Test Report

INVESTIGATION OF WIND PROJECTILE RESISTANCE OF EMMEDUE M2 PANELS

Submitted to

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Overview of Project

Mr. Angelo Candiracci of EMMEDUE S.p.A. contacted the Wind Science and Engineering (WISE) Research Center at Texas Tech University to determine debris impact resistance of their insulated cementuous panels. Tests were conducted on January 21. 2005. The specifics about each test, results, and conclusions follow.

Three series of tests were conducted on M2 panels - PSME80, PSM80HP and the PSME100.

The goals of the tests were 1) to determine the ability of the specimens to comply with the South Florida Hurricane Test Protocol (9-lb., 2-in. x 4-in. wood missile propelled at 34 mph), 2) to determine the ability of the specimens to resist the 15-lb., 2-in. x 4-in. wood hurricane shelter missile propelled at 66 mph, 3) to determine the ability of the specimens to resist the 15-lb., 2-in. x 4-in. wood tornado missile propelled at 66 mph, per the FEMA 320 and FEMA 361 Test Protocol, and 4) to determine the ability of the PDME100 panel to resist the Nuclear Regulatory Agency 75-lb steel pipe missile propelled at 70 mph.

Series 1: The test panel consisted of a 4-ft. x 8-ft. M2 PSME80 panel,see **Figure 1**. The panel was placed inside a 4-ft. x 8-ft. test fixture consisting of C4 x 5.4 steel perimeter members with ¼- in. round x 5 ½-in. long studs welded to the channels at 12-in. centers. The test panel wire frame was wire tied to the studs. The test protocol was the South Florida Hurricane Test.

Series 2: The test panel consisted of a 4-ft. x 8-ft. M2 PSM80HP panel, see **Figure 1**. The panel was placed inside a 4-ft. x 8-ft. test fixture consisting of C4 x 5.4 steel perimeter members with ¼-in. round x 5 ½-in. long studs welded to the channels at 12-in. centers. The test panelm wire frame was wire tied to the studs. The test protocol was for the Hurricane Shelter and the Tornado Shelter Test.

Series 3: The test panel consisted of a 4-ft. x 8-ft. M2 PDME100 panel, see **Figure 1**. The panel was placed inside a 4-ft. x 8-ft. test fixture consisting of C4 x 5.4 steel perimeter members with ¼- in. round x 5 ½-in. long studs welded to the channels at 12-in. centers. The test panel wire frame was wire tied to the studs. The test protocol was for the Tornado Shelter Test and the Nuclear Regulatory Agency Test for containment vessels.

Refer to **Figure 2** for the Material Specifications - Batch Design and Plaster Installation.

Test Protocol

Introduction

The primary objective in debris impact testing of storm shelters and shelter components is to assure compliance with a high standard of performance in protecting shelter occupants from wind-borne debris. Performance criteria include preventing perforation of the shelter or component by the design missile and preventing deformations which could cause injuries to the occupants.

Test Criteria

The testing described is for simulated windborne debris. The primary simulations are impacts of a 2x4-in. wood board traveling along the board's longitudinal axis, striking the test subject perpendicular to the test subject face. Standards that use this type of simulated debris include ASTM E 1886-04 "Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protection Systems Impacted by Missiles and Exposed to Cyclic Pressure Differentials," SSTD 12-99 "SBCII Test Standard for Determining Impact Resistance From Windborne Debris," ANSI A250.13-2003, "Testing and Rating of Severe Windstorm Resistant Components for Swing Door Assemblies," the National Storm Shelter Association (NSSA), "Standard for the Design, Construction, and Performance of Storm Shelters," and Texas Tech University, Wind Science and Engineering's Tornado Test Criterion adopted by the Federal Emergency Management Agency in publication FEMA 320, "Taking Shelter from the Storm," and FEMA 361, " Design and Construction Guidance for Community Shelters." The hurricane test criterion uses a 9-lb. 2x4-in. wood board called a missile, traveling horizontally at 34-mph (50 feet/second), which corresponds to a 110-150-mph wind, and is the criterion used for property protection.

The tornado test criterion uses a 15-lb. 2x4-in. wood board traveling horizontally at 100-mph, which corresponds to a 250-mph wind, and is the criterion used in designing vertical surfaces for occupant protection. The criterion for falling debris from a tornado is a 15-lb. 2x4-in. board traveling at 67-mph striking perpendicular to the surface. The 67-mph criterion is used for surfaces horizontal to the ground and inclined less than 30-degrees. Additional factors of safety are inherent in the criterion since there is a very small probability that a missile will be traveling along its axis and will strike perpendicular to the surface.

