Summary

Title: Impact of damage in concrete caused by inhomogeneous volume change of components on physical properties of concrete and concrete structures
(構成部材・材料の非均質な体積変化による損傷がコンクリート材料・部材の性能へ及ぼす影響)

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This thesis aims to understand the impact of multi-scale cracking induced by the inhomogeneous volume change of components on concrete and concrete structures to enhance the aging management of concrete structures of nuclear power plants (NNPs). In the NNPs, although the reduction in natural frequency over time was found, the mechanism behind this reduction remains uncertain. One explanation is the impact of multi-scale cracking, such as shrinkage-induced cracks in the RC member (millimeters scale) and drying and neutron irradiation-induced cracking (micrometers and sub-millimeters scale) in concrete, decrease the initial stiffness of RC member and Young's modulus of concrete. Besides, these cracks are considered to affect the strength of concrete and RC member. Therefore, this thesis attempts to grasp how inhomogeneous volume changes affect the concrete properties and structural performance of RC members.

First, to clarify the impact of drying on the RC member, the experimental and numerical study on the effect of drying on the RC shear wall was performed. From the experiment, it was found that the drying reduced the initial stiffness by 50 %, which is coincident with the natural frequency reduction in NNPs, and the slight reduction in the ultimate shear strength between sealed and dried specimen was small. In the numerical study, the Rigid Body Spring Model (RBSM), coupled with the water transfer model, was employed. Through the investigation of the numerical results, a mechanism to explain why the ultimate shear strength slightly decreased due to drying was suggested: the increase of the compressive strength in the uniaxial condition and the reduction of the compressive strength due to cracking in the wall balanced each other.

Next, the three-phase – mortar, aggregate, and an interfacial transition zone (ITZ) – mesoscale RBSM for concrete was developed to evaluate the concrete properties subjected to drying. The subroutine to simulate the changes in mechanical properties with cracking has been implemented in this study, and it is found that the presented model can predict reasonably the properties of concrete after drying, compared with the experimental results. Furthermore, through the investigation of numerical results, the mechanism of the influence of drying on concrete properties was clarified: 1) the changes in concrete properties cannot be predicted without considering the properties change of mortar caused by cement paste alternation; 2) the cracks

caused by inhomogeneous shrinkage between mortar and aggregate result in the reduction of stress borne by mortar element, leading to the reduction in Young's modulus; 3) The load-bearing path did not change significantly by the shrinkage gap-induced cracks. This can explain the reason why the compressive strength of concrete showed a similar trend as the cement paste strength in the experiment.

In the end, the numerical study of concrete subjected to drying and neutron-irradiation was conducted. Neutron irradiation causes aggregate expansion and resultant damage in concrete. As a result, the presented numerical model could reproduce the experimental result, and the finishing remarks are as follows: 1) it was found that the mortar expansion strongly affect the compressive strength; 2) the cracking caused by the coarse aggregate is the dominant factor of properties change of concrete rather than the cracking in mortar; 3) The neutron irradiation-induced cracks did not alter the stress-bearing path but cause the reduction in the stress which mortar can bear, leading to the reduction in concrete strength.