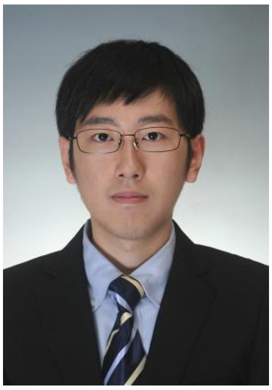
My life in Japan



My name is Qiao Di. Currently, I'm a doctoral student at the Department of Civil Engineering of Nagoya University. It's a great honor for me to get an opportunity from the JSCE Concrete Committee Newsletter to make the student's voice. I'd like to give sincere thanks to the editors of the Newsletter for their kindness. Here I want to talk about my present experiences in Japan, the normal life and also my study in the concrete laboratory.

After some hesitations about my future career at the time when I was going to obtain my master's degree in my home country, I made the decision to keep going on my study concerned about the durability of reinforced concrete, since I was quite curious about this topic which I thought was of significant importance for the ageing structures. To me, studying in Japan was a good option as Japan owned the state of art technology in the field of civil engineering and also placed an emphasis on the relevant research where I could learn a lot. In addition, I belong to the generation growing up accompanied by Japanese animation and I am especially fond of the robot series like Gundam. Luckily, I was accepted by the Forefront Studies Program of Nagoya University and commenced my new life in Japan since the October of 2012.

The initial problem for a fresh foreigner in Japan must be the language. On my side, I just learned some basic sentences and words from animations before I came to Japan. Hence you can imagine some awkward situations that I went outside buying some household items and just unfortunately forgot how to describe those I needed. At that time, the shop assistant always showed great kindness and patience that helped me a lot. The Japanese Language Class I took in Nagoya University and the daily talk with the members of concrete laboratory helps me gradually advance my ability of speaking Japanese. I also took part in the Home Stay twice, which is definitely valuable experience in my life. The host family treated me as a true member, prepared fancy food, talked with me about the local customs and practices, and showed me around. They took me to Gero and we enjoyed the famous hot spring. For the second time, we went together to Koga Ninja Village. I took some Ninja training games and got to know a lot of things about Ninja, an important component of Japanese traditional culture. The rich and colorful life I am experiencing here enables me in touch with so many kind Japanese people and makes me fall in love with this beautiful country.

In my laboratory, the members are more than schoolmates. We not only have some heated discussions about our research projects, but also make lots of nice conversations related with daily life, including some popular restaurants, presently released cinema and drama, and sports game, etc., which leads to a gorgeous atmosphere. Usually, students have their own research topics and I try to clarify the corrosion process of reinforcement from the aspects of corrosive current and develop more sophisticated methods to evaluate the influences of reinforcement corrosion on structure, such as tensile performance degradation of corroded rebars and concrete cover spalling. We hold group meetings on Saturdays in every two weeks, when we present our research progress. The comments or questions came up during the meetings inspire us to dig into our study thoroughly and comprehensively. Meantime, some foreign doctoral students from Australia, USA and Denmark continually come to our lab for joint research, which provides us with great chances to talk with them about the different culture and certainly the different research methods employed in their labs. Apart from the research work, there are some parties for successful submitting the paper or the completion of job hunting. We also make a Gundam mortar for the festival of Nagoya University and climb the Mount of Fuji during the lab's vocation. I extremely enjoy working in this lab, although the research work is a bit intense. As a finish, I would like to introduce part of my ongoing research with an extended abstract.

Farewell party for Ms. Anna from DTU

Homestay with Aoki family

Homestay with Manabe family

Analysis of Concrete Cover Spalling due to Rebar Corrosion

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Abstract: This study examined the applicability of previously proposed corrosion expansion model on the base of rigid body spring method to model the concrete cover spalling, which is a part of research aiming at clarifying the mechanism of corrosion-induced cover spalling. It is also found that localized corrosion can result in the internal cracks developing diagonally to concrete surface and then a sudden spalling, which poses a remarkable threat to the safety of structure.

1. Introduction

The serviceability of ageing reinforced concrete structures is greatly affected by internal rebar corrosion as corrosion products of rebar occupy larger volume than original rebar, impose expansion pressure on surrounding concrete, and then induce concrete cover cracking and spalling. Although there are a number of researches focusing on cracking mechanism of the corroded structures, few of them are extended to cover spalling. However, it cannot be ignored since it's strongly related with the safety of structures in terms of the influences on human's safety.

