaining an acceptable percentage of voids. This process requires temperature as an important parameter to ensure the softness of the asphalt binder and facilitate the recycling of the aggregate in order to achieve the required density and keep the percentage of voids within limits. From the above, it can be noticed the extent of the variation in temperature during the aforementioned stages, indicating that there is a process of hardening or aging taking place for this poor bond at high temperatures for a long period of time [3]. All of this, and the aforementioned asphalt bond must remain active and effective, preserving its strength to fulfill the required role of strengthening.

In the field, when implementing or constructing the different paving layers, temperature plays a major role since the asphalt mixture would be exposed to a large variation in temperature during the transportation process. As temperatures begin to drop, the asphalt binder gradually loses its ability to perform its basic role of adhesive to the aggregate, and it begins to appear [4]. The hardening of the bond between the particles of aggregate originally covered with hardened asphalt is weakened, starting. In fact, a new cycle of thermal activation to facilitate the process of spreading on the prepared surface from everything (leveling and geometric design of the road) except for temperature stability, and thus begins the accelerating countdown to the drop in temperatures within the asphalt binder material itself, which causes a clear difference in bond strength (what this means is the temperature of the surface of the ground and the air around the paving area).

The spreader provides the necessary temperature to re-homogenize the mixture within its basin to facilitate spreading this homogeneous, high-temperature mixture again on the surface of the prepared road within the level and geometric design previously specified [5]. The surface layer and the binder layer are designed to achieve the necessary stability and consistency. In order to prevent air voids and to achieve the required thickness of the paving layers, the process of straightening or pressing the paved mixture is conducted. The paved mixture from the surface area to the bottom suffers from a rapid drop in temperature. The layer is in contact with the surface of the dirt paving layers, where the central area is expected to be at the highest temperature. Thus, this layer most likely will get joined and compressed [6].

The viscosity of the asphalt binder is considered the basic criterion that can be completely relied upon to indicate the effects of temperature changes. Viscosity represents a standard parameter that can be measured practically [7]. The viscosity of the asphalt binder reflects its ability to resist deformation, or more precisely, it represents the form or structural structure of the binder. Heat distorts the bond between the asphalt particles and causes deformation or movement, which weakens the binder's ability to resist deformation [8].

The prototype infrared sensor bar originally developed for NCHRP-IDEA Project 73 was adapted and used by Stroup-Gardiner et al. [9] for monitoring temperature profiles during the reconstruction of selected test track sections at the Auburn University National Center for Asphalt Technology. Sensor bar temperature measurements can accurately predict the hot-mix asphalt cooling curve theoretically predicted from the PaveCool software program. Contour maps were generated and used to identify the start of paving, the consistency of the operation, and the length of time of any stops. Thermal and mechanical segregation are significant asphalt paving issues that affect the quality of asphalt pavements, as noted by Tanquist et al. [10]. An inadequate mix of material production, material delivery, and paving operation can cause both types of segregation. Measuring thermal segregation with technology such as paver-mounted thermal profiling (PMTP) is critical to ensuring pavement quality. PMTP can continuously measure surface temperature profiles behind the trailing edge of a paver screed with an infrared sensor or photogrammetry. PMTP can also track paver speeds, stop locations, and stop durations. This paper introduces the thermal segregation index (TSI), which combines overall 2D sublot thermal uniformity and lateral thermal uniformity to overcome DRS' shortcomings.

Paver-mounted thermal profiling (PMTP) is used by reference [11] to monitor asphalt surface temperatures behind a paver with a thermal scanner and to track paver speeds, stops, and stop durations. Leveraging both IC and PMTP technologies allows for paving and compaction controls in real-time and for executing appropriate adjustments as needed. The data from 2 days of operations, one without the Material Transfer Vehicle (MTV) and another with the MTV were analyzed and compared to illustrate the benefits of using IC, PMTP, and MTV for producing quality pavement products.

National Center for Asphalt Technology (NCAT) conducted a study to evaluate measured versus predicted temperatures, evaluate the effect of mixed type on pavement temperature, and compare the effect of surface layer thickness on pavement temperatures. On the basis of temperature data from the NCAT test track, some of the general conclusions are that (*a*) both the Strategic Highway Research Program (SHRP) and Long-Term Pavement Performance (LTPP) temperature models slightly underpredicted high pavement temperatures at 50% reliability and slightly overpredicted temperatures at 98% reliability and (*b*) the low-temperature models for SHRP over predicted low pavement temperatures for both 50% and 98% reliability. The LTPP models were also overly conservative at 98% reliability. These results indicate that asphalt binders may not need to be as soft as specified in the Superpave performance grading system for low-temperature performance [12].

A computer program was developed at the University of Minnesota to predict asphalt concrete cooling times for road construction during adverse weather conditions. Cooling models require extensive experimental data on the thermal properties of hot-mix paving materials. Two suitable test methods for determining these properties at typical paving temperatures and densities were developed, and preliminary results for dense-graded and stone-matrix asphalt (SMA) mixes agreed well with values reported in the literature [13]. Compaction of any given dense-graded asphalt concrete paving mixture by rolling during construction is influenced by the viscosity-temperature characteristics of the asphalt cement and the temperature of the mixture during compaction [14].

When implementing different paving layers, temperature plays a major role. The asphalt mixture would be exposed to a large variation in temperature during the transportation process and would affect the paving quality. Accordingly, continuous monitoring of the mixture temperature from the production to the end of the paving process is crucial for quality road construction. The current study aims to conduct a thermal imaging survey using infrared radiation with high accuracy for the stages of production and implementation of asphalt mixtures. Also, to monitor and follow the ongoing thermal changes within the process of mixing, transporting, spreading, and flattening. Finally, to show the extent of temperature variation and then attempt to link the results of thermal imaging and Infrared imaging with asphalt binder viscosity.

2. RESEARCH METHODOLOGY

The amount of infrared emissivity of the paving surface is measured, and the spectral images are analyzed digitally. The reliability and credibility of the fieldwork have been proved through scientific programs and by extracting temperature values. The developed procedure of integrating the infrared thermal camera with a smartphone has been applied and validated in a new construction site as a case study.

