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Construction of Measurement System for Stable Infrared Thermographical Image

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Summary

The purpose of this research is to develop a new technique to measure the corrosion level of reinforcing rebar which embedded in reinforced concrete structures using infrared(IR) thermographical image. IR thermography has been used various applications for non-destructive test(NDT) area, however, IR thermographical data depend on many parameters that the assessment of reliability and stability becomes very important issue to utilize IR thermographical system. This study presents a technique to quantitatively measure the corrosion level of a reinforcing bar using proposed infrared thermography measurement system. We found out electric heating method has an important effect on active IR thermography at the connecting position between rebar and power supply. Therefore this study proposed an efficient way for grip standardization to reduce constriction resistance problem, and providing not only stable but also reliable thermal image which reveal qualitative information regarding rebar corrosion.

keywords: Infrared thermography, rebar corrosion, grip standardization

Introduction

Infrared(IR) thermographical image is a non contact sensing method concerned with the measurement of radiated electromagnetic energy. The energy emitted by a surface at a given temperature is called the spectral radiance. The difference of spectral radiance pattern reveals valuable informations regarding various conditions underneath material surfaces. A quantitative measurement technique has been introduced in previous research to detect corrosion level of reinforcement rebar which embeded in reinforced concrete structures. Using passive thermography, relevant temperature differences can be observed on concrete surface and this provides thermal properties of subsurface. This study presents a technique to measure the corrosion level of a reinforcing rebar quantitatively based onstable IR thermographical data. We found out electric heating method have an important effect on thermal data from preliminary test. This study focus on the grip standardization to reduce constriction resistance problem, and provide reliable thermal image. The measurement system to provide stable IR thermographical image mainly consists of two parts. One is contact device between reinforcement rebar and electric cable used to provides electric current. And the other is the level of contact pressure

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at this contact position and contact pressure is applied to the surface of reinforcement rebar controlled by torque wrench. Using vise type earth clamp, the surface resistance of rebar was smaller than that of traditional plier type earth clamp by analysing temperature distribution relationship. Also this study contains important IR experimental conditions which provide reliable and stable IR thermal image for given reinforced concrete specimen to measure accurate level of rebar corrosion.

Experimental Test

A total of 50 test specimens are being cast. A group of 15 test specimens is produced with two cross variables, concrete cover depth(10mm, 20mm, 30mm) and predicted corrosion level (0%, 1%, 3%, 5%, 7%, and 10% loss by weight). The dimension of test specimen is shown in Figure 1. The concrete compressive strength is 210 kgf/cm^{2}and D13 reinforcing steels are used.

After 28 day curing, the reinforcing steels are corroded by electro-chemical acceleration testing method and the level of corrosion of reinforcing steels are being recorded using Faraday's law.

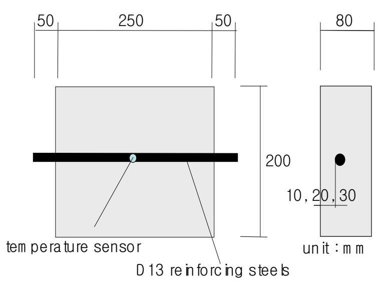

Figure 1: Specimen Dimension

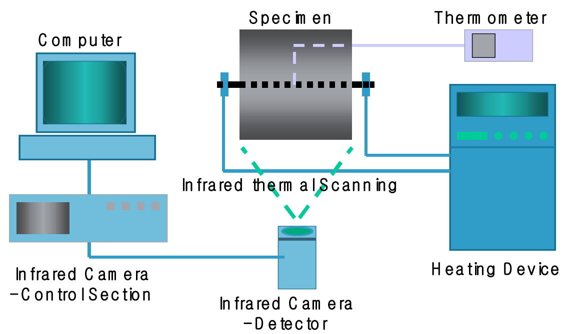

Figure 2: Infrared Thermographic System

Infrared thermographic image data are recorded at every 10 second by heating up the end of reinforcing steel with its surface scanning capability. Schematic view of this infrared thermal scanning system is shown in Figure 2. The test specimen and the infrared camera are set inside a testing frame in order to maintain the same distance throughout experimental testing procedure. The change of reinforcing steel temperature is also detected at every 10 second inside concrete using temperature sensor which has 0.1°resolution. Input current needs to be adjusted with consideration of heat loss due to concrete cover depth. Therefore, 150Amp for C10 series (10mm concrete cover depth), 200Amp for C20 series (20mm concrete cover depth) and 250Amp for C30 series (30mm concrete cover depth) are applied to the ends of reinforcing steels and the distribution of thermographic images caused by temperature increase is recorded. In addition, after taking these thermographic images, the input current is terminated so that the reinforcing steel can be cooled off for 180 second in the air. And infrared thermographic images are also taken for this temperature decrement period.

