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A Determination of Solar Heat Collection in Sepertine Copper and Rubber Pipe Embedded in Asphalt Pavement using Finite Element Method

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Abstract: This project aimed to determine solar heat temperature variations in copper and rubber pipes embedded into the asphalt pavement using finite element method. The significant of the project to explore sustainable energy generation while using pavement surface as a heat collector therefore solar efficiency beneath paved surface has to determine. The arrangement of copper and rubber pipe in asphalt pavement is serpentine. The asphalt pavement size of 300×300 and 300×500 mm is simulated in ANSYS. Asphalt pavement is embedded with serpentine copper and rubber pipes of diameter of 40 mm. The solar heat temperature is collected in asphalt at depths of 50, 100 and 150 mm. Pipes are filled with liquid (water) to maintain or cool the temperature at night time. The stated asphalt pavement size samples have created where copper and rubber pipes are embedded and temperature collection among each sample is recorded. The findings of the project indicated that larger surface area of asphalt pavement (30×500 mm) exposed to the Sunlight collect more energy than smaller (300×300 mm) size of asphalt pavement. The serpentine arrangement of copper and rubber pipes embedded in asphalt pavement has slight difference of solar heat collections. The solar heat collected at 50 mm depth is higher than 100 and 150 mm depths.

Key words: Solar efficiency, copper and rubber pipes, aphalt pavement, finite element method, temperature, paved

INTRODUCTION

Sustainable supply of energy plays key role in the economy of the country. Today, top listed issues of under-developing countries are insufficient and poor supply of energy. A step for concrete effort in the development of sustainable and green energy across the globe has seen using several techniques. This project is among one effort for sustainable energy which has been started to determine the solar energy collection efficiency beneath the paved surface. The solar energy collection in copper and rubber pipes has determined using finite element method.

A finite element simulation is conducted to investigate the heat system inside the asphalt pavement on temperature distributions. Placing the pipes at shallow depths can extract high energy and more stress in pavement. In this way, the effects on materials of the structural and thermal properties have been studied. Furthermore, the comparison has made between 300×300 and 300×500 mm asphalt pavement modeled in ANSYS embedded serpentine copper and rubber pipes at various depths.

Literature review: The nonrenewable energy resources insufficiency will produce globally with the recent rate of consumption (Sheeba and Rohini, 2014). Fossil fuels, coal and natural gas are the top listed nonrenewable energy resource. The adverse effect of nonrenewable energy resource in the result anthropogenic issues has caused (Hook and Tang, 2013). The fossil fuels are the principal contributor of anthropogenic, Green House Gases (GHG) and Carbon dioxide (CO_2) on the Earth (Hook and Tang, 2013; Armstrong and Blundell, 2007). The alternatives to nonrenewable energy resource are essentials.

The asphaltic paved road total length across the world is about 33.8 million km and statistic indicated that 57.4% road is paved. The massive land of paved road infrastructure has a great potential of renewable energy and might significantly contribute to the energy demands (Medas *et al*., 2013; Sheeba and Rohini, 2014; Wu *et al*., 2009; Bijsterveld *et al*., 2001). The asphaltic road pavement receive abundant naturally occurring solar energy long day and this energy absorbed by the road pavement as a thermal energy in their inner sub structure. The cheapest source of energy comes from the Sun. The Sun emits solar energy to the Earth at rate of about

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100,000 TW. The major portion of solar heat is absorbed by the Earth crest without any utilization (Armstrong and Blundell, 2007). The Sun is the source of clean and renewable energy. The energy is captured by solar cells. It receives solar radiation all day and stores the energy. The solar cells in asphalt pavement act as a solar collector which has been developed for heating and cooling of adjacent buildings. Excellent heat absorbing characteristic of asphalt pavement has been observed heat up to 70°C in Summer days (Munoz *et al*., 2013; Wu *et al*., 2009, 2007). The absorbed heat can be retained and provide energy even after Sunset by properly storage.

Application of the thermal energy potential can provide a wide use for parking areas and roadways. The solar thermal energy can be calculated through a circulating fluid in the pipes inserted in the asphalt pavement. The volume of flow rate in the pipes inserted beneath the paved surface has influenced of the efficiency of solar heat collection (Fan and Furbo, 2008). Asphalt collectors have limited energy exchange efficiency also the quality of energy. However, utilization of limited asphalt energy can be providing essential heat energy to the adjacent buildings (Wu *et al*., 2009; Loomans *et al*., 2003). The experimental efficiency equations has key role in the determination to assess the real performance of collected energy in some conditions. The experimental design of investigation of pavement thermal performance is time consuming and expensive. Chen *et al*. (2012) has accomplished finite element model to determine temperature distribution in small scale pavement slab. The result indicated that pavement slab energy absorption can be enhancing with conductive aggregate material. The depth determination in large sample size is crucial so, the computer modeling is essential to save the time and experimental design cost. Gui *et al*. (2007) has presented mathematical model to calculate the hourly solar radiation temperature on the pavement surface, air temperature and wind velocity data.