The study currently conducted try to identify the influence factors of corrosion-induced cover spalling, specifically to clarify the relationship between localized corrosion and cover spalling. Here, the applicability of analytical method, which was based on Rigid Body Spring Method with corrosion expansion model, was verified by comparison with experimental results.

2. Outline of Analysis

2.1 Specimen

Three rebars were embedded into the concrete specimen with a compressive strength of 40MPa during experiment. The specimen dimension is shown in Fig.1. Part of the bottom of concrete specimen, which is marked in red in Fig.1, was in touch with salty water by the link of sponge in order to reach the state of localized corrosion. A DC power was used to carry out accelerated corrosion process and conduction time was determined based on Faraday's law. Three objective corrosion degree varying as 5%, 10% and 15% were studied in the test. After artificial corrosion process, the surface cracking map was monitored and then the specimen was cut in different positions, where the internal crack pattern was investigated. Fig.2 shows the distribution of corrosion degree along rebar. It can be seen that it is distributed in the shape of triangle and the part that was connected with sponge exhibits a higher corrosion rate.

For simulation, RBSM model corresponding to this specimen was established using Voronoi random polygons. It is noted that only one rebar was introduced into the model because the other two rebars were barely corroded and it can also reduce the computation burden.

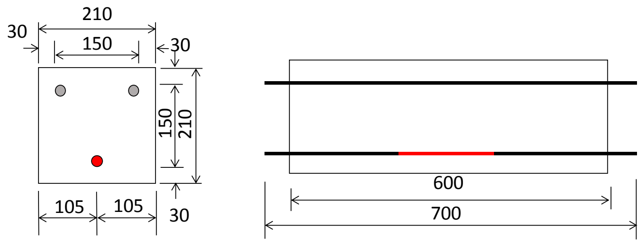
2.2 Corrosion Expansion Model

In previous study of our lab (Tran et al. (2011)), expansion of corrosion products inside concrete due to rebar corrosion was modeled by internal expansion pressure, which was simulated with increment of initial strain applied on the boundary between rust layer and rebar layer as determined by Eq. (1).

$$\Delta\sigma_{cor} = E_r\left(\Delta\varepsilon - \Delta\varepsilon_0\right) = E_r\left(\frac{\Delta U_{cor}}{H} - \frac{\Delta U}{H}\right) \quad (1)$$

Where E_r is elasticity modulus of corrosion product, ΔU_{cor} increment of real increase of rebar radius confined by surrounding concrete, ΔU free increase of rebar radius and H thickness of corrosion product layer. In addition, it was reported in the work of Yuan and Ji (2009) that the corrosion products distribute on the half circumference of rebar facing concrete cover. Hence, during simulation increment of initial strain was only applied over one-quarter of the model, which was also based on the distribution of corrosion degree as shown in Fig 2.

This model combined with RBSM method is appropriate to evaluate corrosion-induced cracking behavior of concrete cover and agrees well with accelerated corrosion test result (Tran et al. (2011)).



a) Section b) Side view

Fig. 1 Specimen dimensions

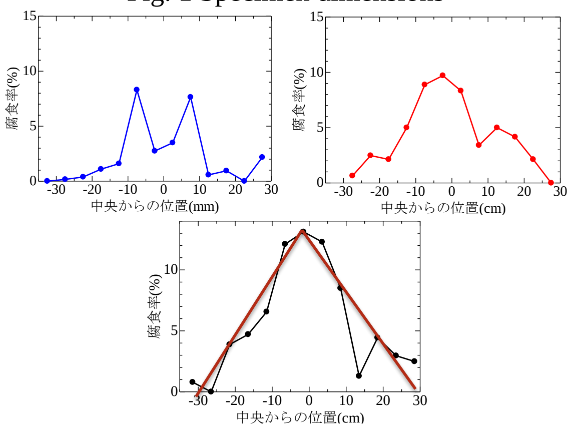


Fig. 2 Distribution of corrosion degree

3. Result and Discussion

It is observed that cover spalling occurs when practical corrosion degree reaches 12.5% at the center part for this specimen size. The comparisons between simulation and experimental results presented here account for two kinds of corrosion degree, a small corrosion degree of 4.84% and a large corrosion degree of 12.5% to illustrate the applicability of the numerical model.