The infrared thermographic image data are transformed to ASCII files to visually show the temperature distribution of concrete surface. These two orthogonal data distributions were collected every 30 seconds and averaged longitudinal direction: longitudinal direction along the reinforcing steel (240 data points among 256 data points), transverse direction perpendicular to the reinforcing steel (181 data points among 207 data points). Figure 3 shows schematic view of IR thermographic data processing procedure.

As it can be seen in Figure 2, reinforcing rebar is connected to the heating device to obtain input current in order to generate electric energy. There are two types of earth clamps at this connection were used; One is regular plier type earth clamp and the other is vise type earth clamp. Different from plier type earth clamp which provides just contact between rebar and heating device, vise type earth clamp can apply pressure on the reinforcing rebar for firm grasp. Plier type earth clamp and vise type earth clamp are shown in Figure 4 and 5, respectively.

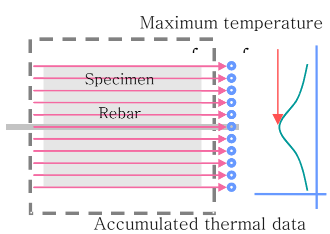

Figure 3: Accumulated thermal data

Figure 4: Plier type earth clamp

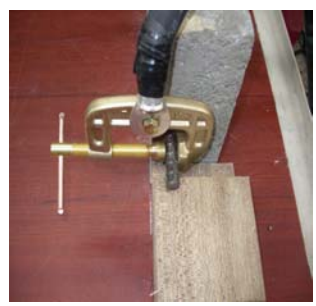

Figure 5: Vise type earth clamp

Test Results

The temperature changes of internal reinforcing steel in each test specimens are investigated in the laboratory. Temperature distributions indicated that temperature increasing rate is accelerated faster with the higher predicted corrosion level. This fact shows that the amount of infrared emission is affected by corrosion state of reinforcing steel and it is a function of time and corrosion rate. Also the temperature of reinforcing steel is not severely affected by ambient temperature, however, concrete surface temperature was increased as ambient temperature increased. Since IR thermography is directly related to the concrete surface temperature, specially designed infrared scanning chamber was constructed in order to reduce temperature interference due to environmental temperature change. Infrared chamber enables NDT inspector to measure corrosion of reinforcing rebar inside of reinforced concrete without any atmospheric turbulences between specimen and IR detecting device.

As it can be seen in Fig. 6, test results showed that plier type earth clamp generates large amount of infrared radiation at the grip between rebar and earth clamp in comparison of vise type earth clamp. The temperature which generated at the end of rebar grip location moved to the center of rebar as time passes. The grip temperature with plier type earth clamp is always higher than that of center location of rebar throughout test period. When the vise type earth clamp was used, on the contrary, the temperature was increased at the center of rebar and move to two end sides of rebar as it can be seen in Fig. 7.

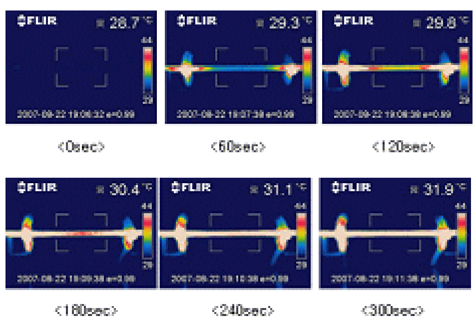

Figure 6: Plier type earth clamp

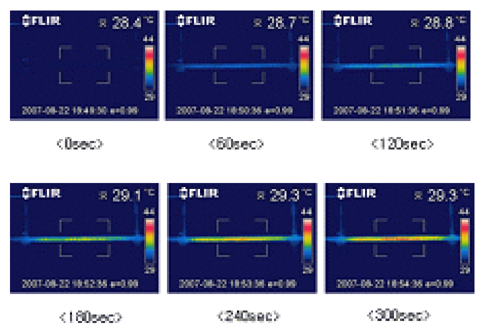

Figure 7: Vise type earth clamp

In case of using plier type earth clamp, there is large amount of contact resistance between rebar and clamp and this resistance generate large amount of unnecessary heat. The temperature at the plier type earth clamp reached almost 110°Cand it is hard to filter off this contact resistance from corrosion effect on the reinforcing rebar. Moreover each clamp yields different contact pressure on each side of rebar and this result produces overestimated IR thermal data.