MATERIALS AND METHODS

Model design using solid work: The asphalt pavement model size of 300×300 and 300×500 mm is prepared in solid research and the depth of test samples is 150 mm as shown in Fig. 1 and 2.

The serpentine arrangement of copper and rubber pipes of 40 mm diameter as shown in Fig. 2 and 3 containing liquid (water) is embedded into the asphalt pavement at a depths of 50, 100 and 150 mm.

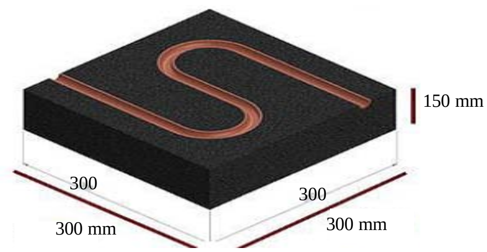

Fig. 1: Model of asphalt pavement 300×300 mm

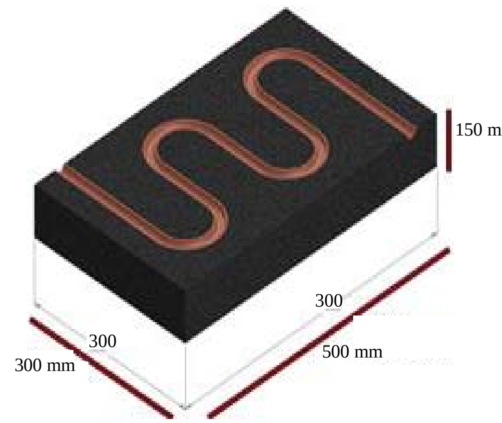

Fig. 2: Model of asphalt pavement 500×300 mm

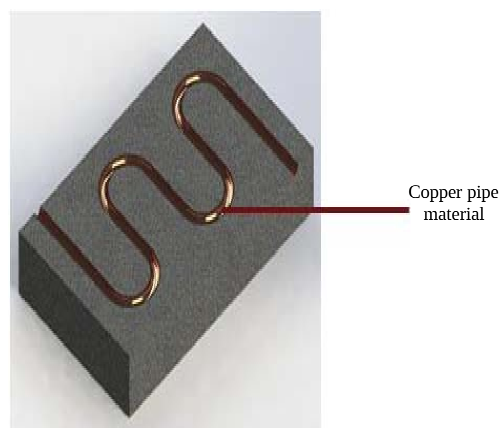

Fig. 3: Serpentine copper pipe embedded in asphalt pavement

Simulation using ANSYS: The asphalt pavement models prepared in solid work has exported into the ANSYS. Asphalt pavement, liquid and pipes geometry is setup. The coordinate is generated to locate the fluid flow in the pipes of inlet and outlets. The meshing process of two regions have established where one is represented the link between pipes and asphalt pavement and second is between pipes and fluid flow in pipes as shown in Fig. 4-6.

