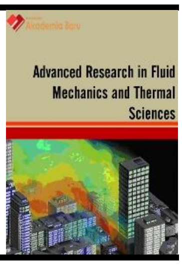
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Study on Heat Loss through Dump Truck Wall Insulated by Sengon Wood

Open Access

Muhammad Muhammad[1], Ahmad Syuhada[2,*], Syifaul Huzni[2], Zahrul Fuadi[2]

[1] Doctoral Student Graduated School of Engineering, Syiah Kuala University, Banda Aceh 23111, Indonesia
[2] Department of Mechanical Engineering, Syiah Kuala University, Banda Aceh 23111, Indonesia

ARTICLE INFO

Article history:
Received 8 September 2018
Received in revised form 22 November 2018
Accepted 18 December 2018
Available online 6 June 2019

ABSTRACT

The quality of road construction using hot mix asphalt is determined by the temperature at the time of compaction. The distance or duration of transportation from the Asphalt Mixing Plant (AMP) plant to the work site causes temperature loss during the trip, especially near the truck wall. As a result of this phenomenon, the temperature available at the time of compaction is decreasing, so that the temperature does not meet the required technical specifications. One way to protect the rate of hot mix asphalt temperature loss is by adding sengon wood insulation to the truck wall so that the temperature does not go out into the air environment. The insulating material used is sea sengon wood, because it has a low thermal conductivity value. The purpose of this work is to study the phenomenon of hot mix asphalt temperature loss rate on the effect of using sengon wood as insulation on the walls of trucks during transport. In this study, the test was carried out as an Asphalt Concrete Binder Course (AC-BC) using a 25-ton intercooler truck, carried out experimentally by measuring the temperature at the specified points for 420 minutes from the AMP factory to the dumping location. From the test results showed that the temperature of the hot mix asphalt near the truck's floor and wall averaged an initial temperature of 102.78°C until the average spread location was 91.48°C. The temperature of the truck's center zone is relatively stable during transport, from loading 145°C and end 143.7°C, the temperature available for deployment still meets the required technical specifications.

Keywords:
Temperature loss; hot mix asphalt; transportation; wooden board insulation

1. Introduction

The quality of the road using hot mix asphalt is determined by the temperature at the time of compaction. The distance or duration of transport from the Asphalt Mixing Plant (AMP) plant to the work location causes the temperature to decrease before compaction is carried out, especially around the surface of the truck wall [1]. So far, road construction contractors in Aceh, 170-200 km is the furthest distance to carry hot mix asphalt from the Asphalt Mixing Plant (AMP) plant to the location of the spread, causing loss of temperature during transportation. The construction of Asphalt

* *Corresponding author.*
E-mail address: ahmadsyuhada@unsyiah.ac.id (Ahmad Syuhada)

Mixing Plant (AMP) factories in each work location requires very high investment costs, and consideration of field needs, the volume of work, consumers, location and source of material [2]. It is necessary to develop a protection system as in the previous study of insulation on the walls of the asphalt storage tank [3] to keep the temperature of the hot mix asphalt stable during transportation.

The effect of weather and wind speed is very susceptible to temperature loss of hot mix asphalt, especially if work is done at night [4]. In urgent cases for 6 (six) hours of transportation from the Asphalt Mixing Plant (AMP) plant to the work location is still effectively used [5]. Asphalt cover sheeting on the top surface of the truck is very important to protect the rate of temperature loss during the trip to the location of the spread [6]. The previous variable which is considered to contribute to a decrease in road quality due to temperature differences, transport time, has little impact on the overall pavement quality. From the results of data analysis also shows a significant correlation between the difference in material temperature due to winter after road construction [7]. Direct road quality is significantly affected if the asphalt crust is formed during transport during compaction [8]. Heat transfer will occur when a fluid has direct contact with a solid surface at different temperatures, and if a temperature gradient occurs on an object, heat will move from a high-temperature area to a low-temperature area [9].

