A study on the load bearing capacity and impact resistance of RC beams with corroded reinforcement by FEM

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1. INTRODUCTION

In disaster-prone Japan, the number of the reinforced concrete (RC) structures with reinforcement corrosion are increasing, which makes it important for the evaluation of the residual load capacity of these structures to be conducted against not only the static loads but also the dynamic and impact loads. In this study, a FEM model for the RC beams with reinforcement corrosion is proposed, then the influence of reinforcement corrosion on load bearing capacity and impact resistance is numerically evaluated.

2. FEM MODELING OF RC BEAMS WITH REINFORCEMENT CORROSION

2.1 The reduction of the effective area of the reinforcement

In this study, the mechanical performance of the reinforcements are re-defined by the corrosion ratio (mass reduction ratio), and the cross-section of the reinforcements remains the same (Fig.1). The reinforcement corrosion is assumed to be evenly distributed, and the yielding strength and the elasticity modulus are simply calculated with the equations shown in Fig.1.

2.2 The decrease in bond strength

To build the model for the decrease in bond strength, an interface element is placed at the boundary between the reinforcement and the concrete. This interface element behaves the same as concrete under compressive and tensile loads, while the relationship between the shear load and the slip displacement must be newly defined. In this study, bond strength is estimated from the results of the existing studies, and the decrease in bond strength is determined according to the corrosion ratio (Fig.2).

2.3 The cracks of the peripheral concrete

To build the model for the cracks of the peripheral concrete, the expansion pressure related to the corrosion ratio is subjected to the peripheral concrete, and the numerical cracks are implemented in the concrete model. First, the expansion pressure for different corrosion ratios is calculated by the equations proposed in the past studies. Then, before the analysis model is subjected to loads, the numerical cracks are generated by applying the calculated expansion pressure on the peripheral concrete (Fig.3). In this study, the FEM analysis consists of 2 steps, the analysis for the cracks and the analysis for the loading.

3 FEM ANALYSIS OF RC BEAMS WITH REINFORCEMENT CORROSION

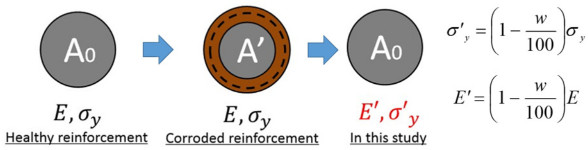
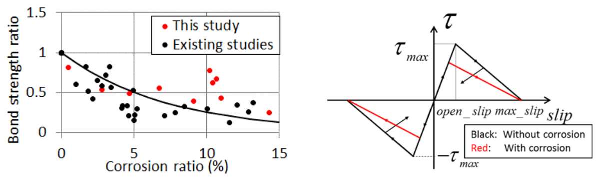
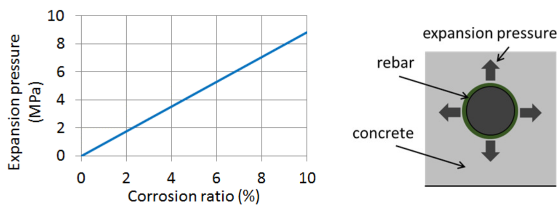


Fig.1 Modeling of reinforcement corrosion



(a) Bond strength ratio-corrosion ratio relationship (b) Shear stress-slip displacement relationship

Fig.2 Determination of the bond strength



(a) Expansion pressure-corrosion ratio relationship (b) Application of the expansion pressure

