



ISSN: 0976-3376

Available Online at <http://www.journalajst.com>

ASIAN JOURNAL OF  
SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology  
Vol. 13, Issue, 12, pp.12325-12330, December, 2022

## RESEARCH ARTICLE

### STUDY OF THE VARIATION IN SERVICE TEMPERATURE ON THE RN°1 ROADWAY IN THE MARITIME REGION (TOGO)

Hèzouwè Bassaï BODJONA<sup>1,2,3,4\*</sup>, Agapi K. HOUANOU<sup>1</sup>, Yawovi M. X. Dany AYITE<sup>3</sup>, Ouro-Djobo E. SAMAH<sup>4</sup> and Antoine VIANOU<sup>2</sup>

<sup>1</sup>Laboratoire d'Energétique et de Mécanique Appliquée, Université d'Abomey – Calavi, Bénin; <sup>2</sup>Laboratoire de Caractérisation Thermophysique des Matériaux et d'Application Energétique, Université d'Abomey – Calavi, Bénin; <sup>3</sup>Laboratoire de Recherche en Sciences de l'Ingénieur, Ecole Nationale Supérieure des Ingénieurs, Université de Lomé, Togo; <sup>4</sup>Centre Régional de Formation pour Entretien Routier, Togo

#### ARTICLE INFO

##### Article History:

Received 19<sup>th</sup> September, 2022  
Received in revised form  
20<sup>th</sup> October, 2022  
Accepted 25<sup>th</sup> November, 2022  
Published online 30<sup>th</sup> December, 2022

##### Keywords:

Asphalt concrete, Marshall Test, Air Temperature, Pavement Surface Temperature, Temperature Inside the Pavement.

#### 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 Maritime 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 63.60°C to 69.30°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.

**Citation:** Hèzouwè Bassaï BODJONA, Agapi K. HOUANOU, Yawovi M. X. Dany AYITE, Ouro-Djobo E. SAMAH and Antoine VIANOU, 2022. "Study of the variation in service temperature on the rn°1 roadway in the maritime region (togo)", *Asian Journal of Science and Technology*, 13, (12), 12325-12330.

Copyright © 2022, Hèzouwè Bassaï BODJONA et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

## INTRODUCTION

Asphaltic concrete is a mixture, produced by an asphalt plant, of gravel, fillers (sand and dust) and a hydrocarbon binder which is generally bitumen. It is mainly used as a coating layer for runways, roads, airports, aprons, etc. This layer is subject to the immediate effects of climate including temperature, rain and sunshine. Its durability depends on the viscoelastic character of the bitumen. In general, bitumen is a heat-sensitive material which results in the creation of stresses and deformations within the material due to thermal expansions and also by the creation in the roadway of tensile forces in the longitudinal direction leading to possible transverse cracks (Commission canadienne de sûreté nucléaire, 2012). When formulating binder, it is therefore necessary to take into account the climatic conditions of use.

In Togo, binder is formulated using the Marshall method developed by Bruce Marshall in 1939 (Didier Lesueur, 2002). This method makes it possible to determine a binder formula based on the mechanical resistance known as stability, subsidence called creep and the Marshall quotient (Fébronlione prince SEVI, 2020; Philippe Marty, 2012). The principle of the test is to determine the bitumen content of a bituminous mixture whose particle size composition is given and to assess its mechanical qualities. This then amounts to measuring the maximum resistance and the corresponding deformation of a mixture specimen previously immersed in a thermal bath at 60 ° C (± 1) for 30 minutes (± 1) then subjected to crushing between two cylindrical jaws. whose entire device is called the Marshall press (Fébronlione prince, 2020; Philippe Marty, 2012). In reality, the exposure time of bituminous pavements, either to temperature or to rain, varies from a few minutes to hours. The objective of this paper is to study the effect of varying the thermal bath storage time of bituminous mixture samples on Marshall stability and creep. It is thus envisaged to vary the storage time in a water bath of the samples of a semi-grained binder 0/14 formulated by the

\*Corresponding author: Hèzouwè Bassaï BODJONA,  
Laboratoire d'Energétique et de Mécanique Appliquée, Université d'Abomey – Calavi, Bénin.

