

# Investigation the Characteristics of Conductive Asphalt Concrete with Carbon Fibre

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**ABSTRACT:** During periods of snow, freezing rain, icing on road surface could cause to transportation safety problems and interrupt the traffic especially some critical sections of roads such as tunnel, bridges and vertical and horizontal curves of roads and etc. Recent years one of the technologies used to help pavement snow melting/de-icing by an asphalt pavement electrical heater is electrically conductive asphalt concrete. Electrically conductivity is ensured by the conductive material added into asphalt concrete. It was known from literature that various conductive materials can be used in asphalt concrete. In this study asphalt concrete specimens with 5, 10 and 15 mm length and 0.1, 0.2, 0.3, 0.4 and 0.5% by weight carbon fibre (CF) additive were produced. Conductivity properties relation with CF characteristics was determined and test results were assessed.

**KEYWORDS:** Asphalt Concrete, Carbon Fibre (CF), Electrical Conductivity, Electrical Conductive Asphalt Concrete (CAC).

## I. INTRODUCTION

Weather conditions such as snow, sleet, ice storm can cause icing on the road's surface and in some cases endangered the road safety especially in ramp, bridge, tunnel entrance and exit sections of the roads also can cause interruption of the traffic. Statistical studies indicated that adverse weather conditions are main causes of 10-15% of traffic accidents and this leads to life and property losses also considerable harm the economy of the countries. In traditional ice melting methods various salts and chemical solutions are used and they adversely affect the environment and asphalt pavements and also require additional machinery and employment. Furthermore, the chemicals when applied in areas such as bridge, they can lead to deterioration on reinforced concrete structural elements of the bridges [1]. Therefore, ice melting on the road surfaces especially in critical road sections and opening to the traffic in colder months are one of the most important issues. Using conductive asphalt concrete (CAC) to melt ice on the road's surface is extremely important at some sections such as bridge, airport's runway, hospital junction roads, roads of garage, roads at north hilly side vertical and horizontal curves of roads[2-4]. Therefore ice melting with CAC is interesting and important research topics of pavement engineering at recent years. Materials which are passed the electric and heat energy called as conductive material [5]. Electrical conductivity in materials at atomic sizes was performed by "load-bearing elements". These are electrons or electron space. In order to high conductivity, resistivity must be low [1, 3, 4, 6]. Traditional asphalt concrete consists from mixture of insulator bitumen, aggregate and mineral filler. According to the conductive polymer composite theory, conducting asphaltic concrete reaches the low electrical resistivity by way of conductive constituents are added to their inside such as shape of powder, fibres and particle [3, 4 7]. When the constituents are added to asphalt concrete mixtures to provide the desired conductivity also required that asphalt concrete meets the highway specification limits and be economical. In this study asphalt concrete with 5, 10 and 15 mm length and 0.1%, 0.2%, 0.3%, 0.4% and 0.5% by weight carbon fibre additive specimens were produced. Conductivity properties relation with carbon fibre characteristics was determined and obtained test results were assessed.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

## II. MATERIALS AND METHODS

### Materials

In this study limestone based aggregate specimen was used to producing of CAC specimens. The aggregate specimen taken from KOLSAN Mining Company in Afyonkarahisar, Turkey. The 60/70 penetration grade bitumen used as binder (ASTM D 946). The engineering properties of the bitumen are given in Table 1. Carbon fibre was used as conductive component. The carbon fibre bobbin (code:24K A-49) specimen obtained from DOWAKSA Company in Yalova, Turkey. Fibre specimens used in bituminous mixture as three different length and five different % by weight (0.1%, 0.2%, 0.3%, 0.4% and 0.5%) as conductive component. The carbon fibre properties were given in Table 2 and CAC specimen's properties were shown in Table 3.

