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QUALITES OF CEMENT PASTE HEATED AT HIGH TEMPERATURE EVALUATED BY X-RAY COMPUTED TOMOGRAPHY

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Summary: The physical and chemical qualities change when surface of concrete is exposed to high temperatures. However, the continuous change of the qualities to the depth direction is not clear. The purpose of this study is applicability of the X-ray CT to evaluation of damage distribution inside of concrete damaged by heating. The results suggested that the CT value can evaluate the change of physical and chemical qualities of the cement paste by fire damage.

1. INTRODUCTION

The physical and chemical transformations that take place when concrete is exposed to high temperatures result in the deterioration of its mechanical properties. As a result of these changes, concrete gradually or quickly loses its mechanical strength and durability. The effects of high-temperature exposure manifest themselves in the form of surface cracks, spalling and disintegration, which render concrete structures unserviceable.

To identify the depth where the qualities of the concrete change, the phenolphthalein solution are sprayed to concrete cores taken from the concrete construction. Also, the method to measure the salt penetration depth in the concrete cores immersed in salt water is suggested. The two-dimensional boundary position is measured by those technique. However, the continuous change of the qualities to the depth direction is not clear.

We thought to use the X-ray computed tomography (CT) method to the concrete cores obtained from the structure. The continuous changes of qualities in the core would be measured by the analysis of the X-rays CT image. Therefore, our purpose in this study is applicability of the X-ray CT to evaluation of damage distribution inside of concrete damaged by heating.

2. EXPERIMENTAL METHOD

Tap-water, high-early strength portland cement, thickener and polycarboxylic superplasticizer were mixed with an omni-mixer. The mixed cement paste was placed into 3 cylinder molds of 100 mm in diameter and 200 mm in height. After curing in the water at 293 K for 28 days, the upper surfaces of 2 specimens were heated at 5 degrees per minute to 1173 K in an electric furnace with a system as shown in Fig. 1 [2]. The temperature in the electric furnace was held at 1173 K for 1 hour and the electric furnace was cooled by natural cooling. In this heating system, the upper surface of each specimen was placed in the hole at a bottom of the electric furnace and the temperature in the electric furnace was increased. A thermal insulation material was placed around the side of the specimen. As a result, only the upper surface of the specimens was heated.

Six thermocouples were embedded in one specimen at 0, 20, 40, 60, 100, 140 and 180 mm in depth from the upper surface. These thermocouples were used to measure internal temperatures in the specimen. At a month later from heating the specimens, the five heated specimens and the five cured specimens were scanned with an X-ray CT apparatus. The CT value distribution in specimen of each 10mm in depth were calculated with the three dimensional image which was gotten by X ray CT method. The most frequent value of the CT value distribution was used as representative CT value for each depth of 10mm. After scanning, the heated specimen was splited in two, and was taken out some pieces with a side length of 5 mm at some depths with a chisel. These piece were measured pore distributions by the mercury intrusion test. Some powders crushing these piece were used for the X ray diffraction (XRD) and the thermal gravimetric-differential thermal analysis (TG-DTA).

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3. RESULTS

As the results that the cement paste test specimens of 100mm in diameter were heated from the upper surface, the maximum temperature at a surface of the specimen was about 1173K. A decrement of the maximum temperature of the depth direction in the specimen was formed approximately from a continuous curve. As the result, the CT value in the depth direction changed as shown Figure 2. Those tendencies were changed by the ranges of internal temperatures of specimen. At less than 373K, the CT value changed little. From 373K to 473K, the CT value changed rapidly. The CT value was increased slowly till 873K. However at more than 873K, The CT value wads decreased rapidly.

The physical and chemical qualities of the cement paste heated at each temperature ranges were measured by the mercury intrusion test, XRD and TG-DTA. Figure 3 shows results of TG. As these results, from 373K to 473K, the free water would be evaporated from the pore and the bond water would be released from the calcium aluminate monosulfate in the cement paste [3]. Till 873K, the calcium hydroxide would be decomposed. I thought that the cement paste heated at more than 873K were hydrated again or became calcium carbonate [3]. It is considered that these physical and chemical changes influence the CT value.

The results of this study suggested that the CT value can evaluate the change of physical and chemical qualities of the cement paste by fire damage.

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Figure 1: Situation of heating an end face of the specimen

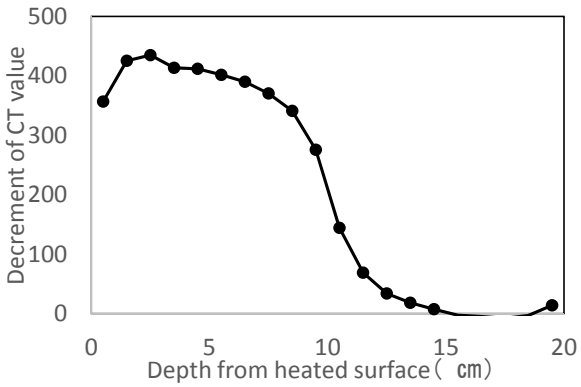

Figure 2: Relationships between depth from heated surface of the specimen and decrement of CT value

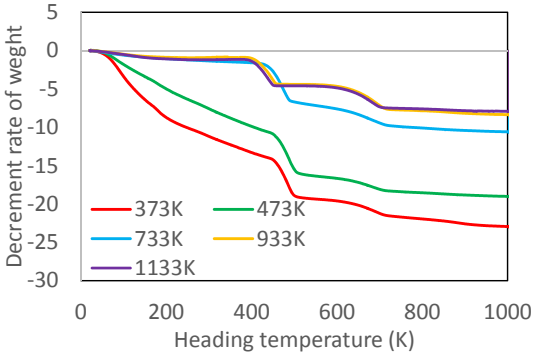

Figure 3: Rsult of TG