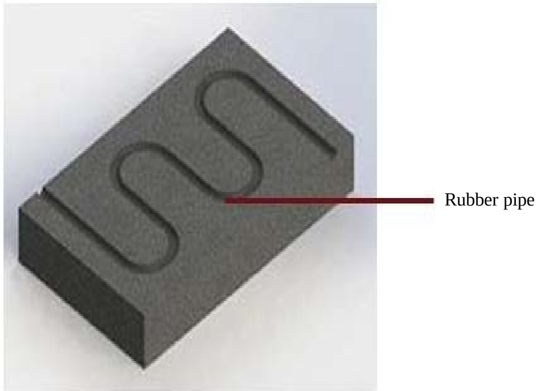

Fig. 4: Serpentine rubber pipe embedded in asphalt pavement

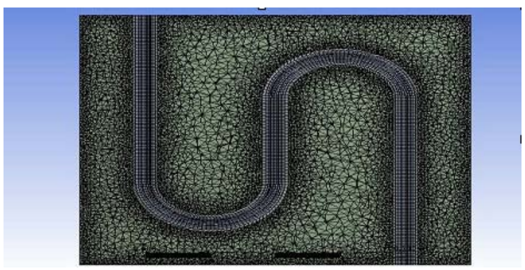

Fig. 5: The meshing of asphalt pavement

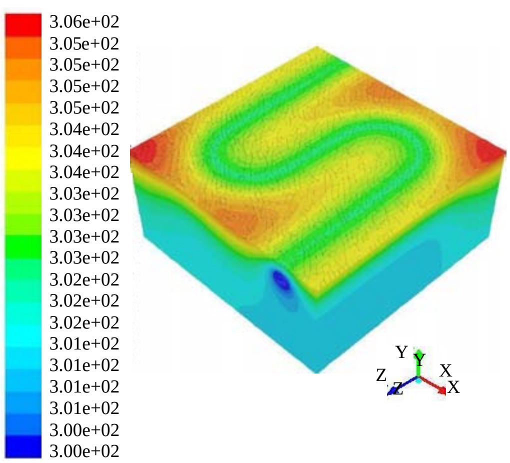

Fig. 6: Graphic contour of the paved surface comprise serpentine pipe; contours of static temerature (k) (time = 2.5920e+05); Aug. 09, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

The sides of the paved surface are considered insulted. The solar heat energy is only collected on the top surface of the pavement. The operation is run for 3 days in the location of longitude (103.0856) and latitude (1.8586) at the Universiti Tune Hussain Onn Malaysia (UTHM). The direct solar radiation is measured 1423 $W.m^{-2}$. Density, specific heat and thermal conductivity of the asphalt pavement have set, respectively 2600 $kg.m^3$, 920 kg and 1.83 W/MK. Figure 6 indicated the contour of asphalt pavement designed in ANSYS where maximum heat energy absorption is shown with red colored area on the top surface of pavement while blue colored area shows lower heat energy at the lower part of asphalt pavement.

RESULTS AND DISCUSSION

The project findings and discussion is compiled into two cases. Case 1 (A_1, A_2) and Case 2 (B_1, B_2) Case 1 (A_1) discuss the findings of asphalt pavement size of 300×300 mm embedded with copper pipe; Case 1 (A_2) discuss rubber pipe.

Case 2 (B_1) direct the findings of asphalt pavement size of 300×500 mm embedded with copper and Case 2 (B_2) represent the finding of rubber embedded pipe in asphalt pavement size of 300×500 mm.

Case 1 (A_1) (simulation of 300×300 mm size of asphalt pavement copper pipe embedded): ANSYS simulation has run for the asphalt pavement of size 300×300 mm is to determine temperature variation in asphalt pavement embedded copper pipe at 50, 100 and 150 mm depth. The pipe is filled with water. Figure 7-9 indicated the simulation of asphalt pavement with copper pipe at the depth of 50, 100 and 150 mm the effect of temperature variation can be seen. The obtained result of temperature variation at various depths using copper pipes embedded in asphalt pavement of 300×300 mm is drawn in Fig. 10.

Case 1 (A_2) (simulation of 300×300 mm size of asphalt pavement rubber pipe embedded): The temperature variation in rubber pipe of 40 mm diameter embedded in asphalt pavement has simulated using ANSYS. The temperature variation has recorded on depths of 50, 100 and 150 mm. Figure 11-13 shows the simulation findings on each depth using rubber pipe.

The 3 days solar heat collection in asphalt pavement size of 300×300 mm copper and rubber pipe embedded at depths of 50, 100 and 150 mm simulation results is shown in Table 1. The findings indicated that copper pipe embedded in asphalt pavement collect more solar energy than rubber pipe. The max. 53.5°C solar energy is collected

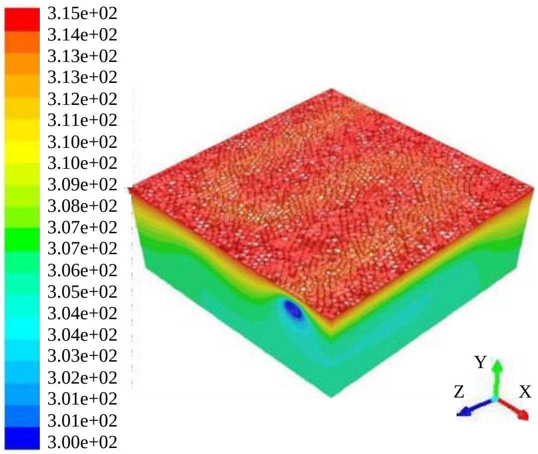

Fig. 7: The 300×300 mm size asphalt pavement copper pipe inserted on 50 mm; contours of static temerature (k) (time = 6.0000e+04); Sep. 06, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