2.1 Case study

Budoor-Baghdad residential condominium is one of the modern residential areas under construction in the capital of Iraq. It is located near Baghdad International Airport in the Abu Ghraib area (west of the capital, Baghdad) and occupies an area of 1,600,000. It includes many residential houses that do not exceed two floors each. There is a wide network of internal roads that ensure vehicles access each residential unit with two main roads connecting the three main condominiums in two directions and with three lanes in each direction, as shown in Figure 1. The aforementioned complex includes an integrated network of various roads to serve all the different needs during and after the implementation of the residents and executors (internal roads, collective roads, and arterial roads). The R01 road is considered one of these arterial roads, with a length of 1,100 m and a width of 12 m, divided into three lanes for both directions, back and forth, with a central island 1.5 m wide, wooded, with side shoulders 1.5 m wide. The road is paved with hot asphalt concrete, with a thickness ranging from 8 to 10 cm.

2.2 Research plan and data acquisition

The fieldwork plan included the following steps.

1. An infrared thermal imaging camera is a device that photographs using infrared rays instead of visible light, so instead of the 450-750 nm wavelength of visible light, a 14,000 nm infrared wavelength is used [15].
2. Thermal imaging using a FLIR Pro One thermal camera from Teledyne FLIR LLC that measures temperatures up to 400°C with sensitivity to detect temperature differences up to 70 m·K [16].
3. Use of FLIR Tools software version 6.4.18039.1003. FLIR Tools/Tools+ include the following activities (Import images from your camera to your computer; apply filters when searching for images; and layout, move, and resize measurement tools on any infrared image [17].

Through this application attached to the camera, thermal and regular images could be displayed at the same time, as well as measure temperatures on three different scales at all points of the thermal image consisting of a 640 × 480-pixel matrix, which is equivalent to a real area of 1,000 × 1,000 mm, with a fixed shooting height of 1 meter for all aspects that were photographed during the fieldwork, and then producing a thermal and regular photographic report of the phenomenon with an Excel file showing the temperatures and the amount of emissivity with all the details of the photography, including the date and time of the geographical location during the photography [15], and shown in Figure 2.

For the purpose of conducting studies on asphalt paving, the proposed values of emissivity to obtain the required accuracy within the spectral range from 5.6 to 20 micrometers at a temperature of 4 degrees Celsius were 0.9 6 7 according to what was stated in studies [15, 18].

The parameters of the infrared thermal camera were fixed with the following data and for all thermal images (emissivity 0.95, relative temperature 22°C, distance 1 m, atmospheric temp. 20°C, ext. optics temperature 25°C, ext. optics trans. 0.8, and relative humidity 50%).

1. The viscosity of the asphalt binder is considered one of the especially important factors in determining its properties, and it is a factor that varies with temperature. For the purpose of demonstrating this effect, 12 samples were taken from the asphalt used on the site, as follows:
   a) Measuring the viscosity of the asphalt binder at high temperatures from 100 to 200°C. The test was performed using a Brookfield viscometer according to ASTM D4402-06 [19].
   b) Measuring the dynamic shear viscosity of the asphalt binder at low temperatures from 5 to 90°C using a dynamic shear Rheometer (DSR) device. The test was conducted at the National Center for Research and Construction Laboratories-Baghdad. The test was conducted within the requirements of ASTM D7175 [20].

Figure 1. The study area is within the Budoor-Baghdad residential condominium project

c) The relationship between the results obtained from steps a and b above is drawn, and the best mathematical equation that represents this relationship is found with a statistically acceptable error rate by trying all the proposed equations, as shown in Figure 3.

d) Using the proposed equation in step c to calculate the estimated viscosity values at different temperatures measured in the field using infrared thermography.

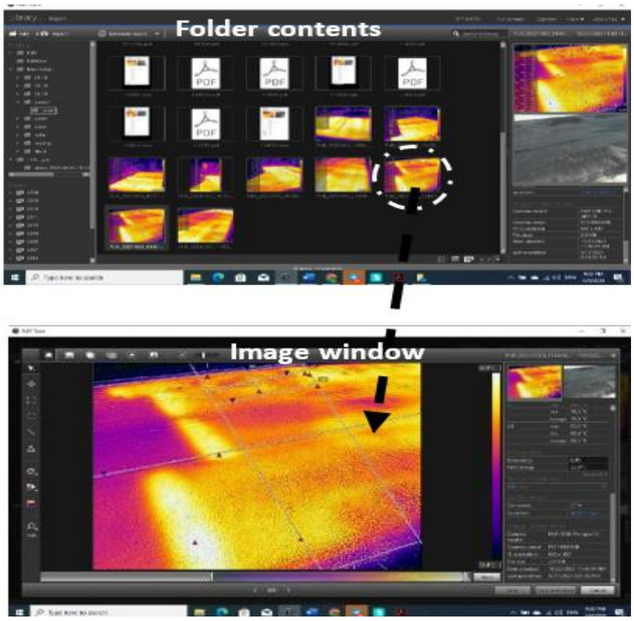


Figure 2. Windows of FLIR Tool software

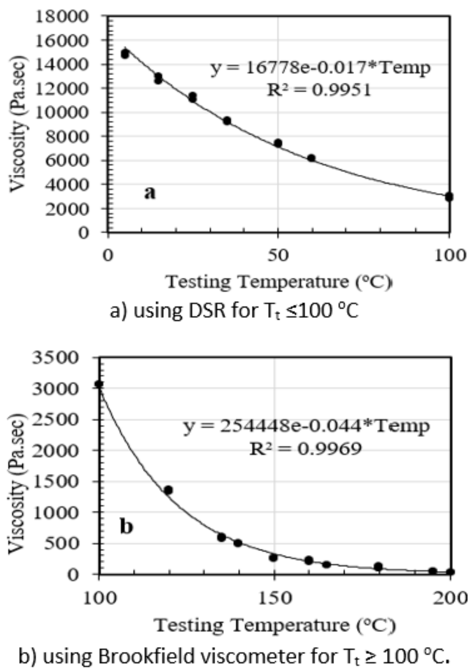


Figure 3. The best fitting of the variation in asphalt binder viscosity with the testing temperature

3. ANALYSIS OF THE FIELD OBSERVATIONS

In order to investigate the effect of temperature changes on the resistance of the asphalt binder during the stages of producing the hot asphalt mixture that includes the asphalt plant and transporting it to the work site and then spreading it and grinding it to the required thickness, in the following paragraphs, a quick overview will be given of the changes occurring in temperatures and linking these changes to the stiffness of asphalt binder.