Therefore, the development of a protection system on hot mix asphalt temperature loss during transportation by adding insulation to the truck wall is expected to be able to withstand heat not evaporate to the air, so that the temperature remains stable according to technical specifications [10]. Thermal conductivity (k) of hot mix asphalt is also strongly influenced by the quality of the material in the mixture, as the results of previous studies were 0.896-2.06 w/m.k [11,12,13,14]. In general, wood has insulative properties with a value of thermal conductivity (k) 0.17 w/m.k [9]. Sengon wood is the best insulating material with a small thermal conductivity value (k) 0.123 w/m.k, compared to other wood species, such as teak 0.142 w/m.k, acacia 0.139 w/m.k, mahogany 0.133 w/m.k [15]. In this study, the use of Sengon wood (Paraserianthes Falcataria) as insulation on the walls of the truck is one way to protect the heat transfer of hot mix asphalt during transportation. Sengon wood is environmentally friendly and often used as raw material in building construction, the raw material for the manufacture of paper pulp, matches, school equipment, particle boards and many other uses [16]. Sengon wood is economically profitable since is cheap and easy to obtain [17].

From the above phenomena, the authors want to develop a protection system against heat loss on hot mix asphalt during transportation by using Sengon wood on the wall as insulation, then comparing it with trucks which are not using insulation. The results of this study are the data on temperature loss during transportation usable for an overview before compaction is carried out.

2. Methodology

2.1 Materials and Instruments

2.1.1 Hot mix asphalt material

The hot mix asphalt material used in this study is the Asphalt Concrete Binder Course (AC-BC), from the production of the Asphalt Mixing Plant (AMP) factory, North Aceh Sawang, Aceh Province, Indonesia. The amount of material is 150 tons in granular conditions, at mixing temperatures 155°C-145°C and loading 150°C-135°C, consisting of 6 (six) trucks with a capacity of 25 tons.

2.1.2 Sengon wood

The wood used as an insulating material on the truck walls in this study was Sengon wood produced from Aceh Province. In general, wood has a thermal conductivity value (k) 0.17 w/m.k (9). Sengon wood has a small thermal conductivity (k) value of 0.123 w/m.k, compared to other wood species, such as mahogany and acacia (15). The wood of 2.5 cm thick board with a maximum moisture content of 20% was installed on the truck wall.

2.1.3 Instruments

The equipment used in this study was a thermometer and thermocouple with a measurement capacity of -50-400^{0}C, and a cover sheeting of 0.02 cm thick. The truck used is a type of intercooler trucks already installed Sengon wood insulation on the surface of the walls and trucks without insulation (existing trucks) capacity of 25-tons with a length of 530 cm x width of 225 cm x height of 140 cm and wall thickness of 0.04 cm made of steel carbon steels with thermal conductivity (k) 60.5 w/m.k (9).

2.2 Raw Material Preparation

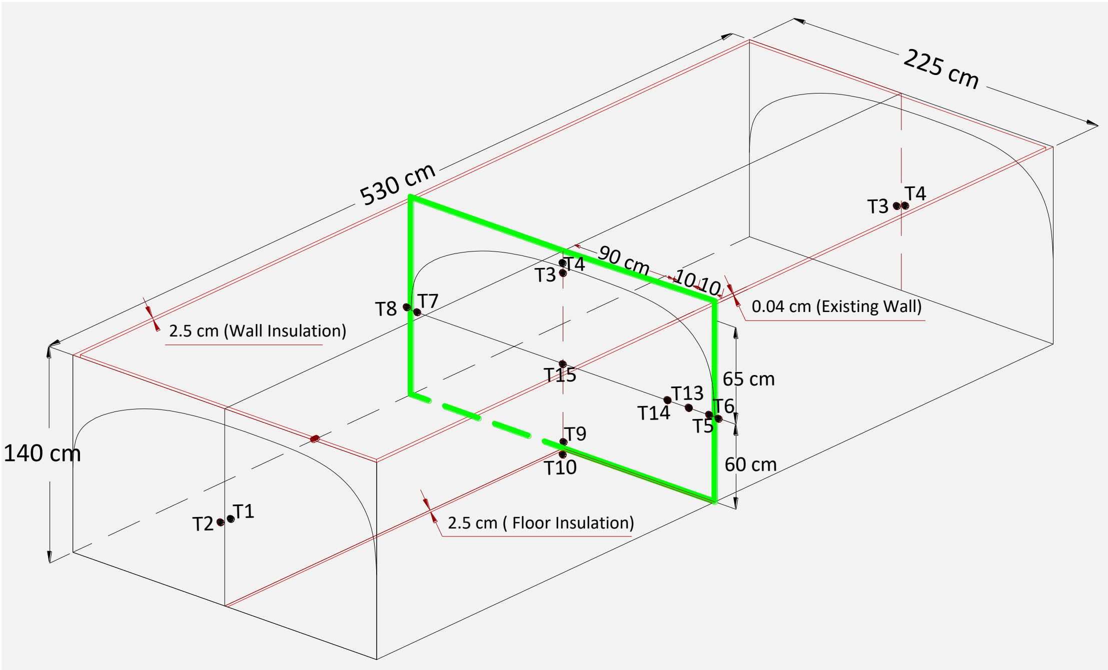
The raw material for the manufacture of Asphalt Concrete Binder Course (AC-BC) is prepared at the factory site of the Asphalt Mixing Plant (AMP), consisting of coarse aggregates and fine aggregates, coming from hard, durable, broken stones clean of all types of dirt or other objects. The source of the material used to produce coarse aggregates, fine aggregates, must meet the requirements of both the size of the sieve and the broken field, according to technical specifications [10]. All types of aggregates are attempted to be stacked, each separately, before being supplied to the asphalt mixing unit, using cold bin feeds, so that the combined aggregate gradations used in making hot mix asphalt can be controlled correctly.

