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Research paper



Research of Measuring Device in Surface of Road Temperature

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Abstract

Background/Objectives: Measuring device of road surface temperature installed all kinds of road makes it possible to predict not only road surface temperature as well as its trend of temperature change by providing real time information of road surface temperature which has an important effect of ice on the road in winter season but also time invested in snow removal and workload. It is suggested method to improve measurement precision of road surface temperature.

Methods/Statistical analysis: Sample is installed in a constant temperature chamber before test implementation and leaves it in natural conditions without configuring settings to make upper surface temperature becoming constant temperature. Upper surface temperature leaves until a certain temperature after setting below zero temperature when the target temperature is reached.

Findings: Correction formula that is satisfied maximum error range±0.5℃ between surface temperature of concrete test piece and temperature correction through measuring device is drawn based on analysis of trend in measuring device of the temperature change and its gradient.

Improvements/Applications: Surface temperature measuring device applied correction formula increases the accuracy of surface road temperature as an important factor of ice protection system on the road and the effect of preventing traffic accident due to freezing will be increased**.**

Keywords: *Road, Temperature, Black Ice, freezing, road surface*

1. Introduction

The error between real road surface temperature and collecting data from temperature measuring device which is manufactured to serve many purpose for highway and general road resulted in a large when is installed real road. Infrared thermometer is used for measuring method of road surface temperature but it is unavailable for accurate measurement of road surface temperature due to a large error range based on indirect measurement. Road surface temperature device is implanted in a road to measure its surface temperature but an error is unavoidable according to the installed location of temperature sensor inside device. This study attempts to evaluate the effectiveness of road surface measuring device which is able to gather reliable data for the variation of temperature according to air temperature changes. Artificial test environment is created for evaluation to calculate correction equation through not only data gathering but also analysis of the collected data. Error between road surface temperature measuring device and its real temperature was able to reduce by applying correction equation to road surface temperature data which was actually measured. In result, accuracy of road surface temperature device can be increased as maximum error range between measuring temperature device and real road surface temperature was within 0.5℃.

2. Materials and Methods

2.1. *Related Works*

2.1.1. Temperature Measuring Method

There are two kind of temperature measurement like contact and contactless
Contact measurement : Object to be measured is contacted directly with detecting element of measuring device and its temperature is numbered within balance of thermal contact between the two.
Contactless measurement : Object temperature to be measured is displayed by measuring the thermal radiation intensity [1].

2.1.2. Type of Thermometer

2.1.2.1. Thermometer Utilizing Expansion

Glass thermometer : A thermometer utilizing thermal expansion of liquid is widely used due to good accuracy and simplicity. Liquid is sealed in thin glass tube where thermal expansion difference between glass tube and liquid can be seen markings. There are Beckmann's thermometer and maximum and minimum thermometer according to type of using liquid and its range of use. Mercury is most widely used among them because it has a good thermal conductivity without sticking to a glass tube. But organic fluid is used in low temperature.
Bimetal thermometer : It is possible to measure temperature using bending difference due to temperature change in case of putting

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two sheets of materials together with the different coefficient of expansion.
Pressure thermometer : A pressure gauge of Bourdon tube which is injected by liquid or gas or both of them is connected in a capillary tube and pressure change according to temperature change is provided to the gauge. There are three types of gauge such as liquid type, steam pressure type, and gas type according to its structure. Liquid type is filled with liquid all in capillary and Bourdon tube and is used under critical temperature due to using completely thermal expansion of liquid. Liquid like aniline and mercury is used. Steam pressure type takes advantage of constant relationship between steam pressure of liquid and its temperature. A gas thermometer using helium, mercury, neon, and nitrogen is considered as a foundation of measuring temperature. Glass, quartz glass and platinum are used in the container while mercury column is used to measure pressure [2][3].

2.1.2.2. Electrical Thermometer

Resistance thermometer : Temperature is measured by the quantity of electricity with changing temperature together. Temperature is measured by using not only a thermoelectric thermometer that Electromotive force in thermoelectric couple is set by temperature difference of contact point but also an electrical resistance of metal and semiconductor which can be changed by different temperatures. Thermistor that is sintered semiconductor with metallic oxide powder of manganese, nickel, and cobalt can measure temperature using the characteristic of greatly changing electric resistance in temperature variation. Measuring methods are various, such as a way to use potentiometer or bridge, transposition coil type ratio meter and bridge type ratio meter.

Thermocouple thermometer : The end of thermocouple wire is welded to make electric contact point. Thermocouple is made by copper or combination of copper-nickel alloy according to usage of thermocouple. Measuring error is within maximum 1% when using a thermocouple with a good accuracy and instrument [4][5].