Asphalt mixing plants of the E-MAK "Express" series are designed and manufactured for small and medium-sized productions with a production capacity of 80-320 tons/hour. These plants are preferably used in projects for the construction or maintenance of urban and long-distance roads that require frequent replacement. This type of plant manufactured in Turkey is characterized by durable, minimal energy consumption, economical running costs, user-friendly, advanced control and operating system, worldwide online maintenance support, and up to 300 tons of asphalt storage possibility with loading silos [21].

3.1 Hot asphalt cement storage

Figure 4 displays the imaging results in the cement storage tank, while Figure 5 displays the measured temperatures and the predicted viscosity of the asphalt-cement storage tank. Each asphalt mixture production plant must have a protected warehouse designed for storing the asphalt transported from the oil refinery to the plant to secure the asphalt needed for paving. It must be in a safe location, as this tank includes the presence of special heaters to heat the asphalt to the required temperatures and according to the specifications it is designed for. Figure 4 explains the asphalt storage tank heater.

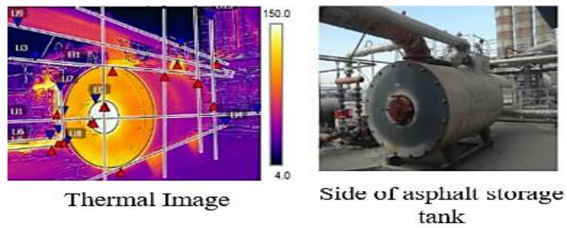


Figure 4. Heat distribution for hot asphalt cement storage [23 Oct. 2023]

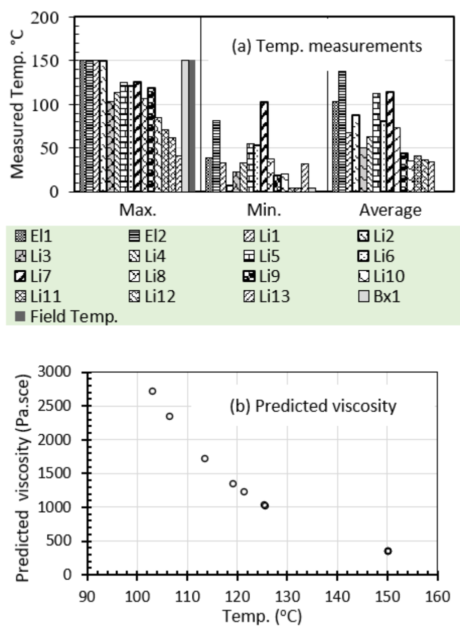


Figure 5. Hot asphalt cement storage tank

The hot asphalt storage tank is an essential part of the plant and deals with high temperatures to maintain the flow of the used asphalt with a high flow through the pipes that transport it from the tank to the mixing basin, where the maximum temperature was recorded at 150.3℃ predicted from Figure 5(a) where we notice that the estimated viscosity painted with varying temperatures as in the Figure 5(b). Figure 5(b) shows that there is a sharp increase in the temperature, which represents the temperature of the prepared cement asphalt and, consequently, a significant decrease in the viscosity [22].

3.2 Hot asphalt transportation pipes

The asphalt heated in the tank must be transported to the mixing place, and therefore, it must have a high level of flow inside the pipes. Since the infrared thermal camera records the amount of reflectivity from the surface of the pipes, it is expected that the temperature inside the pipe will be greater than what is mentioned in Figures 6 and 7.

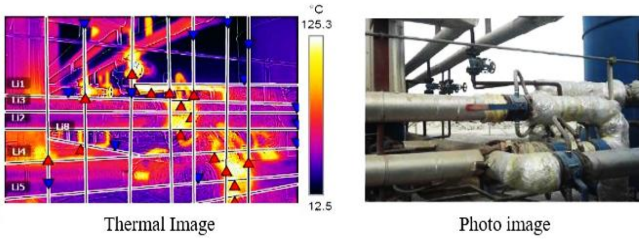


Figure 6. Heat distribution for hot asphalt transportation pipes [23 Oct.2023]

The normal picture shows that the conveyor pipes are coated with heat-insulating materials with high precision to maintain the asphalt at a high temperature to ensure the flow and flow of asphalt within the pipes.

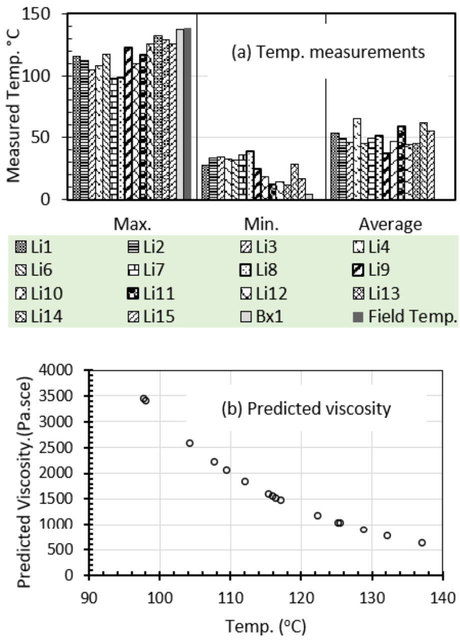


Figure 7. Hot asphalt transportation pipes

There is an exceedingly small discrepancy between the real values of temperature measurement and the values calculated by the infrared thermal camera, which gives sufficient reassurance of the accuracy of the method. For the purpose of identifying the ability of the hot asphalt binder to resist movement within the conveyor pipe network, the kinematic viscosity values can be estimated from the equation shown in Figure 7(b). Figure 7(a) shows that the temperatures inside the pipes have risen to more than the permissible values within the specification. There is a decrease in the hypothetically estimated viscosity, which is required to facilitate the movement and flow of the asphalt [23].

