TEMPERATURE PREDICTION OF ASPHALT CONCRETE AND CORRECTION OF DEFLECTION ON BRIDGE SLABS FOR FWD TESTING

Hiroshi HIGASHIYAMA¹, Masaya TSUKAMOTO² and Hiroyuki MASHITO³

¹Member of JSCE, Professor, Dept. of Civil & Environ. Eng., Kindai University
(3-4-1 Kowakae, Higashiosaka, Osaka 577-8502, Japan)
E-mail: h-hirosi@civileng.kindai.ac.jp (Corresponding Author)

²Member of JSCE, Technical Research Institute, Toa Road Corporation
(315-126 Kaname, Tsukuba, Ibaraki 300-2622, Japan)
E-mail: m_tukamoto@toadoro.co.jp

³Member of JSCE, Technical Research Institute, Toa Road Corporation
(315-126 Kaname, Tsukuba, Ibaraki 300-2622, Japan)
E-mail: h_mashito@toadoro.co.jp

The authors have investigated the soundness evaluation of existing reinforced concrete (RC) slabs supported by girders using deflection at a loading point and an integrated deflection area through falling weight deflectometer (FWD) tests. In FWD tests, an asphalt concrete layer deforms locally around a loading point under an impact load. The deflection of RC slabs thus needs to be determined with an appropriate correction method. This study proposes an equation to determine the average temperature of asphalt concrete layer using a regression analysis with measured results. The results show that the proposed equation can accurately predict the average temperature by incorporating a one-hour difference in asphalt concrete surface temperature. Furthermore, the correction method of deflection using the average temperature during FWD tests proposed was analytically verified for asphalt concrete layers with temperature gradients throughout the depth. The influence of temperature gradients in correcting the deflection was also noted to be small and the previously proposed correction method was applicable to determine the deflection of RC slabs in FWD tests.

Key Words: bridge slabs, falling weight deflectometer, asphalt concrete, prediction of average temperature, correction method of deflection

1. INTRODUCTION

An efficient and appropriate soundness evaluation is required to assess the deterioration of reinforced concrete (RC) slabs supported by girders. The authors focused on the deflection of RC slabs using a falling weight deflectometer (FWD) as one of the soundness evaluation methods and investigated the deflection at the loading point and the deflection area calculated from the distribution of slab deflection as the soundness indexes¹. In FWD tests, when a weight is dropped on the surface of the asphalt concrete on bridge slabs, the asphalt concrete deforms locally around the loading area. This phenomenon is the same as with asphalt pavement on subgrades. Determining the deflection of a RC slab itself requires appropriate correction procedures in the FWD tests. The authors have previously proposed a correction method for asphalt concrete on bridge slabs using the thickness and the average temperature of the asphalt concrete during the FWD tests². There have been many studies on the prediction and correction of temperature of asphalt pavements on subgrades in FWD tests³⁻¹¹. However, few reports are available in the literature on the behavior and temperature prediction of asphalt concrete on bridge slabs. From the previous experimental results¹², the authors have suggested that the average temperature predicting models for asphalt pavements on subgrades had a large variation when compared with the measured average temperature of the asphalt concrete on a bridge slab. In the FWD tests on bridge slabs, determining the deflection of bridge slabs and estimating the soundness require the temperature prediction of asphalt concrete and the correction of deflection.
In this study, three temperature prediction models were first calibrated based on the temperature measurement on a concrete slab. After that, those empirically derived models were verified from temperature measurements on specimens with different thickness of asphalt concrete layer and concrete slab. Furthermore, a correction method of deflection on bridge slabs was proposed from the results of elastic finite element analysis in the previous study\(^2\) using the average temperature of asphalt concrete layer throughout the depth. However, actual asphalt concrete have temperature gradients in the depth direction, rather than having uniform temperature distribution. In this study, additional elastic finite element analysis was carried out considering such temperature gradients in the asphalt concrete, and their influence on the correction method proposed\(^2\) was analytically verified.