2.1.3. Radiation type thermometer

Radiation thermometer : It is called an omnidirectional radiation thermometer due to use all kind of radiation. It is used mostly by measuring high temperature. Radiation is composed of heat ray and temperature of radiator can be estimated if it is absorbed by appropriate absorber to measure temperature rise. Thermocouple is widely used to measure temperature rise.
Optics thermometer : Narrow wavelength radiation in visible ray is used to measure high temperature up to 7,000 and Red ray with wavelength of 0.65 is usually used. There is other type to measure automatically or to control using photocell or phototube.
Infrared thermometer: Detection devices of thermometer to use infrared up to 15 ㎛ for temperature measuring are composed of two types. One is thermal energy detector like thermistor or superconducting element and the other is photometric detector based on photoelectric device like pbs, ge, and si [6][7].

2.2. Temperature Measuring Test of Road Surface

Test from room temperature to low temperature: Test sample is set in thermos-hygrostat chamber before testing to make upper surface temperature reach -4±2°C naturally.
Test from low temperature to room temperature: Test sample is set in thermos-hygrostat chamber before testing and set it to sub-zero temperature. Leave upper surface temperature in concrete to reach -4±2°C. And then it maintains to increase up to 20±2°C when it reaches -4±2°C. Thermocouple is installed inside test sample and thermos-hygrostat chamber respectively to connect data logger for measuring. Measuring temperature based on upper surface temperature of test piece in concrete is offered twice from room temperature to low and the other way. Total four points are measured for data gathering in concrete surface temperature and the rest data is used for result analysis except two data which has a big temperature difference after testing. Test temperature in start and stop is proceeded based on upper surface temperature in concrete
Methods adapted (pl include reference), any modification of regular methods, the extraction methodology/ simulation models, the growth conditions and measurement of plants/ animals should be stated. Wherever necessary provide (citation)references1[8][9].

2.3. *Sample Manufacture*

Temperature measuring device with 76 X 100 X 15mm shape is installed in concrete test piece with 276 x 300 X 75 mm shape like shown in Figure 2 where the devise inserted in center position from four corners in separation distance of 100 mm.
Lower part of sensor in temperature measuring device is finishing touches by a form with 36 X 5 0 X 10 mm shape to minimize upper part temperature of concrete surface as well as other influence of the temperature shown in Figure1.
Divide concrete test piece in four equal parts and install thermocouple at each four central part to collect temperature data of concrete upper part shown I figure 3.
In order to collect temperature data in sensor of temperature measuring device, each thermocouple is installed according to part as follows A: exposed surface of upper surface part, B: upper part of sensor, C: middle part of sensor, D: lower part of sensor.
To prevent rapid changes in temperature, the one third point of lower part of Styrofoam with 715 x 435 x 240 mm shape is filled with cod pack. Concrete test piece of the side and lower part which is practiced finishing touches with insulator is installed as it is shown in Figure 4. Air cap is put to prevent contact between concrete test piece and cold pack and then it is sealed with a cover after the rest parts are filled in cold pack.

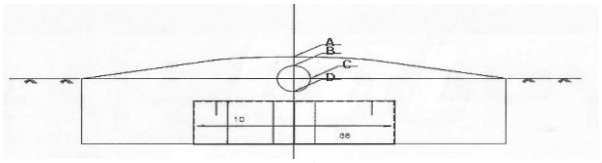


Figure 1.: Cross-sectional drawing of temperature measuring device for road surface

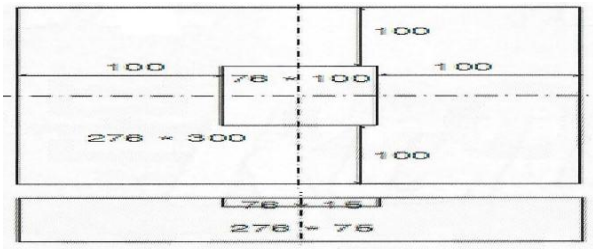


Figure 2:. Concrete test piece and specification of measuring device

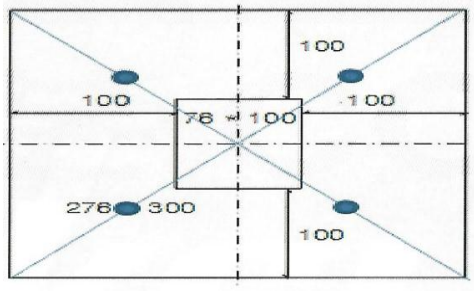


Figure 3.: Installation location of thermocouple in upper surface of concrete test piece

Test sample used an actual test is shown in Figure 4 and the left is surface temperature measuring device while the right is test sample which treats the rubber with form. Formed rubber after processing is shown in Figure 5 and the right is the condition of test sample that is buried measuring device.

