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Research Article

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Study of the Variation in Service Temperature on the RN°1 Roadway in the Central Region (Togo)

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Abstract Togo, like many other West African countries, does not have precise data on the nature of the temperature variation cycle on pavements, even though they are subject to an aggressive tropical climate, warm in nature. The bituminous mixes used on the roads of Togo have a viscoelastic behaviour strongly influenced by the temperature cycle within the pavements with bituminous coating, thus causing premature deformations. In order to better appreciate the influence of the variation of the temperature on the roadway in accordance with that which is taken in geotechnical laboratories in Togo, our study consisted in checking the variation of the temperature on the surface of the roadway and at 2.5 cm deep during the day on the national N°1 in the Center Region in Togo. The measurements were carried out using the thermocouple and the hygrometer which made it possible to have the temperatures of the roadway and the air respectively. At the end of this study, it appears that the temperature at the surface of the roadway at certain times of the day reaches a peak varying between 64,60°C to 72,50°C exceeding that taken as a reference in the laboratory which is 60°C. In addition, it was found that the observation time of the values of the temperature which remains greater than or equal to 60°C vary between two (02) and four (04) hours.

Keywords Air temperature, Asphalt concrete, Marshall test, pavement surface temperature, temperature inside the pavement

Introduction

The presence of ruts on the roads has always been and continues to be a problem for the performance of the bituminous mixes that make up the roadway. Rutting not only decreases the service life of roads but also creates a hazard for motorists.These quickly reach their limits of resistance to permanent deformations, which leads to a subsidence of the roadway at the places where the wheels of the vehicles pass [13].

This situation influences the durability of the surface layers of bituminous pavements, which is a function of the viscoelastic nature of the asphalt. The viscoelastic behavior of this material, in the medium and long term, depends mainly on the qualities at the origin of the bitumen and its thermal history. The climatic agents then participate in the evolution of the chemical and rheological properties of the binders and remain a main cause of the degradation of pavements based on black products.

In each country, or even regions, the thermal differences between day and night are very significant. The climate is often unstable, associated with sudden variations in temperature, which leads to a heating/cooling phenomenon due to the sunshine and air ventilation. These thermal gradients cause internal thermal stresses and changes in the viscoelastic properties of the surface layers.

During operation, it is noticed that the structure of the wearing course suffers under the effect of these cyclic thermal phenomena and gradually deteriorates. This loss of quality can lead to insufficient performance [8].

Hence the premature deformation by rutting observed on the surface of wearing courses.

The thermal history of the bitumen can then cause a change in its rheological and mechanical behaviour due to complex processes and the inter-conversions of the different chemical species that constitute it. It is therefore important to take this phenomenon into account in order to predict the behaviour and lifespan of road structures in the short and long term [2].

To do this, many researchers have implemented formulation methods that simulate the effect of temperature on the performance level of bituminous mixtures in the laboratory. This is the case of the Marshall NP 198-251-2 method in 1939 [6] which is an empirical method chosen by Togolese laboratories. This method consists in evaluating the level of stability and deformation by creep on the universal press of the bituminous sample after it has passed through the thermal bath set at a temperature of 60°C for a period of 30 min.

The statement that the higher the ambient temperature, the more the rut formation will be accentuated [12]; led us in our research work to verify the level of validity of taking into account the value of 60°C as the laboratory test temperature and 30 min as the shelf life.

Our works, which are the first in Togo, consist in checking on the national road N°1 (RN°1) in one of the regions of Togo which is the Center region, the nature of the temperature variation on the surface of the roadway, and at 2.5 cm depth as well as the variation in air temperature.

Material and Method

Location of the measurement location

The environment chosen for the measurements is the Center region in the locality of Blitta on the national N°1 whose geolocation is presented below. National N°1 is the route chosen, because it is the busiest route. In order to avoid traffic disturbances and to have an area completely free of dwellings bordering the road and which can reduce the effect of radiation, the tests were carried out at the entrance to the city at Blitta. The location of the test area and the chosen route is shown on the map below.