Marshall method and thus to assess the effect of the storage time on the stability and creep of binders.

**MATERIALS AND METHODS**

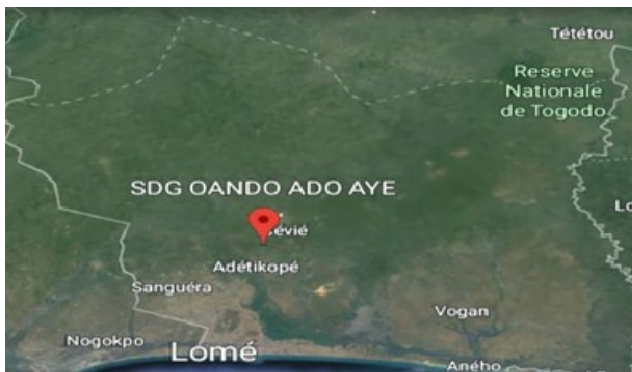
**Location of the measurement location:** The environment chosen for the measurements is the Maritime region in the locality of Adetikopé on the national N°1 whose geolocation is presented below. National N°1 is the route chosen, because it is the busiest route. In order to avoid traffic disturbances and to have an area completely clear of the houses bordering the road and able to reduce the effect of radiation, the tests were carried out outside the city by positioning themselves at the exit of Grand Lomé at Adetikome. The location of the test area and the chosen route is shown on the map below.

**MATERIALS AND METHODS**

The temperature measurement is made based on the high precision thermocouple comprising a double display with backlighting and two inputs.

Tableau 1 . Géolocalisation du lieu de mesure

Geolocation of the place where the measurements were taken	
Longitude (X)	1.208056
Latitude (Y)	6.355278
Height (H)	47.000000



Gure 1. Map of Togo showing the trial location in the Maritime Region in Lomé



Photo 1. Test area on RN°1 in Adetikopé (Lomé-Togo)

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.

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

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

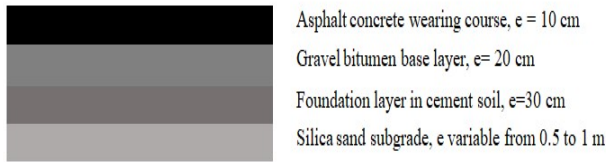


Photo 2. Thermocouple type PST05-FR



Photo 3. KTT320 type hygrometer

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. 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.



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

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<sub>2</sub>. 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.

**Metering arrangements :** The environment chosen for the measurements is the Maritime region in the locality of Adetikopé on the national N°1 whose geolocation is presented above. 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.



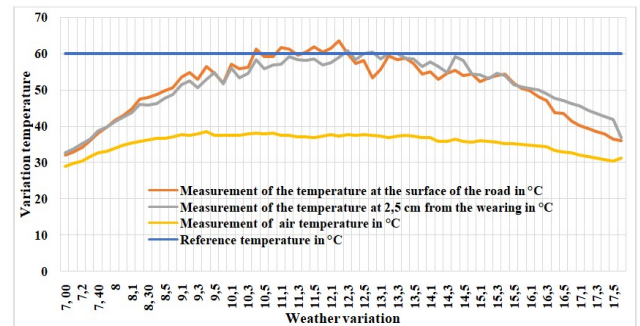
**Photo 4 . Temperature measurement arrangements**

**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).

**RESULTS AND DISCUSSION**

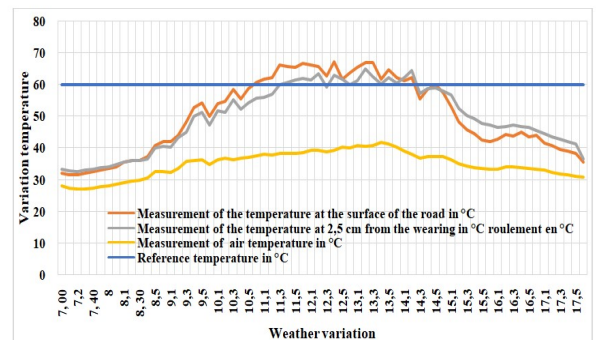
The road and air temperature measurements were taken on the RN°1 in the Maritime Region for 6 days in April of the year 2021.