2. CALIBRATION OF MODELS

(1) Models

Many empirical models have been developed for predicting the temperature of asphalt pavement on subgrades based on temperature measurements\(^{11}\). The developed empirical equations usually involve variables including air temperature, pavement surface temperature, pavement depth, and meteorological data, such as solar radiation. Since this study aims to propose an equation to easily and accurately predict the average temperature of asphalt concrete throughout the depth in the FWD tests on bridge slabs, the following three models were examined to be incorporated into the soundness evaluation system for bridge slabs in this study:

\[
T_{\text{ave}} = (aT_{\text{sur}} + bT_{\text{air}} + c) \cdot \alpha \cdot H_a^\beta \quad (1)
\]

\[
T_{\text{ave}} = aT_{\text{sur}} + bT_{\text{air}} + cT_{\text{air, dif}} + dH_a + e \quad (2)
\]

\[
T_{\text{ave}} = (aT_{\text{sur}} + bT_{\text{air}} + cT_{\text{sur, dif}} + d) \cdot \alpha \cdot H_a^\beta \quad (3)
\]

where \(T_{\text{ave}}\) is the average temperature of the asphalt concrete throughout the depth (°C), \(T_{\text{sur}}\) is the surface temperature of the asphalt concrete (°C), \(T_{\text{air}}\) is the air temperature (°C), \(T_{\text{air, dif}}\) is the air temperature difference between the measurement time and one hour before the measurement time (°C), \(T_{\text{sur, dif}}\) is the surface temperature difference between the measurement time and one hour before the measurement time (°C), \(H_a\) is the asphalt concrete thickness (cm), \(a, b, c, d,\) and \(e\) are the empirical coefficients, and \(\alpha\) and \(\beta\) are the coefficients related to the asphalt concrete thickness.

In this study, considering the accuracy of the predicted average temperature, it is better to incorporate the one-hour difference in the air temperature or the surface temperature of asphalt concrete on site when the FWD tests are carried out. The models expressed by Eqs. (1) and (2) were used by Saika et al.\(^4\) and Hayashi et al.\(^5\), respectively. Although Eq. (3) is a model similar to Eq. (1), the authors suggested to additionally incorporate the difference in the surface temperature of asphalt concrete, as one of the affecting factors, between the measurement time and the one hour before the measurement time. It is noted that Saika et al.\(^4\) divided a year into three groups of different seasons, and Hayashi et al.\(^5\) also divided a year into four groups reflecting the characteristics of temperature distribution of asphalt pavement throughout the depth. They analyzed the applicability of asphalt pavements on subgrades to the measured results.

In this study, a year was divided into two groups (i.e., November-March and April-October) in Eqs. (1) and (3), and Eq. (2) was maintained into four groups as in the original research work. From preliminary consideration for Eq. (3), when a year was divided into four groups as with Hayashi et al.\(^5\), no significant improvement was seen in the predicted accuracy of the average temperature.

(2) Outline of measurement

The test site was located at the Technical Research Institute of Toa Road Corporation (Kaname, Tsukuba City, Japan). As shown in Fig.1, the test site was selected where the specimen did not interfere with solar radiation on the asphalt concrete surface, and the specimen was placed on a concrete block with a height of 900 mm simulating a real bridge slab\(^{12}\). The specimen was a concrete slab 1 m square and 200 mm thick, having a surface course 40 mm thick and a binder course 40 mm thick (total thickness of asphalt concrete layer: 80 mm). An asphalt
Table 1 Accuracy of predicted results.

| Temperature difference range | Eq. (1) | Eq. (2) | Eq. (3) |
|------------------------------|---------|---------|---------|
| -1°C ≤ ΔT ≤ 1°C             | 72.0    | 78.5    | 81.8    |
| -2°C ≤ ΔT ≤ 2°C             | 91.6    | 95.7    | 97.6    |
| -5°C ≤ ΔT ≤ 5°C             | 99.8    | 100     | 100     |

emulsion was used to provide a bond between the surface and binder courses. A waterproof sheet with a thickness of 6 mm was also laid between the binder course and the concrete slab.