All fillers in the hot mix asphalt mixture, consisting of stone ash or cement are ensured to be dry, free of clumps, pass the sieve and are available at the AMP factory location as needed. The asphalt used in this study is 60/70 and anti-lubricating material (additive), all of these materials must meet the properties required by technical specifications [10].

2.3 Research Design and Data Analysis

Temperature measurements were carried out experimentally using thermometers and thermocouples, already installed before loading hot mix asphalt. This study used 2 (two) intercooler truck models with a capacity of 25-tons, first using wood insulation and the second one did not use insulation (existing trucks). In this test there are 15 (fifteen) temperature observation points as shown in Figure 1. The inside of the truck has 9 (nine) measurement points, and 6 (six) outer points. Temperature measurements began to be carried out 15 minutes after loading into the truck, time intervals of 20, 40, 60, 80, up to 420 minutes, all the time traveling from the AMP factory to the location of the truck with an average speed of 30 km/hour. During the trip from the AMP factory to the dumping location with an average truck speed of 30 km/hour.

Data from the results of the study were analyzed using a descriptive method of the heat loss rate of hot mix asphalt using sengon wood insulation on the wall which compared with trucks not using insulation



Legends;

T1	=	Inner front wall	T9	=	Inner floor surface
T2	=	The outer front wall	T10	=	Floor surface outside
T3	=	Inner rear wall	T11	=	Upper surface under tarpaulin
T4	=	The outer rear wall	T12	=	Top surface of tarpaulin
T5	=	The right side wall	T13	=	10 cm from the right wall surface
T6	=	Outer right wall	T14	=	20 cm from the right wall surface
T7	=	Inside left side wall	T15	=	Middle of the Truck
T8	=	Outer left side wall			

Fig. 1. Schematics measurements point of temperature distribution

3. Results and Discussion

The results of temperature measurements, experimentally for 420 minutes the along transport time is shown in Figure 2, Figure 3, Figure 4 and Figure 5.

