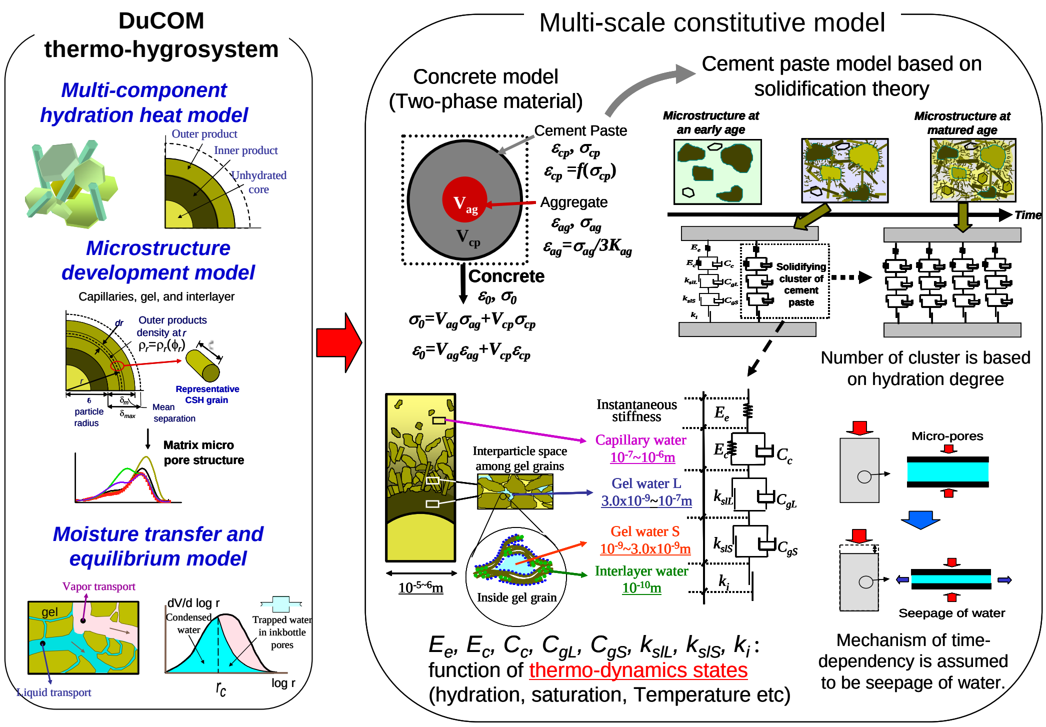
Unification of Thermo-Dynamics and Nonlinear Constitutive Laws of Cementitious Solids

Non-organic multi-scale porous solids and structural systems are the targets of this study. Thermodynamic equilibrium of moisture and the internal stress/deformation in micro-scale are incorporated with cement hydration and micro-macro fracture and its propagation. Volume change associated with transition of thermodynamic states and long-term creep are aimed to be predicted for structural analysis under coupled ambient conditions and mechanical forces. The short-term time dependency of concrete composite is also discussed for accurate post-peak analysis of structures for collapse simulation under earthquake. The multi chemo-physical and mechanical modeling is applied to safety performance assessment of reinforced concrete infrastructures with aging defects and damages.

Muti-scale constitutive model of concrete based on thermodynamics states of moisture in micro-pores

By coupling thermodynamic integrated computational system (DuCOM) and structural computational system (COM3), it is possible to simulate time-dependent deformation of aging cementitious composite. In this model, concrete is treated as a two-phase material namely, aggregate and cement paste. Aggregate is treated as a perfectly elastic material. Cement paste is modeled using the solidification theory where it is assumed to solidify in the form of clusters. The solidifying mechanical unit is shown in Fig.1. Pore water in a cementitious material is classified into several components: condensed water in capillary pores, gel water, and interlayer water. The time-dependent deformation rooted in thermodynamics states of moisture in pores should be taken into account in each individual solidifying component as shown in Fig. 2. The assembly of solidifying components corresponds to cement paste. This model can treat shrinkage and creep of concrete as several aspects of one physical phenomenon without the conventional separation between autogenous shrinkage, drying shrinkage, drying creep, and basic creep. The analytical results have acceptable agreements with experimental data under arbitrary temperature and relative humidity.



Further development is continued along with the enhancement of moisture model. The application will be expanded to simulate more generic behavior under arbitrary environmental conditions including high temperature condition with higher accuracy.

<u>Modeling of Non-linear Time-Dependent Deformation and Post Peak Structural Softening</u>

Non-linear time-dependent constitutive model is proposed for collapse analysis of reinforced concrete structure. Based on observation of experiments, the plastic and fracturing rates of concrete were successfully extracted from the compression tests of cyclic loadings. Moreover, the plastic evolution law is formulated in terms of updated elastic strain and the accumulated plasticity as demonstrated by the elasto-plastic and fracturing concept. Similar to plasticity, the continuum-fracturing rate is proposed as a function of updated elastic strain and the accumulated fracture parameter to indicate the reduction rate of unloading/reloading stiffness. Through this study, the delayed fracture proportional to the static volume of concrete is newly conceptualized. Integrated modeling leads to total stress-strain relation by differential form and the modeling is verified with experiments under uni-axial conditions.

The elasto-plastic and fracturing model is also improved to include the effect of confining pressure consider uni-axial relation to be widely used in the analysis of reinforced concrete structures. Based on proposed model, reduction of the non-linear creep, creep failure and other typical no-linear time-dependent deformations can be successfully simulated.