The Investigation Thermal Efficiency of High Performance Fiber Reinforced Composites with additive Multi-Wall Carbon Nanotubes

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Research Article

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Abstract

Every year thousands of traffic accidents occur due to icing of roads, which challenge lives and property. In this study the suitability of steel fibers and multi wall carbon Nano tube (MWCNT) for electrical (Joule), heating was determined by cluster heating test, which is novel for the literature. In this study, the bearing elements of the buildings and roads are intended to be a heater. Experiments are tested for a total of four weeks, once every week. During the tests, the top surface temperature, the voltage supplied and the current were recorded. The temperature increase and temperature increase rate were determined. Mortar having MWCNT ratio showed a superior heating performance for 4 weeks. In this study, the bearing elements of the buildings and roads are intended to be a heater. The thermal efficiency of the high performance fiber reinforced composites are investigated.

Keywords: Self-heating, Multifunctional Smart Material, Electrical Heating, Cement, Multi-Wall Carbon Nanotube

Introduction

Pavement and runway icing is a major challenge for highway and air transportation. Numerous accidents due to icing causes loss of lives, injuries and damage to property. In USA, more than 1300 people lose their lives and 116,800 people are injured annually due to snowy- slushy-icing pavements while 900 people are killed and 76,000 people are injured in accidents during snowfall and sleet. Besides, winter road maintenance costs are 20% of state DOT maintenance costs. More than 2.3 billion dollars (USD) were spend by state and local agencies for snow and ice controls on pavements annually; while millions of dollars are, spend by road agencies to repair infrastructure damage caused by snow and ice [1]. The projection of the problem to whole world ends up with considerable loss and cost.

In Turkey, during 2006-2007 winter, 50422 tons of salt was used for deicing roads [2]. Salt is detrimental for concrete [3]. Use of salt and other deicers on asphalt degrades the mechanical properties [4-8]. The salt and other deicers corrode the vehicles; pollute the soil and underground water sources.

The chemicals used for deicing of runways at airports are detrimental for the runway, for the aircraft and environment. Organic salts (potassium format and acetate, etc.), oxidizes the carbon in brakes, which challenges safety while damaging the body, electric cables and landing gear [9-11]. Moreover, the runways deicers are sprayed by wheels during takeoff and landing to wings, which had anti-icing agent. The anti-icing agent loses its function when runway deicer is mixed with it which dangers the aircraft due to icing during flight [12].

Zhang et al. applied DC current to nickel particle reinforced cement based composites and reported that the composite was heated [13]. Carbon fiber reinforced mortar was heated by applying electric current [14]. It was reported that the cement composite with steel fiber of 8 μm, 0.7 volume % had resistivity of 0.85 Ohm.cm and was heated when electric current was applied [15, 16]. Gomis et al. reported that cement composites reinforced with carbonaceous materials were able to heating by electric current [17]. Galao et al, tested carbon fiber reinforced concrete with electrical heating test.

Fiala et al. eported that alkali-activated aluminosilicates with carbon black can be improved for self-heating material technology [18, 19]. Kim et al, stated that cement composites with CNT less than 0.6% by weight is appropriate for self-heating. Galao et al. stated that shotcrete of carbon Nano fiber reinforced cement paste (5% by cement mass) had electrical heating performance [20, 21].

Materials and Method

Cem II 42,5R type cement and the fine aggregate (0-5mm) were used. In the mixture, plasticiser was used. Stainless steel wire mesh was used as electrode. Brass fiber was used as conductive additive. Single walled carbon nano tube was also used as conductive additive.

According to the information given by the producer (LANXESS), Characteristic of MWCNT Rhenofit® CNT-3 is a water-based dispersion of single wall carbon nanotubes (MWCNT) which can be used directly for production of formulations. The dispersion is highly homogeneous and stabilized and the applied process ensures non-destructive dispersing of carbon nanotubes under mild conditions. Characteristic properties of MWCNT are presented in table as obtained from the producer:

- Composition: 2 wt% multi wall carbon nanotubes 2 wt% low molecular weight dispersing agent 96 wt% water
- Appearance: Black dispersion
- Odour: No odour
- Compatibility: Can be mixed with liquid systems and appropriate polar organic solvents
- PH value: Slightly basic (approximately pH = 8-10).