3.1 Effects of Without and Using Insulations on Front and Rear Truck Walls Against Heat Loss Rate During Transport Time

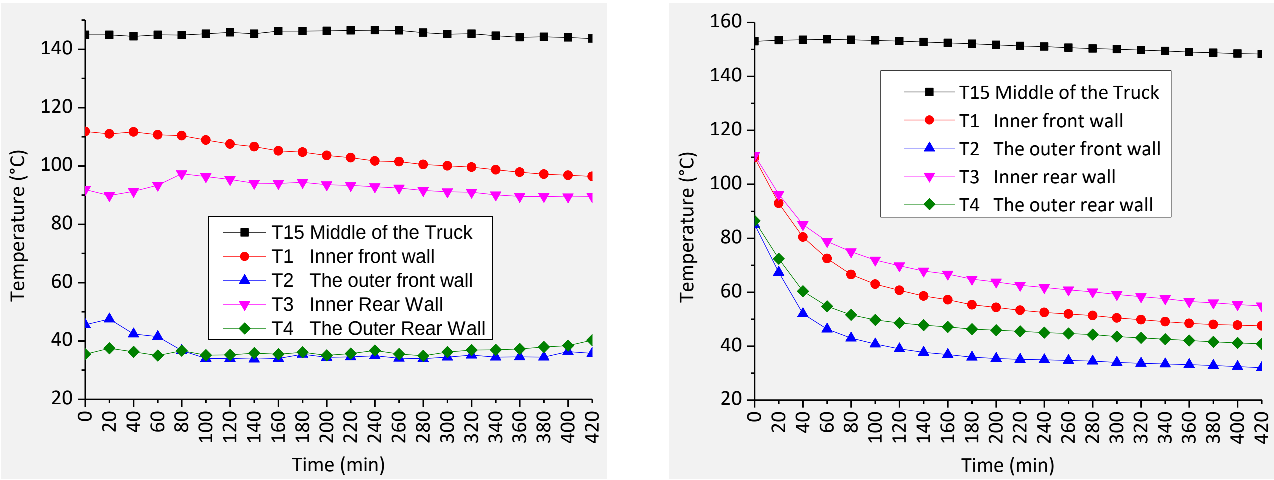
Temperature variations in the monitoring point in the middle of the truck (T15), on the right wall (T1, T2) and on the left wall (T3, T4), along transport time, with both conductivity, can be seen in Figure 2.

Test results are shown in Figure 2(a), It can be observed that as long as 420 minutes of transport time the asphalt temperature at T15 point is practically stable, the decrease is only 1.5^{o}C from the loading temperature of 145.0^{o}C. The asphalt temperature at point T1, and point T3, decreases by 15.4^{o}C and 2,4^{o}C, from the initial temperature 111.8^{o}C and end 91.9^{o}C. The decrease is relatively smaller, caused by an increase in the intensity of conduction heat transfer from the area of the center of the truck to the surface of the wall. The use of wood as insulation can also affect the rate of conduction heat transfer, from the asphalt zone near the surface of the inner wall to the surface of the outer wall.

Heat loss at point T2, amounting to 9.8°C, from the initial temperature of 45.6°C, is relatively stable, this is due to the intensity of convection heat transfer on the wall surface to the environmental air (29.0°C), smaller. While the temperature of the T4 point, the entire time of transport increases by 4.8°C, from the initial temperature of 35.5°C. This increase in temperature is due to decreasing convection and outside air turbulence (environmental air) which flows lower on the T4 wall surface, in other words, more laminar flow.

Test results trucks which are not using insulation in Figure 2(b), indicating that during the transport time of asphalt temperature in the truck's center zone (T15), it is also relatively stable, the decrease is only 3.9°C, from the loading temperature of 151.9°C, the heat transfer intensity is not far different from trucks using insulation. While the asphalt temperature at T1 and T3 points, the decrease was very significant at 61.9°C and 54.9°C from the initial temperatures of 108.8°C and 110.2°C. This decrease in asphalt temperature is due to the increased intensity of conduction heat transfer from the asphalt zone near the inner wall to the outer wall surface.

Whereas the convection heat transfer rate at the surface of T2 and T4 points, the temperature decrease was also very significant 54,1°C and 46,8°C, from the initial temperature 85,7°C and 88,4°C. This decrease in temperature is caused by the intensity of convection heat transfer from the surface of the truck wall to the environment air (29.0°C), relatively greater, and also due to the influence of air turbulence flowing on the surface of the truck wall.



(a) Using insulation (b) Without insulation

Fig. 2. Temperature variation of the front and the rear truck walls along transport time

From the results of temperature measurements along the time of transportation, indicating that trucks use wood insulation on the wall surface, the intensity of heat loss on hot mix asphalt is relatively more stable, compared to trucks not using greater heat loss rate insulation, shown in Figure 2.