The temperature in the asphalt concrete was measured with thermocouples, and the atmospheric temperature was also measured with a thermocouple inside a radiation seal, which was set at a height of 1.5 m from the ground. Two thermocouples were installed at each depth in the asphalt concrete (i.e., 5 mm, 20 mm, 40 mm, 60 mm, and 80 mm from the surface). The thermocouples at the depth of 40 mm were installed on the top surface of the binder course. The two measurements at each depth were averaged to calculate the average temperature throughout the depth of the asphalt concrete layer. In this measurement, the temperature measured with the thermocouples at the depth of 5 mm was used as the surface temperature as with Saika et al.\(^4\). To eliminate or minimize the influence of horizontal heat transfer in maintaining the one-dimensional heat transfer condition, the side surface of the specimen was covered with Styrofoam 100 mm thick for heat insulation. The temperature measurement was carried out for one year starting from March 2018.

(3) Calibration and comparison of predicted accuracy

For each of the above three predicting models, multiple regression analyses were carried out based on the data measured at 30 min intervals, and each coefficient in the predicting Eqs. (1) to (3) was determined. The average temperature throughout the asphalt concrete layer was determined by integrating and averaging the measured data. The relationship between the predicted average temperature and the measured average temperature is shown in Fig. 2 for each predicting equation. As to the accuracy of the predicted results, Table 1 shows the probability related to the number of data sets within each temperature difference range to the total number of data sets. The temperature difference range is the difference between the measured average temperature and the predicted average temperature.

The probability within ±2°C was 90% or more in all the three predicting equations. Furthermore, the probability within ±1°C was 72% in Eq. (1), 79% in Eq. (2), and 82% in Eq. (3). The probability was not
very different between Eq. (2) and Eq. (3). The results show that the air temperature difference or the surface temperature difference has a great effect on the average temperature in the predicting model. Eqs. (2) and (3) can have effective accuracy in practice for predicting the average temperature during the FWD tests on bridge slabs.

3. EVALUATION OF PREDICTING EQUATIONS

As Chen et al.\textsuperscript{11)} pointed out, tall buildings around viaducts and high-rise noise barriers may shield asphalt concrete on bridge slabs in urban viaducts from solar radiation depending on season and time of day, as shown in Fig.3, and double deck viaducts. When the FWD test is carried out at such locations, the temperature of asphalt concrete layer differs from when the sunlight directly reaches the surface of asphalt concrete, even if the atmospheric temperature is the same. Therefore, the authors carried out temperature measurements again at a site of the Research Building in Kindai University (Shinke, Yao City, Japan). In this measurement, three specimens were prepared and set up in a selected place where the sunlight was blocked during a certain period in the morning to simulate the above situation in urban viaducts. After the measurement, the predicted accuracy of the average temperature using the above three predicting equations calibrated and determined in section 2(3) was also verified.

(1) Specimens and measurements

Three specimens were simply mounted on steel beams with a height of 900 mm as shown in Fig.4. Each test specimen was a concrete slab of a 900 mm square that was 200 mm or 250 mm thick, having a 40 mm thick surface course and a 40 mm or 80 mm thick binder course as shown in Fig.5. The reason for setting the total asphalt concrete thickness of 120 mm was that the thickness from the surface of asphalt concrete to the top surface of a RC slab on seven existing bridges was measured; the maximum thickness was about 120 mm after repeated mill and overlay\textsuperscript{13)}. An asphalt emulsion was used to provide a bond between the surface and binder courses. A 6 mm thick waterproof sheet was laid between the binder course and the concrete slab.

