

Prediction variation in asphalt pavement temperature during summer season in Ramadi city, Anbar Province, Iraq.

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Abstract

Asphalt pavement temperatures were estimated at surface and depth of 50 mm. Differences between estimated maximum surface temperatures and maximum air temperatures were found to be remarkably high, whereas the minimum surface temperatures were slightly different from minimum air temperatures.

Different studies showed that the maximum pavement temperatures at depth (50 mm) were less than that of the maximum surface temperatures, whereas, minimum pavement temperature at the same depth showed slightly higher readings than that of the minimum surface temperatures.

Algorithms that discussed in this research work found to produce remarkably different estimations of depth temperatures. The undergoing research work aims to cast light on the performance of these models in terms of data regarding Anbar province of Iraq.

Keywords: Prediction, Asphalt pavement, temperature, Ramadi city, summer season.

التنبؤ بتغير درجات حرارة التبليط الاسفلاتي خلال فصل الصيف لمدينة الرمادي ، محافظة الانبار ، العراق
خالد عوض

الخلاصة

تم تقدير درجات حرارة اسفلت التبليط عند السطح وعلى عمق ٥٠ ملم. الفروقات بين درجات الحرارة العليا المقدرة عند السطح و درجات حرارة الهواء كانت عالية، بينما كانت الفروقات بين درجات الحرارة الدنيا عند السطح و درجات حرارة الهواء تختلف قليلا. عدد من الدراسات بينت ان درجات الحرارة العظمى على عمق ٥٠ ملم هي اقل من نظيراتها عند السطح، بينما درجات الحرارة الدنيا عند نفس العمق تختلف قليلا مع نظيراتها عند السطح. الخوارزمية التي نوقشت في هذا البحث وجدت فروقات واضحة في تقديرات درجات الحرارة عند العمق. لقد كان هدف هذا البحث التاء الضوء على انجاز النماذج المستخدمة للتقدير على بيانات لمحافظة الانبار-العراق.

1. Introduction

Asphalt pavement commonly exposed to many factors that affect in a way or another the durability and quality of the pavement.

Solar irradiation for long hours during a day will contribute to the fact that the temperature of the pavement surface will be very high in comparison to the temperature degree in the depth of the pavement. Such a variation will result in pavement damage due to the potential expansion and

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contraction. Qiang Li¹, et al., 2011, found that extreme temperature variations can lead to catastrophic failure. Flexible and rigid pavement can suffer large transverse cracks as a result of the excessive contraction in cold weather.

The effect of temperature on asphalt pavement has the attention of many researchers²⁻⁴. The main issue that concerns most of the researchers who worked on the effect of temperature of asphalt pavement, was the damage that will occur according to temperature variation. Pavement overlay thickness will be affected² and cracks will also happen and extended by time¹.

When pavement overlay thickness affected it is a very sufficient evidence that the durability of asphalt pavement will be reduced. Certainly, that would make additional costs for maintenance or even remove this pavement and put a new one. Accordingly, such treatment will affect traffic flow as well as the allocation of additional budgets.

As mentioned previously, the costs of maintenance are subjected to the durability of the pavement. In the cases that temperature significantly affects the pavement, a decision should be made to investigate the materials of the pavement and attempts and efforts must be made to find well durable pavement materials.

2- a Literature review

Prediction variation in surface and depth layers of asphalt pavement was the main concern of many researchers. Manuel J C Minhoto⁵, 2005, developed a finite element model (FEM) to predict the temperature of an asphalt rubber pavement. Khalid S Shibib⁴, et al., 2012, expected the variation between surface and depth of asphalt pavement during summer.

Artificial neural networks ANN was also used as a mathematical technique to predict low-temperature performances of modified asphalt mixture⁶.

Hozayen Hozayen², 2015, measured directly pavement temperature at a different depth of asphalt pavement by using experimental and analytical procedures.

Shobha Rani Arangi and Dr. R K Jain⁷, 2015, cited different approaches of predicting surface and depth temperatures of asphalt pavement. The models that presented by Shobha Rani Arangi and Dr R K Jain⁷, 2015, were adopted in this research work. The algorithms that they used in calculating the variation between surface and depth temperatures were used in the same manner for predicting the variation in temperatures of asphalt pavement in Ramadi city of Anbar Province, Iraq.

