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主　論　文　の　要　旨

論 文 題 目 Effect of aggregate type on change in properties of concrete under drying（乾燥下にあるコンクリートの物性変化に及ぼす骨材種類の影響）

氏　　　名 林 懋　（ＬＩＮ　Ｍａｏ）

論　文　内　容　の　要　旨

It has been reported that many reinforced concrete structures showed decrease of natural frequency after construction. It is attributed to the stiffness reduction of concrete structure. The underlying reason could be Young’s Modulus decrease and shrinkage-induced cracking of concrete caused by drying.

Structural cracking and aging is considered by the way of Time index *T*. The time index *T* implicitly indicates the performance of construction, shrinkage-induced deterioration, and apparent concrete strength change due to cracking. But there is no clear background data to evaluate the index *T* as a function of material deterioration.

Compressive strength of concrete is a key parameter in the calculation of strength index *C* and ductility index. As used for seismic evaluation, compressive strength can be obtained by core sampling. In the current design method, both Young’s modulus and splitting tensile strength are expressed as a function of compressive strength. These formulas are valid at saturated condition but not appropriate after drying.

Changes in temperature and relative humidity affect splitting tensile strength of concrete. Its mechanism is clarified through experiments using control mortar specimens and concrete specimens with two types of coarse aggregate of different shrinkage behavior mixed with the control mortar. Drying of various temperatures or humidity was maintained till the mass of specimens become constant. Then changes in length and mass from the saturated state and splitting tensile strength were determined.

The results elucidate that shrinkage property of aggregate have large influence on the change of splitting tensile strength of concrete under drying. The alteration of concrete during drying composes of: (1) strength change of harden cement paste, and (2) micro-cracking caused by aggregate restraint. In the case of aggregate with high shrinkage which is similar to that of mortar, there was less damage, and thus the decline in strength was smaller in the range from 80% RH to 20% RH. On the other hand, in the case of aggregate with low shrinkage, the decline in strength was higher in that range. Therefore, for aging management of concrete structures, the knowledge of aggregate is needed to predict concrete properties change.

The mechanism of change of compressive strength under drying is almost the same as that of splitting tensile strength, but the slight difference was observed with regards to compressive load-bearing pass in concrete. The micro-cracking cause the limitation of load-bearing pass under compressive load, especially in the range between 100% to 80% RH. Below this range, the drying influence crack opening of micro-cracks around aggregates but will not change the load-bearing passes in concrete. Resultantly, change in nature of hardened cement paste directly affects concrete property in compressive load condition, while such crack opening has large influence on stress concentration in tensile load condition. This mechanism is newly clarified in this dissertation.

Because moisture transport determines shrinkage strain in concrete, it is one of the key parameters for the time-dependent prediction of performance of concrete structure. In this study, drying experiments of both mortar and concrete specimens was conducted to evaluate moisture transport behavior. Boltzmann-Matano method is applied to the experimental data to calculate the water diffusion coefficient. By comparing the results of drying experiments of mortar, concrete and cement paste specimens, it is found that water diffusion coefficient is not greatly influenced by aggregate under the first drying condition. In other word, moisture transport behavior is governed by harden cement paste. Temperature impact was also assessed. The results confirm that the temperature dependence of water diffusion coefficient is governed by power law. This work would aid the prediction of drying rate in concrete member. The numerical modelling which takes into account of colloidal nature of calcium silicate hydrate in Portland cement system is required.

It has been reported that different coarse aggregate leads to different numbers of through cracks and surface cracks in concrete under restrained condition. Through cracking has much impact on durability. In this study, concrete specimens were prepared with the same mixture proportion except for their constituent coarse aggregates, namely limestone and sandstone that possess different inherent drying shrinkage values. The strain at a cross section perpendicular to the drying direction was observed using a digital image correlation method (DICM) under unrestrained and restrained condition. Rigid-body-spring networks (RBSN) was applied to reproduce the trends of crack initiation and propagation behavior in order to understand the impact of aggregate properties on these processes. Truss networks model was used for moisture transfer.

The results of both experimental and numerical study on shrinkage-induced cracking in restrained concrete indicate that the fracture energy of interfacial transition zone (ITZ) has large influence on cracking behavior. If the bonding on the interface between aggregate and harden cement paste is strong, which is the case of limestone, there are numerous minor surface cracks, and it leads to the reduction of Young’s modulus of concrete. But the benefit in this case is that it reduces localized large cracking. This is the trade-off relationship. On the other hand, when aggregate has large shrinkage and the surface bonding is less, which is the case of sandstone, there is slight smaller decrease in Young’s modulus, and in restrained condition large visible cracking is found. Large visible cracking has larger impact on reduction of stiffness of concrete members than that of Young’s modulus reduction due to drying. Therefore, the large shrinkage of aggregate and weak bond between aggregate and paste is not good for structure performance. If ITZ properties are modified, concrete properties can be changed as well.

It was concluded that both the shrinkage of aggregate and the fracture energy of ITZ are important for aging management of concrete structures. If such properties are obtained from existing structure, the possible degradation trend can be assessed. This new method of evaluating the existing structure is also one of the new proposals from this dissertation.