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EXPEREIMENTAL AND NUMERICAL EVALUATION OF FRP-RETROFITTED RC STRUCTURE BEHAVIOR UNDER BLAST LOADING

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ABSTRACT

Generally, concrete is known to have a relatively high blast resistance compared to other construction materials. However, some existing concrete structures require retrofitting during their service life to improve their resistance against impact and blast loads. The application of composite materials such as FRPs can enhance the ductility of concrete structures and improve the resistance to extreme loading where strips or plates are attached to the surface for either repair or upgrade of the energy-absorption ability.

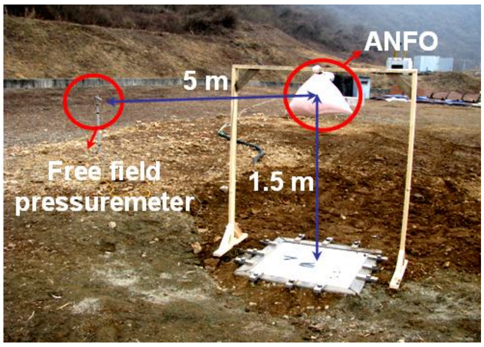
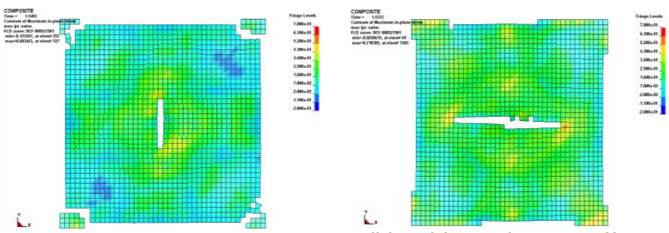


Figure 1: Blast test setup



(a) Without strain-rate effect (b) With strain-rate effect

Figure 2: Comparison of max. in-plane stress distribution according to strain rate dependency

To study the FRP retrofitting effect under blast loading, experimental studies and numerical simulation have been carried out. The blast load was generated by a detonation of ANFO explosive charge at 1.5m standoff distance from CFRP retrofitted RC specimens of 1000×1000×150 mm as shown in Figure 1. The data acquisitions not only included blast waves of incident pressure, reflected pressure and impulse but also central deflections and strains at steel, concrete, and FRP surfaces. The failure mode of CFRP retrofitted specimen was observed and compared with a control specimen. From the test results, it showed that FRP retrofitted concrete structures had sufficient resistance under the specified damage.

Based on the test results, numerical simulations of CFRP-retrofitted RC specimens were carried out and verified using LS-Dyna. Previous studies have focused on the performance of FRP retrofitted structures by making simplifications in modeling, without accurately implementing failure mechanism of FRP. Therefore, in this study, FRP material characteristics and failure mechanisms are incorporated as rate-dependent failure mechanisms and debonding failures. The failure model of FRP is based on progressive failure criteria of Chang and Chang's model (1987). Meanwhile, strain-rate effect of dynamic material strengths can be expressed by constitutive equation as a function of strain-rate based on Al-Hassani and Kaddour's work (1998). As shown in Figure 2, the analysis using rate-dependent model shows local failure at the center, which agrees with the experimental observation. This comparison shows that the proposed rate-dependent failure model can predict well the dynamic failure response of FRP under blast load. Also, the debonding failure model of FRP retrofitted concrete under blast loading is proposed considering the ratio of extreme loading to static bond strength based on Lorenzis and Tegola's model (2005).

To evaluate the effect of debonding failure with strain-rate dependent failure, this study performed blast test simulation of the blast test results. The analysis results using the proposed method show good agreement with the experimental results as shown in Figure 3. The different experimental data can be measured even under the same test conditions due to varying environmental conditions such as atmosphere, pressure, temperature, and wind. As shown in Figure 4, the analysis result agrees well with local structural behavior of RC slabs such as debonding failure and delamination. Therefore, the analytical application confirms that the debonding failure of FRP can be effectively simulated.

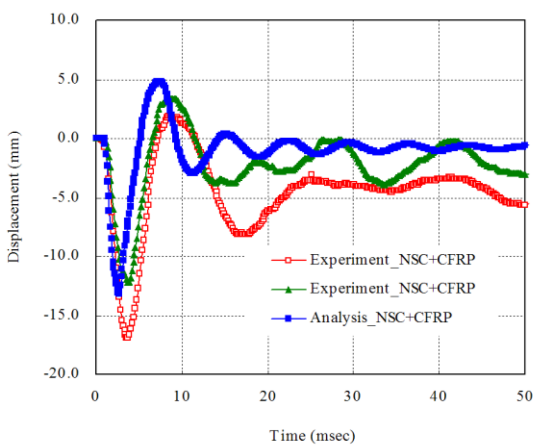


Figure 3: CFRP retrofitted displacement behavior

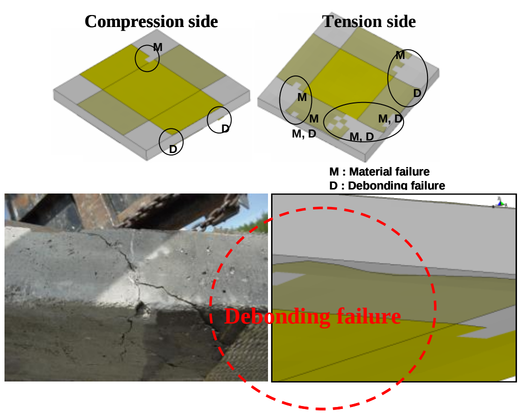


Figure 4: Analytical prediction of the local debonding failure