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A Comprehensive Analysis of Projectile Impact on Concrete Panels

*Seong Ryong Ahn[1)] and Thomas Kang[2)]

[1), 2)] *Department of Architecture & Architectural Engineering, Seoul National University, Seoul, Korea*
[2)] *tkang@snu.ac.kr*

ABSTRACT

Nuclear power plants are critical infrastructures for achieving carbon neutrality. Twenty-two countries, including South Korea, the United States, France, the United Kingdom, and Japan, have agreed to collaborate in tripling the global nuclear power capacity by 2050 to reach their carbon neutrality goals. Nuclear containment structures face the potential risk of projectile impacts resulting from natural disasters and human-induced incidents (ACI Committee 349 2014; NEI 2011; U.S. NRC 2007). The response of concrete structures to missile impacts exhibits complex characteristics distinctly different from those under static loads. Specifically, local failures such as penetration, spalling, scabbing, and perforation occur, directly affecting the protective performance of the structures (Kennedy 1976). This study investigated the impact resistance of concrete panels subjected to missile impacts through experimental and computational analyses. Both reinforced and prestressed concrete panels were fabricated to determine the effect of prestressing in nuclear containment structures. Hard and soft missile impact tests were conducted on two-way simply supported concrete panels measuring 2,000 × 2,000 × 500 mm, utilizing a propulsion impact machine in the Extreme Performance Testing Center at Seoul National University. The missiles, accelerated by compressed gas, achieved an impact velocity of 240 m/s, similar to the velocity of an aircraft collision (Sugano et al. 1993). Hard and soft missiles, identical in diameter (150 mm), mass (50 kg), and nose shape (flat), caused completely different damages to the concrete panels. Subsequently, finite element analysis with nonlinear material models that account for the strain rate effect was carried out, as shown in Fig. 1. Parametric studies incorporating various design variables, such as the level of prestressing force, were performed (Ahn and Kang 2021). The penetration, scabbing, and perforation phenomena in concrete panels were accurately analyzed. All simulations were processed using ANSYS LS-DYNA. The results indicated that the prestressing force significantly enhances both local failure resistance and global stiffness of the panels, offering superior impact resistance compared to reinforced concrete panels. The findings of this study are anticipated to enhance the design and safety of nuclear power plants.

[1)] Graduate Student
[2)] Professor

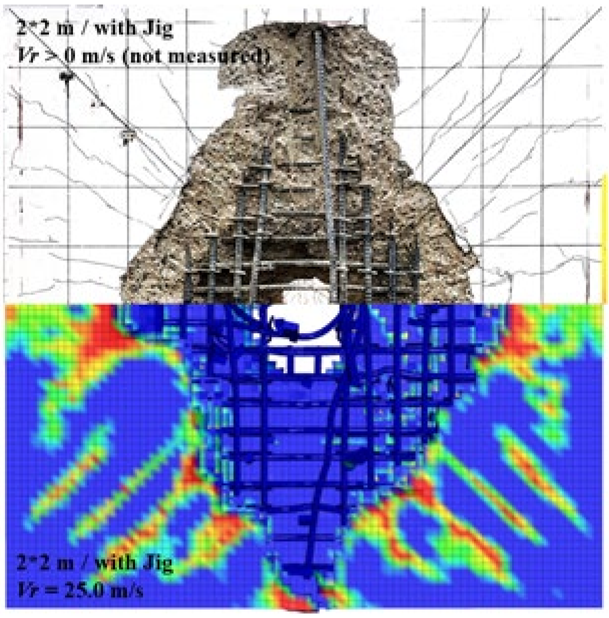

Fig. 1 Rear fracture shape of RC panel: Experimental and analytical results

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