The results of the measurements are shown below.



**Figure 3: Variation in road and air temperature on 04/10/2021: Maritime Region**

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



**Figure 4. Variation in road and air temperature on 04/11/2021: Maritime Region**

- The temperature taken at the surface of the roadway:
- Between 7 a.m. and 10 a.m., the surface temperature value increases but remains below 60°C;

- Between 10:30 a.m. and 1:30 p.m. the temperature continues to rise, this time exceeding the value of 60°C to a peak of 63.6°C taken at 12:20 p.m.,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 36.1°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
- Between 7 a.m. and 12 p.m., the temperature value increases but remains below 60°C;
- Between 12:30 p.m. and 1:30 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 60.9°C taken at 12:30 p.m.,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 36.8°C. 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 which is 38.6°C taken at 9 hours 40 min.

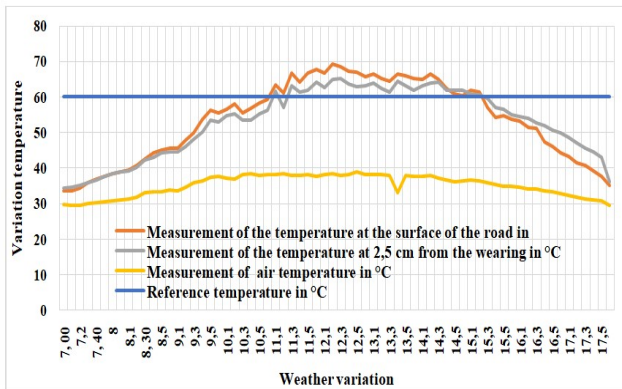


Figure 5. Variation in road and air temperature on 04/13/2021: Maritime region

The three temperatures taken during the day of 04/11/2021 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 11:00 a.m. and 2:30 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 67.3°C taken at 12:40 p.m.;
- From 2:30 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 30.8°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
- Between 12:00 p.m. and 2:30 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 65°C taken at 1:20 p.m.;
- From 2:30 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 36.8°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 41.8°C taken at 13 hours 40 minutes.

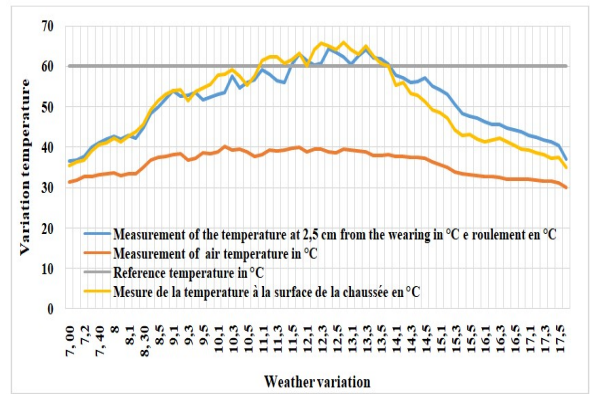


Figure 6. Variation in road and air temperature on 04/14/2021: Maritime Region

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 a.m. and 11 a.m., the surface temperature value increases but remains below 60°C;
- Between 11 a.m. and 2 p.m. the temperature continues to increase, exceeding the value of 60°C up to a peak of 65.7°C taken at 12:30 p.m.,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 35°C.
- The temperature taken at a depth of 2.5 cm from the road surface:
- Between 7 a.m. and 11 a.m., the temperature value increases but remains below 60°C;
- Between 11:00 a.m. and 2:00 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 64.3°C taken at 12:40 p.m.,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 37.1°C.
- The temperature of the air taken at a height of 1.2 meters from the surface of the roadway:

The air temperature evolves in the same direction as the other two with a peak which is 40.2°C taken at 10 hours 20 min.