Test Procedure

The first test on a system is to determine if the basic concept or structural element is capable of resisting the impact. This done by impacting the target in a general field or the area deemed most vulnerable. If the system resists the impact then the testing is concentrated on connections and material support conditions. Shelter walls or test panels are impacted with three test missiles in different and vulnerable locations. Shelter roofs/ceilings constructed differently from the walls are impacted with three test missiles in different and vulnerable locations. Shelter appurtenances, vents, louvers, windows, electrical boxes, shelves, seats, etc., are impacted by a single missile.

Laboratory pressure tests are not conducted on shelters and shelter panels. Numerical analysis of wind pressures is outlined in the above listed standards in the **Test Criteria**.

Pass/Fail Criteria

The criterion for the shelter/shell/panel test pass/fail is as follows:

1) The test subject must be impacted by a minimum three missiles in areas of perceived vulnerability;

2) the missile may penetrate that test subject, but may not perforate the safe side (back face) of the subject;

3) the test subject permanent deflection after impact must be less than 3-in.;

4) segments, spallings or otherwise de-laminated portions of the test subject, though still attached to the subject, may not extend into the safe compartment 3-in. or more; and

5) segments of the test subject or appurtenances attached to the test subject must not be ejected or otherwise released into the safe compartment by the impact force.

Test Equipment

Debris Impact Air Cannon:

1) Air Tank – 30 gallon, Manchester Model Number 301853.

2) Electric Over Air Valve – Matryx Model Number MX200 – 600501.

3) 4-in. aluminum quick coupler to connect barrel to valve.

4) 4-in. x 20-ft. long schedule 40 PVC barrel.

5) Pair Optical Timing Sensors – Keyence Model Number PZ251R and PZ125T 12/24-volt.

6) Signal Conditioner.

7) Pair Precision Timers – BK Precision Timer Model Number 1823 Universal Counter.

8) Control panel with pressure controls, laser sighting and a three stage firing system to eliminate unintentional missile shots.

9) Horizontal articulating cannon carriage with DC motor drive and variable speed controller.

10) Cannon carriage mounted to a hydraulic scissor lift on wheels - Autoquip Model Number 84B16F20.

11) Steel reaction frame made of vertical and horizontal steel beams anchored to the floor to provide simple support at the top and bottom of the test specimen.