3.3 The mixer (pugmill)

This is the final unit in the plant, which plays a fundamental and pivotal role which is mixing the components of the mixture according to the grades and proportions determined in the laboratory and at the recommended temperature, as shown in Figure 8.

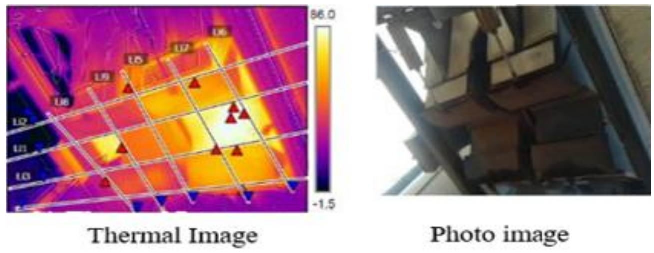


Figure 8. Heat distribution in the pugmill unit

The contrast in temperature is clear between the previous stage and the current stage, as shown in Figures 9(a) and 9(b), where the decrease in the temperature section is remarkable. This leads to an increase in the viscosity, as shown in Figure 9(b), and thus, the properties of the asphalt binder change repeatedly and may be accelerated, requiring designers to pay attention to this carefully.

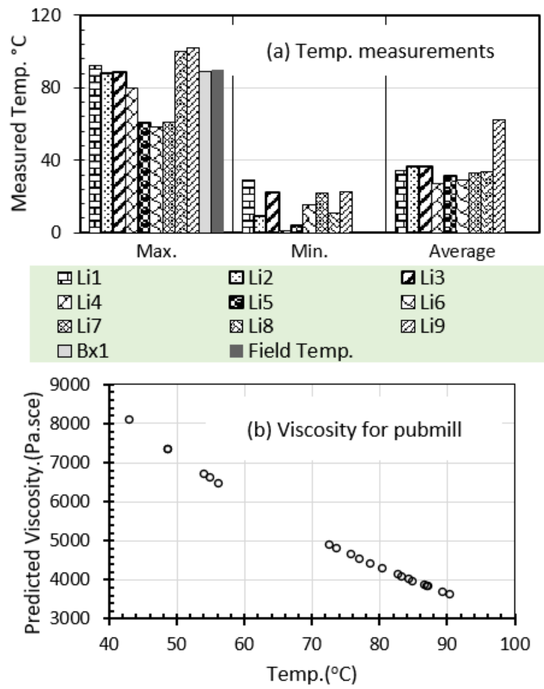


Figure 9. Pugmill unit

It is necessary to review the design mechanism in a way that is compatible with the real changes in the field to understand the behavior of the asphalt bond. This is done by building mechanical models that can be analyzed numerically and included as an important criterion in the design [24].

3.4 Transportation of the HAM

After the hot asphalt mixture has been prepared according to the requirements of the designed mixture, it is transported to the implementation site. During this stage, the mixture is exposed to weather conditions, which causes temperature leakage at high speed, which requires taking some important measures to maintain the temperature of the mixture within the required limits and, at the same time, the stiffness of the asphalt binder is as shown in Figure 10.

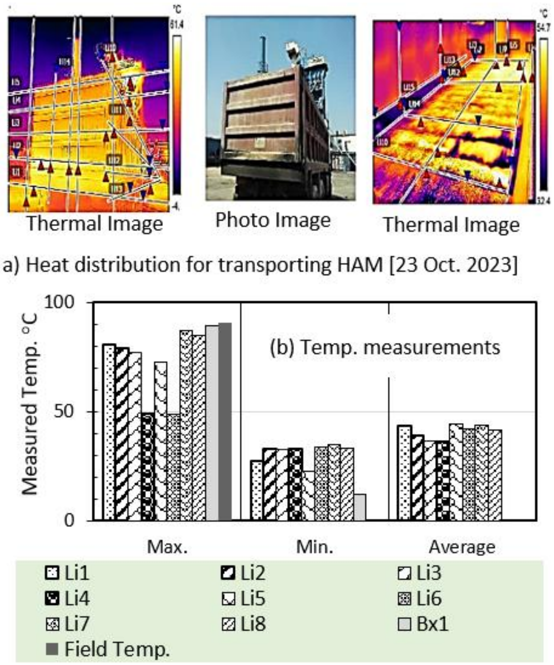


Figure 10. Heat distribution for transporting hot asphalt mix

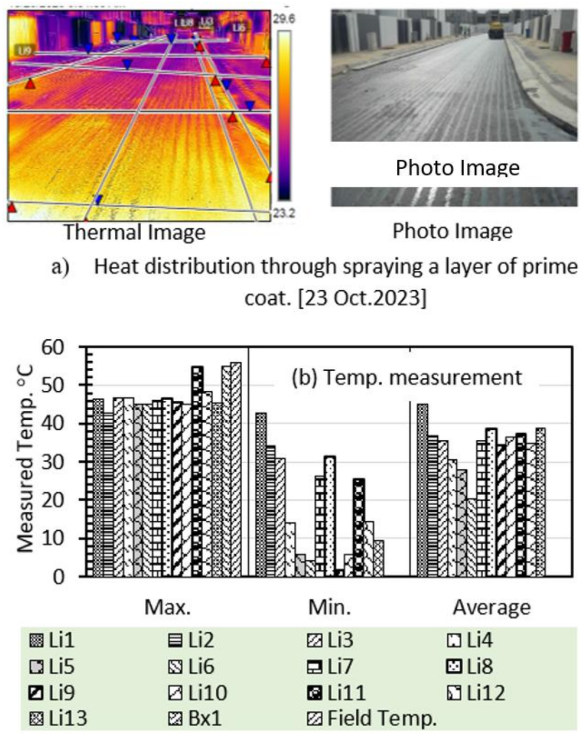


Figure 11. Spraying a layer of prime coat

By comparing the bone measured temperatures in Figure 10, which represents the truck empty of the asphalt mixture, and represents the temperature of the walls of the truck bed with the bone temperatures of the same vehicle, which is loaded with the asphalt mixture, we notice a clear increase in temperatures. Thus, the decrease in the viscosity of the asphalt binder leads to the weakness of the mixture.