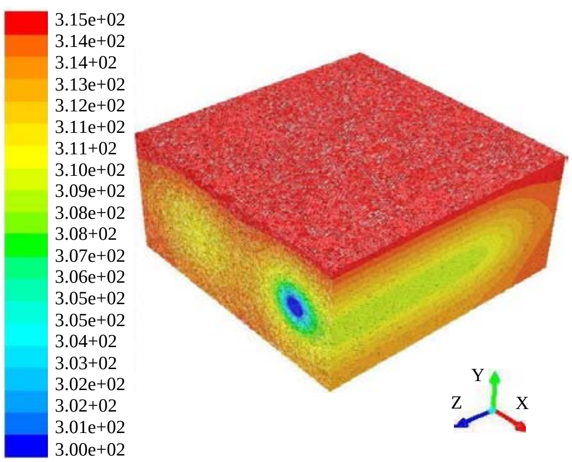

Fig. 8: The 300×300 mm size asphalt pavement copper pipe inserted on 100 mm; contours of static temerature (k) (time = 3.60000e+03); Sep. 06, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient

at a depth of 50 mm in copper pipe while min 42.0°C heat energy is collected at depth of 150 mm in rubber pipe. Table 1 temperature in copper and rubber pipes at various depths embedded in asphalt pavement using ANSYS simulations.

Case 2 (B_1) (simulation of 300×500 mm size of asphalt pavement embedded with copper pipe): Figure 15-17 indicated that asphalt pavement sample size 300×500 mm embedded with copper pipe of 40 mm diameter. The pipes are embedded at depth of 50, 100.

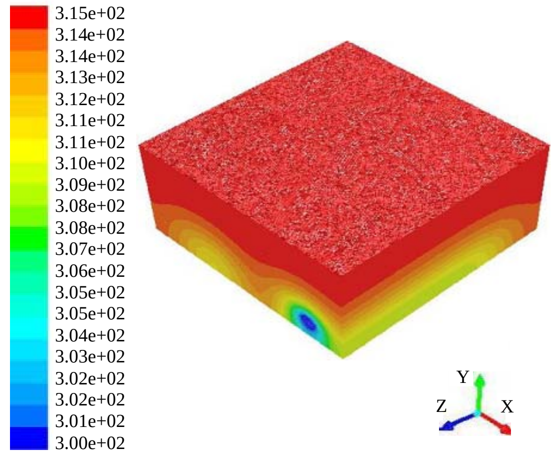

Fig. 9: The 300×300 mm size asphalt pavement copper pipe inserted on 150 mm; contours of static temerature (k) (time = 2.40000e+03); Sep. 18, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

Table 1: Temperature in copper and rubber pipes at various depths embedded in asphalt pavement using ANSYS simulations

		Highest temperature (20C) 12:00-05:00 pm	
Days	Depth (mm)	300×300 mm copper pipe	300×300 mm rubber pipe
1	500	53.5	47.5
	100	50.5	45.5
	150	49.5	44.5
2	500	53.0	46.0
	100	50.0	45.0
	150	49.0	43.0
3	500	53.0	44.5
	100	50.3	44.3
	150	49.0	42.0

and 150 mm. The obtained result of simulation for 300×500 mm size effect of temperature variation is shown in Fig. 18.

Case 2 (B_2) (simulation of 300×500 mm size of asphalt pavement embedded with rubber pipe): The temperature variation in rubber pipe of 40 mm diameter embedded in asphalt pavement has simulated using ANSYS. The temperature variation has recorded on depths of 50, 100 and 150 mm (Fig. 19-21).

The obtained result of temperature variation at various depths using rubber pipes embedded in asphalt pavement of 300×500 mm is shown in Fig. 22.

The result is shown in Table 2. The 3 days solar heat collection in asphalt pavement using copper and rubber pipes indicated temperature with slight variations. The maximum heat energy of 57.0°C is recorded at depth of 50.0 mm in copper and rubber embedded asphalt pavement. The minimum heat energy 48.5°C is recorded in rubber embedded pipe at depth of 150 mm.

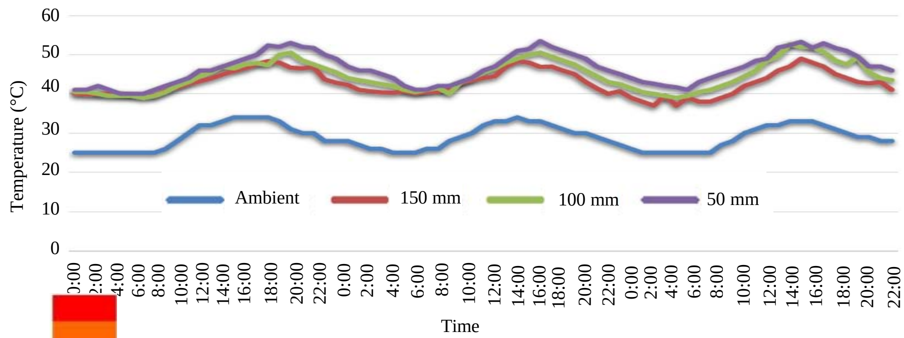

Fig. 10: Temperature ion in asphalt pavement of 300×300 mm embedded with copper pipe at 50, 100 and 150 mm depths