Table 1. Bitumen Properties

Properties	Value	Standard
Source	Aliaga/Turkey	-
Penetration Grade	50/70	-
Penetration at 25 °C	64	ASTM D5-06e1,
Specific gravity	1.030	ASTM D70-09e1
Softening point (°C)	47	ASTM D36/D36M-09
Loss on heating (%)	2.2	ASTM D6-95
Flash point (°C)	280	ASTM D92-05a
Ductility (5 cm/min at 25°C)	>100 cm	ASTM D113-07
Viscosity at 135 °C	0.400 Pa s	
Viscosity at 165 °C	0.101 Pa s	ASTM D4402-06

Table 2. Carbon Fibre Engineering Properties

Fibre Properties	Value	Test Method
Tensile Strength (MPa)	4900	ISO 10618
Tensile Modulus (GPa)	250	ISO 10618
Strain (%)	2.0	ISO 10618
Density (g/cm <sup>3</sup> )	1.79	ISO 10119
Yield (g/1000 m)	1600	ISO 1889

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Vol. 6, Special Issue 10, May 2017

Table 3. Specimens of CAC Properties

Serial	Fibre Length (mm)	Fibre Raito % (by weight of asphalt briquette)	Fibre weight/ Briquette(g)
1	5	0.1	1.2
		0.2	2.4
		0.3	3.6
		0.4	4.8
		0.5	6.0
2	10	0.1	1.2
		0.2	2.4
		0.3	3.6
		0.4	4.8
		0.5	6.0
3	15	0.1	1.2
		0.2	2.4
		0.3	3.6
		0.4	4.8
		0.5	6.0

## Method

In this study, two different conductivity tests were performed on the conductive asphalt concrete briquettes in order to determine what kind of carbon fibre is effective on the electrical conductivity and which weight ratio of carbon fibre can improve the conductivity property. Resistivity with two electrode method and measuring temperature increasing value of specimens under constant electric voltage were performed.

### Electrical Resistivity Measurements via Two Electrode Method

A power supply (GWINSTEK SPM-6003) and a digital multimeter (Fluke) were employed to measure resistivity. The electrodes made of copper sheets were stuck to the cross profiles of a specimen by mechanic clamp (see in Fig.1). The stabilized power supply and digital multimeter were connected to the electrodes by the wires with crocodile mouth. Subsequently, the resistances under constant voltage (20 Volt) were measured. Resistivity of specimens ( $\rho$ ) was calculated according to the equation (4).

$$\rho = R \times \frac{S}{L} \quad (4)$$

Where  $\rho$  = electrical resistivity ( $\Omega m$ );  $L$  is the internal electrode distance ( $m$ );  $R$  is the measured resistance ( $\Omega$ ); and  $S$  is the electrode conductive area ( $m^2$ ). In order to electrode distance, specimen height was measured three different point and their average heights were used as “ $L$ ” value [2, 5].

# International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Special Issue 10, May 2017



Fig. 1. Measuring Resistivity with two probe method

### Heating of Specimens with Electrical Conductivity

Specimens were subjected to constant voltage (20 Volt) in order to determine change in their temperature. Two electrode method was used for this test, a DC current had been passed through the heights of the specimens the change in the temperatures were determined by measuring from every 2 minutes at the 3 different point at centre of the specimens along 10 minutes.

### III. FINDINGS

#### Electrical Resistivity Test Results

In order to compare the electrical conductivities of the asphalt specimens, electrical resistivity measurements were made by external contact using two electrode methods and the obtained results were compared with each other. The resistivity changes of carbon fibre additive CAC specimens (5, 10, 15 mm) are shown in Figure 2, 3 and 4 respectively.

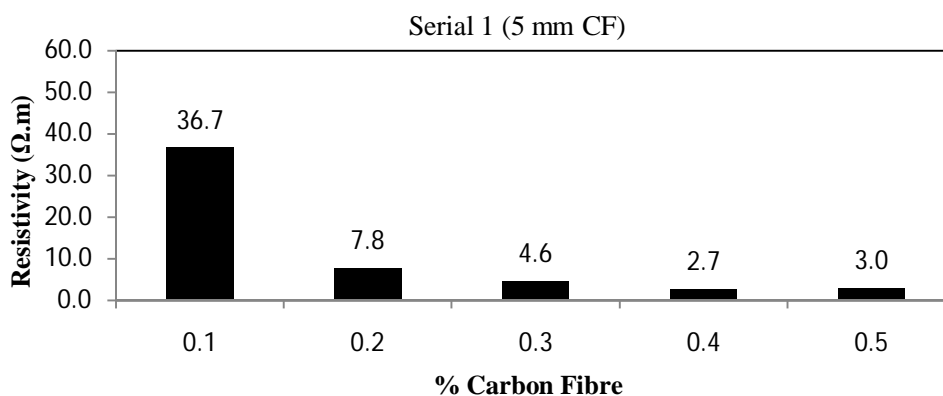


Fig. 2. Resistivity Change According to Carbon Fibre Percentage in Serial 1 Specimens