3.2 Effect of Without and Using Insulation on the Right and Left Truck Wall Against Heat Loss Along Transport Time

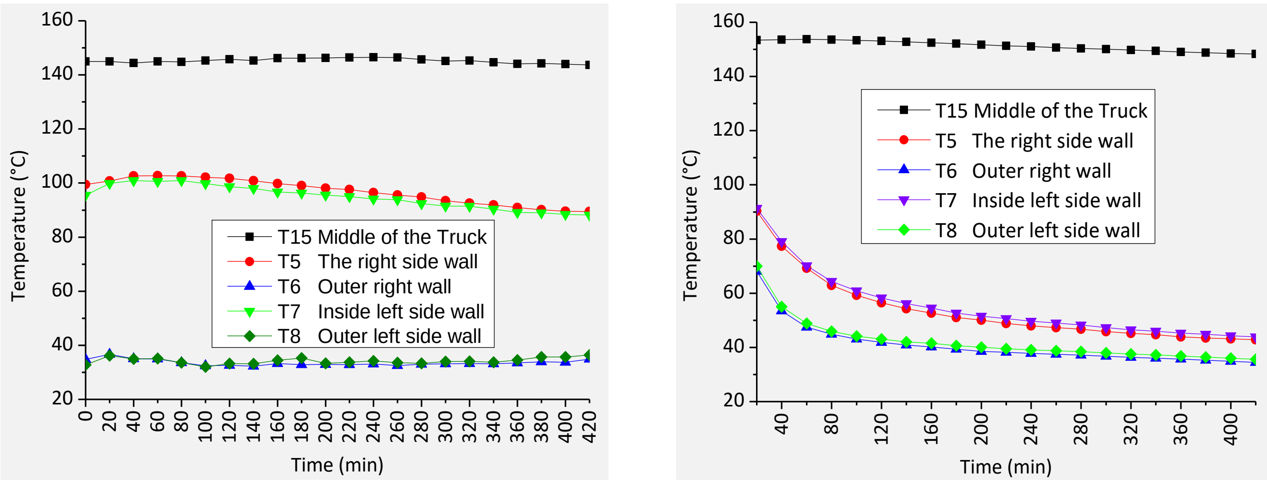
Temperature variations in the monitoring point in the middle of the truck (T15), the right wall (T5,T6) and the left wall (T7,T8), along transport time, with both conductivity can be seen in Figure 3.

It can also be observed based on Figure 3(a), during the transport time of asphalt temperature at the wall surface zone of points T5 and T7, decreasing 10.0°C and 7.3°C from the initial temperature of 99.5°C and end 95.5°C. The decline was relatively stable, due to the influence of the use of wood insulation on the truck walls, despite the increase in the intensity of conduction heat transfer from the asphalt zone near the inner wall to the outer wall surface zone. The decline was relatively stable, due to the influence of the use of wood insulation on the truck walls, despite the increase in the intensity of conduction heat transfer from the asphalt zone near the inner wall to the outer wall surface zone.

Whereas the temperature in the zone near the wall surface point T6, and T8, increased by 0.1°C, and 3.7°C from the initial temperature of 34.8°C, and 32.7°C, this is caused by the decrease in the intensity of convection heat transfer from the surface zone of the truck's outer wall into the environment air.

Can be seen in Figure 3(b), indicating that the truck does not use asphalt temperature insulation near the wall surface zone T5 and T7, down very significantly by 64.4°C and 65.5°C, from the initial temperatures of 106.9°C and 108.5°C. The decrease in the temperature of the asphalt is due to the increased intensity of conduction heat transfer from the asphalt zone near the inner wall to the surface of the exterior wall of the truck.

Whereas the surface temperature of the walls of T6 and T8 points is 51.9 51°C and 51.4°C lower, from the initial temperature of 86.4°C and 87.1°C. This decrease in temperature is due to an increase in the intensity of convection heat transfer from the surface zone of the outer wall of the truck to the environment air.



(a) Using insulation (b) Without insulation

Fig. 3. Temperature variation of the right and the left truck walls along transport time

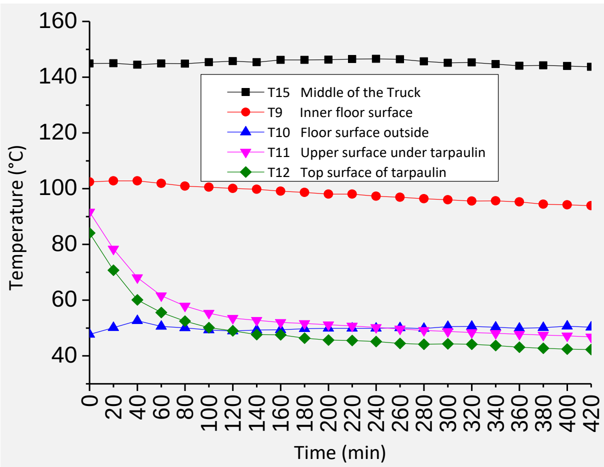
3.3 Effect of Without and Using Insulation on Floor Surfaces and Over Trucks Against Heat Loss Along Transport Time