Table 1: Geolocation of the measurement location

Geolocation of the place where the measurements were taken	
Longitude (X)	1,208056
Latitude (Y)	6,355278
Height (H)	47

Figure 1: Map of Togo showing the trial location in the Center Region in Blitta

Photo 1: Test area on RN°1 in Blitta (Togo) (Lomé-Togo)

Material

The temperature measurement is made based on the high precision thermocouple comprising a double display with backlighting and two inputs. This model PST05-FR thermocouple allows direct measurements to be taken via temperature sensors (cables) with a diameter of 0.35 mm, connected to the two inputs. The accuracy level is ±1.5% with a sensitivity level that is 0.1°C. The capacity of the measurement varies according to the types of adjustment chosen.

Table 2: Thermocouple Type and Measurement Range

Type	Measurement Interval
J	-210 à +1200 °C
K	-200 à +1372 °C
T	-250 à +400 °C
E	-150 à +1000°C
N	-200 à +1300 °C
R et S	0 à +1767 °C

The thermocouple chosen for temperature measurement is the T type whose error is very negligible and varies from 0.75% to 1% compared to the other types whose values are higher.The error values indicated above are suitable for measurements with temperatures below 0°C and varying up to the limit of 400°C and are not affected in humid atmospheres.

For the case of air temperature measurement, it is made on the basis of the KTT320 type hygrometer, having the internal measurement capacity of temperature, humidity, atmospheric pressure, CO_2. Capable of taking nearly 2,000,000 measurements, the KTT 320 Hygrometer has several types of displays, as shown in the table below, the storage temperature of which is -40 to +85°C. The display units are °C, °F, %RH, hPa, ppm and the level of precision is ±0.4 °C for measurements varying from 0 to 50 °C and for measurements below 0 °C or exceeding 50°C the level of accuracy is ±0.8°C. The thermocouple chosen for the case of air temperature measurement is type T with a recording rate that varies from 1 min to 24 hours. The type KTT320 hygrometer is pre-programmed and is able to measure the ambient temperature and the relative humidity of the air. The two devices used are shown below.

Table 3: Hygrometer Type and Measurement Range

Type	Measurement Interval
J	-100 à +1300 °C
K	-200 à +750°C
T	-200 à +400 °C
N	-200 à 1300 °C
S	0 à +1767 °C

Photo 2: Thermocouple type PST05-FR

Photo 3: KTT320 type hygrometer

Asphalt concrete wearing course, e = 10 cm
Gravel bitumen base layer, e= 20 cm
Foundation layer in cement soil, e=30 cm
Silica sand subgrade, e variable from 0.5 to 1 m

Figure 2: Cross-section of the test semi-grained asphalt concrete pavement

Methodology

Metering arrangements

The environment chosen for the measurements is the Center region in the locality at Blitta on the national N°1 whose geolocation is presented above.

Photo 4 : Dispositions de mesure de températures

The test consisted of positioning ourselves on the east side of the road coming from Lomé by installing beacons. Based on a 12 mm steel nail, the semi-grained bituminous concrete pavement, the structural section of which is shown above, was drilled to a depth of 2.5 cm, where the cable connected to the first input of the thermocouple denoted T1 and the second cable placed in direct contact with the surface of the roadway and connected to the second input of the thermocouple denoted T2. In the case of the hygrometer, which measures air temperature, it was positioned 1.2 meters from the road. The photo below shows the layout of the measuring devices on site.

Temperature measurement protocol

The purpose of the tests is to measure the temperature variation at the surface and at 2.5 cm depth of the asphalt concrete pavement based on the thermocouple. And at the same time determine the variation in air temperature 1.2 meters from the roadway based on the hygrometer.

The measurement time of the pavement temperature values covers the whole day (from 7 a.m. to 6 p.m.) whose measurement frequency is 10 seconds. As for the air temperature values, it is set in advance according to the time interval of the temperature taken on the pavement whose data is retrieved at the end of the test.

The values of the temperature of the road taken are read on the luminous screen with double reading after every 10 seconds and whose maximum value is noted on a form previously prepared and all this during a period of 11 hours of time (from 7 hours at 18 hours).