3.1 Small corrosion degree

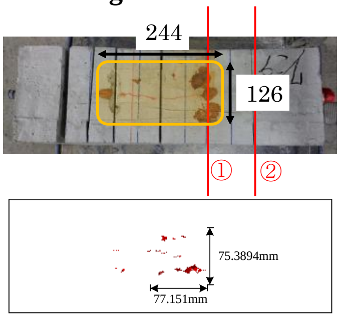


Fig. 3 Comparison of surface cracking map

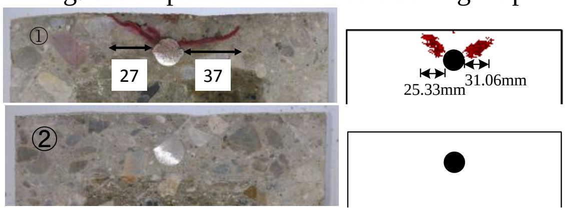


Fig. 4 Comparison of internal cracks

Fig. 3 displays the surface cracking map obtained from accelerated corrosion experiment and analytical method separately. The rust trace demonstrates the mostly cracked part, which is in agreement with the simulation result as shown in the figure below. Fig. 4 depicts the internal crack pattern at different positions, which are indicated in Fig 3. Meantime, the simulation results, in which a red sign represents cracks with a width larger than 0.3mm, are shown correspondingly. It is shown that the numerical method agrees with the experiment not only in the internal crack pattern but also in the length of lateral cracks.

It is proposed in the work of Tsutsumi et al (1996) that if the ratio of cover thickness to rebar diameter less than 1, internal cracks develop toward concrete surface diagonally. Comparatively, internal crack propagate respectively to sides and surface in the shortest path when this ratio larger than 1. Although the ratio of cover thickness to rebar diameter for studied specimens is larger than 1, the internal cracks propagate diagonally to concrete surface, which can be attributed to localized corrosion. It is worth noting that localized corrosion will result in the internal cracks developing to concrete surface and then a sudden cover spalling even if the cover thickness is considerably big. Besides, there are few cracks produced at the concrete surface, which reduces the accuracy of predicting cover spalling by monitoring surface cracking conditions.

3.2 Large corrosion degree

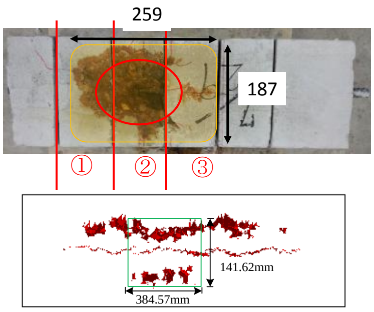


Fig. 5 Comparison of surface cracking map

Fig. 5 presents surface cracking under a corrosion degree of 12.5% for the center part of rebar. It is shown that a small part with an approximate area of 120cm^2 is dropped out of the specimen, which is indicated with a red circle in Fig 5. The green square marked in simulation result of Fig 5 gives an estimation of potential spalling area, which is a little larger than the experiment and need to be further examined.

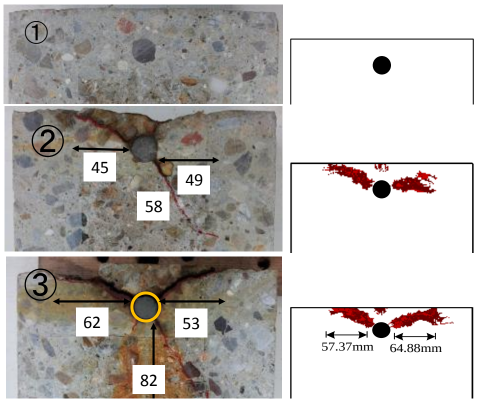


Fig. 6 Comparison of internal cracks

Fig.6 shows the internal crack pattern at three locations, which are marked in Fig.5. It is proved that current analytical model is capable of modeling the evolution of inside cracks resulted from local corrosion.

Consequently, it can be concluded that the corrosion expansion model owns sufficient accuracy to model the cover spalling caused by localized corrosion when the practical distribution of corrosion degree is introduced into the modeling.

4. Conclusion

Trough comparing the numerical results based on corrosion expansion model with experimental results in detail, the applicability of the analytical method proposed formerly is confirmed. Besides, it is found that localized corrosion will lead to the internal cracks propagate diagonally to concrete surface and finally spalling of concrete cover.

It is known that the crack development of concrete due to internal rebar corrosion is also related with the geometrical features of concrete specimen, such as the width of specimen. Further research is required to study the spalling phenomena of concrete slab due to localized corrosion. At present, the related experiment is being conducted to identify the mechanism of spalling.

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