3.5 Hot asphalt mixture spreaders

A basic and especially important stage is the spreading of the asphalt mixture layer with the required thickness. The measured temperatures and predicted viscosities in each sub-stage in the spreading are shown in the set of measurement and prediction Figures 11 to 24. The asphalt mixture is exposed to weather conditions on the one hand, as well as the base layer, and thus, a huge temperature dispersion occurs, resulting in a variety of the mixture viscosities, as shown in Figures 11 to 24.

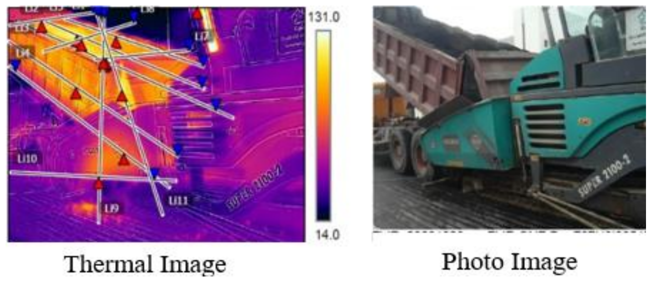


Figure 12. Heat distribution at the beginning of unloading the asphalt mixture from the truck to the paver bin

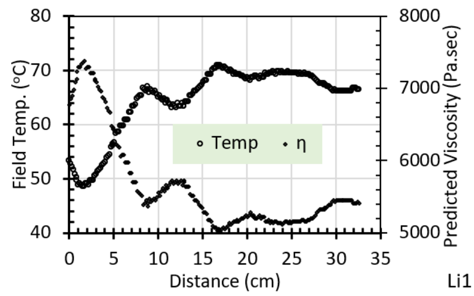


Figure 13. Predicted viscosity with field temperatures for selected line for asphalt concrete block in truck bed

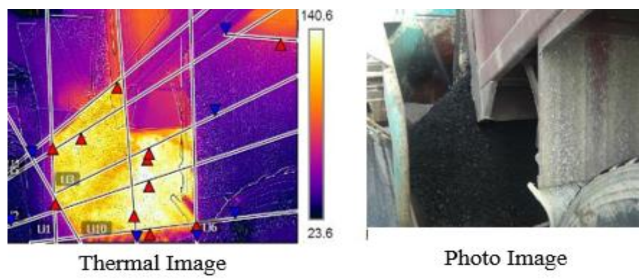


Figure 14. Heat distribution through unloading the asphalt mixture from the truck to the paver bin

Figure 19(b) shows the large difference between the temperature of the surface prepared for paving in advance and sprayed with a layer of prime coat as an adhesive between the layers and the temperature of the tiling layer, and this appears clearly in Figure 19(b). This wide disparity between the surface of the paving and its bottom generates significant changes in the viscosity of the asphalt binder used within the thickness of one layer, which causes a clear discrepancy in the viscosity values and thus weakens the paving layer.

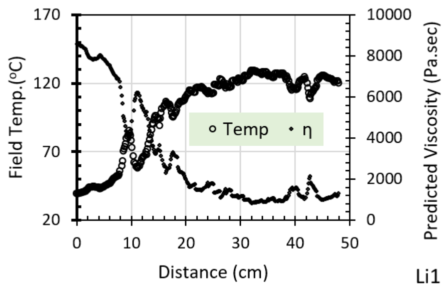


Figure 15. Thermal distribution and estimated viscosity of the asphalt mixture during the first stage of the mixture spread process for the selected line

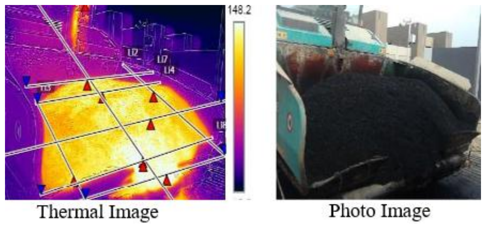


Figure 16. Heat distribution of the truck to the paver bin

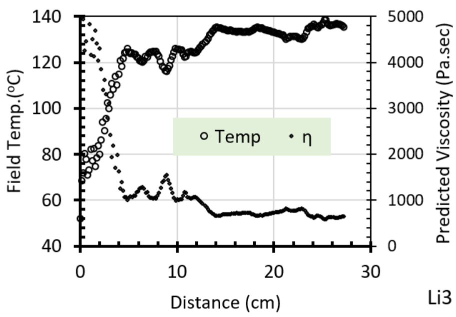


Figure 17. Thermal distribution and estimated viscosity of the asphalt mixture placed in the paver tank and within the selected lines

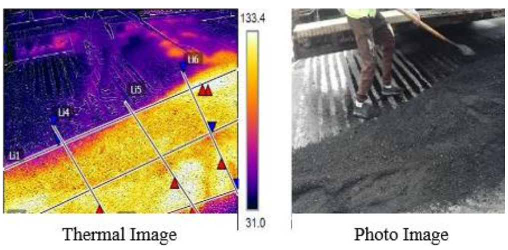
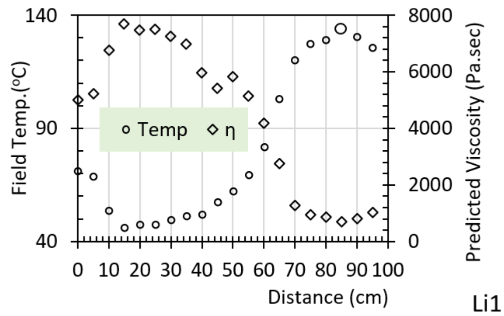
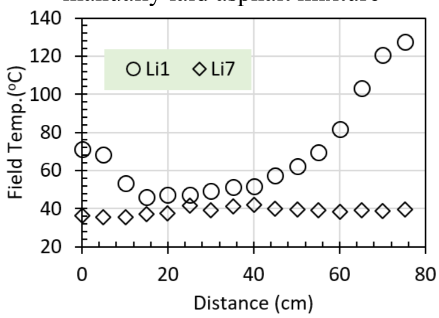