Cement and aggregates were put in mixer. Water with MWCNT and plasticizer were weighed in separate cups then mixed in a cup. Water and plasticizer mix were added to dry aggregate and cement in 3 stages and mixed every time.

Mixture was cast into the molds in 2 stages. The mix was rodded 10 times. Mold with mixture were vibrated on a vibration table. After 24 hours, sample was demolded and cured in room temperature (20°C) water for 28 days. Mold size was 10 × 10 × 3.5 cm³. Mold size was 10 × 10 × 3.5 cm³.

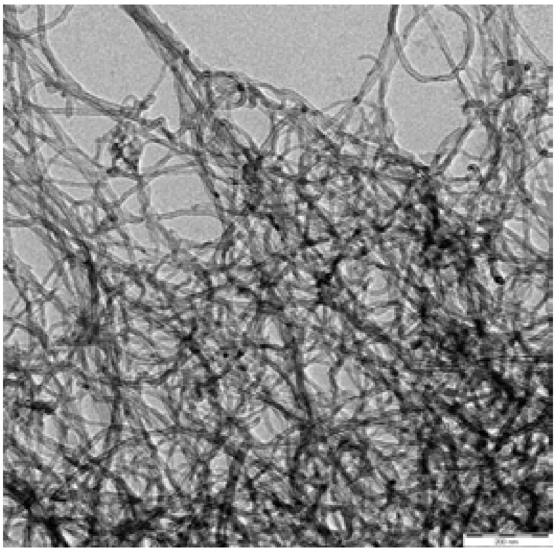

Figure 1: SEM image of MWCNT (Scale is 200 nm)

The mixtures were designed according to TS 802 “Design of Concrete Mixtures” standard. In this study, concrete were designed which had 3% volume of brass fiber.

Three 10 × 10× 3.5 cm prismatic sample from each mixture were tested. Experiments of the sample was made on 35th of production. A thermal camera was recorded during the experiment. A direct current source was used. The test diagram and experiment are presented in (Figure 2, 3). During the electrical heating test, direct current was supplied from the two electrodes to the sample with the DC source. To measure the electrical resistivity of the samples, the sample potential differences (Vs) were measured from both electrodes. Current passing through the circuit (I) and the potential difference (Vs) was recorded. The instantaneous electrical resistance (Rs) of the sample using Ohm’s law was calculated by using Equation 1.