3. Results and Discussion

The roadway and air temperature measurements were taken on the RN°1 in the Maritime Region for 5 days in March and April of the year 2021.

The results of the measurements are shown below

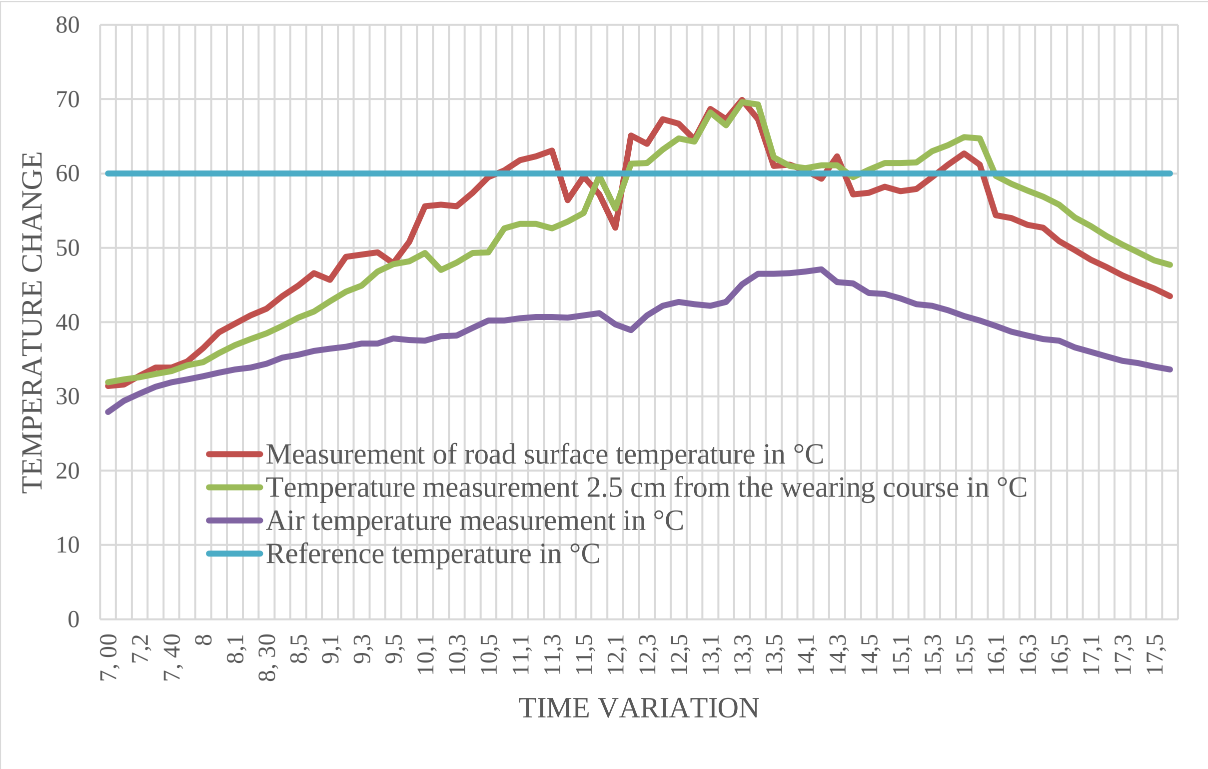

Figure 3: Variation in road and air temperature on 03/28/2021: central region

The three temperatures taken during the day of 04/10/2021 are as follows:

- The temperature taken at the surface of the roadway:
  - ✓ Between 7:00 a.m. and 10:50 a.m., the surface temperature value increases but remains below 60°C;
  - ✓ Between 10:50 a.m. and 4:10 p.m. the temperature continues to rise, this time exceeding the value of 60°C to a peak of 66.9°C taken at 1:30 p.m.,
  - ✓ From 4:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 43.5°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
  - ✓ Between 7:00 a.m. and 10:50 a.m., the temperature value increases but remains below 60°C;
  - ✓ Between 10:50 a.m. and 4:10 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 66.6°C taken at 1:30 p.m.,
  - ✓ From 4:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 47.7°C.
- The air temperature taken at a height of 1.2 meters from the road surface:

The air temperature is moving in the same direction as the other two with a peak of 47.1°C taken at 2:20 p.m.