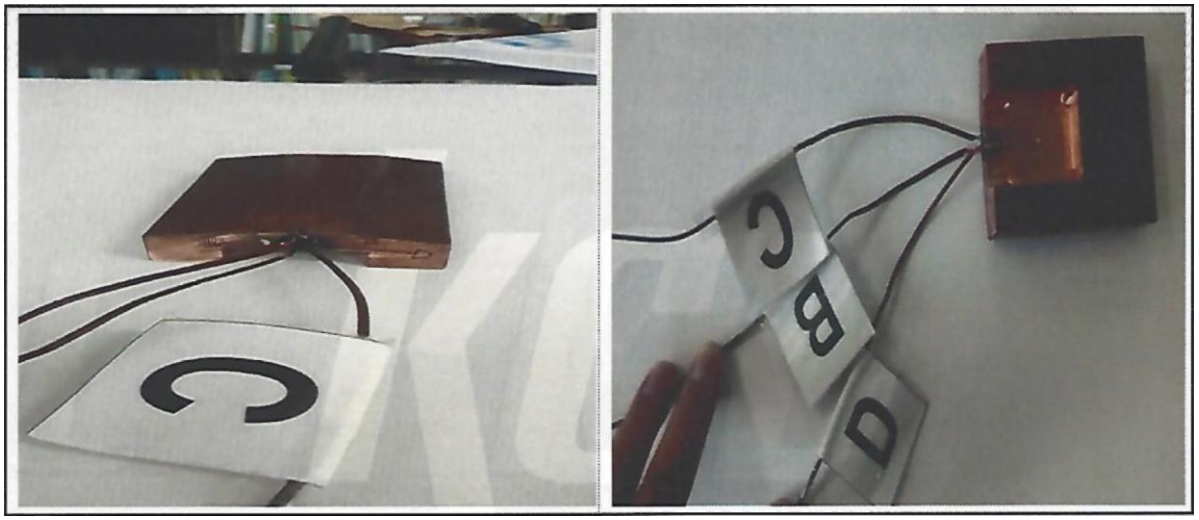


Figure4:. Measuring device of road surface temperature(left), Formed rubber before processing(right)



Figure 5:. Lay measuring device(right), Formed rubber after processing(left)

2.4. *Temperature Measurement Test in Road Surface Temperature Measuring Device*

Test environment which surface temperature of certain temperature range is -4±2℃ - 20 ±2 ℃is created to evaluate field application of measuring device in road surface temperature. Measurement error of collected temperature data through surface temperature in concrete test piece and measuring sensor according to air temperature changes is evaluated based on analysis of collected temperature data through data logger[10].

2.5. *Test Item*

Test environment which surface temperature of certain temperature range is -4±2℃ - 20 ±2 ℃is created to evaluate field application of measuring device in road surface temperature. Measurement error of collected

3. Results and Discussion

Temperature variation between surface of concrete test piece and measuring device indicates that distribution is within maximum 0.7℃ according to temperature change of test result in -4±2 ℃ ~ 20±2℃. Temperature changes in measuring device per unit time is distributed within +0.03℃/min. Temperature variation during temperature rise is shown in Figure 6.

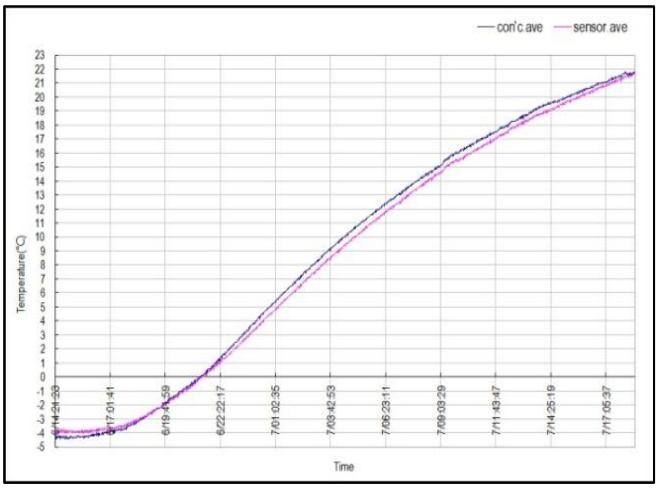


Figure 6:. Graph showing changes of surface temperature in concrete test piece during a descent of temperature

Is created to evaluate field application of measuring device in road surface temperature. Measurement error of collected temperature data through surface temperature in concrete test piece and measuring sensor according to air temperature changes is shown in Figure 6.