Temperature variations in the monitoring point, in the middle of the truck (T15), the floor surface (T9, T10) and the top surface (T11, T12), along transport time, with both conductivity can be seen in Figure 4.

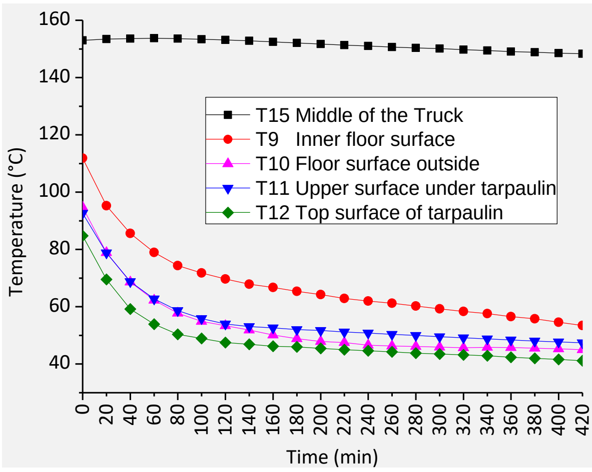
Figure 4(a) the test results are obtained, the asphalt temperature in the floor surface zone and the top of the truck point T9 and T11, the final temperature is lower 10.3°C and 44.8°C from the initial temperature 102.4°C and 91.6°C. The asphalt temperature in the inner floor surface zone is relatively stable, despite an increase in the intensity of conduction heat transfer from the asphalt zone near the wall to the outer wall surface zone. While the asphalt temperature in the upper surface zone, the decrease occurs very significantly, due to the high intensity of heat conduction from the surface zone of the cover sheet to the outer surface zone.

The temperature of the outer floor surface (T10), shows an increase of 2.6^{o}C, from 47.7^{o}C previously, this is due to the high intensity of conduction heat transfer from the middle zone to the inner floor surface and decreased convection heat transfer from the outer floor surface to the environmental air (29.0^{o}C). The temperature decrease actually occurs at T12, very significant 41.8^{o}C, from the initial temperature of 84.1^{o}C. The results of the observations are that the intensity of heat transfer T10 and T12 is very different, this is due to the turbulence of air flowing on the surface of the outer floor greater than the surface of the cover sheeting.

The asphalt temperature in the zone near the floor surface (T9), and the upper surface (T11), from the results of observations throughout the transport time can be seen in Figure 4(b), the final temperature is lower 57.9^{o}C, and 45.2^{o}C from the initial temperature 110 , 1^{o}C, and 92.7^{o}C. It can also be observed that the asphalt temperature in zone T10, and T12, the final temperature drops by 49.1^{o}C, and 44.3^{o}C from the initial temperature of 94.8^{o}C, and 85.8^{o}C, this occurs due to the high intensity of convection heat transfer from the truck's outer surface zone to environmental air or greater turbulence of flowing air.



(a) Using insulation



(b) Without insulation

Fig. 4. Temperature variation of the floor surface and the top surface along transport time