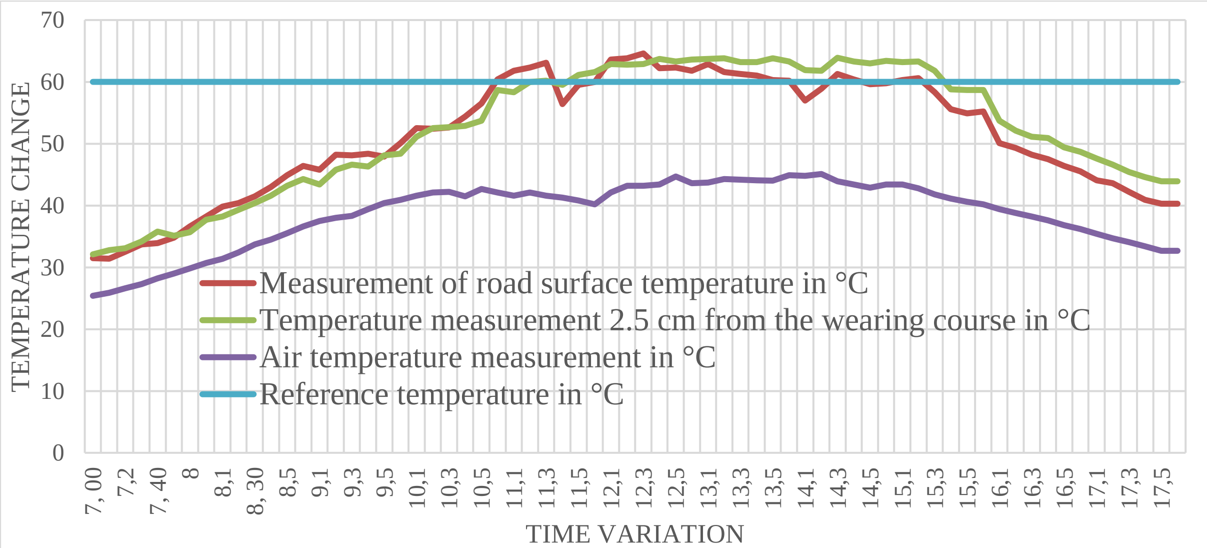

Figure 4: Variation in road and air temperature on 03/29/2021: central region

The three temperatures taken during the day of 03/29/2021 are as follows:

- The temperature taken at the surface of the roadway:
  - ✓ Between 7:00 a.m. and 10:50 a.m., the surface temperature value increases but remains below 60°C;
  - ✓ Between 11 a.m. to 3 p.m. 10 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 69.9°C taken at 1:30 pm,
  - ✓ From 15 hours 10 min, the temperature begins to decrease. And at 6 p.m. it drops to 40.3°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
  - ✓ Between 7:00 a.m. and 11:30 a.m., the temperature value increases but remains below 60°C;
  - ✓ Between 11 am to 3 pm 10 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 69.6°C taken at 1:30 pm,
  - ✓ From 15 hours 10 min, the temperature begins to decrease. And at 6:10 p.m. it drops to 33.6°C.
- The air temperature taken at a height of 1.2 meters from the road surface:

The air temperature is moving in the same direction as the other two with a peak of 46.8°C taken at 2:10 p.m.