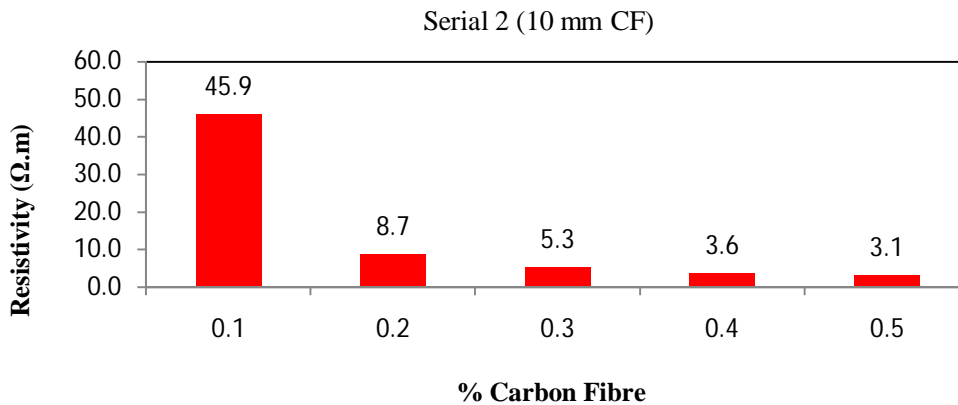


Fig. 3 Resistivity Change According to Carbon Fibre Percentage in Serial 2 Specimens

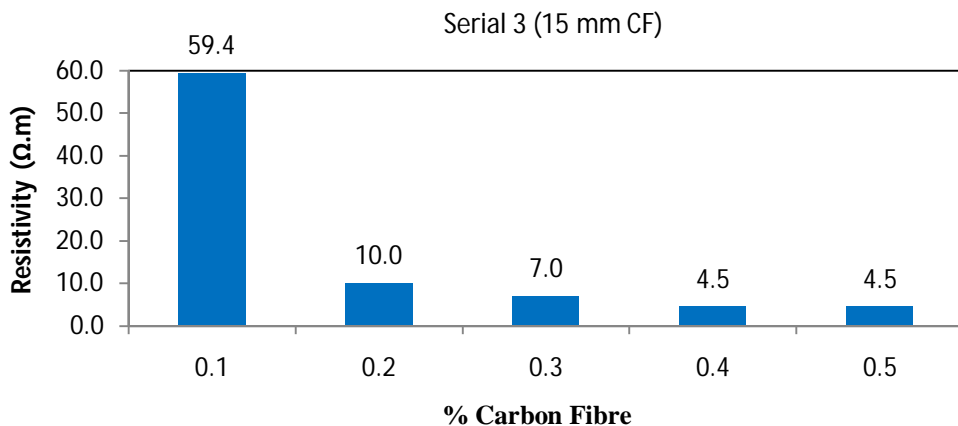


Fig. 4 Resistivity Change According to Carbon Fibre Percentage in Serial 3 Specimens

With the increasing of carbon fibres in the mixtures, resistivity value of specimens was decreased. The greatest decrease in resistivity was obtained in Series-1 specimens. Therefore, when carbon fibre is used in 5mm length, it is considered to be less pelletized than other series. However, the results of Series 1 and 2 are closer to each other. Lowest resistivity value of 0.1 specimens was assigned serial 1, 2 and 3 respectively. Resistivity is significantly reduced in samples with 0.2% carbon fibre added. Wu et al. [8] illustrated that the resistivity of asphalt concrete was reduced to lower than 100 Ωm by the addition of 8% (volume of asphalt binder) carbon fibre. Generally fibres have much lower electrical resistivity than the conductive powders because of its high aspect ratio. Obtained test results from the specimens confirm this [8]. As a result of this experiment, it was determined that the amount of carbon fibre in the mixture and the fibre length were very effective to the specimens to convert into a electrically conductive.

