論 文 の 内 容 の 要 旨

氏 名　ジラディロック パンヤウット

Modeling of local bond behavior and meso-scale 3D discrete analysis of corroded RC structures
（腐食した RC 構造の局所付着モデルの開発と三次元メソスケール離散解析）

Nowadays, many reinforced concrete structures are exposed to the marine environments which result in chloride ion penetration, subsequently decreasing in structural capacity due to the corrosion. The main problem is we don’t know the residual capacity of the deteriorated structure. Therefore, an estimation of internal damage and residual capacity of corroded reinforced concrete is important for maintenance and predicting service life of the structures.

This research aims to develop the numerical system to predict the structure behaviors and residual capacity after the corrosion damage take place based on Rigid Body Spring Model (RBSM).

In this study, first the simulation scheme is divided into two section, the corrosion damage simulation and mechanical loading simulation. The original RBSM model of author’s research group already have the ability to predict the structure performance and predict the local damage appropriately. However, the function for introduced the corrosion damage into the model had not been developed yet by the time that the author started this research. Hence, the originality of this research is to develop the simulation model of corrosion behavior in reinforced concrete based on meso-scale 3D discrete and adapt that function into the RBSM program.

The corrosion behaviors that were considered in this study including the non-uniformity of the corrosion pattern, the rebar reduction, the rust expansion and the bond deterioration. By developing these functions one by one and implement into RBSM model, the numerical model for simulating the residual capacity and behavior of corroded RC structure can be achieved.

Firstly, the non-uniform corrosion pattern was considered in RBSM simulation. In reality or even under control condition in experiment room, the corrosion is formed up non-uniformly along the rebar. In RBSM simulation, the rebar reduction area, the expansion of rust and other corrosion behaviors are modeled vary in each location along the rebar location. In this research, the rebar corrosion profile every 5 mm obtained by X-ray photogram technique of previous corroded beam experiment are used as an input information to verify the applicability of the final corrosion model.

Next, the expansion corrosion damage simulation is developed based on expansive strain model. In

reality, once the corrosion occurs, it will create the voluminous rust product at the interface between rebar and concrete. As a result, the increment of internal pressure will damage the adjacent concrete. This behavior was simulated in RBSM by expansive strain model. By gradually give the initial strain at the interface between rebar and concrete, the simulation model will calculate the additional stress based on given expansive strain. By this method, the expansion of corrosion product can be simulated in the same manner as reality. However, the relationship between expansive strain at interface and corrosion degree are varied based on environment condition. For example, under fast corrosion i.e. corrosion acceleration test, the corrosion product will form up as liquidity, while the slow corrosion process i.e. in real structure, the corrosion product will form up as solid form which crate more damage to surrounded concrete. Hence, in this study, the inverse method has been used to develop the constitutive model for corrosion expansion. In RBSM simulation, the model with the same dimension, covering depth and material properties is modeled. Then, the expansive strain model gradually gives at the interface for introducing the expansion damage until the same damage crack width as reality appears in simulation. By this method, the constitutive model for corrosion can be achieved.

In reality, the bond of RC structure consists with mechanical bond from interlocking between rebar and concrete and friction bond at the interface. While the bond in RBSM are represented by the response of normal spring and shear spring at interface between element. When the corrosion take place not only the formation of corrosion product that changes the rebar surface property, the rebar also deformed its shape due to the corrosion. However, in RBSM simulation, the rebar is modeled as rigid body which the shape cannot be deformed. Hence, the equivalent modification of shear spring and normal spring at interface need to be performed for represent the changing of mechanical bond and chemical bond. In this study, the constitutive models of bond deterioration were well developed based on the designed experiment program. The changing of the chemical bond and mechanical bond was extracted from the experiment results and was used for developed the modification factors in shear spring and normal spring. The concrete specimens reinforced with round bar and deformed bar were subjected to the corrosion acceleration test to generate the different corrosion percentage on the reinforcement. The corrosion acceleration electrical current-time were varied in each specimen for obtaining different corrosion percentage. (0, 3, 5,3 and 12.3% in round bar reinforcement and 0, 10.5 and 23.1% in deformed bar specimen). To eliminate the effect of corrosion cracking concrete, the specimen with non-crack concrete were prepared. After the pull-out test on cracked concrete specimen, the cover concrete was removed. The same corroded rebars were used as reinforcement in casting of new specimen. The pull-out tests were performed on non-crack concrete specimen. The pull-out capacity of different corrosion percentage and different type of reinforcement (round bar and deformed bar) were analyzed. The new constitutive model of shear spring and normal spring were proposed based on the changing of maximum pull-out capacities at different corrosion degree.

Finally, the member scale simulations were simulated for verification the applicability of numerical model. By combining all corrosion functions into the program, the corroded beam simulations were simulated by using the real corrosion profiles from previous experiment. The beams simulation with non-uniform corrosion and uniform corrosion are simulated to study the effect of spatial corrosion profiles. Also, the effect of corrosion at the anchorage zone was studied by intentionally set the corrosion profiles at anchorage zone and shear span zone. By introducing the initial damage from corrosion by corrosion models, the stiffness reduction and lower loading capacities of corroded beam were simulated well. The local failure behavior like local cracking, local strain distribution of rebar shows a good agreement with the input corrosion profiles. In conclusion, the numerical model can simulate the stiffness reduction, residual capacity and failure pattern appropriately comparing with the experimental results.