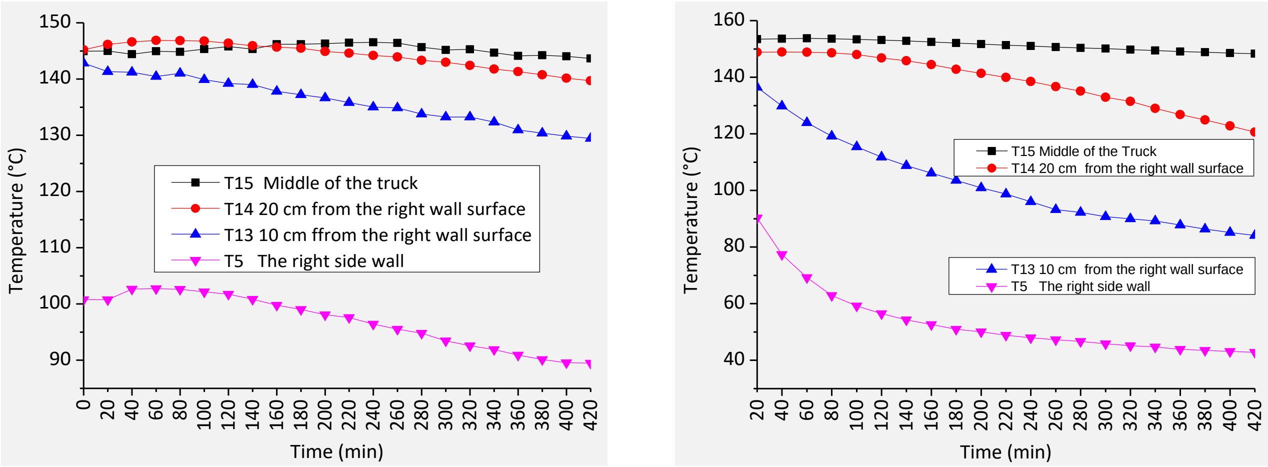
3.4 Effect of Without and Using Insulation 10 cm and 20 cm from the Truck Right Walls Against the Heat Loss Along Transport Time

Temperature variations at the monitoring point T15 in the middle of the truck, T3, T14, distances of 10 cm and 20 from the surface of the T5 truck wall, the along transport time, with both conductivity can be seen in Figure 5.

The temperature of zone T13, T14, as long as 420 minutes of transport time can be observed in Figure 5(a), a decrease of 13.4^{o}C and 5.8^{o}C, from the initial temperature of 142.8^{o}C and 145.2^{o}C. This asphalt temperature drop is relatively stable, despite an increase in conduction heat transfer intensity from the asphalt zone near the inner wall (T5), to the outer wall surface zone (T6).

In Figure 5(b), shows that the asphalt temperature at points T13 and T14, dropped to 62.1^{o}C and 18.3^{o}C, from the initial temperature of 146.7^{o}C, and 148.3^{o}C. The temperature drop was very significant, despite an increase in the intensity of conduction heat transfer from the asphalt zone in the middle of the truck to the zone near the inner wall (T5).

From the results of observations of temperature throughout the transportation period, it shows that the truck uses wood insulation, the heat transfer intensity is relatively smaller, compared to trucks not using insulation, except in the middle zone (T15), both types of trucks decrease in temperature relatively stable.



(a) Using insulation (b) Without insulation

Fig. 5. Temperature variation of 20 cm, and 10 cm from the right walls along transport time

4. Conclusions

From the results of observations, for 7 hours of transportation time, the asphalt temperature near the trucks wall using wood insulation is still relatively stable, compared to trucks not using insulation, which could only maintain temperature that meet the specifications for only 5.5 hours. The experimental data also describes the temperature of the asphalt near the floor and wall surfaces, using wood insulation at a more stable final temperature, averaging 91.48^{o}C, compared to. That of the trucks not using insulation with a lower final temperatures, averaging 46.4^{o}C. The greater asphalt temperature loss occurs in the front surface of the truck wall, the smaller near the floor surface, and the rear wall, while in the middle of the two types of trucks are relatively stable with the final temperature of 143.5^{o}C and 148.0^{o}C.

Acknowledgement
The author would like to thank the Director of PT. Bohana Jaya Nusantara, North Aceh District, Aceh Province, Indonesia, as the leader of the Asphalt Mixing Plant (AMP) factory, which has provided all facilities and permits using Asphalt Concrete Binder Course (AC-BC) material.

References

[1] Howard, Isaac L. "Measurement of asphalt concrete temperatures during transport with the use of an instrumented probe system." *Transportation Research Record* 2408, no. 1 (2014): 78-85.
[2] Syaiful Bahri. "Analisa Pemilihan Lokasi Asphalt Mixing Plant (AMP) Pada Pekerjaan di Ruas Jalan Pelahari-Sebamban." Prosiding Seminar Nasional Manajemen Teknologi II, Surabaya. (in Bahasa Indonesia). (2005).
[3] Bražiūnas, Justas, and Henrikas Sivilevičius. "Heat transfer and energy loss in bitumen batching system of asphalt mixing plant." In *9th International Conference on Environmental Engineering. Vilnius, Lithuania*. 2014.