**Heating of Specimens with Electrical Conductivity Test Results**

In this experiment, the specimens were heated by electric current under constant voltage and the changes occurring in their temperature were determined. The changes in the temperatures of the specimens under constant voltage (20 Volt) along 10 minutes were shown in Figure 5, 6 and 7.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 10, May 2017

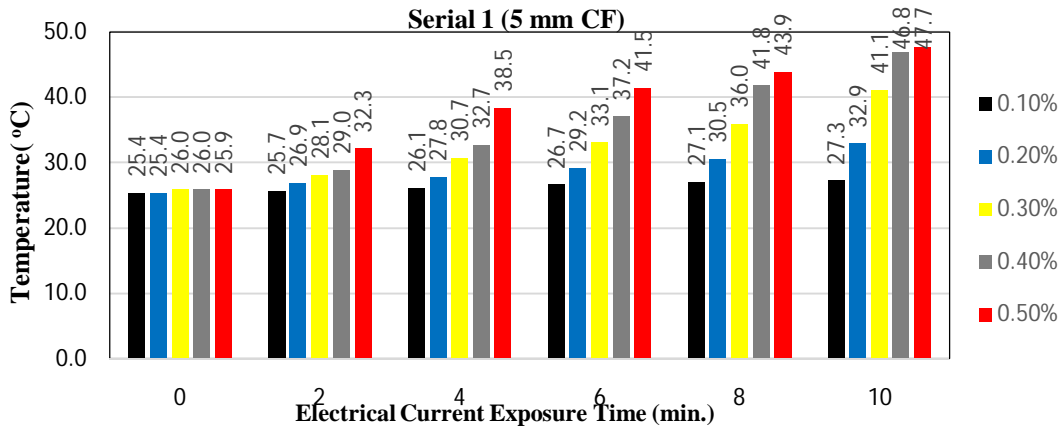


Fig.5. Temperature Changing According to the Electrical Current Exposure Time in Serial 1

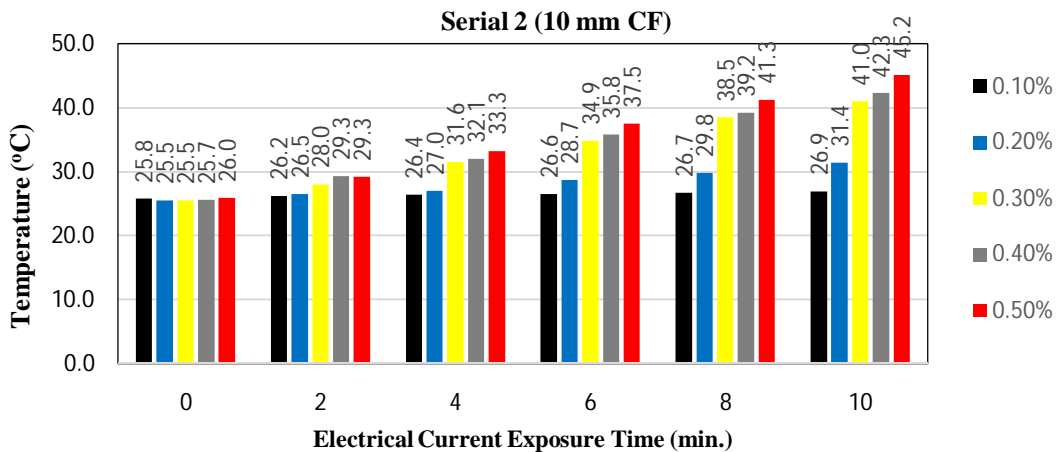


Fig 6. Temperature Changing According to the Electrical Current Exposure Time in Serial 2

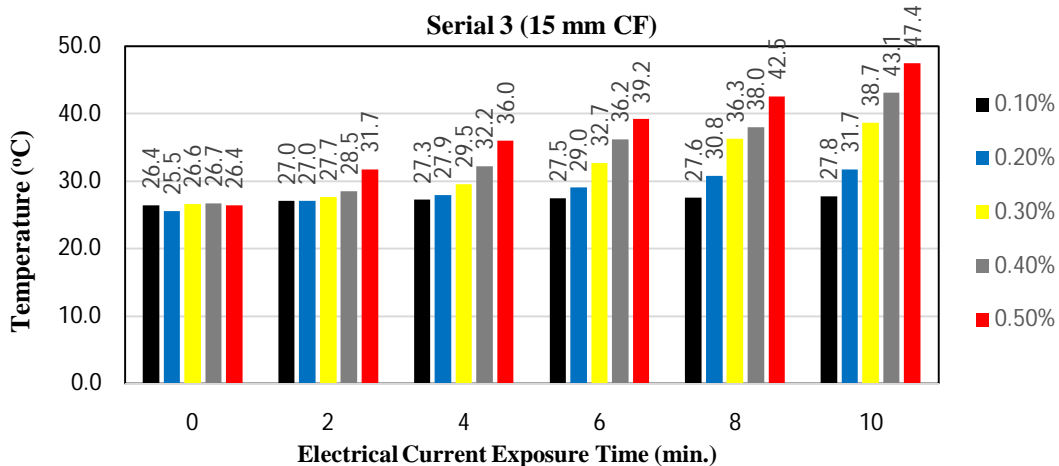


Fig. 7. Temperature Changing According to the Electrical Current Exposure Time in Serial 3