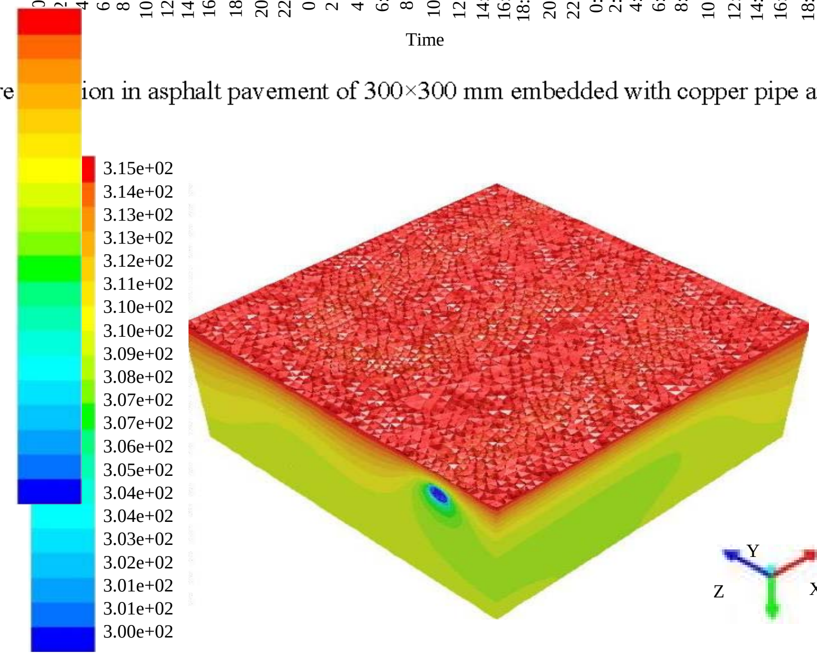

Fig. 11: The 300×300 mm asphalt pavement rubber pipe at 100 mm; contours of static temerature (k) (time = 6.0000e+04); Sep. 18, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

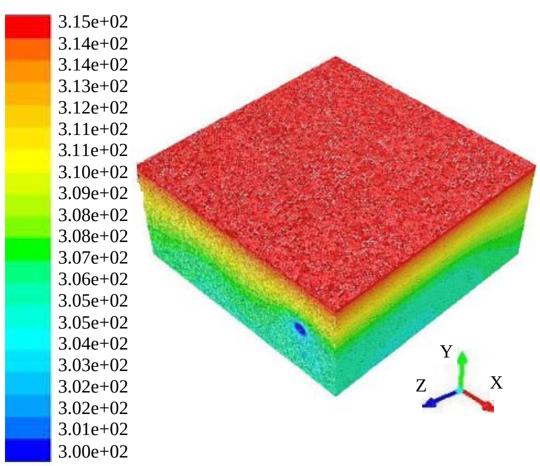

Fig. 12: The 300×300 mm asphalt pavement rubber pipe at 150 mm; contours of static temerature (k) (time = 6.0000e+04); Sep. 18, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

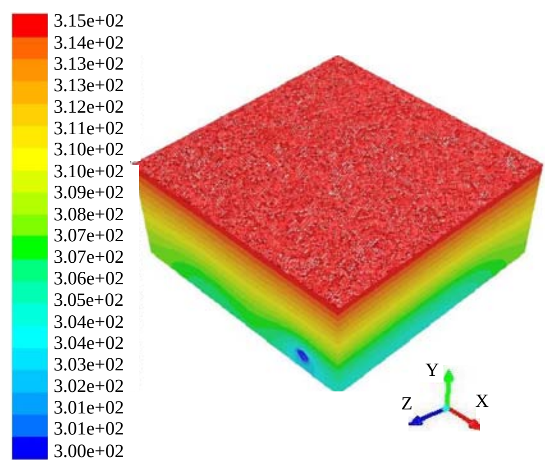

Fig. 13: The 300×300 mm asphalt pavement rubber pipe at 150 mm; contours of static temerature (k) (time = 2.04000e+04); Sep. 18, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