The models that were used to predict maximum and minimum temperatures of asphalt pavement surface are

$$T_s(\max) = T_{air}(\max) - 0.00618 \times (\text{latitude})^2 + 0.2289 \times \text{latitude} + 24.4 \quad (1)$$

Where :

$T_s(\max)$ is the maximum temperature of asphalt pavement surface

$T_{air}(\max)$ is the maximum air temperature

Latitude is the latitude (deg) of the place where you like to measure surface temperature

Equation (1) is actually designed to predict surface temperature of Superpave in which it is also valid for the summer season or when predicting daily temperature variation.

Equation (2) is used to predict the minimum surface temperature of asphalt pavement.

$$T_s(\min) = 0.89 \times T_{air}(\min) + 5.2 \quad (2)$$

Where

$T_s(\min)$ is the minimum surface temperature

$T_{air}(\min)$ is the minimum air temperature

The depth temperature of asphalt pavement depends on the depth as well as surface temperature.

Equations (3) and (4) showed the method of prediction such temperatures.

$$T_d(\max) = T_s(\max) (1 - 4.237 \times 10^{-3} d + 2.95 \times 10^{-5} d^2 - 8.53 \times 10^{-8} d^3) \quad (3)$$

$$T_d(\min) = T_s(\min) + 3.7 \times 10^{-2} d - 6.29 \times 10^{-5} d^2 \quad (4)$$

Where

$T_d(\max)$ is the maximum depth temperature

$T_d(\min)$ is the minimum depth temperature

d is the depth in (mm)

According to the equations above, it will not be difficult to predict the variation in temperature between the surface and the depth of asphalt pavement.

With regard to the equations of predicting max the maximum and minimum temperatures of the depth of asphalt pavement, Ethe veritt8, P R, 2001, has adopted almost the same equations above to predict asphalt pavement temperature in South Africa.

Md Rashadul Islam9, et al., 2015, compared the output of three models used to predict maximum depth temperature of hot-mix asphalt in the flexible pavement. These models are:

1. Strategic Highway Research Program (SHRP)

$$T_d(\max) = T_s(\max) (1 - 0.0063d + 0.007d^2 - 0.0004d^3) \quad (5)$$

where

$T_d(\max)$ is the maximum pavement temperature ($^{\circ}\text{F}$) at depth d (in)

$T_s(\max)$ is the maximum surface temperature ($^{\circ}\text{F}$)

2. Long-Term Pavement Performance Program (LTPP)

$$T_d(\max) = (T_s(\max) + 17.8) (1 - 0.00248d + 0.000011d^2 - 0.0024d^3) - 17.8 \quad (6)$$

Where

$T_d(\max)$ is the maximum pavement temperature ($^{\circ}\text{C}$) at depth, d (m)

$T_s(\max)$ is the maximum surface temperature ($^{\circ}\text{C}$)

3. Diefenderfer Statistical Model (DSM)

$$T_d(\max) = 0.686x_1 + 0.000567x_2 - 27.87x + 2.7875 \quad (7)$$

Where

$T_d(\max)$ and $T_s(\max)$ are as in equation (6)

x_1 : is the maximum air temperature, x_2 is the calculated daily solar radiation (KJ/m^2 daily), and x is the depth from surface (M)

3- Data collection

Anbar province is the largest province in Iraq, it is situated to the west of Iraq and its geographical coordinates *Latitude: 33°25'14"N, Longitude 43°18'28" E*. Coordinates of Ramadi in decimal degrees are Latitude 33. 4205600 and Longitude 433077800.

The monthly climatology profile was considered in this study for the summer months (may, June, July, August and September) of Ramadi city, Anbar Province, Iraq for the year 2015.

Since we have no daily data about Ramadi city regarding solar radiation, the last model (DSM) will not be used.

Converting Celsius to Fahrenheit formula will be used whenever it is needed.

4- Results and discussion

The temperature prediction algorithms that are cited by Shobha Rani Arangi and Dr. R K Jain⁷, 2015 are going to be used and compared to that of the SHRP and LTPP models.

The minimum and maximum pavement surface temperatures were all predicted by the use of the proposed algorithm of Shobha and Jain⁷. The pavement temperature at depth (d) were predicted by using three different formulas.

Figure 1 shows the air temperatures and pavement surface temperatures. Both, maximum and minimum pavement surface temperatures are higher than the corresponding air temperatures. The difference between maximum and minimum pavement surface temperatures is highly significant ($t=22.47$, $df=7$, $p\text{-value}<0.001$). Figure 2, shows the boxplot of the pavement surface temperatures. The plot indicates slight temperature variation at each group, which also means that such a huge difference is well identified and it almost approach **37.57°C**.

According to Shobha and Jain⁷, the maximum and minimum pavement temperatures at depth (50 mm) were calculated and presented in figure 3.

