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INVESTIGATING FLEXURAL DAMAGE EFFECTS FROM BLAST AND SHOCK – IMPROVING PENETRATING WEAPON PERFORMANCE AGAINST HARDENED STRUCTURES

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The weapon-target interaction being considered in this paper involves penetration into soil and concrete layers and detonation in or near hardened underground structures. Elements of the methodology include concrete and soil cratering, subsequent penetration into the resulting crater and surrounding damaged regions, and reduction in the penetration resistance characteristics of reinforced concrete structures subjected to explosive detonations. In the past, weaponeering and effectiveness methodologies for conventional air-to-surface weapons were designed to model weapon interactions with an undamaged target. Highly accurate Precision-Guided Munitions (PGMs) repeatedly attacking the same hardened target require more fidelity in accounting for accumulated damage - this has been generally referred to as the *multi-hit problem*. The 46th Test Wing Munitions Test Division at Eglin AFB, Florida carried out an extensive scaled test program conducting 57 static detonations (up to 21 lbs. of explosive) in 31 concrete targets and shot 32 penetrators (up to 90 lbs.), 24 of which were fully instrumented with tri-axial accelerometers. We developed an innovative model from the test data using combination of discriminant analysis to separate damage into distinct damage modes, multi-variable linear regression for crater shape and related factors, as well as non-linear regression for the penetration softening curves. In partnership with the *Defense Threat Reduction Agency (DTRA)*, a full scale, highly-instrumented penetration test was successfully conducted to validate this model in a critical part of its domain. A peer review from the weapons effects community validated the model over a defined range of military applications. This paper will describe two years of subsequent investigations into the limitations inherent to the original methodology, and steps taken to broaden its military utility.