Experimental and Numerical Study on the Influence of Reinforcing Steel Bars on the Crushing Effect in Blasting Reinforced Concrete

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1. Introduction

The ageing of structures in Japan's urban areas is becoming increasingly serious, making demolition and renovation an urgent issue. However, most structures in Japan are made of reinforced concrete to protect against earthquakes, and buildings are becoming increasingly overcrowded, especially in urban areas, making it difficult to demolish them using only conventional heavy machinery. Small-scale controlled blasting techniques have been proposed as a solution of this problem, but there are concerns about the risk of flying debris due to the presence of rebar and, on the contrary, insufficient destruction. Therefore, there is a need to establish design guidelines for reinforced concrete blasting that satisfy both safety and demolition efficiency. In this study, the influence of reinforcing bars on stress wave propagation behaviour and fracture was investigated experimentally and numerically.

2. Indoor blasting tests and Numerical simulations

1) Indoor blasting tests

Concrete plate specimens with rebar inside were used in the experiments as shown in Fig.1. In this experiment, the strain around the rebar was measured using Digital Image Correlation (DIC) based on images taken by a high-speed camera at 2M fps. Based on the obtained strains, it was performed by assuming a plane stress state to analyze the stress propagation through the specimen

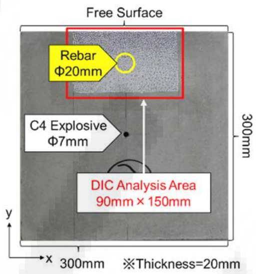


Fig. 1 Specimen for Indoor blasting tests

2) Numerical simulations

The finite element impact analysis software ANSYS®AUTODYN® was used. The concept of numerical simulation model is shown in Table.1. Coupled fluid-structure analysis was performed to analyze structural damage caused by explosions. The model shown in Fig.2 was created with the same dimensions as the specimen used in the experiments, but a two-dimensional model was used because a plane stress state was assumed. A tensile stress of 8.63 MPa was set as the failure criterion based on the values obtained from the physical property tests.

Table. 1 Concept of numerical simulation model

	C4 Explosive	Concrete
Solver	Euler	Lagrange
EOS	JWL	Linear
Failure criterion	-	Hydro (Tensile Failure)
Constitutive law	-	Drucker-Prager (Non-Linear)

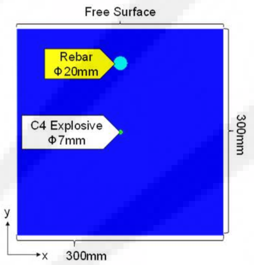
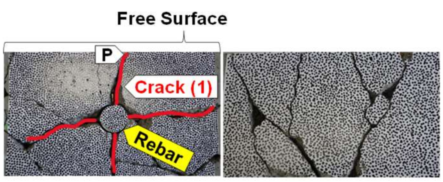


Fig. 2 Numerical simulation model

3. Results and Discussion

When there is a rebar in the concrete, characteristic cross-shaped cracks were observed around the rebar, as shown in Fig. 3(a). On the other hand, when there is no rebar, no such characteristic cracks were observed (Fig. 3(b)). By analyzing the data of Indoor blasting tests and Numerical simulation, it is revealed that these characteristic cracks around the rebar were caused by the reflection of stress waves in the rebar, stress concentration and changes in propagation velocity. For example, "Crack(1)" in Fig.3(a) was caused by an increasing of stress wave velocity(Fig.4,Fig.5) in the path through the rebar. Due to the elastic wave velocity of the rebar being greater than that of the concrete, the compressive stress wave that passes through the rebar reaches the free surface (point P) earlier than the compressive stress wave that does not pass through the rebar. Therefore, at point P, the compressive stress wave changes into tensile stress earlier than other point . Because of this reflected tensile stress from point P, Crack(1) occurred. Thus, if a rebar is present in the blasting target, cracks are more likely to occur around it. This suggests that the location of crack caused by blasting can be controlled considering the position of the rebar. For example, it can be expected to reduce the risk of unexpected flying debris. To sum up, it indicates the possibility of achieving safer and more efficient blasting demolition through appropriate blasting design.



(a) with rebar (b) without rebar

Fig. 3 Cracks in the specimen after Indoor blasting tests

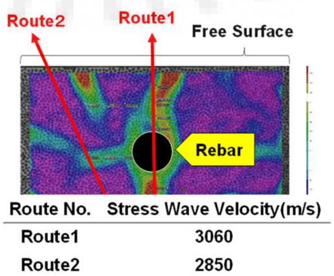


Fig. 4 Stress Wave Velocity (from strain measured by DIC)

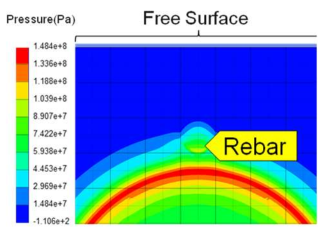


Fig. 5 Pressure distribution in Numerical simulation