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Blast analysis of high-performance fiber-reinforced cement composite panels

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ABSTRACT

A Karagoziam & Case (K&C) model [1], which is one of plastic-based concrete material models, can describe accurately the response of concrete structures subjected to blast and impact loadings. However, since automatically determined parameters are based on plain concrete, these are not appropriate for high-performance fiber-reinforced cement composites (HPFRCC). The K&C model is calibrated based on the quasi-static and dynamic experimental data of HPFRCC. The multi-element analysis for material tests was performed to investigate the mesh-size dependency in numerical simulations. The modified K&C model is implemented into LS-DYNA program to perform numerical simulations of the HPFRCC panels. The numerical model was verified through comparisons with the experimental results. The failure mechanism of HPFRCC panels was investigated according to explosive geometry, and scaled distance.

1. INTRODUCTION

As concerns about explosion accidents and bombing attacks, an improvement of blast-resistance capacity has become one of the most important factors in terms of the safety of concrete structures. High performance fiber-reinforced cement composite (HPFRCC), which is one of advanced construction materials, is promising for application to protective structures [2]. The performance of HPFRCC structures has been evaluated from many experiments [3, 4, 5]. However, due to spatial and financial limitation, it is difficult to perform various explosion tests, and thus several numerical studies have been actively carried out based on available experimental results. LS-DYNA program is a popular program used in dynamic analysis such as high-velocity impact and blast analysis. In the LS-DYNA [6], Load Blast Enhanced (LBE) method and Multi-Materials Arbitrary Lagrangian-Eulerian (MM-ALE) method are generally adopted to simulate the structures subjected to blast load. The LBE method provides the blast pressure-time curves from the empirical equations, while in the MM-ALE method, the blast pressure-time curve can be obtained from blast wave propagation through TNT

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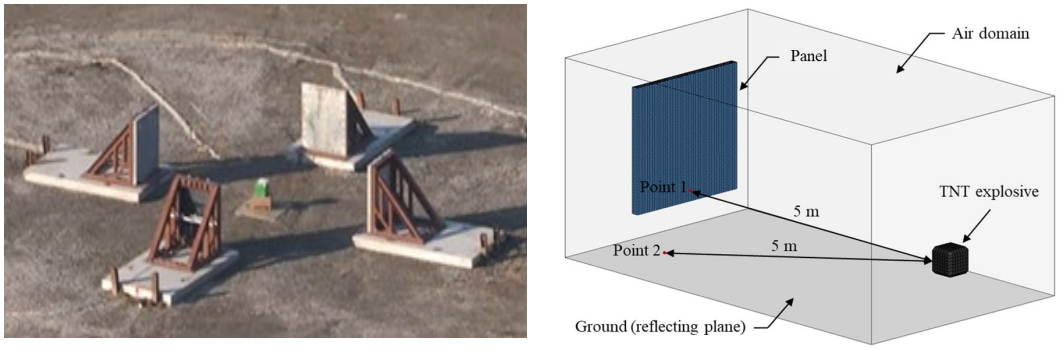
and air domain modelled by Eulerian elements. In this study, numerical simulations for HPFRCC panels suffered from near filed blast are performed using MM-ALE method. Numerical results obtained from MM-ALE method are compared to those from LBE method. Additionally, parametric studies are conducted to investigate the differences between the explosive characteristics and failure shape of the specimens according to the modelling shapes of TNT explosive and scaled distance.

2. Methods

TNT explosion test conducted by Korea Institute of Civil Engineering and Building (KICT) is used for blast simulations [7]. HPFRCC and RC panels were subjected to the TNT explosion. In the test, a TNT with a mass of 100 kg was employed and a standoff distance from the panel is 5 m. The TNT explosive has the cubic shape. Numerical simulations for the TNT explosion can be performed by Load Blast Enhanced (LBE) method or Multi-material Arbitrary Lagrangian Eulerian (MM-ALE) method in the LS-DYNA program. The Air and TNT was modelled using Eulerian elements, while the panel was modelled by Lagrangian elements. Both the incident and reflected pressures are measured by *Database_Tracer at points 1 and 2, respectively (see Fig. 1(b)).