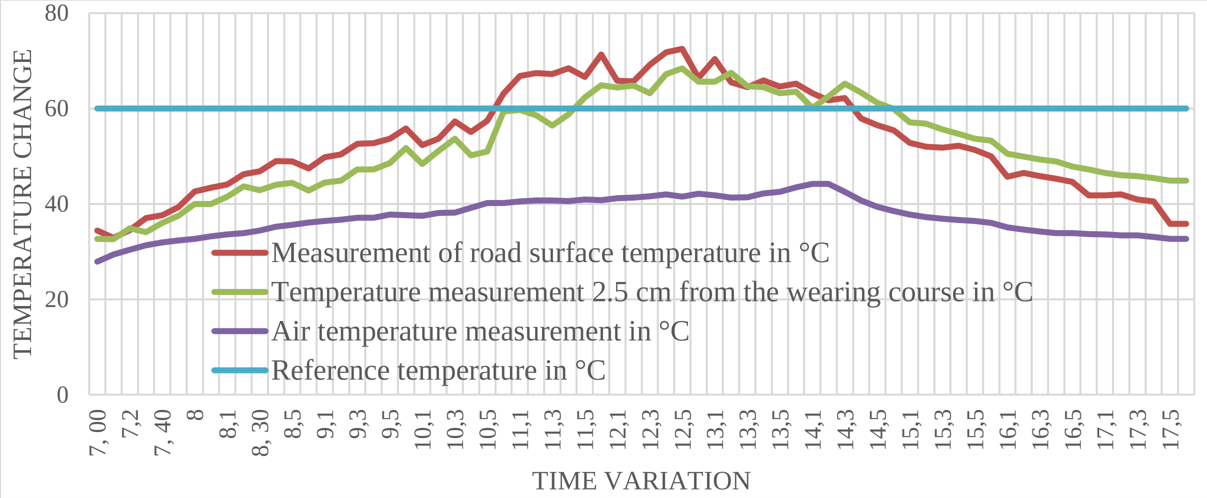

Figure 5: Variation in pavement and air temperature on 04/21/2021: central region

The three temperatures taken during the day of 04/21/2021 are as follows:

- The temperature taken at the surface of the roadway:
  - ✓ Between 7:00 a.m. and 10:50 a.m., the surface temperature value increases but remains below 60°C;
  - ✓ Between 11 a.m. to 2 p.m. 10 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 72.5°C taken at 12:50 p.m.,
  - ✓ From 2:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 35, 80°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
  - ✓ Between 7:00 a.m. and 10:50 a.m., the temperature value increases but remains below 60°C;
  - ✓ Between 11 a.m. to 2 p.m. 10 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 68.4°C taken at 12:50 p.m.,
  - ✓ From 2:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 44.9°C.
- The air temperature taken at a height of 1.2 meters from the road surface:

The air temperature evolves in the same direction as the other two with a peak of 44.2°C taken at 2:10 p.m.

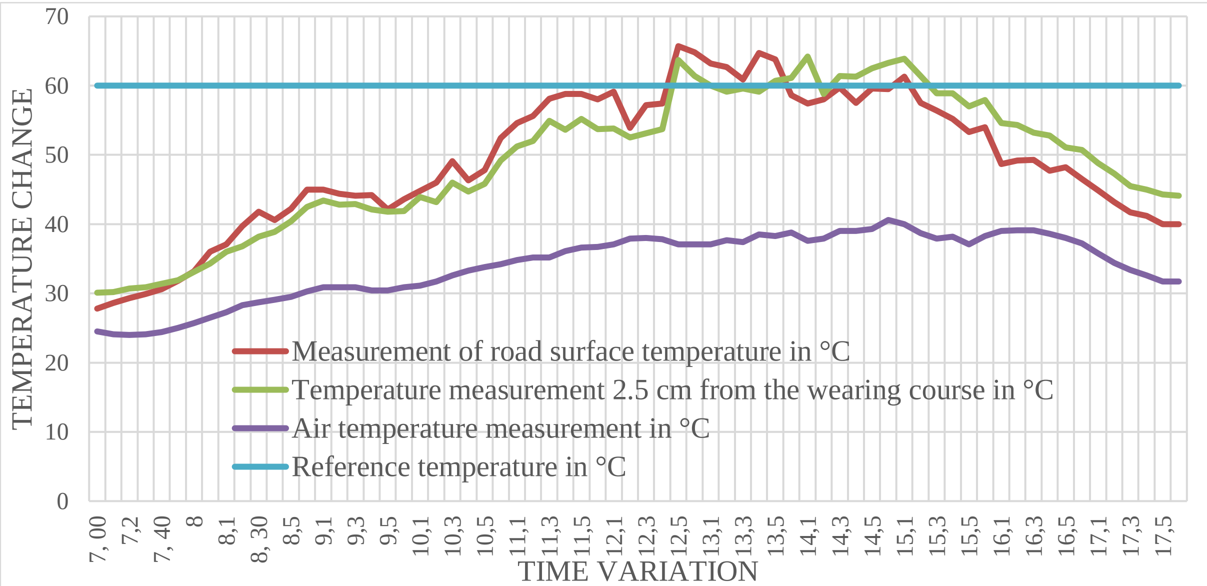

Figure 6: Variation in pavement and air temperature on 04/22/2021: central region