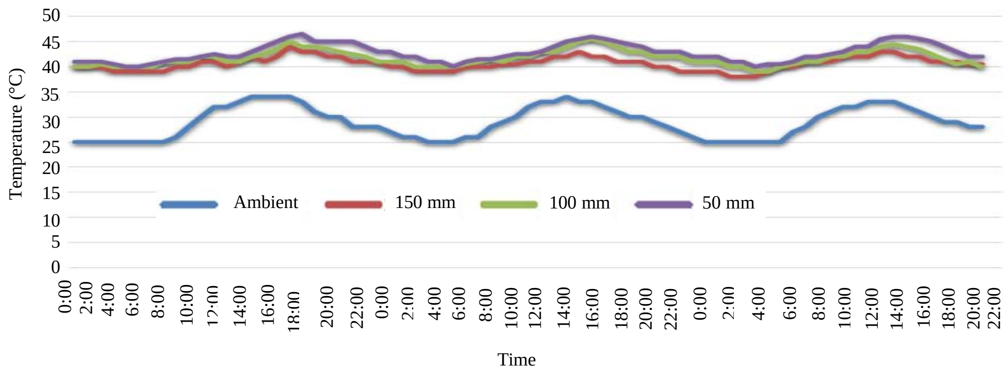

Fig. 14: Temperature variation in asphalt pavement of 300×300 mm rubber pipe embedded at 50, 100 and 150 mm depths

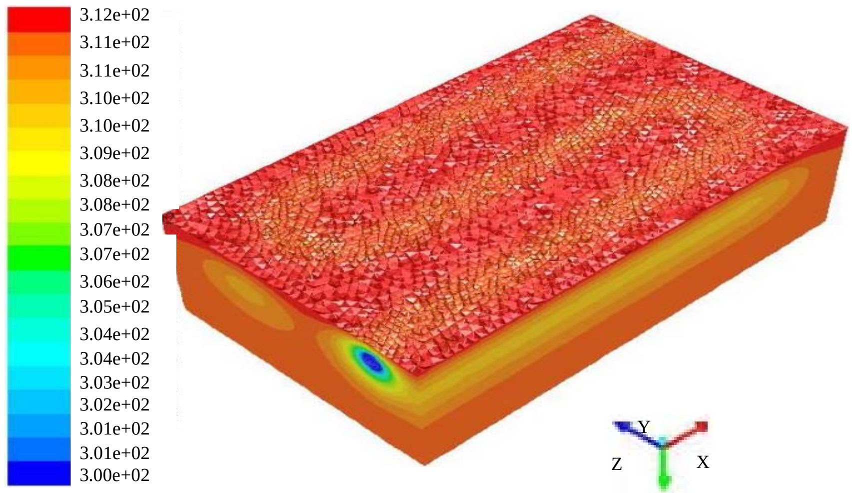

Fig. 15: The 300×500 mm size asphalt pavement copper pipe embedded at 50 mm; contours of static temerature (k) (time = 1.8000e+03); Sep. 18, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

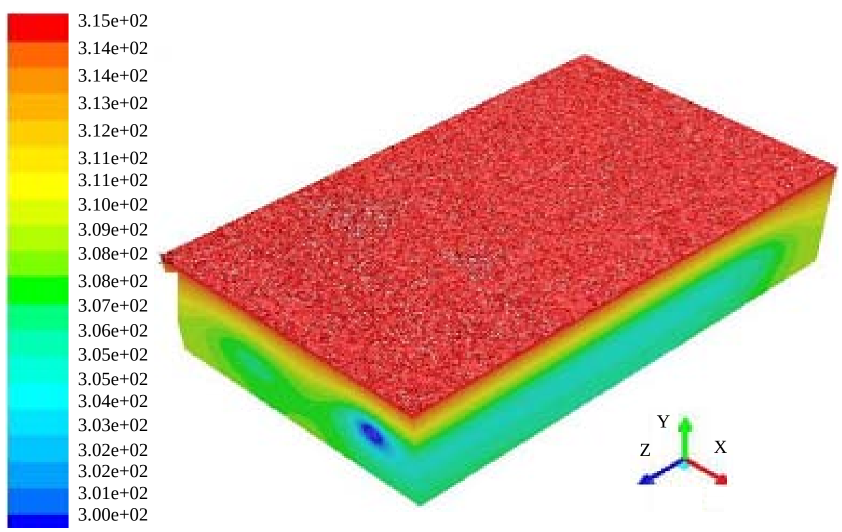

Fig. 16: The 300×500 mm size asphalt pavement copper pipe embedded at 100 mm; contours of static temerature (k) (time = 1.2000e+04); Sep. 19, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