Figure 18. Heat distribution at starting of paving [23 Oct. 2023]

Figure 21 confirms what was previously concluded from Figure 20, that there is a wide temperature difference between the surface of the paving layer and the surface of the base layer, and supports the proposal that includes strengthening this paragraph by proposing a mathematically documented standard that can be applied practically and is included in the design equation for the structure. The basic paving represents the change in the viscosity of the asphalt binder. Locationally and throughout the thickness of the paving layer [24].



(a) Temperature distribution and estimated viscosity of manually laid asphalt mixture



(b) Temperature distribution and estimated viscosity of manually laid asphalt mixture

Figure 19. Temperature distribution and estimated viscosity of manually laid asphalt mixture

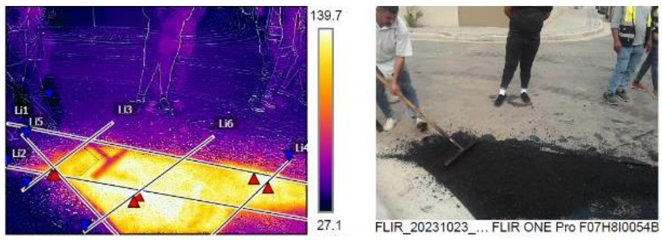
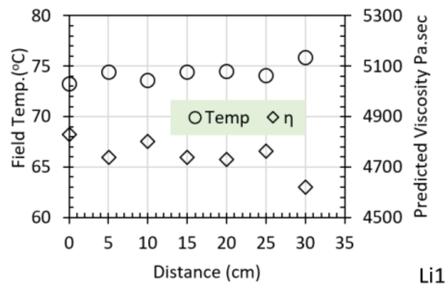
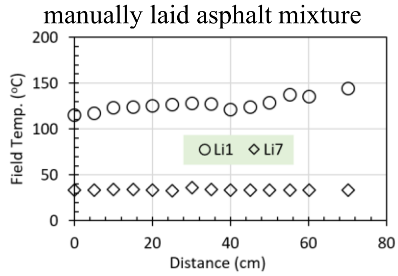


Figure 20. Heat distribution for manual paving [23 Oct. 2023]



(a) Temperature distribution and estimated viscosity of manually laid asphalt mixture



(b) Comparison of the thermal distribution of the prepared road before and after manual paving

Figure 21. Temperature distribution and estimated viscosity of manually laid asphalt mixture

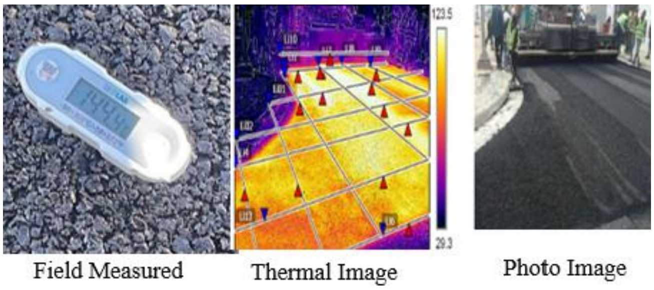
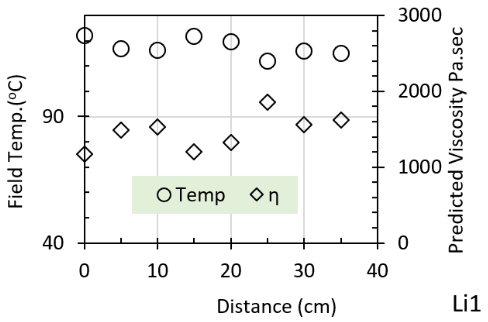
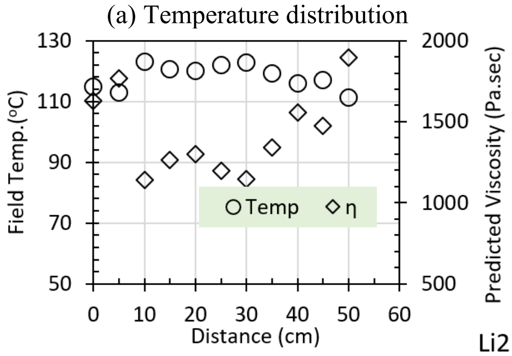


Figure 22. Heat distribution for mechanical paving [23 Oct. 2023]



(a) Temperature distribution



(b) Predicted viscosity

Figure 23. Mechanically laid asphalt mixture for the selected lines

For the purpose of showing the clear change in the estimated viscosity values as a result of the effect of the clear variation in temperature during the spreading process of the surface layer of the asphalt mixture, as shown in Figure 24.