Figure 3, indicates a clear significant difference between maximum and minimum temperatures at depth (50 mm), ($t=17.08$, $df=7$, $p\text{-value}<0.001$). The average difference is found to be **26.15°C**. The variation between maximum and minimum temperatures with regard to Shobha and Jain⁷, was found to be less in depth of (50 mm) in comparison to that of the pavement surface. Moreover, the maximum temperature of depth (50 mm) was found to be less than that of the corresponding temperature in pavement surface, whereas minimum temperature at depth (50 mm) was found to be higher than that of the corresponding temperature in pavement surface.

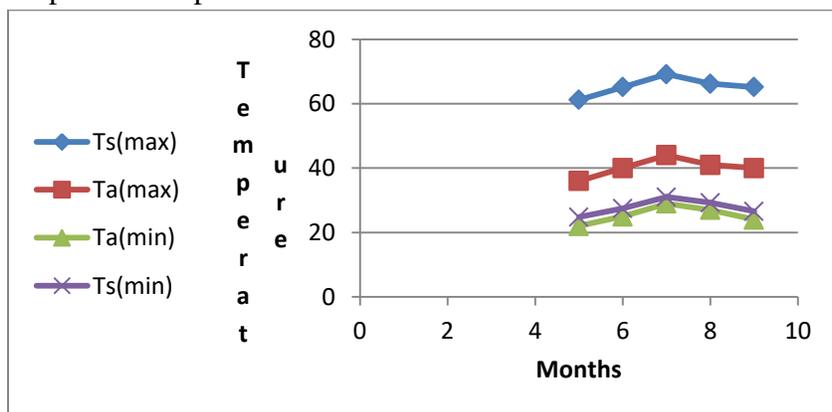


Figure 1. Maximum and minimum temperatures in Celsius of air and pavement surface.

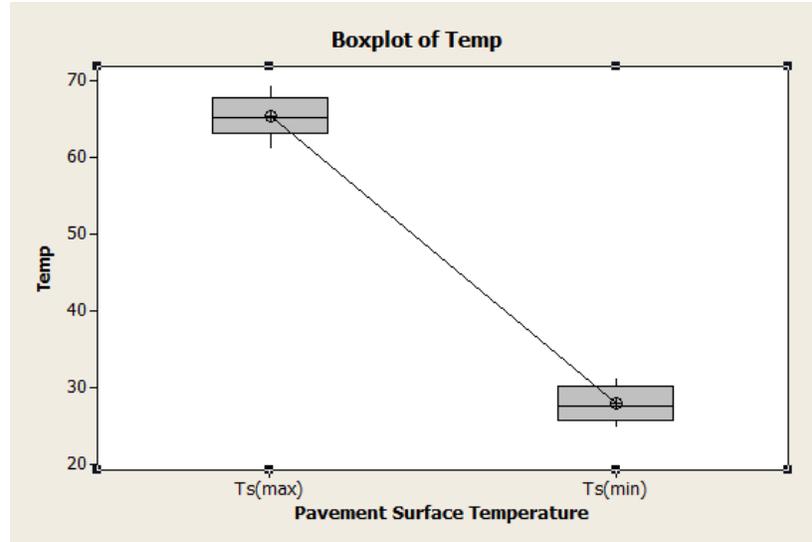


Figure 2. Boxplot for the data of the maximum and minimum surface pavement temperatures.

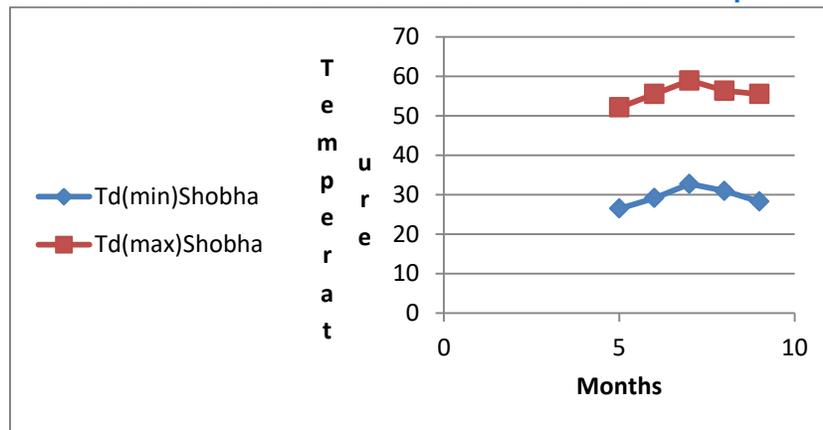


Figure 3. Maximum and minimum temperatures in Celsius of pavement surface temperatures at depth (50 mm).

