Critical Impact Angle for Medium Class Debris

By
Russell Carter & Ameri Stuckley

Introduction

The critical angle is the impact angle at which the missile will ricochet from a target. For this work the critical angle is the angle of the target surface to the missile. The missile is traveling in the direction of its longitudinal axis and the target is rotated. When the target is at 0° the missile impact is normal to the plan of the target.

Overview of Project

The target was chosen because it had a definable missile perforation threshold and its surface would not readily allow penetration of the missile. Penetration occurs when the missile enters the target but does not extend through the non-impact surface. Perforation has occurred any time the missile can be seen from the non-impact surface of the target.

Testing was performed to determine the critical angle. The same target configuration was used for all shots. A perforation threshold was found for the target concept at a 0° angle or the missile perpendicular to the target. The perforation threshold range was from 115 mph to 117 mph. The target was then rotated counterclockwise at 5° increments and impacted until the missile ricochet from the impact surface.

The missile used for the tests was a 15-lb. 2 x 4-in wood board traveling along the board's longitudinal axis, striking the panel traveling at 115 mph. The tornado test criterion uses this missile traveling at 100-mph which corresponds to a 250-mph wind. The tornado test criterion has the missile impact the target normal to the target. The tornado test criterion is used in designing for occupant protection. The testing presented uses the same missile criterion for shape and weight but exceeds the 100-mph speed test configuration.

Test Configuration

Targets tested were simply supported at top and bottom of the panel by a steel reaction frame. All targets consisted of steel and plywood panels mounted on a 4x4 ft, double stud frame. The double studs were attached to each other with 3-in. #8 wood deck screws spaced 6-in. on center. The screws were inserted from alternate sides of the double studs. Plywood used for the targets was C/D exterior grade plywood. The steel and plywood layers were attached using #8, 3-in. wood deck screws. The steel used in the targets was cold rolled 14-gage A366 steel.