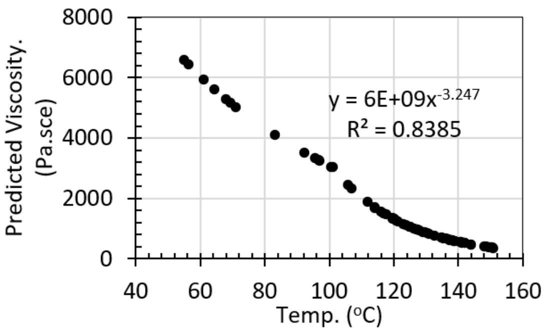
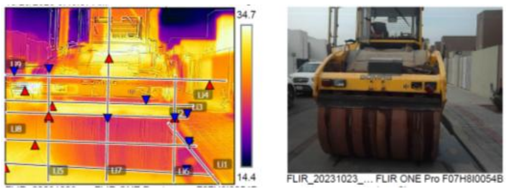


Figure 24. Predicted asphalt viscosity paved process

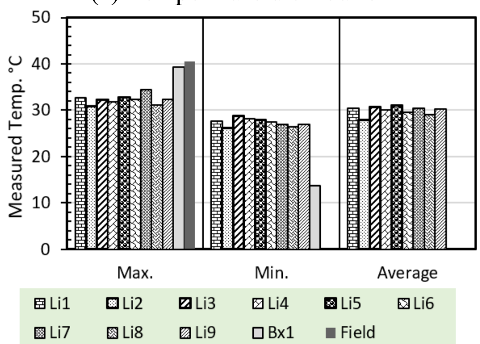
From observing the data in Figures 23 and 24, we notice that there is a clear increase in the mixing temperature values more than the permissible values, and therefore, this increase reduces the viscosity, weakens the paving strength, and decreases the life of the paving [25].

3.6 Hot mixture asphalt compaction

The final stage of the project is represented by the process of compacting the layer of hot asphalt mixture spread from the previous step to achieve the required density, as well as the proportion of air voids designed for it. This process is conducted in two stages. The first stage is the passage of rollers with iron wheels with tandem 2-axles, weighing from 8 to 12 tons and at a speed of no more. Exceed 5 km/hr with a frequency of 2 to 3 times to obtain the required density by taking samples of a cylindrical core to calculate the field density and then estimate the percentage of relative compaction reached by the furnished layer [26]. The second stage includes the use of a tandem 3-axle rubber wheel with a weight ranging from 8 to 10 tons and a speed of 25 km/hr [27] so that the expected tire pressure is 3.15 kg/cm^3 to give a small percentage of compaction and reach the acceptable compaction rate. This compaction process must be rapid to confront the rapid drop in temperature and its leakage into the upper layers of the atmosphere, the foundation layers, or the natural earth [28], as shown in Figure 25.



(a) Temperature distribution



(b) Temperature measurements

Figure 25. Compaction process

The temperature values shown in Figure 26 represent the values for the compacted pavement after 1.5 hours of paving and compacting, where we notice a wide range of temperature drops, as shown more clearly in Figure 26.

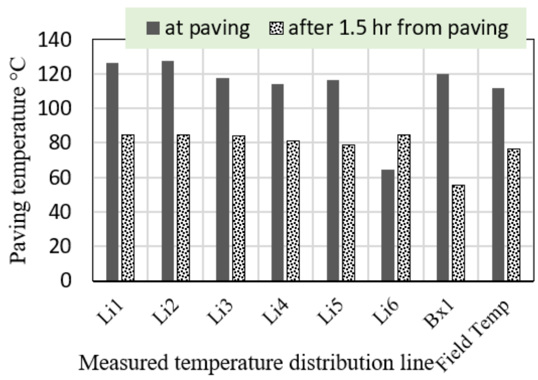


Figure 26. Comparing the temperatures of the paving surface at starting of compacting and after 1.5 hours

There is an exceedingly small discrepancy between the real values of temperature measurement and the values calculated by the infrared thermal camera, which gives sufficient reassurance of the accuracy of the method.

4. CONCLUSIONS

A field measurement technique by integration of an infrared camera with a smartphone has been developed and used in a construction site in Baghdad—Iraq. Analysis of the field-acquired data concluded the following.

- IR thermography is a method that has acceptable accuracy and is easy to apply, in addition to its effectiveness, speed in the field, and inexpensive way to estimate and evaluate surface pavement temperatures.
- There are exceptionally large changes in temperature during the stages of preparing the asphalt mixture, as we notice that the extent of the changes in the stage of the laboratory, transportation, manual and mechanical spreading, and forging was successive.
- A wide spectrum of temperature changes causes depletion of the life span of the asphalt binder, where it reached 165°C, and decreased during paving and tiling to reach less than 100°C.
- The properties of the asphalt binder change repeatedly, and may be accelerating, requiring designers to pay attention to this carefully. It is necessary to review the design mechanism in a way that is compatible with the real changes in the field to understand the behavior of the asphalt binder.
- Transporting the asphalt mixture from the factory to the work site represents an important stage in the deterioration of temperatures. This process takes place quickly and gets worse as the transport distance increases. The temperature of the asphalt mixture is within the permissible limits by following additional precautions in transport trucks.
- This requires from the designers much more attention. It is necessary to review the design mechanism in a way that is compatible with the real changes in the field.

Infrared thermal imaging can be used as a proposed standard to ensure the quality of fieldwork and, at the same time, as a measure to ensure the accuracy of implementation and act appropriately to solve immediate problems during implementation or organize a mechanism to monitor fieldwork at its various stages.

ACKNOWLEDGMENTS

The author acknowledges thanking the Mustansiriyah University Engineering College, Highway, and Transportation Dept. for supporting this research.

REFERENCE

[1] MS-4 The Asphalt Handbook 7th Edition. (2007). https://my.asphaltinstitute.org/Shop/Product-Details?productid=9E5A6840-361B-E811-80F2-000D3A011CEC.

[2] Hunter, R.N., Self, A., Read, J., Hobson, E. (2015). The Shell Bitumen Handbook (vol. 514). London, UK: Ice Publishing. https://doi.org/10.1680/tsbh.58378

[3] Bahia, H.U., Zhai, H., Zeng, M., Hu, Y., Turner, P. (2001). Development of binder specification parameters based on characterization of damage behavior (with discussion). Journal of the Association of Asphalt Paving Technologists, 70: 442-470.

[4] Cuadri, A.A., Partal, P., Navarro, F.J., García-Morales, M., Gallegos, C. (2011). Influence of processing temperature on the modification route and rheological properties of thiourea dioxide-modified bitumen. Energy & Fuels, 25(9): 4055-4062. https://doi.org/10.1021/ef200801h

[5] Fernandez Cerdas, S. (2012). Thermal segregation: Causes and effects on in-place density and fatigue performance of asphalt mixtures. Doctoral Dissertation. https://www.semanticscholar.org/paper/Thermal-Segregation%3A-Causes-and-Effects-on-In-Place-Cerdas-Watson/17582747b3a84f241916cb7fd63f2ce6d2ca9f6a.