In order to calculate the maximum temperature at depth d for the SHRP and LTPP models, the depth (50 mm) was converted to inches when calculating $T_d(\max)$ for the SHRP model, and also temperature of pavement surface was converted to Fahrenheit, whereas when calculating $T_d(\max)$ of the LTPP model, only the (50 mm) depth was converted to (0.05 m). In both cases, the output temperatures were again converted to Celsius for the purposes of comparisons.

Figure 4, shows the distribution of the $T_d(\max)$ on summer months with respect to the three adopted algorithms. In this figure, it can be easily noticed that SHRP and LTPP models produced almost equal outputs and that their outputs are remarkably higher than that obtained by Shobha and Jain7. The one-way analysis of variance showed a significant difference ($p\text{-value} < 0.001$) between the former two algorithms and the latter one. Figure 5, shows the boxplot produced by the one-way analysis of variance when comparing means temperature of pavement depth.

Unlike the findings of Islam9, the SHRP and LTPP algorithms were found to produce similar results. The mean difference between their estimated temperatures was almost 1 Celsius. They both significantly different from Shobha algorithm by a mean of almost 10 Celsius.

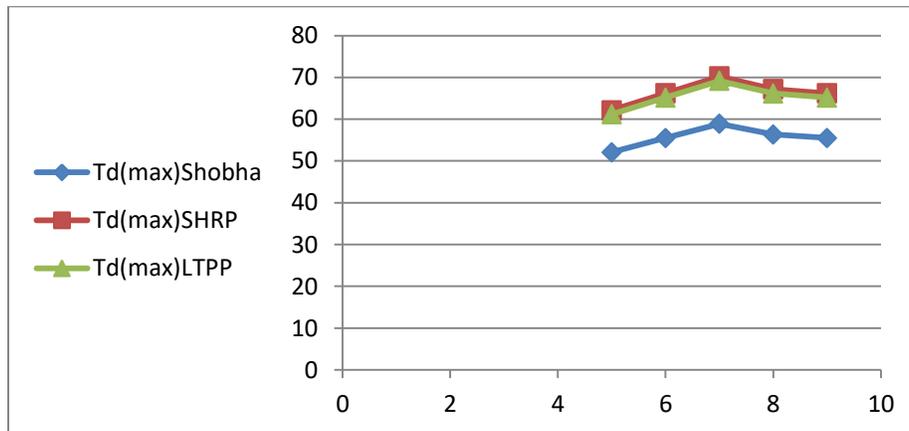


Figure 4. Maximum temperatures in Celsius of pavement at depth (50 mm) with regard to three prediction algorithms.

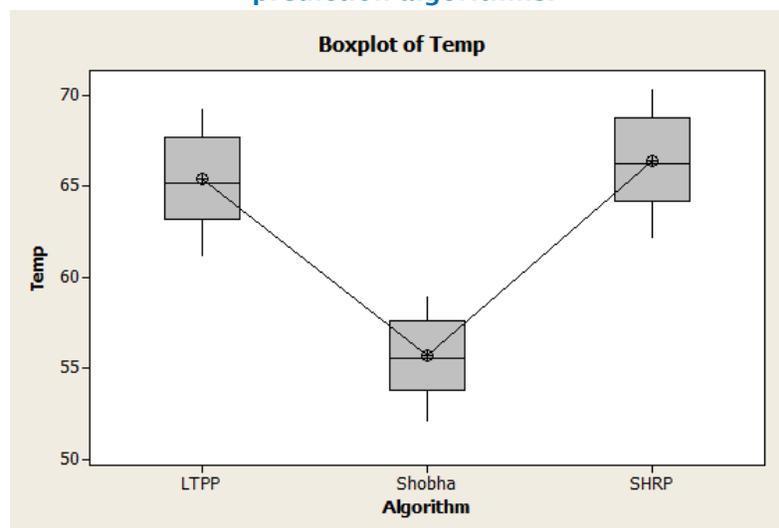


Figure 5. Boxplot of means maximum temperatures in Celsius of pavement at depth (50 mm) with regard to three prediction algorithms.

5- Conclusions

Nothing better than a direct measure of temperature at different depths or even surface temperature. The variability in the suggested algorithms of the Superpave and hot-mix asphalt is actually related to the way that such algorithms used. It is highly recommended to adjust these models whenever new real data are available.

It may be better-estimated temperatures with respect to days of the month than estimated for the whole month as variation within the month probably occurred.

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