The temperature in the asphalt concrete was measured with thermocouples, and the atmospheric temperature was also measured with a thermocouple inside a radiation seal, which was set at a height of 1.5 m from the ground. Two thermocouples were installed at each depth in the asphalt concrete as shown in Table 2. The thermocouples at the depth of 40 mm were installed on the top surface of the binder course. The two measurements at each depth were averaged to calculate the average temperature throughout the depth of the asphalt concrete layer. The temperature measured with thermocouples at a depth of 5 mm was used as the surface temperature. To eliminate or minimize the influence of horizontal
heat transfer in maintaining the one-dimensional heat transfer condition, the side surface of a specimen was covered with a 50 mm thick Styrofoam for heat insulation.

Table 2 Embedment depth of each thermocouple.

| Specimen   | Depth from asphalt concrete surface (mm) |
|------------|------------------------------------------|
| S250-120   | 5, 20, 40, 80, 120                      |
| S250-80    | 5, 20, 40, 60, 80                       |
| S200-120   | 5, 20, 40, 80, 120                      |

The temperature measurement was carried out for one year starting from September 2019. Since the Research Building is on the near side shown in Fig.4, solar radiation on the asphalt concrete surface in the morning started from around 8:00 in the summer season and around 10:00 in the winter season. Then, a time lag occurred in the rise of the asphalt concrete temperature. This situation possibly simulates urban viaducts having high-rise noise barriers or near tall buildings, which block solar radiation.

(2) Results of temperature measurements

For example, the temperature distributions of asphalt concrete throughout the depth, when the daily maximum surface temperature in a sunny day was recorded as the highest and lowest during the measurement, are shown in Figs.6 to 8 for each specimen.

(a) in 21st August.

(b) in 4th February.

Fig.6 Temperature distribution of S250-120.

(a) in 21st August.

(b) in 4th February.

Fig.7 Temperature distribution of S250-80.
In the summer season, as seen in Figs.6(a) to 8(a), the surface temperature rapidly increased after 8:00, and a steep temperature gradient was observed from 10:00 to 14:00. The surface temperature reached around 60°C at around 14:00. After that, the temperature started to drop and the temperature gradient became small. Figs.6(b) to 8(b) show that in the winter season, the surface temperature increased after 10:00, and a steep temperature gradient was observed from 12:00 to 14:00. After that, the temperature started to drop and the temperature gradient became small.

The maximum temperature difference between the surface and the bottom of asphalt concrete was about 10°C to 15°C in the two seasons. The influence of the asphalt concrete thickness and the slab thickness on the temperature distribution was relatively small in this study.

(3) Predicted accuracy of average temperature

The relationship between the predicted average temperature and the measured average temperature for each specimen is shown in Figs.9 to 11. As to the accuracy of the predicted results for each specimen, Tables 3 to 5 show the probability related to the number of data sets within each temperature difference range to the total number of data sets. The temperature difference range is the difference between the measured and the predicted average temperature.

From Figs.9 to 11, Eq. (1) predicts the average temperature with a larger variation. Eqs. (2) and (3) tend to predict relatively high in the higher temperature region; however, the variation is small when compared with Eq. (1). From Tables 3 to 5, the probability decreased in the specimens with thicker asphalt concrete layers. Eq. (3) is effective for predicting the average temperature when compared with Eqs. (1) and (2). The probability within ±2°C of Eq.

| Temperature difference range | Probability (%) |
|-----------------------------|-----------------|
| Eq. (1) | Eq. (2) | Eq. (3) |
| -1°C ≤ ΔT ≤ 1°C | 39.3 | 51.5 | 60.9 |
| -2°C ≤ ΔT ≤ 2°C | 62.9 | 76.0 | 87.6 |
| -5°C ≤ ΔT ≤ 5°C | 95.5 | 98.6 | 99.8 |

Table 4 Accuracy of predicted results for S250-80.

| Temperature difference range | Probability (%) |
|-----------------------------|-----------------|
| Eq. (1) | Eq. (2) | Eq. (3) |
| -1°C ≤ ΔT ≤ 1°C | 41.2 | 53.8 | 64.8 |
| -2°C ≤ ΔT ≤ 2°C | 69.9 | 87.1 | 92.4 |
| -5°C ≤ ΔT ≤ 5°C | 98.6 | 99.4 | 100 |