[6] Wang, T., Faßbender, S., Dong, W., Schulze, C., Oeser, M., Liu, P. (2023). Sensitive surface layer: A review on conductive and piezoresistive pavement materials with carbon-based additives. Construction and Building Materials, 387: 131611. https://doi.org/10.1016/j.conbuildmat.2023.131611

[7] Baliello, A. (2020). The role of road pavements in the phenomenon of urban heat island. Università degli Studi di Trieste. https://arts.units.it/handle/11368/2961015.

[8] Lyapin, A.A., Parinov, I.A., Buravchuk, N.I., Cherpakov, A.V., Shilyaeva, O.V., Guryanova, O.V. (2020). Improving Road Pavement Characteristics. Springer, Cham, 978-983. https://doi.org/10.1007/978-3-030-59230-1

[9] Stroup-Gardiner, M., Nixon, J., Das, P. (2004). Automated temperature profiling during hot-mix asphalt construction. Transportation Research Record, 1900(1): 41-49. https://doi.org/10.3141/1900-05

[10] Tanquist, B., Embacher, R., Chang, G.K., Dick, J. (2022). Quantification of thermal uniformity for asphalt paving using the thermal segregation index. Transportation Research Record, 2676(7): 608-616. https://doi.org/10.1177/03611981221080168

[11] Chang, G.K., Mohanraj, K., Stone, W.A., Oesch, D.J., Gallivan, V. (2018). Leveraging intelligent compaction and thermal profiling technologies to improve asphalt pavement construction quality: A case study. Transportation Research Record, 2672(26): 48-56. https://doi.org/10.1177/0361198118758285

[12] Watson, D.E., Zhang, J., Powell, R.B. (2004). Analysis of temperature data for the national center for asphalt technology test track. Transportation Research Record, 1891(1): 68-75. https://doi.org/10.3141/1891-10

[13] Chadbourn, B.A., Luoma, J.A., Newcomb, D.E., Voller, V.R. (1996). Consideration of hot mix asphalt thermal properties during compaction. In Quality management of hot mix asphalt. ASTM International. https://doi.org/10.1520/STP16312S

[14] McLeod, N.W. (1967). Influence of viscosity of asphalt-cements on compaction of paving mixtures in the field and discussion. Highway Research Record, 158: 76-115.

[15] Warren, J.R. (1984). Thermal Infrared User Manual (Vol. 34). US Department of Agriculture, Forest Service.

[16] FLIR ONE Pro User's Manual. (1984). https://www.manua.ls/flir/one-pro/manual?p=1.

[17] Kern, C.D. (1965). Evaluation of infrared emission of clouds and ground as measured by weather satellites (No. 155). Air Force Cambridge Research Laboratories, Office of Aerospace Research, United States Air Force.
[18] Xue, E.Y., Chandler, L.K., Viviano, S.L., Keith, J.D. (2018). Use of FLIR ONE smartphone thermography in burn wound assessment. Annals of plastic surgery, 80(4): S236-S238. https://doi.org/10.1097/SAP.0000000000001363
[19] ASTM, D. (2015). Standard test method for viscosity determination of asphalt at elevated temperatures using a rotational viscometer. In American Society for Testing and Materials.
[20] ASTM, D7175 (2015). Standard test method for determining the rheological properties of asphalt binder using a dynamic shear rheometer. In American society for testing and materials.
[21] E-MAK. https://e-mak.com/de/products/express.
[22] Lavin, P. (2003). Asphalt Pavements: A Practical Guide to Design, Production and Maintenance for Engineers and Architects. CRC Press. https://doi.org/10.1201/9781482267716
[23] Nikolaides, A. (2014). Highway Engineering: Pavements, Materials and Control of Quality. CRC Press. https://www.taylorfrancis.com/books/mono/10.1201/b17690/highway-engineering-athanassios-nikolaides.
[24] Riaz, A., Yasir, N., Badin, G., Mahmood, Y. (2024). Innovative pavement solutions: A comprehensive review from conventional asphalt to sustainable colored alternatives. Infrastructures, 9(10): 186. https://doi.org/10.3390/infrastructures9100186
[25] Wang, S., Sui, X., Leng, Z., Jiang, J., Lu, G. (2022). Asphalt pavement density measurement using non-destructive testing methods: Current practices, challenges, and future vision. Construction and Building Materials, 344: 128154. https://doi.org/10.1016/j.conbuildmat.2022.128154
[26] Phan, T.M., Kim, J.H., Kim, H.J., Park, D.W. (2024). Automated repair of asphalt pavement cracks and potholes utilizing 3D printing and LiDAR scanning. Construction and Building Materials, 450: 138748. https://doi.org/10.1016/j.conbuildmat.2024.138748
[27] Uddin, W. (2013). A synthesis study of noncontact nondestructive evaluation of top-down cracking in asphalt pavements. https://rosap.ntl.bts.gov/view/dot/27038/dot_27038_DS1.pdf.
[28] Mehdi, M.A., Cherradi, T., Bouyahyaoui, A., El Karkouri, S., Qachar, A. (2022). Evolution of a flexible pavement deterioration, analyzing the road inspections results. Materials Today: Proceedings, 58: 1222-1228. https://doi.org/10.1016/j.matpr.2022.01.452

NOMENCLATURE

T_t	testing temperature, °C
μ	viscosity, Pa.sec
AI	asphalt institute
NCHRP	national cooperative highway research program
PMTP	paver mounted thermal profiling.
TSI	thermal segregation index
MTV	material transfer vehicle
SHRP	strategic highway research program
NCAT	north Carolina A&T state university
LTPP	long-term pavement performance
SMA	stone-matrix asphalt
Li	thermal line No. *i*.
Bx1	field maximum temperature
HAM	hot asphalt mixture