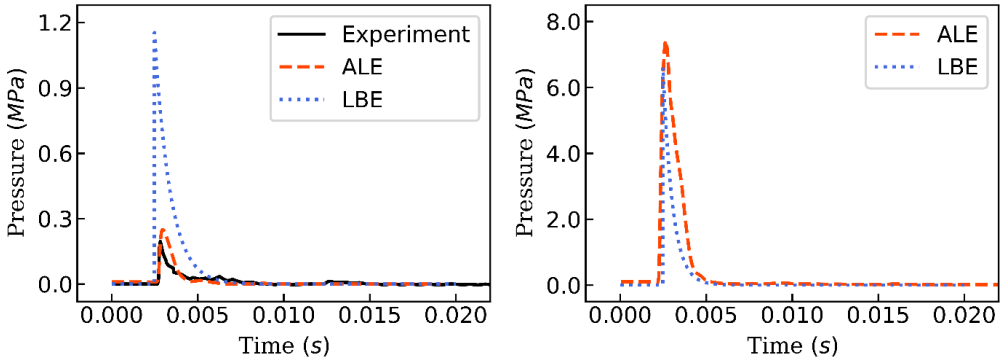
(a) test setup [7] (b) numeircal setup

Figure 1. TNT explosion test and numerical setup

3. Results

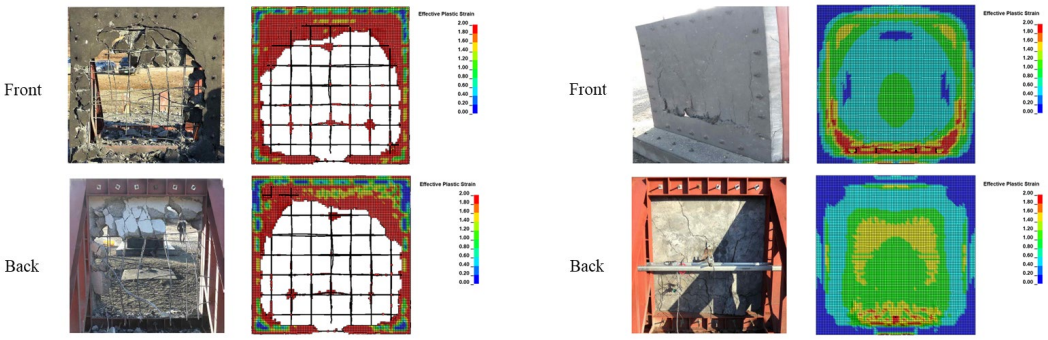
As shown in Fig. 2, in order to demonstrate the accuracy of the MM_ALE method, incident pressure-time profile obtained from both MM_ALE and LBE methods is compared with that obtained from pressure gauge in the explosion test. In this case of the LBE method, blast type was set to the hemispherical blast burst. The maximum incident pressure of 0.24 MPa obtained from the MM_ALE provides a good approximation to the experimental value of 0.2 MPa. On the other hand, that of the LBE method assuming a hemi-spherical surface burst is 1.15 MPa (see Fig. 2(a)). Nevertheless, the reflected pressures applied on the slab from the MM_ALE and LBE methods are similar as about 7 MPa in Fig. 2(b). The LBE method gives the high accuracy in the spherical free-air burst occurred at the long-distance from the target, but it tends to show low accuracy in complex explosion conditions such as contact

explosion or air burst near ground without considering the shape of an explosive. Figure 3 shows the failure mode and damage distribution of the RC and HPFRCC panels for TNT explosion. The RC panel is completely destroyed and the reinforcing bars were severely deformed, while the HPFRCC panel shows a considerable reduction in damage compared to the RC panel. It can be found that the high content of the steel fibers in the cement matrix plays an important role in the blast-resistance.



(a) Incident pressure-time profile (b) Reflected pressure-time profile

Figure 2. Pressure-time profiles



(a) RC (b) HPFRCC

Figure 3. Numerical results of RC and HPFRCC panels

In order to confirm the effect of the explosive shape on the blast pressure and impulse, the parametric study was additionally conducted. The numerical simulations for two different explosives in this case, spherical and cylindrical explosives, were performed using the MM-ALE method. The reflected pressures at the different scaled distances depending on the explosive geometry were additionally analyzed. The scaled of distances were calculated for the 100 kg TNT at five stand-off distances (5 m, 6 m, 7 m, 8 m, and 9 m). As the scaled distance increases, the maximum reflected pressure considerably decreased. It can be found that the effect of TNT geometry on the reflected pressure was reduced. On the other hand, the time for the maximum reflected pressure to reach the slab increased, and the difference in the arrival time rather greatly increased.

4. CONCLUSIONS

This study numerically investigated the performance of RC and HPFRCC panels suffered from near field TNT explosion. The accuracy and reliability of the numerical simulations using MM-ALE method were verified through comparison with the LBE method and test results. Also, it was confirmed that the RC slab made of HPFRCC has superior blast resistance performance than normal concrete from simulations and experiments. The parametric study showed that the geometry of an explosive affected the blast wave propagation, pressure magnitude, and arrival time, resulting in changes in the failure mechanism of structures.

Acknowledgements

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