Table 5 Accuracy of predicted results for S200-120.

| Temperature difference range | Probability (%) |
|-----------------------------|-----------------|
| Eq. (1) | Eq. (2) | Eq. (3) |
| -1°C ≤ ΔT ≤ 1°C | 28.4 | 35.2 | 48.5 |
| -2°C ≤ ΔT ≤ 2°C | 60.8 | 72.5 | 84.0 |
| -5°C ≤ ΔT ≤ 5°C | 94.8 | 98.5 | 99.8 |

Table 3 Accuracy of predicted results for S200-120.
Fig. 9 Predicted results for S250-120.

Fig. 10 Predicted results for S250-80.
(3) is over 80% for three specimens. In the future, the temperature prediction will be needed to evaluate actual urban viaducts where solar radiation is blocked by tall buildings or high-rise noise barriers. The coefficients for Eq. (3) are summarized in Appendix A. For reference, the maximum and minimum air temperatures are described in each group during the measurements.

### 4. VERIFICATION OF CORRECTION METHOD FOR DEFLECTION

The authors performed elastic finite element analysis to establish a correction method for deflection of asphalt concrete on bridge slabs during the FWD tests\(^2\). The average temperature throughout the depth was used in the correction procedures. However, from the temperature measurements described above, a large temperature gradient actually occurred inside the asphalt concrete depending on the season and time of day. There is a need to verify whether the previously proposed correction method\(^2\) is applicable to asphalt concrete with temperature gradients.

#### (1) Overview of correction method

**a) Analytical model**

An analytical model of concrete slabs shown in Fig.12 was simply supported in the longitudinal direction and with slab span lengths of 2 m, 3 m, and 4 m. The length of analytical model in the longitudinal direction was three times the slab span length according to the previous study\(^4\). The concrete slabs were 190 mm, 230 mm, and 270 mm thick, corresponding to the slab span length from the Japanese Specifications for Highway Bridges\(^14\), and the asphalt concrete layers were 0 mm, 40 mm, 80 mm, and 120 mm thick. The loading plate was a circular plate with a diameter of 300 mm as indicated by the green-color arrows in Fig.12, which is usually employed in FWD tests. The applied load in this analysis was 100 kN. The analytical model was a 1/4 model. The Young’s modulus of the concrete was 25 kN/mm\(^2\), and the Young’s modulus of the asphalt concrete\(^4\), which was sensitive to the temperature, was determined by Eq. (4) at the asphalt concrete temperatures of 0°C, 20°C, 40°C, and 60°C. The temperature in the asphalt concrete layer was assumed to uniformly distribute throughout the depth.

#### Table 6 Poisson’s ratio of asphalt concrete\(^{15}\).

| Temperature (°C) | 0   | 20  | 40  | 60  |
|------------------|-----|-----|-----|-----|
| Poisson’s ratio  | 0.25| 0.30| 0.35| 0.45|

Fig.11 Predicted results for S200-120.
Furthermore, as the Poisson’s ratio of the asphalt concrete was also changed along with the temperature, the values used are shown in Table 6.

\[ E_{as} = \frac{6000}{10^{0.0184(T - 20)}} \]  

where \( E_{as} \) is the Young’s modulus of the asphalt concrete (N/mm²), and \( T \) is the asphalt concrete temperature (°C).

b) Correction method

For the correction method in the previous study \(^2\), the authors focused on the deflection at 200 mm apart from the loading point in the longitudinal direction of a bridge. The reason for selecting the deflection at this position was that the deflection sensor could be placed on the asphalt concrete close to the loading area and the influence of local deformation of the asphalt concrete layer due to an impact load was smaller. The target deflection was finally converted to the deflection of the concrete slab without the asphalt concrete layer through the correction procedures. First, the target deflection, \( D_{200,as} \), shown in Fig.12(a), was converted to the deflection of the concrete slab without the asphalt concrete layer at the same position, \( D_{200,co} \), shown in Fig.12(b). The correction factor used in this conversion can be calculated using Eq. (5) and Table 7. The nonlinear model of Eq. (5) was determined from a regression analysis using the results of the elastic finite element analysis \(^2\). The deflection of the concrete slab at each deflection sensor away from the position of 200 mm in the longitudinal direction can be obtained using the same correction factor. Moreover, the deflection in the transverse direction can also be converted with the same procedure, which was confirmed in the previous study \(^2\).