$$Rs = (Vs) / (I) \quad (1)$$

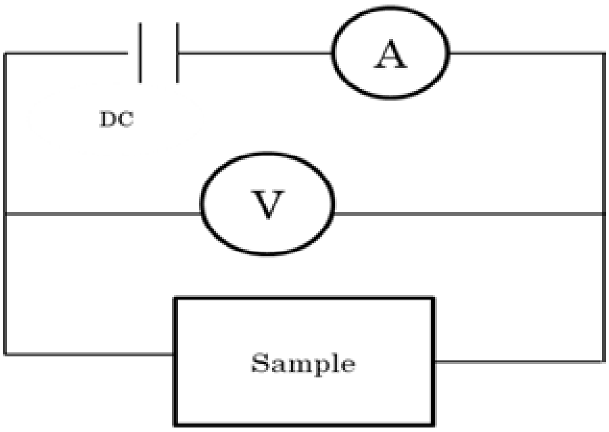

Figure 2: Circuit diagram

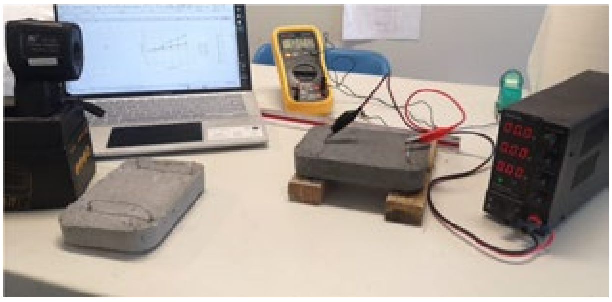

Figure 3: Concrete and Schematic of Experiment

Results and Conclusions

This experimental study is trying to solve the heating problem by means of a concrete system that can be heated by electricity. The concrete was tested once a week for a total of 4 weeks under 112V voltage. In addition, total experiment time was determined as 5 minutes and the results were recorded. It has been observed that a sample reached high temperature in a very short time. After first week experiment, it has been observed that current and temperature increase getting decrease every week.

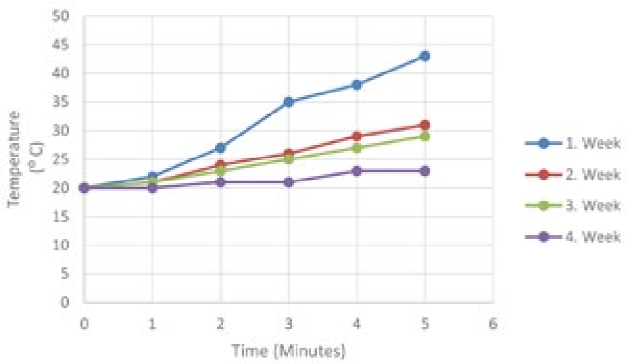

Figure 4: Temperature-Minute Graphs

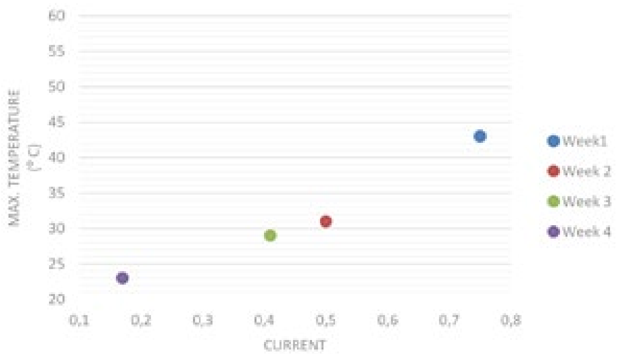

Figure 5: Max. Temperature-Current Graphs

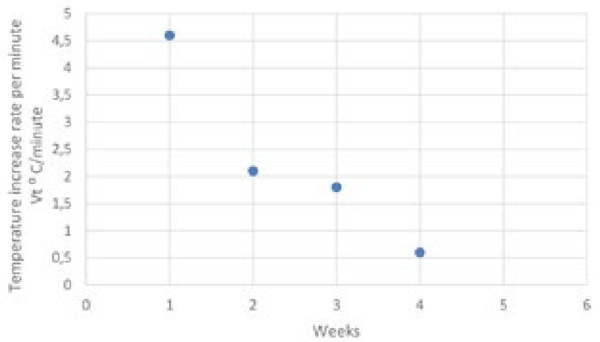

Figure 6: Temperature increase rate per minute

In this study cement matrix composite was designed. Designed with MWCNT and 3 percent of brass fiber. Sample was prepared, cured and tested. The effect of electrical conductivity, the amount of temperature increase per minute were experimentally tested. Important results are presented as bellow;

The temperature-time curves obtained from the 112V electrical heating tests are given in

- There was almost a non-linear relation among the temperature increase and temperature increase is the same every week.
- The temperature rise is the MWCNT ratio, have different temperature increases every week.
- The temperature rise rates are the MWCNT ratio, have decreasing every week.
- The mixture of MWCNT, the temperature increase and temperature increase rates are decreasing every week.

The MWCNT cement can be develop as electrical-heating cement but it need to observe the relation of humidity-temperature increase and also whether there is damage caused by voltage should be examined with a microscope.

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