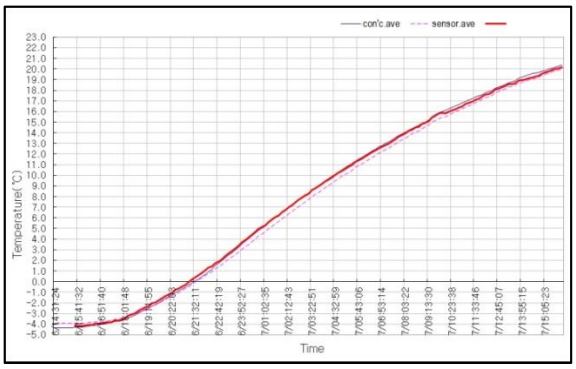


Figure 7:. Graph showing changes of surface temperature in concrete test piece during a descent of temperature

Grape showing changes of surface temperature in concrete test piece during a decent of temperature is shown in Figure 7
Trend of temperature change and its slope is analyzed according to performance test evaluation and correction equation is provided to be able to satisfy maximum error range in ±0.5℃between correction temperature derived from measuring device and real surface temperature in concrete test piece. Correction equation is as in the following.

$$J = D + 37(\min) \times I + C \quad (1)$$

J = Correction temperature

D = Measuring temperature of measuring device

I = Temperature gradient (Temperature variation of measuring device per hour)

C = -0.254

Test result of temperature fall between 20±2℃ and -4±2℃ showed that temperature difference according to temperature variation between the surface of concrete test piece and measuring device is distributed within a maximum of 1.5℃ and temperature variation of measuring device per hour times is distributed within minus 0.03℃/min. Test result of temperature rise between -4±2℃and 20±2℃ showed that temperature difference according to temperature variation between the surface of concrete test piece and measuring device is distributed within a maximum of 0.7℃ and temperature variation of measuring device per hour times is distributed within +0.03℃/min. Temperature variation and changes of temperature gradient in measuring device is analyzed by performance test and evaluation. Correction equation to satisfied maximum error range ±0.5℃ between temperature correction through measuring device and actual surface temperature of concrete test piece is provided and its correction equation is as in the following
Resulting graph which is applied correction equation into measuring data during temperature rise is shown in Figure 8

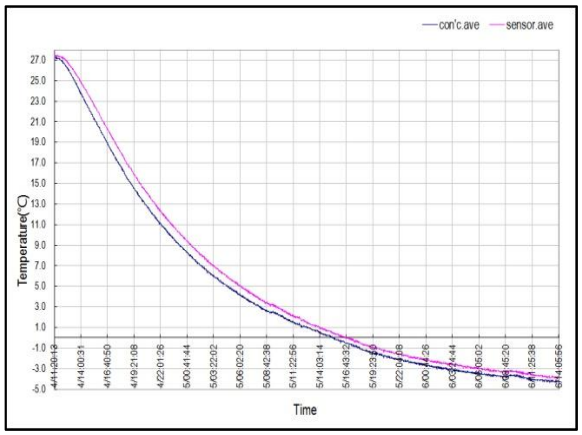


Figure 8:. Correction result graph during temperature rise

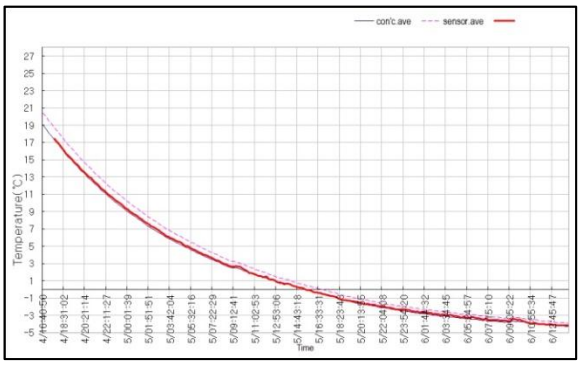


Figure 9:. Correction result graph during temperature descents

4. Conclusion

Correction equation is generated in this study to measure temperature within 0.5℃ error between temperature in measuring device and actual temperature in road surface. That allows adjustable equipment which is able to collect temperature variation data according to air temperature changes to be applied prevention system of icy road in winter season
There are variety sensors to measure surface temperature in road but accuracy may reduce to detect the condition of icy road due to large error between real surface temperature and measuring temperature in sensor. Measuring accuracy of surface temperature on road can be increased by putting in measuring data into correction equation

Acknowledgment

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