Fig.3 Generation of cracks

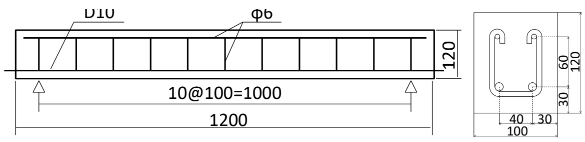


Fig.4 Specimen dimensions and reinforcement

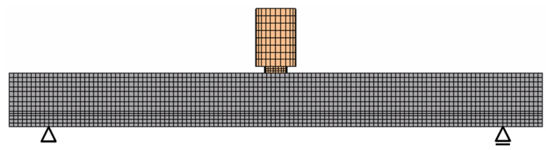


Fig.5 FEM model

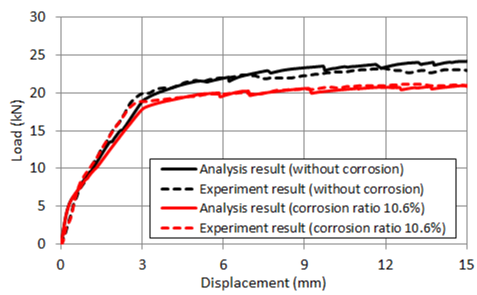


Fig.6 Analysis and experiment result for static loading

Keywords Corroded reinforcement, load bearing capacity, FEM analysis
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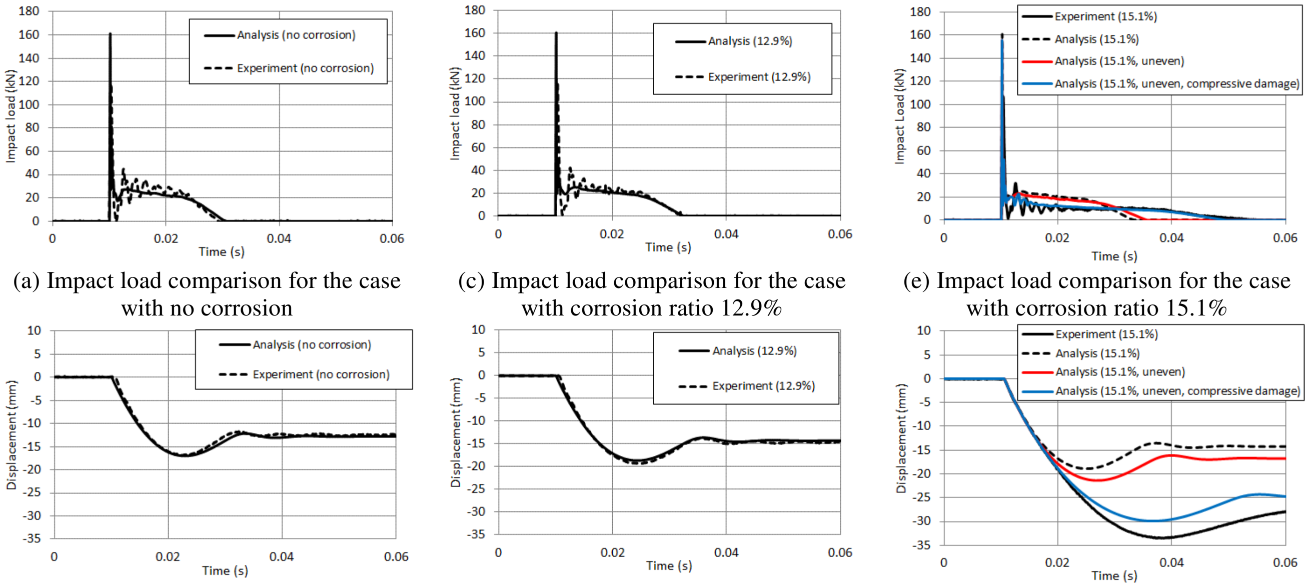

(a) Impact load comparison for the case with no corrosion

(c) Impact load comparison for the case with corrosion ratio 12.9%

(e) Impact load comparison for the case with corrosion ratio 15.1%

(b) Displacement comparison for the case with no corrosion

(d) Displacement comparison for the case with corrosion ratio 12.9%

(f) Displacement comparison for the case with corrosion ratio 15.1%

Fig.7 Analysis and experiment result for impact loading

3.1 The analysis object and model

The analysis object is an experiment conducted in the existing studies. The dimensions and the reinforcement arrangement of specimens are in Fig.4. The analysis model is shown in Fig.5. In this study, the generic FEM analysis software MSC.Marc is utilized. The concrete and tensile reinforcements are modeled in 3D 8-node solid elements, the stirrups and the compressive reinforcements are modeled in 2-node truss elements, and the interface elements were implemented. The elastic-plastic constitutive law based on the non-linear Drucker-Prager condition is adopted for the concrete, and the elastic-plastic constitutive law based on the von Mises condition is adopted for the reinforcements.

3.2 The analysis results for the static loading experiment

The static experiment was a 3 point bending test. Fig.6 shows the comparison between the experiment results and analysis results. When comparing the analysis results with the experiment results, the results are in good agreement, and the decrease of the stiffness before the yielding of the reinforcement and the reduction of the maximum load are qualitatively reproduced.

3.3 The analysis results for the falling weight impact experiment

In the falling weight impact experiment, a 100kg steel weight fell freely from a prescribed height to the middle span of the specimen. The comparison between the experiment results and analysis results are shown in Fig.7. When comparing the analysis results with the experiment results, it can be found that in the cases with no corrosion and corrosion ratio of 12.9%, the results are in good agreement. While in the case with corrosion ratio of 15.1%, there is a large difference between the experiment result and the analysis result, which may be caused by the unevenly distributed reinforcement corrosion in the specimen, as shown in Fig.8.

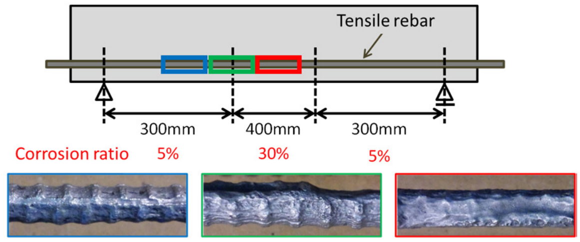

Fig.8 Uneven corrosion distribution

For this case, a new FEM model was built according to the corrosion distribution, and the analysis result is shown in Fig.7. Furthermore, in this case, the bending damage was the contributing damage pattern, where the compressive damage of the concrete contributed to the damage process. To simulate this, when the average compressive stress of a single element is over 1.5 times the compressive strength, this element would be deleted. From the analysis results shown in Fig.7, it can be found that the difference between the analysis result and experiment result is reduced by considering the compressive concrete damage. For a quantitative evaluation, the damage model should be improved by considering factors such as the uneven distribution of the reinforcement corrosion and the compressive damage of the concrete.

4. CONCLUSION

1) By proposing a FEM model for the RC beams with reinforcement corrosion considering the reduction of the cross-section area of the reinforcement, the decrease in bond strength between reinforcement and concrete, and the cracks of the peripheral concrete, the experiment result of static loading and falling weight impact loading can be reproduced.
2) For the quantitative evaluation of the impact resistance of the beam members with higher and unevenly distributed reinforcement corrosion, the damage model should be improved by considering factors such as the uneven distribution of the reinforcement corrosion and the compressive damage of the concrete.