\[
\log \left( \frac{D_{200,co}}{D_{200,as}} \right) = (aH_a^2T_{ave}^2 + bH_a^2T_{ave} + cH_a^2 + dH_aT_{ave}^2 + eH_aT_{ave} + fH_a) \times 10^{-4}
\]  

where \( H_a \) is the asphalt concrete thickness (mm), and \( T_{ave} \) is the average temperature of the asphalt concrete throughout the depth (°C). Furthermore, from \( D_{200,co} \), the deflection at a loading point, \( D_{0,co} \), of the concrete slab without the asphalt concrete layer can be calculated by the following equation \(^2\):

\[
\frac{D_{0,co}}{D_{200,co}} = 0.011L^2 - 0.088L + 1.214
\]  

where \( L \) is the slab span length of the RC slab in the transverse direction of a bridge (m) (i.e., the space between girders).

(2) Influence of temperature gradients

a) Analytical models

In this study, an additional analysis was carried out for asphalt concrete with temperature gradients throughout the depth on a bridge slab to verify the correction method described above. The analytical model was similar to the model shown in Fig.12; however, the model with limited variations, such as a slab span length of 3 m, a slab thickness of 230 mm, and an asphalt concrete thickness of 80 mm, was used. The temperature distributions of the asphalt concrete throughout the depth were set to six patterns as shown in Fig.13 by referring to the measurement results described in chapter 3(2). The element
division in the depth direction for the asphalt concrete was 10 mm \times 4 layers and 20 mm \times 2 layers from the top surface. The material properties of the Young’s modulus and the Poisson’s ratio for each layer were given with respect to the corresponding average temperature in each layer from Eq. (4) and Table 6.

b) Verification of correction method

For the results of the temperature gradient of 60°C-40°C as a sample shown in Fig.13, the distribution of deflection in the transverse and longitudinal directions are shown in Figs.14(a) and 14(b), respectively. In the correction procedure for the asphalt concrete with temperature gradients, the average temperature used was the average of the temperatures on the top and the bottom surfaces of the asphalt concrete layer.

The green-color square mark is the deflection of the top surface of the asphalt concrete, i.e., before the correction procedures, which can be considered as the deflection measured in the FWD test. The red-color circular mark is the deflection after the correction procedures. The blue-color line is the deflection directly determined from the analysis for the concrete slab without the asphalt concrete layer. The deflection at each point after the correction procedures agrees well with the deflection of the concrete slab without the asphalt concrete layer. For the six temperature gradients shown in Fig. 13, the relative error of $D_{0_{\text{co}}}$, which is the difference between the deflection after the correction procedures and the deflection of the concrete slab without the asphalt concrete layer directly analyzed, is shown in Fig.15, with the results evaluated in the previous study\textsuperscript{2).} The relative error of the deflection for temperature gradients indicated by the red-color square mark is within ±2%. These results show the same error level as the results for those without temperature gradients indicated by the blue-color circular mark. This suggests that the influence of temperature gradients is small with the correction method proposed in the previous study\textsuperscript{2).}
The correction factor, $D_{200,\text{col}}/D_{200,\text{ave}}$, from Eq. (5) depends on the thickness and the average temperature of the asphalt concrete. In this paper, the temperature difference ranges were set within $\pm 1^\circ\text{C}$, $\pm 2^\circ\text{C}$, and $\pm 5^\circ\text{C}$ to evaluate the predicted accuracy of the average temperature described in section 3(3). In this section, the influence of the temperature difference range is verified; this is the difference between the measured and the predicted average temperatures, on the correction factor determined from Eq. (5). The details of the variables considered are shown in Table 8.