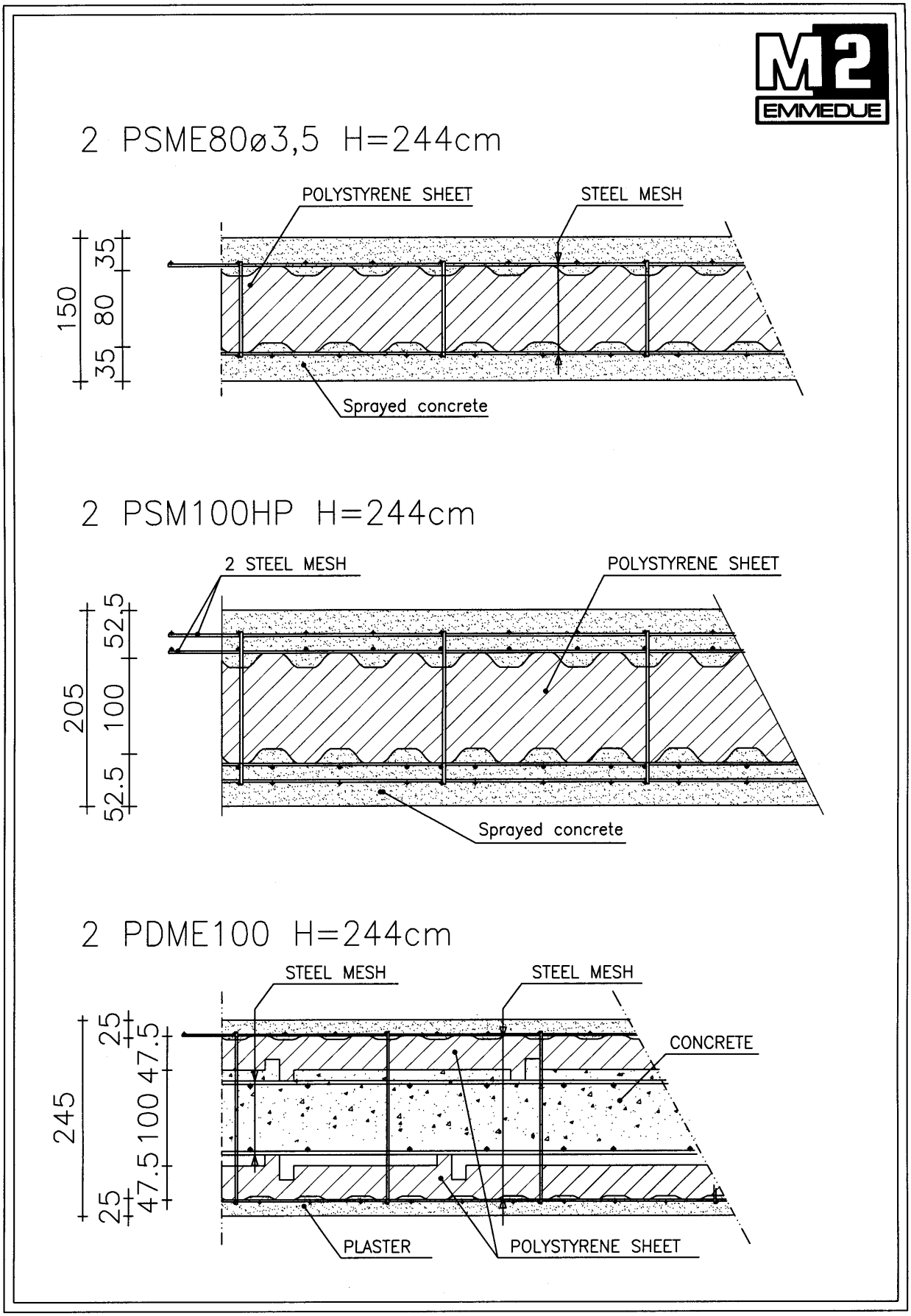
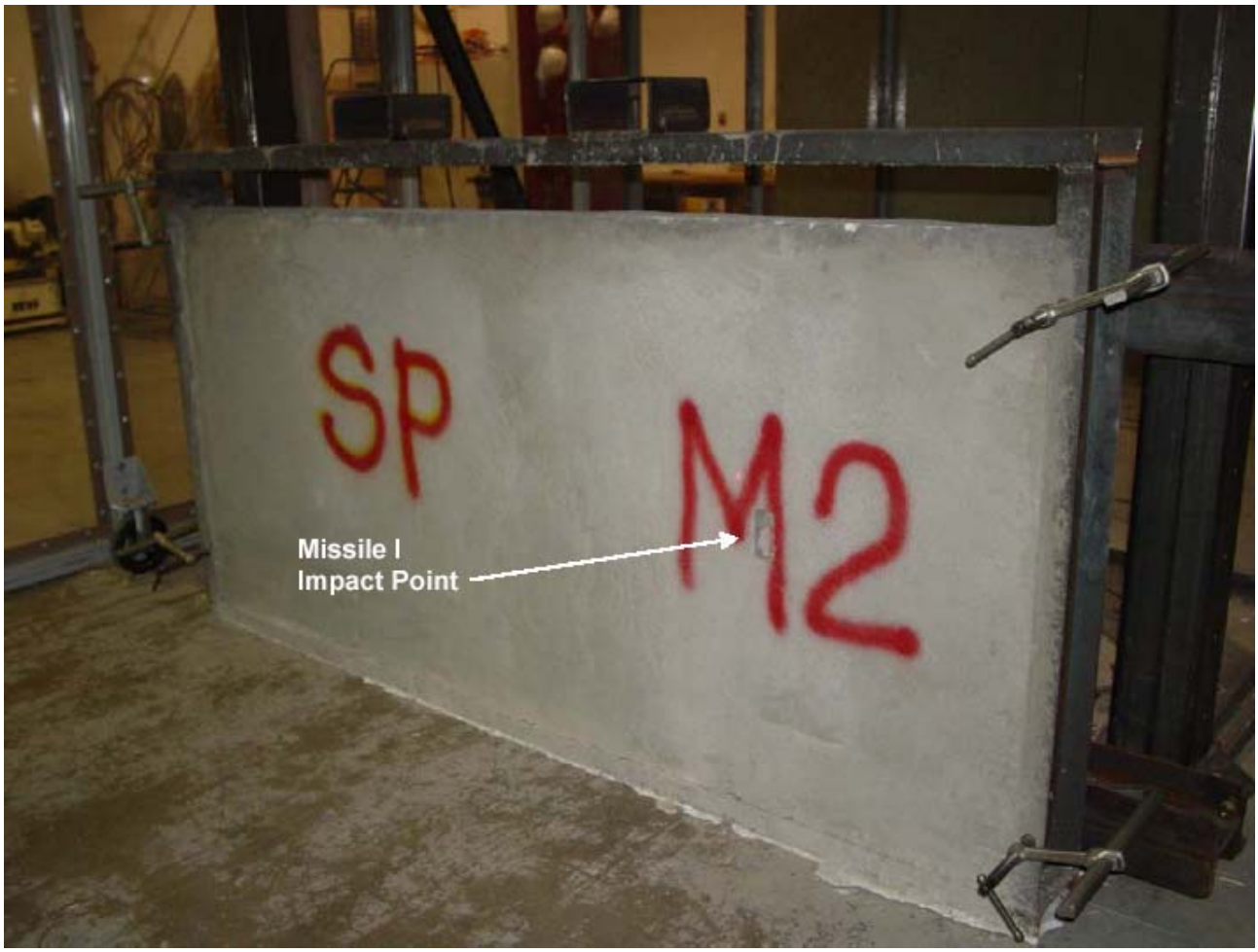