[4] Hashim, Wardati, Mohd Rosli Hainin, Norfarah Nadia Ismail, Nur Izzi Md Yusoff, Mohd Ezree Abdullah, and Norhidayah Abdul Hassan. "Evaluating the cooling rate of hot mix asphalt in tropical climate." *Jurnal Teknologi* 78, no. 4 (2016): 97-104.

[5] Howard, Isaac L., Gaylon L. Baumgardner, Walter S. Jordan III, Andrew M. Menapace, Walaa S. Mogawer, and James Michael Hemsley Jr. "Haul time effects on unmodified, foamed, and additive-modified binders used in hot-mix asphalt." *Transportation Research Record* 2347, no. 1 (2013): 88-95.

[6] Byzyka, Juliana, Mujib Rahman, and Denis Albert Chamberlain. "Thermal segregation of asphalt material in road repair." *Journal of Traffic and Transportation Engineering (English Edition)* 4, no. 4 (2017): 360-371.

[7] Bode, Thaddaeus A. "An Analysis of the Impacts of Temperature Segregation on Hot Mix Asphalt." (2012).

[8] Florin Bode, Paula V, and Mugur C. Balan. "Study Concerning The Forming of Asphalt Crust During Transport." Technical University of Cluj-Napoca, România, *Proceedings of the Department of Mechanical Engineering*. https://www. researchgate.net/publication /296333729. (2015).

[9] Bergman. Lavine. De Witt. Incropera.2007. *Chapter 1 and 6. Fundamentals of Heat and Mass Transfer*, Edition 6, Publisher: Wiley, Page 1-9 and 355-381, Appendix A, Page: 930-941.

[10] Kementrian Pekerjaan Umum Direktorat Jenderal Bina Marga. *General Specification Division 6 Asphalt Pavement Pp 6.1- 6.5 (in Bahasa Indonesia)* (2010).

[11] Luca, Joseph, and Donath Mrawira. "New measurement of thermal properties of superpave asphalt concrete." *Journal of Materials in Civil Engineering* 17, no. 1 (2005): 72-79.

[12] Carlson, J. D., R. Bhardwaj, P. E. Phelan, K. E. Kaloush, and J. S. Golden. "Determining thermal conductivity of paving materials using cylindrical sample geometry." *Journal of materials in civil engineering* 22, no. 2 (2010): 186-195.

[13] Nguyen, Quang Tuan, Hervé Di Benedetto, and Cédric Sauzéat. "Determination of thermal properties of asphalt mixtures as another output from cyclic tension-compression test." *Road Materials and Pavement Design* 13, no. 1 (2012): 85-103.

[14] Minhoto, Manuel JC, Jorge C. Pais, Paulo AA Pereira, and Luís G. Picado-Santos. "Predicting asphalt pavement temperature with a three-dimensional finite element method." *Transportation Research Record* 1919, no. 1 (2005): 96-110.

[15] Anton Prasojo, Joko Sulistyo, Tomy Listyanto. "Konduktivitas Panas Empat Jenis Kayu Dalam Kondisi Kadar Air yang Berbeda." *Prosiding Seminar Nasional Masyarakat Peneliti Kayu Indonesia (MAPEXI) XIV*. Teknologi Hasil Hutan Fakultas Kehutanan Universitas Gajah Mada Indonesia. Teknologihutan.fkt.ugm.ac.id. (in Bahasa Indonesia). (2002).

[16] Jm. Sri Hardiatmi. *Study on Sengon (Paraserianthes falcataria) as Economical and Ecological Tree*. Balai Penelitian Kehutanan Solo. *Article Jurnal Inovasi Pertanian* Vol.9, No. 2. (2010): 17-21. portalgaruda.org/article.

[17] Heru Dwi, R., and Ragil BWMP. "Kajian Sengon (Paraserianthes Falcataria) Sebagai Pohon Bernilai Ekonomi Dan Lingkungan." *Jurnal Penelitian Hutan Tanaman* 6, no. 3 (2009): 201-208.