Fig. 16 shows the relative error of the correction factor, which is the difference between the corrected factor using the average temperature, $T_{\text{ave}}$, and the correction factor using the average temperature with the deviation of $\Delta T$, is shown in Fig. 16. The relative error increases positively and negatively with the increase in the asphalt concrete thickness and decrease in the temperature in the asphalt concrete layer. In Fig. 16(a), when the temperature difference from the average temperature, i.e., the deviation of $\Delta T$, is within $\pm 2^\circ\text{C}$, the correction factor is provided within $\pm 5\%$. Furthermore, in Fig. 16(b), the relative error for the deviation of $\pm 5^\circ\text{C}$ becomes more than twice that for the deviation of $\pm 2^\circ\text{C}$.

5. CONCLUSIONS

In this paper, the equation for predicting the average asphalt concrete temperature on bridge slabs was empirically derived based on the measurement results. The correction method of deflection was analytically evaluated for the asphalt concrete layer with temperature gradients. Based on the results, the following conclusions were drawn:

1. Among the three predicting models for the average asphalt concrete temperature on bridge slabs, the model using surface temperature, air temperature, and the difference in surface temperature between the measurement time and one hour before the measurement time agreed well with the measured results.

2. The previously proposed correction method of deflection in the FWD tests was verified for the asphalt concrete with temperature gradients through elastic finite element analysis. The relative error of deflection was within $\pm 2\%$ for the asphalt concrete having temperature gradients, and was the same error level for the asphalt concrete without temperature gradient.