This contact pressure which might causes contact resistance can be controlled by using vise type earth clamp. The rebar temperature resulting of vise type earth clamp remains constant throughout the tests. For the best results, torque ranch was used with vise type earth clamp to apply constant contact pressure on each clamp ends. As Fig. 7 shows, temperature of reinforcing rebar increased from center of the rebar and well-distributed through all length of rebar. Comparing each different clamp, the vise type earth clamp produced much less amount of grip temperature about 10% of plier type earth clamp. Fig. 8 and 9 showed temperature distribution of accumulated thermal data versus time for each different trial using vise type and plier type earth clamp, respectively. As figure 8 and 9 showed, the temperature distributions of plier type earth clamp represent various maximum values for each different trials.

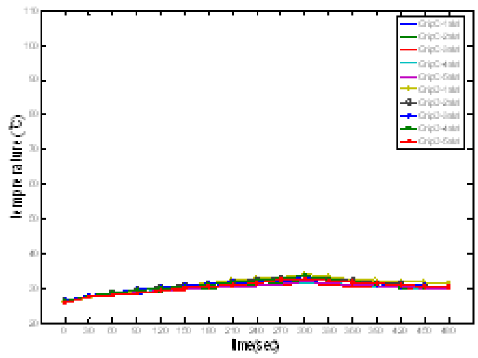

Figure 8: Temperature distribution for vise type earth clamp

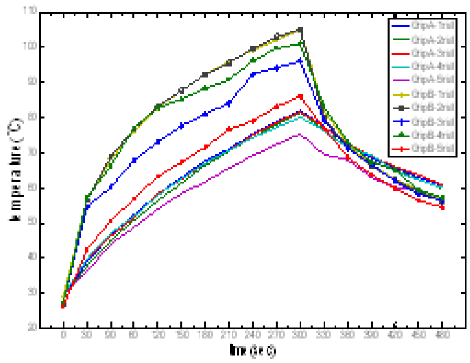

Figure 9: Temperature distribtion for plier type earth clamp

In order to estimate contact resistance of reinforcing rebar, following equations have been used. Eq. 1 was used to obtain the amount of heat generated from electric heater. Energy of electricity(Eq. 2) can be used to get voltage and resistance can be calculated from using Eq. 3. Electrical resistance of reinforcing rebar after using Eq. 1 to 3 was 1.279×10^{-4} for vise type earth clamp and 1.092×10^{-3} for plier type earth clamp. As it is expected, vise type earth clamp have smaller contact pressure than that of plier type earth clamp.

$$Q = c\cdot m\cdot t = 333.5g\times 0.442\text{J/g°C}\times(33.34-27.48)\text{°C} = 863.8\text{J} \quad (1)$$

$$V = \frac{E}{I\cdot t} = \frac{863.8J}{150\text{Amp}\cdot 300\text{sec}} = 0.0192\text{volt} \quad (2)$$

$$R = \frac{V}{I} = \frac{0.0192}{150\text{Amp}} = 1.279\times10^{-4}\Omega \quad (3)$$

Torque ranch was used to control constant contact pressure at each grips with vise type earth clamp. As torque ranch pressure is increased, contact resistance was decreased and infrared intensity was also decreased slightly. The optimum torque pressure was analyzed about 10N.m to produce stable infrared thermal data.

Discussions

The main issue of this paper is to construct corrosion measurement system with minimum damage to reinforced concrete structures using IR thermographical image. Infrared radiation from concrete surface mainly depends on two restrictive conditions. One is the outside condition which is ambient air current nearby concrete surface, the other is the inside condition which is temperature of reinforcing rebar itself. Outside condition can be eliminated by using auxiliary chamber previously developed from this research. And inside condition can be reduced by using following measurement techniques.

- The optimum conditions of temperature measurement system are 40cm photographing distance, 150Amp, 200Amp, 250Amp electric current for 10mm, 20mm, 30mm concrete cover depth, respectively, and 300second heating time and 180second natural cooling time.

  To reduce contact resistance at the grip location between reinforcing rebar and clamp, following grip standardization system has been proposed.
- By using vise type earth clamp instead of using traditional plier type earth clamp, not only can be minimized the contact resistance but also temperature distribution on the concrete surface can be evenly distributed throughout the rebar. These effects provide more stable and reliable infrared thermal data for given corrosion measurement system.
- The torque ranch was used to apply constant pressure on each grips so that infrared radiation represents only corrosion effect and the optimum amount of grip pressure turned out to be 10N.m.

Acknowledgement

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