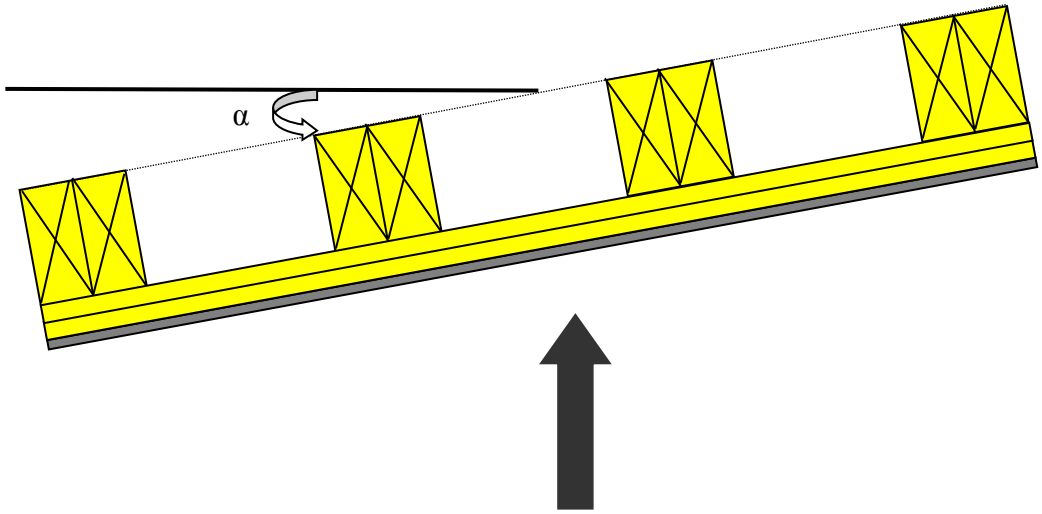

Figure 1: Plan of target with plywood and steel layers

Figure 2: Target Configuration

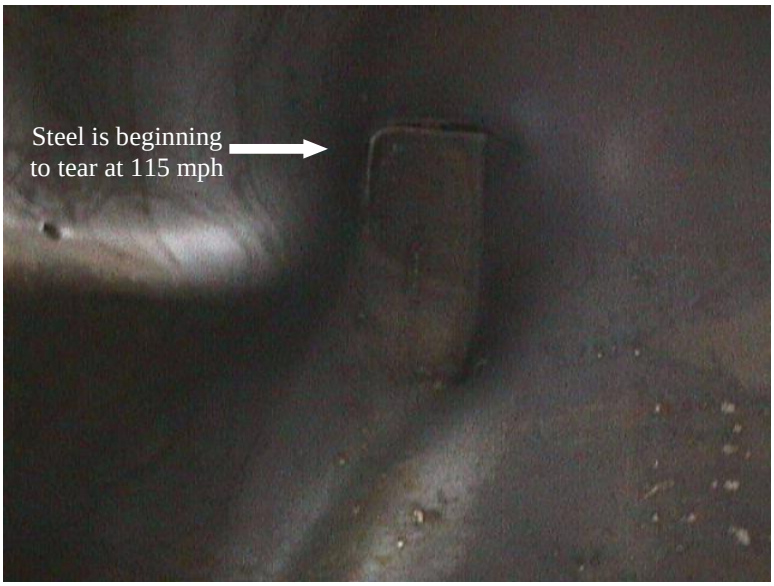

Figure 3: Threshold at 115 mph

Figure 4: Impact at 117 mph

Testing

Using templates at 5° increments, the reaction frame with the attached target was rotated and set at the desired degree for impact. When tested at 0°, 5° and 10°, the missile perforated the target. The frame with target was then rotated to 15°, where the missile ricocheted. The frame and target were then moved to 12.5°, where the missile ricocheted once more. An estimated angel of 11.25° was then tested with similar results. To confirm the testing procedure, the reaction frame with the target was moved to 10° where the missile perforated the target.

5° Angle

The reaction frame was rotated to an angle of 5°. The missile perforated the target.

Figure 5: 5° Angle

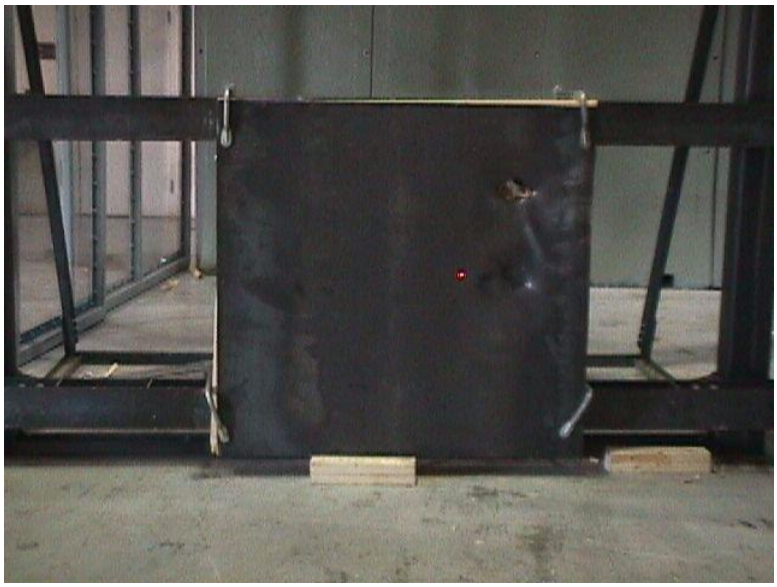

Figure 6: 5° Impact side

10° Angle

The reaction frame was rotated to 10°. The missile perforated the target.

Figure 7: 10° Angle

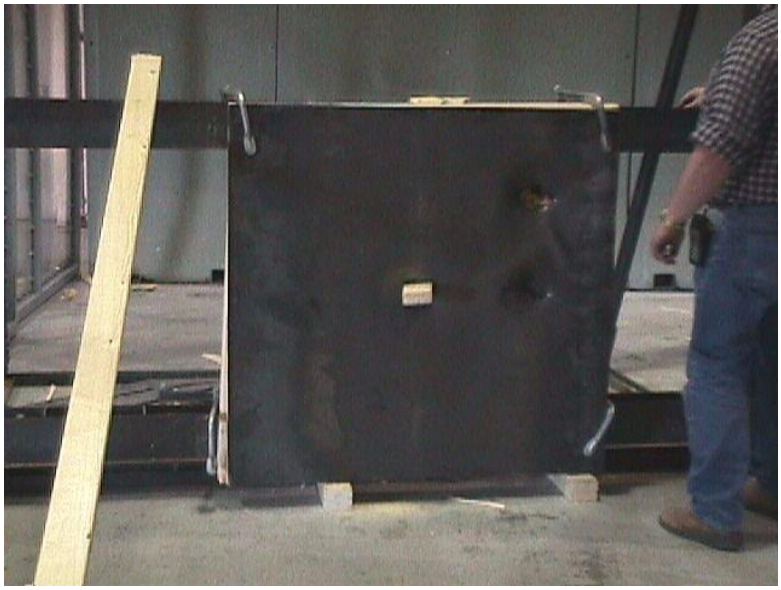

Figure 8: 10° Impact side

12.5° Angle

The reaction from was rotated to 12.5°. The missile ricocheted from the target.

Figure 9: 12.5° Angle

Figure 10: 12.5° Impact side

11.25° Angle

The reaction from was rotated to 11.25°. The missile ricocheted from the target.

Figure 11: 11.25° Angle Impact side

Figure 12: 11.25° Non-impact side

Results

The missile ricochets at 15°, 12.5° and at 11.25° and perforated at any angle lower than 10°. Repeat shots were fired at 12.5°, 10° and 0° resulting in confirmed conclusions that the critical angle lay within 11° and 13°. Although the missile does not perforate the target, permanent deflection and some structural damage were recorded.