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

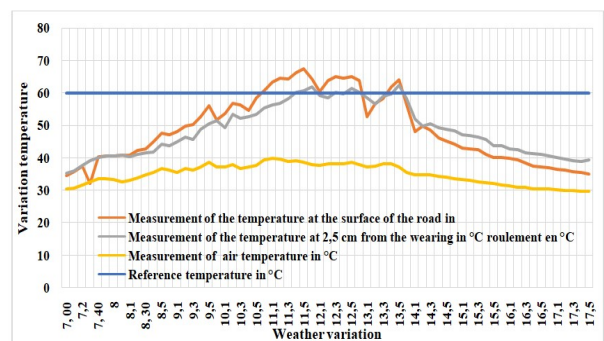
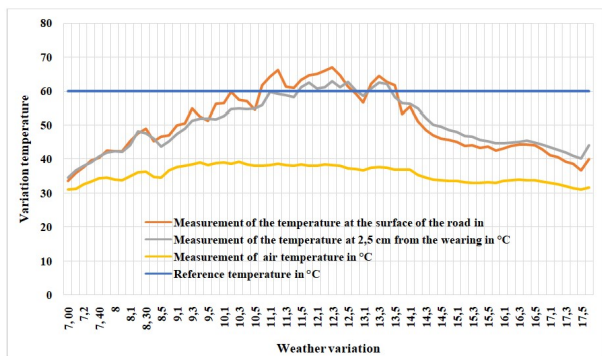


Figure 7. Variation in road and air temperature on 04/15/2021: Maritime Region

- 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 1:50 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 67.40°C taken at 11:50 a.m.,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 34.9°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 11:30 a.m. and 1:50 p.m. the temperature continues to rise, exceeding the value of 60°C to a peak of 62°C taken at 12 noon,
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 36.3°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 39.8°C taken at 11 a.m.

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



**Figure 8. Variation in road and air temperature on 04/16/2021: Maritime Region**

- The temperature taken at the surface of the roadway:
- Between 7 a.m. and 11 a.m., the surface temperature value increases but remains below 60°C;
- Between 11:00 a.m. and 2:00 p.m. the temperature continues to rise, exceeding the value of 60°C to a peak of 67°C taken at 12:30 min;
- From 2 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 7:00 a.m. and 11:30 a.m., the temperature value increases but remains below 60°C;
- Between 11:30 a.m. and 1:50 p.m. the temperature continues to increase, exceeding the value of 60°C to a peak of 62.90°C taken at 12:30 p.m.;
- From 2 p.m., the temperature begins to decrease. And at 6 p.m. it drops to 44.10°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 which is 39.30°C taken at 10 hours 30 min.

The pavement temperature measurements taken in the Maritime region were taken in the month of April of the year 2021. A total of three measurements were taken over a period of six (6) days, namely the 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 (Olivier, 2007). In the progression of the sunrise during the 6 days, it is noted that the temperature on the surface remains higher than that taken inside the roadway (Sarah Asfour, 2016) with values which reach more than 60°C between 10:30 a.m. min to 3:30 p.m. An observation made for a period of 2 to 4 hours of time (Fébronlionel, 2020; Philippe Marty, 2012). The peaks observed per day vary from 63.60°C to 69.30°C observed between 12 p.m. and 1 p.m. The observation of the 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 the cloud cover (Jean-Charles, 2008), which shows the level of sensitivity of the pavement to solar radiation. The test results carried out for the moment in the month of April in the Maritime 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 69.30°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 (Tommy ALBARELO, 2016), whereas in the laboratory, verification of the performance of the bituminous mixture under the effect of temperature in accordance with the Marshall standard (SAGAWEB, 2003) is carried out in the thermal bath in the presence of water. This analysis shows that for the case of the Maritime 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.

## 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  $RN^{\circ}1$  in the Adétikopé area. 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  $60^{\circ}C$  and its duration varies from 2 hours to 4 hours. As for the peaks observed, they vary between  $63.60^{\circ}C$  and  $69.30^{\circ}C$ . 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.