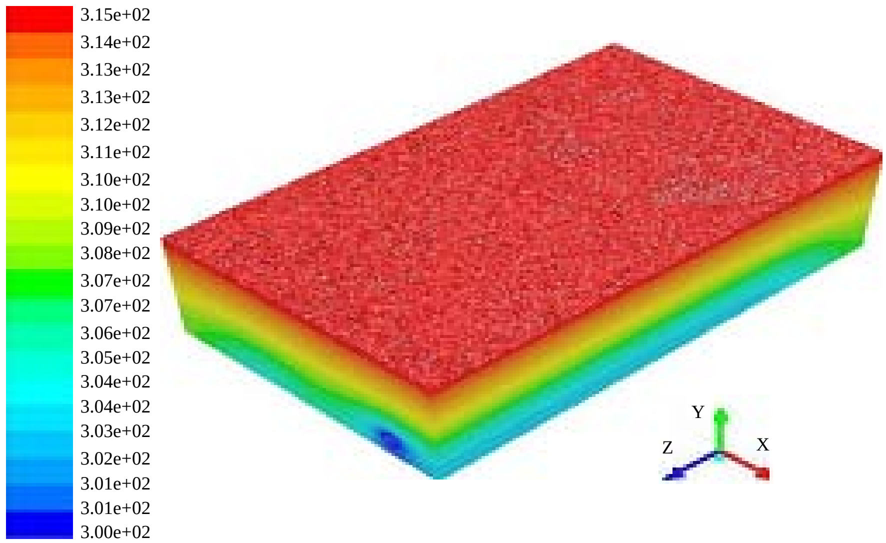

Fig. 17: The 300×500 mm size asphalt pavement copper pipe embedded at 150 mm; contours of static temerature (k) (time = 1.2000e+04); Sep 20, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

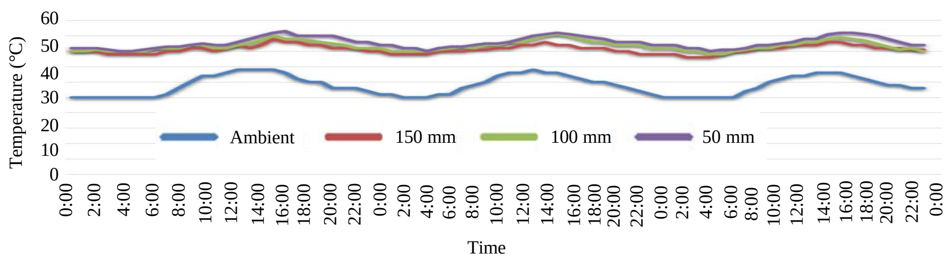

Fig. 18: Temperature variation in asphalt pavement of 300×500 mm embedded with copper pipe at 50, 100 and 150 mm depths

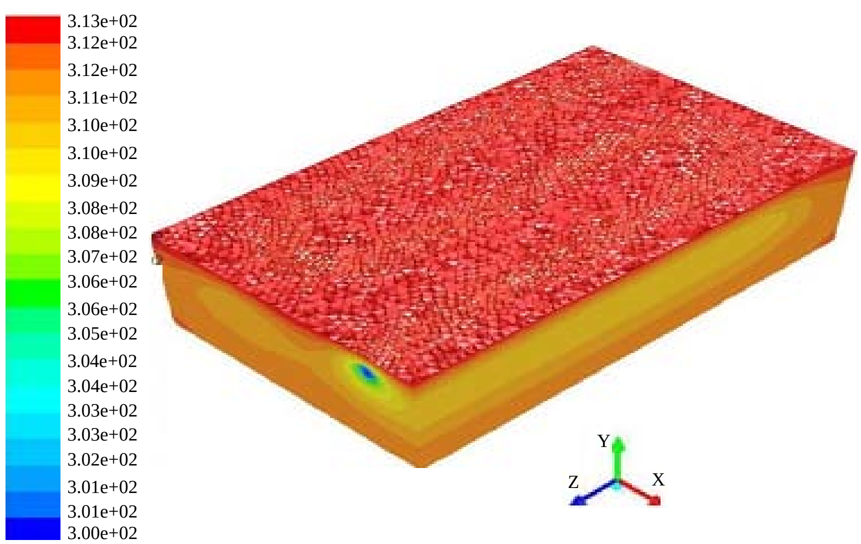

Fig. 19: The 300×500 mm size asphalt pavement rubber pipe embedded at 50 mm; contours of static temerature (k) (time = 1.2000e+04); Sep. 20, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

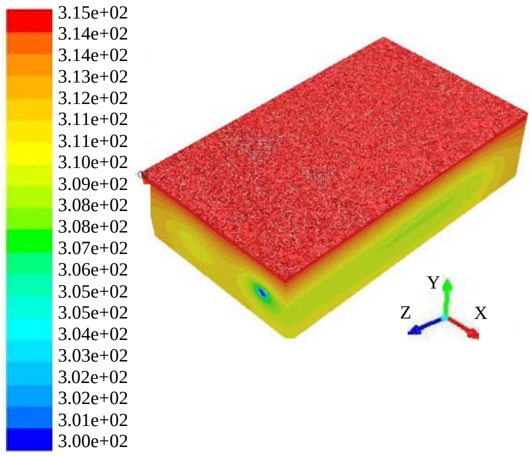

Fig. 20: The 300×500 mm size asphalt pavement rubber pipe embedded at 100 mm; contours of static temerature (k) (time = 1.2000e+04); Sep. 19, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

