Blast and Impact Effect Analysis of Cementitious Armor Panels

Mason Hickman

Vanderbilt University

Background

The U.S. Army Corps of Engineers has been undertaking extensive research regarding the usability of cementitious materials for defense applications. The Advanced Fundamental Concrete (AFC) Model was developed in order to more accurately model high-velocity projectile impact of Ultra-High Performance Concrete (UHPC) armors by defining a reduced tensile failure surface which included the effects of shockwave propagation caused by ballistic projectile impact.

Purpose

This research focused on developing an improved material model to simulate the performance of Ashcrete, a UHPC developed for the purpose, subject to high-velocity projectile impact and accurately characterize the parameters of the model based on a series of standardized test undertaken for the purpose. The resulting model was then used to simulate scenarios likely to be encountered during asymmetric warfare, such as IDE blast action and small arms fire. Projectile penetration resistance of a single and stacked armor panels were undertaken to assess the relative effectiveness.

Design/Method

Experimental results detailing the behavior of Ashcrete in compression, tension, flexure, as well as strain-rate dependence were generated by the research team working on the U.S. Army project. An algorithm was developed in MATLAB to characterize the material constants for implementation in several previous material models for concrete. The constitutive equations of the AFC model provided the most reasonable fit of the experimental data. Improvements were made to the AFC Model to more accurately describe the high-strain rate as well as confining behavior of UHPC. ABAQUS Commercial Finite Element Software was used to perform several projectile impact simulations by implementing VUMAT code to represent the improved material model. Blast wave data were generated by DOD's software ConWep for 25 lbs of TNT detonated at a distance of 25' from the panel to determine if the added effect of the pressure shock wave during projectile impact caused significantly more damage to the armor panel.

Results

A fragment simulating projectile test was undertaken using the improved AFC Model. An element model yielded only a 5.22% difference in projectile exit velocity as compared to experimental findings. However, using a hydrocode model, a 2.12% difference was achieved. Both models exhibited localized cratering and tensile spalling effects as seen in actual ballistics experiments. It was determined that a 1" panel of Ashcrete is more effective in resisting projectile penetration than a stacked ½" panel arrangement. The effects of added TNT detonation showed no significant increase in panel damage during projectile penetration, because the damaging effect of the blast wave was found to be negligible as compared to that from the projectile by itself.

Conclusions

A thorough analysis of potential material models was found to be necessary prior to modeling UHPC armor, because alternate constitutive equations may, sometimes, provide an improved fit of material strength properties. The improvements made to the AFC Model were effective in modeling the high-velocity impact performance of Ashcrete. The material parameters determined for Ashcrete have potential for use in different asymmetric warfare situation in assessing the effectiveness of Ashcrete armors in withstanding enemy aggression.