The three temperatures taken during the day of 04/14/2021 are as follows:

- The temperature taken at the surface of the roadway:

Between 7:00 a.m. and 12:50 p.m., the surface temperature value increases but remains below 60°C;

- ✓ Between 1 p.m. to 3 p.m. 30 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 64.7°C taken at 1:30 p.m.,
- ✓ From 3:30 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 40°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
- ✓ Between 7 a.m. and 12.50 p.m., the temperature value increases but remains below 60°C;
- ✓ Between 1 p.m. to 3 p.m. 30 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 64.2°C taken at 2:10 p.m.,
- ✓ From 3:30 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 43.1°C.
- The temperature of the air taken at a height of 1.2 meters from the surface of the roadway:

The air temperature is moving in the same direction as the other two with a peak of 40.6°C taken at 3 p.m.

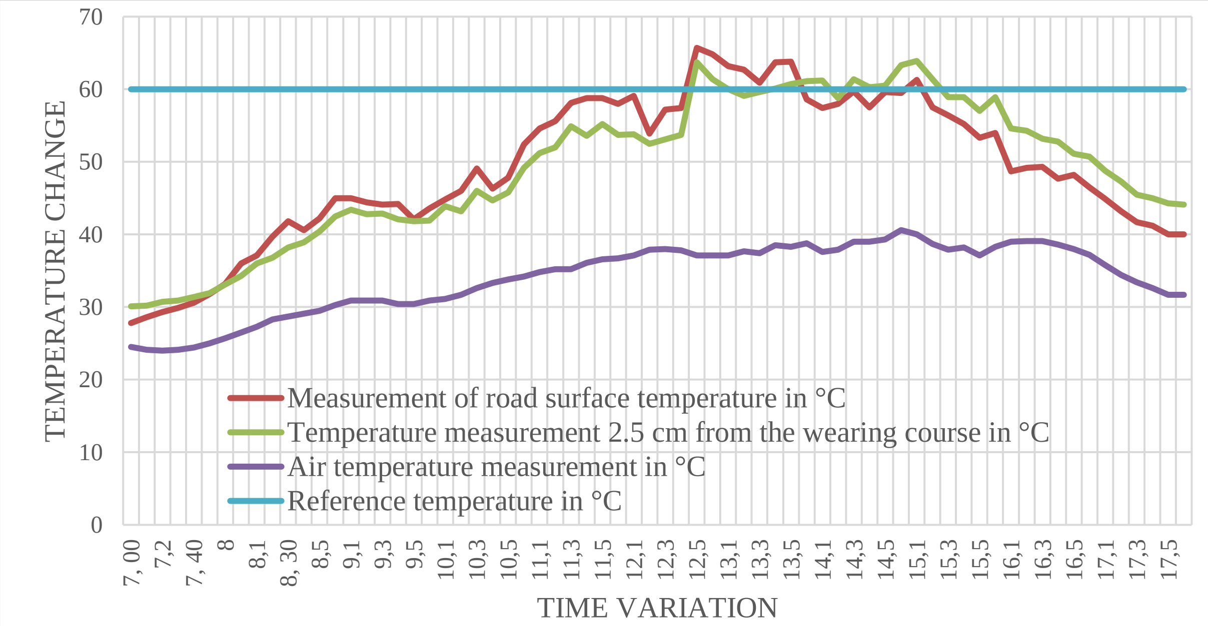

Figure 7: Variation in pavement and air temperature on 04/23/2021: central region

The three temperatures taken during the day of 04/15/2021 are as follows:

- The temperature taken at the surface of the roadway:
- ✓ Between 7:00 a.m. and 12:50 p.m., the surface temperature value increases but remains below 60°C;
- ✓ Between 12 hours 50 min to 15 hours 10 min the temperature continues to increase, exceeding the value of 60°C up to a peak of 65.70°C taken at 12:50 p.m.,
- ✓ From 3:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 40°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
- ✓ Between 7 a.m. and 12.50 p.m., the temperature value increases but remains below 60°C;
- ✓ Between 12:50 p.m. and 3:10 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 63.7°C taken at 12:50 p.m.,
- ✓ From 3:10 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 44.1°C.
- The air temperature taken at a height of 1.2 meters from the road surface:

The air temperature is moving in the same direction as the other two with a peak of 40.6°C taken at 3 p.m.

The temperature measurements on the roadway taken in the Central region were made in the months of March and April of the year 2021. Three measurements in total were made over a period of five (5) days, these are temperature at the pavement surface and at 2.5 cm depth as well as the air temperature positioned at 1.2 meters above the pavement surface.
For the 6 days, 11 hours of time were devoted to the measurements, which varied between 7 a.m. and 6 p.m.
For the pavement temperature values during the 11 hours of measurement, the summary of the results obtained is divided into two main parts:

- At sunrise (between 7 a.m. and 8 a.m.) and at sunset (between 3 p.m. and 6 p.m.), the temperature taken at 2.5 cm depth of the road remains higher than that taken at the surface.
- From 8:30 a.m. until 3 p.m., the temperature taken on the surface of the roadway takes precedence over that of the interior.

The observation of the three types of temperature measurement (inside the roadway, on the surface of the roadway and the air temperature at 1.2 meters) allow us to see that they evolve in the same direction. [10].
In the progression of the sunrise during the 5 days, it is noted that the temperature on the surface remains higher than that taken inside the roadway [12] with values which reach more than 60°C between 10:30 a.m. min to 4 p.m. 10 min. An observation made for a period of 2 to 4 hours of time [3], [4]. The peaks observed per day vary from 64.60°C to 72.50°C observed between 12 p.m. and 1 p.m.
The observation of temperature values at 2.5 cm depth of the pavement during the day which at times exceed the temperature taken at the surface, are caused by cloud cover [7], which shows the level of sensitivity of the pavement to solar radiation.

The test results carried out for the moment in March and April in the Central region show us that the critical service temperature often taken in the laboratory in Togo for the verification of the mechanical performance of the bituminous mixture, is not verified. on the construction site. Since the tests did not only cover the whole month of April, but also the whole year, there could be other values higher than 72.50°C.
This observation shows that taking into account the test temperature of bituminous mixtures in the laboratory, which is 60°C kept in the thermal bath for 30 minutes in accordance with the Marshall standard, does not reflect the reality of the site in the Maritime region. . In addition, it has been found that the wearing course is more influenced by the effect of light and ultraviolet radiation [14], whereas in the laboratory, verification of the performance of the bituminous mixture under the effect of temperature in accordance with the Marshall standard [11] is carried out in the thermal bath in the presence of water.
This analysis shows that for the case of the Center region, the integration of the ultimate stress temperature is not sufficiently taken into account and could be part of one of the reasons for the limit of the service life of asphalt pavements.

3. Conclusion

The purpose of this work is to verify on site the nature of the service temperature and its duration in order to ensure the correctness of the choice of the test temperature made in the laboratories in Togo. For this, from a PST05-FR type Thermocouple and the KCC320 type Hygrometer, the temperature measurements on the surface and at 2.5 cm depth of the roadway as well as the air temperature 1.2 meters above the road surface were made on the RN°1 in the Blitta area in the Central region. All the values showed that the three measurements have the same appearance and that only the surface of the pavement is influenced by sunlight and ultraviolet rays, which in turn influences the other two layers. It shows that the service temperature observed at the surface of the pavement is greater than 60°C and its duration varies from 2 hours to 4 hours. As for the peaks observed, they vary between 64.60°C and 72.50°C. It is therefore important to update the test principles of the Marshall standard to the realities of each construction site. In order to make the pavements in Togo much more durable, it is important to have a reliable knowledge of the variation of the pavement surface temperature.

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