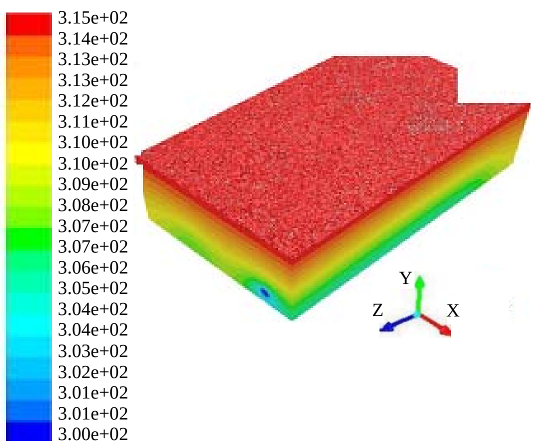

Fig. 21: The 300×500 mm size asphalt pavement rubber pipe embedded at 150 mm; contours of static temerature (k) (time = 1.2000e+04); Sep. 20, 2016 ANSYS fluent release 16.0 (3D, PBNs, LAM, Transient)

Table 2: Temperature variation in 300×500 mm size asphalt pavement embedded with copper and rubber pipe ANSYS simulations

		Highest temperature (°C) 12:00-05:00 p.m.	
Days	Depth (mm)	300×500 mm copper pipe	300×500 mm rubber pipe
1	500	57.0	57.0
	100	55.0	54.0
	150	50.0	50.0
2	500	55.0	55.0
	100	50.0	53.0
	150	53.0	49.0
3	500	53.5	53.0
	100	51.5	51.5
	150	49.0	48.5

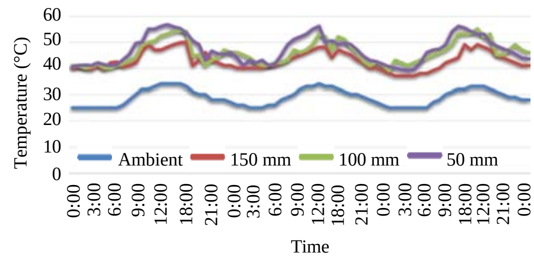

Fig. 22: Temperature variation in asphalt pavement of 300×500 mm embedded with rubber pipe at 50, 100 and 150 mm depths

CONCLUSION

This study is aimed to determine solar heat variation using ANSYS simulation. Asphalt pavement size of 300×300 and 300×500 mm is simulated in ANSYS. Asphalt pavement is embedded with serpentine copper and rubber pipe of diameter of 40 mm. Pipes are filled with water to maintain or cool the temperature at night time. The study is divided into two cases where in first case 300×300 mm asphalt pavement embedded with serpentine copper and rubber was compared. While in second case larger size of asphalt pavement of 300×500 mm embedded with serpentine copper and rubber was compared. In 300×300 mm size asphalt pavement embedded with copper and rubber pipes shows that copper pipes collect higher solar heat energy at depth of 50 mm than rubber pipe. The maximum temperature of 53.5°C is recorded in copper pipe at depth of 50 mm. While maximum temperature of 47.5°C is recorded in rubber pipe at depth of 50 mm. Minimum temperature of 49.0°C is recorded in copper pipe while minimum temperature of 42.0°C is recorded in rubber pipe at depth of 150 mm. Unlike 300×300 mm size asphalt pavement, the result in 300×500 mm size asphalt pavement embedded with copper and rubber pipes shows similar solar energy (temperature) collections in serpentine copper and rubber with slight difference. The maximum temperature of 57.0°C is recorded at depth of 50.0 mm in copper and rubber embedded asphalt pavement. The minimum temperature of 49.0°C is recorded in copper pipe and minimum temperature of 48.5°C is recorded in rubber pipe at depth of 150 mm. The findings indicated that larger surface area of asphalt pavement (300×500 mm) exposed to the Sunlight collect more energy than smaller (300×300 mm) size of asphalt pavement. The study findings also indicated that serpentine copper and rubber pipes embedded in asphalt pavement has slight difference of solar heat collections. The simulation results indicated that maximum solar energy is collected in upper part of the asphalt pavement while lower part collects less solar energy. On 50 mm depth collect more energy than 100 and 150 mm showing descending orders in both cases.

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