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### APPENDIX A

| Months          | Maximum and minimum air temperatures | Hours | a     | b     | c   | d   | a     | β     |
|-----------------|-------------------------------------|-------|-------|-------|-----|-----|-------|-------|
| November to March | 26.1°C to -6.2°C                     |       |       |       |     |     |       |       |
| 0               | 1.246 -0.301 0.000 1.707 0.653 0.205 |       |       |       |     |     |       |       |
| 1               | 1.231 -0.294 0.000 1.610 0.673 0.190 |       |       |       |     |     |       |       |
| 2               | 1.222 -0.282 0.000 1.554 0.656 0.202 |       |       |       |     |     |       |       |
| 3               | 1.206 -0.270 0.000 1.609 0.680 0.185 |       |       |       |     |     |       |       |
| 4               | 1.177 -0.219 0.000 1.369 0.675 0.189 |       |       |       |     |     |       |       |
| 5               | 1.201 -0.262 0.000 1.480 0.705 0.168 |       |       |       |     |     |       |       |
| 6               | 1.216 -0.293 -0.554 1.620 0.732 0.150 |       |       |       |     |     |       |       |
| 7               | 0.986 -0.051 -0.546 1.267 0.900 0.051 |       |       |       |     |     |       |       |
| 8               | 1.019 -0.060 -0.592 0.472 1.387 -0.157 |       |       |       |     |     |       |       |
| 9               | 0.728 0.212 -0.565 0.121 1.685 -0.251 |       |       |       |     |     |       |       |
| 10              | 0.747 0.238 -0.612 -1.044 1.523 -0.202 |       |       |       |     |     |       |       |
| 11              | 0.741 0.232 -0.475 -1.303 1.414 -0.167 |       |       |       |     |     |       |       |
| 12              | 0.751 0.208 -0.484 -0.911 1.314 -0.131 |       |       |       |     |     |       |       |
| 13              | 0.781 0.182 -0.487 -0.672 1.225 -0.097 |       |       |       |     |     |       |       |
| 14              | 0.813 0.145 -0.478 -0.208 1.124 -0.056 |       |       |       |     |     |       |       |
| 15              | 0.866 0.121 -0.286 0.660 1.003 -0.001 |       |       |       |     |     |       |       |
| 16              | 0.909 0.054 -0.529 1.057 0.927 0.036 |       |       |       |     |     |       |       |
| 17              | 1.194 -0.246 -0.418 1.786 0.870 0.067 |       |       |       |     |     |       |       |
| 18              | 1.133 -0.183 -0.769 1.539 0.829 0.090 |       |       |       |     |     |       |       |
| 19              | 1.203 -0.240 -1.144 1.264 0.795 0.110 |       |       |       |     |     |       |       |
| 20              | 1.298 -0.341 -1.156 1.415 0.803 0.105 |       |       |       |     |     |       |       |
| 21              | 1.368 -0.423 -0.898 1.658 0.736 0.148 |       |       |       |     |     |       |       |
| 22              | 1.313 -0.370 -0.848 1.676 0.712 0.163 |       |       |       |     |     |       |       |
| 23              | 1.272 -0.324 -0.925 1.596 0.673 0.190 |       |       |       |     |     |       |       |
| April to October | 38.3°C to 3.7°C                       |       |       |       |     |     |       |       |
| 0               | 1.402 -0.431 0.000 1.469 0.930 0.035 |       |       |       |     |     |       |       |
| 1               | 1.360 -0.391 0.000 1.418 0.931 0.035 |       |       |       |     |     |       |       |
| 2               | 1.339 -0.370 0.000 1.474 0.933 0.033 |       |       |       |     |     |       |       |
| 3               | 1.332 -0.368 0.000 1.541 0.935 0.032 |       |       |       |     |     |       |       |
| 4               | 1.311 -0.342 0.000 1.441 0.936 0.032 |       |       |       |     |     |       |       |
| 5               | 1.316 -0.351 0.000 1.485 0.950 0.025 |       |       |       |     |     |       |       |
| 6               | 1.106 -0.150 -0.684 1.635 1.007 -0.003 |       |       |       |     |     |       |       |
| 7               | 0.792 0.168 -0.608 1.433 1.094 -0.043 |       |       |       |     |     |       |       |
| 8               | 0.656 0.323 -0.493 0.761 1.160 -0.071 |       |       |       |     |     |       |       |
| 9               | 0.616 0.386 -0.398 0.023 1.194 -0.085 |       |       |       |     |     |       |       |
| 10              | 0.643 0.358 -0.346 -0.249 1.202 -0.088 |       |       |       |     |     |       |       |
| 11              | 0.671 0.334 -0.376 -0.238 1.189 -0.083 |       |       |       |     |     |       |       |
| 12              | 0.699 0.314 -0.364 -0.374 1.169 -0.075 |       |       |       |     |     |       |       |
| 13              | 0.736 0.286 -0.367 -0.481 1.126 -0.057 |       |       |       |     |     |       |       |
| 14              | 0.780 0.242 -0.393 -0.298 1.060 -0.028 |       |       |       |     |     |       |       |
| 15              | 0.814 0.211 -0.394 0.120 1.021 -0.010 |       |       |       |     |     |       |       |
| 16              | 0.889 0.103 -0.518 0.880 0.996 0.002 |       |       |       |     |     |       |       |
| 17              | 1.106 -0.128 -0.249 1.545 0.958 0.021 |       |       |       |     |     |       |       |
| 18              | 1.200 -0.229 -0.445 1.598 0.936 0.032 |       |       |       |     |     |       |       |
| 19              | 1.297 -0.326 -0.520 1.617 0.928 0.036 |       |       |       |     |     |       |       |
| 20              | 1.312 -0.335 -0.726 1.455 0.926 0.037 |       |       |       |     |     |       |       |
| 21              | 1.350 -0.371 -0.684 1.398 0.927 0.036 |       |       |       |     |     |       |       |
| 22              | 1.358 -0.379 -0.822 1.307 0.928 0.036 |       |       |       |     |     |       |       |
| 23              | 1.374 -0.400 -0.721 1.420 0.929 0.036 |       |       |       |     |     |       |       |
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