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Vol. 6, Special Issue 10, May 2017

All specimens were shown a temperature increasing depending on the duration of the electric current. As the amount of carbon fibre in the mixtures increased in all three serial, increase in temperature of the specimens were also determined. The highest temperature increasing was obtained at 0.5% carbon fibre added specimens of serial 1 as in resistivity measurements.

## IV. CONCLUSION

As a result of a series of experimental studies, the following conclusions could be drawn:

It was found that carbon fibres were very effective component for converting asphalt concrete into electrically conductive material. Significant reduction in the resistivity's of the specimens was determined when the weight of the carbon fibres in the mixture increased. According to the Garcia et al. if there is a conductive path with sufficient length through the specimen, the asphalt concrete can be transformed from an insulator to a conductor [9]. Therefore, it is thought that 5 mm carbon fibres have the ability to form more conductive paths in the mixture. When the amounts of the carbon fibres were increased to 0.2% by weight and above, the resistivity in all specimens were significantly reduced. The highest temperature increase was determined in serial 1 specimens with 0.5% carbon fibre added.

## ACKNOWLEDGEMENTS

This research was sponsored by the AfyonKocatepe University, Scientific Research Projects Coordination Department (AKÜ BAP) (Project Numbers: **16.KARİYER.183** and **15.MUH.14**).The authors wish to express their gratitude to the AfyonKocatepe University, Scientific Research Projects Coordination Department for their supports. Also authors wish to special thanks to Afyonkarahisar Municipality, team of Asphalt Department's Laboratory, Kubilay Akin (Director), FaikKarakoç (Chef Chemical Engineer), Laboratory assistants Ahmet İba, Recep Balı Engiz, Muratcan Akin, KOLSAN Mining Company (Afyonkarahisar/Turkey), DOWAKSA Company (Yalova/Turkey) and senior BSc. students KadirDüzgün and Mehmet FıratÖzüğür for their supports and helps.

## REFERENCES

- [1] C. Gürer, C. Düşmez, "Anti-icing in bridges by way of conductive asphalt concrete", inProc. of 3th Bridges and Viaducts Symposium. 53 p., 2015 (inTurkish).
- [2] Q. Yang, X. Li, P. Wang, "Resistivity measurement of conductive asphalt concrete based on two-electrode method", J. Cent. South Univ.20: 2599-2604., 2013.
- [3] P. Pan, S. Wu, F. Xiao, L. Pang, Y. Xiao. "Conductive asphalt concrete: A review on structure design, performance, and practical applications", Journal of Intelligent Material Systems and Structures, 1-15, 2014.
- [4] C. Gürer, C. Düşmez, L. Gevrek, "Conductive asphalt concrete applications", inProc. of Engineering and Technology Symposium Proceeding Book. 2015. (in Turkish).
- [5] K. Gopalakrishnan, H. Ceylan, S. Kim, S. Yang, H. Abdualla, "Electrically conductive mortar characterization for self-heating airfield concrete pavement mix design", International Journal of Pavement Research and Technology, Vol.8, No.5, pp.315-324, 2015.
- [6] B.S. Huang, X.W. Chen, X. Shu, "Effects of electrically conductive additives laboratory-measured properties of asphalt mixtures", Journal of Materials in Civil Engineering 21(10): 612-617, 2009.
- [7] A. Garcı'a, E. Schlangen, M. van de Ven, "Electrical conductivity of asphalt mortar containing conductive fibers and fillers", Construction and Building Materials, 23(10): 3175-3181, 2009.
- [8] S.P. Wu, L.T. Mo, Z.H. Shui, ZH., "Investigation of the conductivity of asphalt concrete containing conductive fillers". Carbon 43(7): 1358-1363, 2005.