## REFERENCES

- Commission canadienne de sûreté nucléaire (CCSN), Introduction au rayonnement, Ministre de Travaux publics et Services gouvernementaux Canada (TPSGC) 2012 Numéro de catalogue de TPSGC CC172-93/2012F-PDF ISBN 978-0-662-71632-7, Décembre 2012, suretenucleaire.gc.ca.
- Didier Lesueur, La Rhéologie des Bitumes : Principes et Modification, Eurovia Management - Polo de Emulsiones Probisa - Pol. Ind. « Las Arenas » - c/ Ronda, 9 - 28320 Pinto (Madrid), Version finale acceptée le 19 septembre 2002, <https://www.researchgate.net/publication/228582763>
- Fébronlione prince SEVI, démonstrateur de stockage thermique inter-saisonnier couplé à un échangeur thermique routier ; mémoire pour l'obtention du diplôme d'ingénieur à 2<sup>ie</sup> avec grade de master en génie électrique et énergétique, 09/2020, [www.2ie-edu.org](http://www.2ie-edu.org)
- Philippe Marty, cours de transferts thermiques Conduction et rayonnement, version 9 Juillet 2012 ; [Philippe.Marty@hmg.inpg.fr](mailto:Philippe.Marty@hmg.inpg.fr);
- Kévin Lamy, Projection Climatique du Rayonnement Ultraviolet au cours du 21<sup>ème</sup> siècle : Impact de différents scénarios climatiques, Thèse de Doctorat de l'Université de la Réunion Spécialité : Physique de l'atmosphère École doctorale : « Sciences, Technologies et Santé (STS) ED542 », 178 pages, 26 Juin 2018, <https://tel.archives-ouvertes.fr/tel-01979875>
- Mathieu Meunier, Contribution à la mise au point des critères de formulation pour les enrobés SMA adaptés à la formulation du laboratoire des chaussées du ministère des transports du Québec, 2005
- Jean-Charles DUPONT, Impact des nuages de haute altitude sur le bilan radiatif à la surface de la Terre : quantification expérimentale et analyse, Laboratoire de Météorologie Dynamique, Ecole Doctorale de Mécanique, Ecole Polytechnique, 91128 Palaiseau Cedex, France, 218 pages, 21 Octobre 2008
- Mehdi Ould-Henia, ing. dipl. ENP Alger, Margarita Rodríguez, ing. dipl. EPFL, André-Gilles Dumont, professeur, Élaboration d'une méthode prédictive de l'ornièrage des revêtements bitumineux, Août 2004
- NIA Mohamed, Etude comparative des méthodes d'estimation du rayonnement solaire, Université Ferhat Abbas - Setif faculté des sciences département de physique, République Algérienne Démocratique et populaire, MAGISTER Option : Énergétique et Mécanique des Fluides, 107 pages, 2010
- Olivier PILATE ; Evolution de la température d'une couche d'enrobé bitumineux nouvellement posée, Edité par le Centre de recherches routières Etablissement reconnu par application de l'Arrêté-loi du 30 janvier 1947 Boulevard de la Woluwe 42 - 1200 Bruxelles, 2007 ; [www.crr.be](http://www.crr.be)
- SAGAWEB, essai relative aux chaussées, essais statiques sur mélange bitumineux, partie 2, essai Marshall ; 10/2003 ;
- Sarah Asfour, Récupération d'énergie dans les chaussées pour leur maintien hors gel ; Doctorat l'école doctorale sciences pour l'ingénieur de Clermont-Ferrand, 262 pages, décembre 2016, <https://tel.archives-ouvertes.fr/tel-01511966>
- SOMEa, S.C. V. GAUDEFROYa, D. DELAUNAYb, Méthode thermique d'évaluation de la qualité du collage bitume sur granulats par mesure de la résistance thermique de contact dans les conditions de fabrication d'enrobé bitumineux ; 29 août au 2 septembre 2011.
- Tommy ALBARELO, Estimation de l'irradiation solaire sur le plateau des guyanes: apport de la télédétection satellite, Université de la Guyane Ecole Doctorale 587 « Diversités, santé et développement en Amazonie » DFR « Sciences et Technologies », 108 pages, 07 Décembre 2016, <https://tel.archives-ouvertes.fr/tel-01527108>

\*\*\*\*\*