論文の内容の要旨

論文題目　Development of self-healing concrete incorporating geo-materials
: A study on its mechanism and behavior in cracked concrete

（ジオマテリアルを含有した自己治癒コンクリートの開発に関する研究
:ひび割れを有するコンクリートでの自己治癒メカニズムとその挙動）

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Autogenous or self-healing of fine cracks in concrete is often mentioned in literature but there is little quantitative data regarding its mechanism. This is generally attributed to the hydration of previously unhydrated cement grains and may be aided by carbonation since the bonding material so formed containing crystals of calcium carbonate and calcium hydroxide. Recently, several researchers have observed the formation of cementitious products such as AFt, AFm and $CaCO_3$ in cracks and calcium hydroxide crystals in air voids in cracked concrete. It was hypothesized that these hydration products had been leached and recrystallized in water that had flown through the crack. However, although it is generally acknowledged that unhydrated cement grains affect the recrystallization of cracked concrete, no detailed examinations have been reported on the healing conditions for this cementitious recrystallization. In this study, the self-healing properties of concrete incorporating geo-materials as a partial cement replacement were investigated in terms of recrystallization in cracked concrete as well as the effects of various carbonates for the recrystallization.

The aim of this study is the development of autogenous healing concrete using mineral admixtures, especially geo-materials [Alumina Silicate Materials, Magnesium Silicate Materials], for practical application in industrial fields, and includes the following four issues: (1) experimentally and analytically investigate self-healing behaviors of old concrete structures and masonry mortars, (2) experimentally and analytically design cementitious materials with self-healing capabilities, (3) develop self-healing concrete using these new cementitious materials at normal water/binder ratio [over W/B=0.45], and (4) its application in an actual tunnel and an investigation of the self-healing behavior of fire-deteriorated concrete in a tunnel as a basic experiment on the management of self-

healing concrete.

In the first objective, old concrete structures and masonry mortars in the Netherlands were investigated and characterized by microscopic study in order to evaluate the self-healing mechanism and its products between cracks. Its mechanism and autogenous healing behavior are also proposed in this research. In the second objective, new cementitious materials incorporating geo-materials based on the concept of natural self-healing products of old masonry mortars were designed, and these geo-materials were key factors for the fabrication of the cementitious recrystallization between cracks in the new composite system. Three different carbonates, Na_2CO_3, $NaHCO_3$ and Li_2CO_3, were then used to investigate their effect on cementitious recrystallization. Morphology and the shape and size of precipitated particles in the cracks were examined by microscopy and SEM-EDS. The results show that cracked concrete incorporating expansive agent exhibit much higher self-healing behaviour than cracked normal concrete when they are cured in water after cracking. Carbonates seem to be effective in inducing the precipitation of calcium salts in the cracks due to the general increase in the OH^- ion and SO_4^{2-} concentration in the pore solution. In particular, the expansive agent also plays an important role in the formation of various AFm phases such as sulphate AFm(=SO4·AFm), Hydroxy AFm(=OH·AFm) and Hemicarboaluminate for the crystalline phases. In the third objective, various concretes with self-healing abilities were investigated. Slump and slump flow concerning slump retention for industrial applications were evaluated. The effects of mineral admixture content in cementitious materials and the compatibility of superplasticizers on the properties of cementitious pastes and concretes were also investigated. Three mix proportions, having the high potential to be useful for underground structures surrounded by groundwater, were carefully selected for the fabrication of artificial water-retaining structures. These tests were conducted using the actual ready-mixed cars in the ready-mixed concrete factory and were used for evaluating waterproofing and self-healing abilities. Finally, in the forth objective, self-healing abilities of fire-deteriorated cementitious materials were evaluated according by deterioration zone for the management and development of a new repair method for fire-deteriorated concrete in tunnel

From the results of the study on the effects of geo-materials, it was found that the influence of cementitious recrystallization on the self-healing behaviour of cementitious composite materials depends greatly on the type of geo-materials; the addition of geo-materials is generally more effective for self-healing behaviour when compared to the addition of expansive agent by itself. However, the

expansive agent has the bridging effect and ion supply for the fabrication of composited AFt or AFm phases between cracks in cracked concrete made with a normal water/binder ratio. Therefore, it is considered that the utilization of appropriate dosages of expansive agent, geo-materials and carbonates for self-healing of cracked concrete is desirable. As a result, self-healing behaviour has a high potential for application to underground structures surrounded by groundwater. Finally, it was found that fire-deteriorated cementitious materials also has self-healing abilities defined by deterioration zone. This self-healing behaviour study was conducted to evaluate the potential for the application of new repair method of fire-deteriorated concrete.