Time-Dependent Structural Analysis for Life Simulation of Concrete Structures

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1. INTRODUCTION

Infrastructures in Japan are ageing, for example 50% road bridges become more than 50 years old in 2030's. The approach of the life cycle management that aims at making long-lived and lowering the maintenance cost of ageing infrastructures has been started. The quality of the management depends on long-term prediction technique of the structural performance and it can be discussed only after the prediction will be done in high accuracy. Therefore, the simulation method for long-term behaviour of concrete structures should be developed. In this seminar, a method to simulate the deterioration process induced by mass transfer is presented in which structural analysis and mass transfer analysis are combined[1].

2. TIME-DEPENDENT STRUCTURAL ANALYSIS CONSIDERING MASS TRANSFER

An important point to select the structural analysis method combining with mass transfer analysis is target scale. Mass transfer can be represented in various scales from micrometer scale of pore structures to millimeter of cracks. On the other hand, the structures also have several mechanical scales such as crack, specimen and member. In the analysis, the target scale is selected at crack which is important route of mass transfer and mechanical feature of concrete structures. Rigid-Body-Spring Networks (RBSN), which is one of discrete approaches, are used as structural analysis, since it is easy to deal with crack propagation of concrete directly. The method represents a continuum material as an assemblage of rigid particle elements interconnected by zero-size springs along their boundaries.

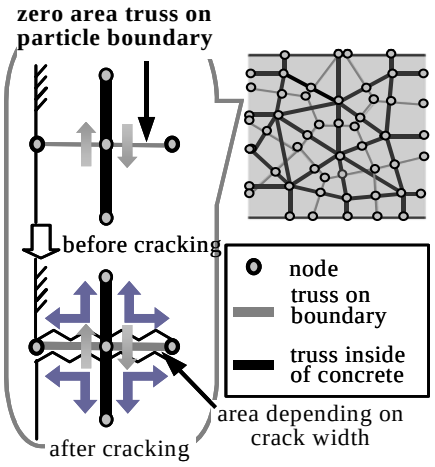


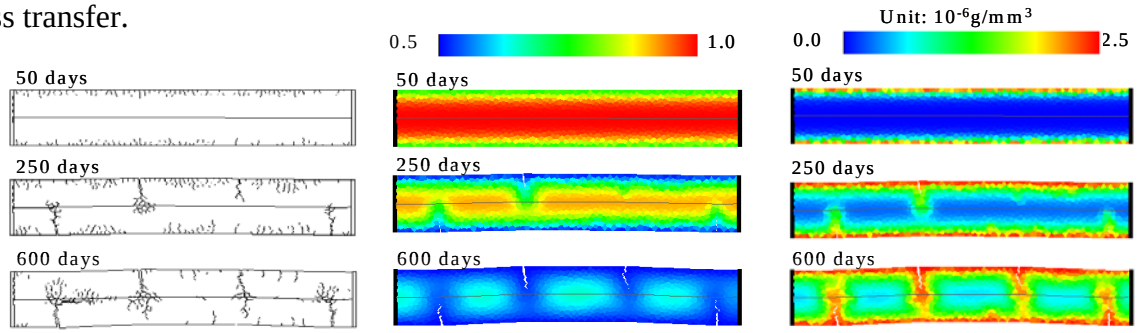
Figure 1 – Truss networks

Mass transfer is continuous flow and it is usually analyzed by continuum model same as Finite Element approach, which is represented by partial differential equation. RBSN, however, does not require continuality condition. Therefore, truss networks model is used for mass transfer analysis to adjust the concept of structural analysis by using RBSN. Then, a simplified one dimensional diffusion equation using truss element is employed to carry out mass transfer.

The truss networks set between rigid body nuclei and on boundaries as shown in Figure-1 The networks between rigid body nuclei represent the mass transfer within bulk concrete and the networks on boundaries represent mass transfer through crack. Therefore, the mass transfer through the crack can be considered in addition to through the bulk concrete, in which different diffusion coefficient from concrete material is assumed.

3. AN EXAMPLE OF ANALYTICAL RESULT -CRACK PROPAGATION ANALYSIS DUE TO DRYING SHRINKAGE AND CORROSION-

Reinforced concrete bar in which rebar of 1.0% is arranged at the center was simulated as an example to confirm the effectiveness of the developed method. The moisture transfer and the chloride ions penetration are considered in mass transfer analysis. Moreover, corrosion expansion of re-bar is considered by the compelling displacement when the concentration of chloride ion at the surface of rebar exceed a threshold value. Figure-2 shows cracking behaviors, the distributions of relative humidity and the concentration of chloride ions at 50, 250 and 600 days obtained from the developed analysis method. At 50 days, many micro-cracks occurred at the specimen surface due to the effect of drying shrinkage. The soluble chloride ions gradually penetrated into the specimen via the boundary surface and the surface cracks. At 250 days, more shrinkage cracks occurred and major cracks reached the rebar, which led to diffusion of moisture and chloride ions through the cracks, causing the corrosion of the rebar. At 600 days, mass transfer through cracks accelerated because of the increase in crack widths. Moreover the cracks propagated along the rebar, since the specific concentration of chloride ions at the surface of rebar exceeded the threshold value. The analysis simulated well structural damages due to mass transfer.



(a)crack patterns (b)Relative humidity (c)Chloride ions

Figure 2 – Combined analysis of drying shrinkage and corrosion

4. CONCLUSION

The simulation method for long-term behaviour of concrete structures become important, because the age is changing from construction to maintenance of infrastructures in Japan. In this study, an analytical method combined with structural analysis and mass transfer analysis was represented. Then, the deterioration process such as the cracking behavior under multi actions in consideration of drying shrinkage and rebar corrosion expansion were simulated considering the effect of mass transfer through cracks. The analysis was well simulated of the structural damages with deterioration process due to mass transfer.

REFERENCES

1. Nakamura, H. et.al. (2006) “Time-Dependent Structural Analysis considering Mass Transfer to Evaluate Deterioration Process of RC Structures.” *Journal of Advanced Concrete Technology*, 4(1), 147-158.