Figure 1. Series 1 – 3 M2Panels

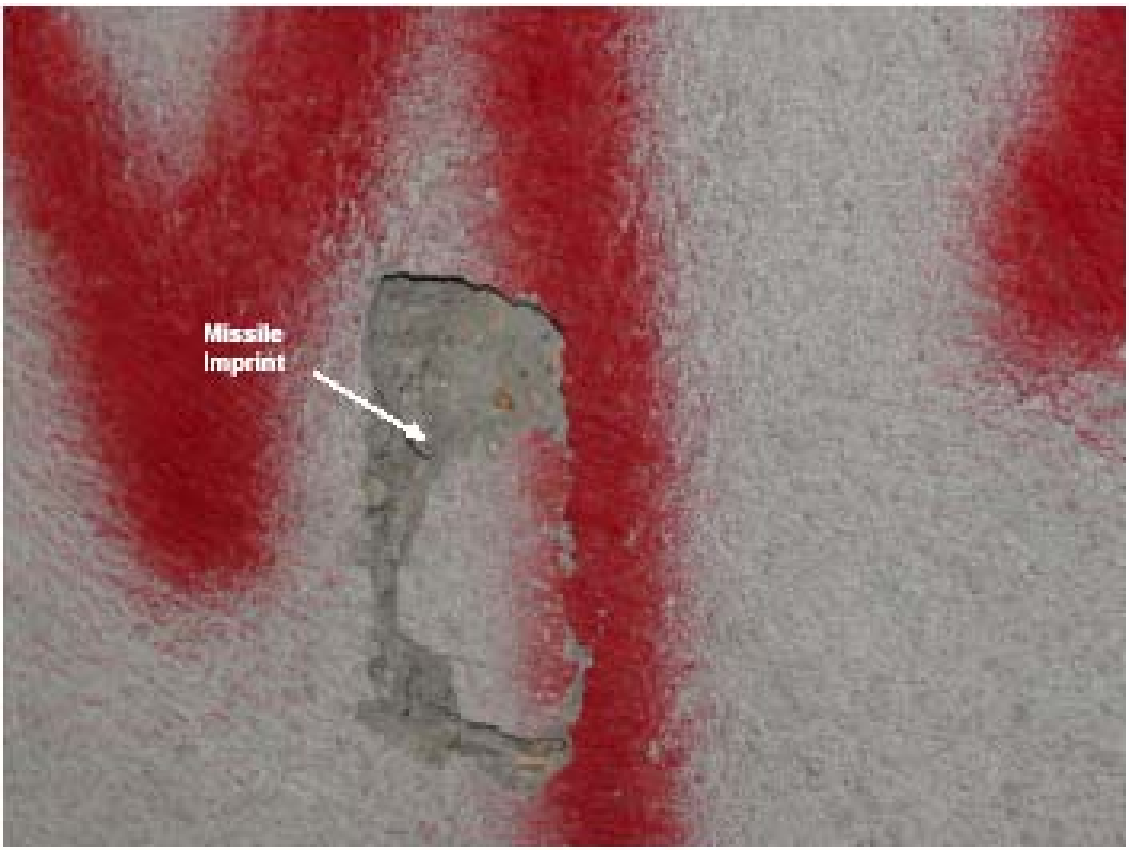
Series 1 Testing, Protocol 1

Missile Shot I – 9-lb. 35 mph Hurricane Test Protocol

The Series 1 PSME80 panel was mounted against the test frame. The missile impacted the center right half of the specimen producing a 2-in. x 4-in. impact print ¼-in. deep. There was no remarkable damage to the backside of the panel.



Series 1 Panel Impacted by Missile I

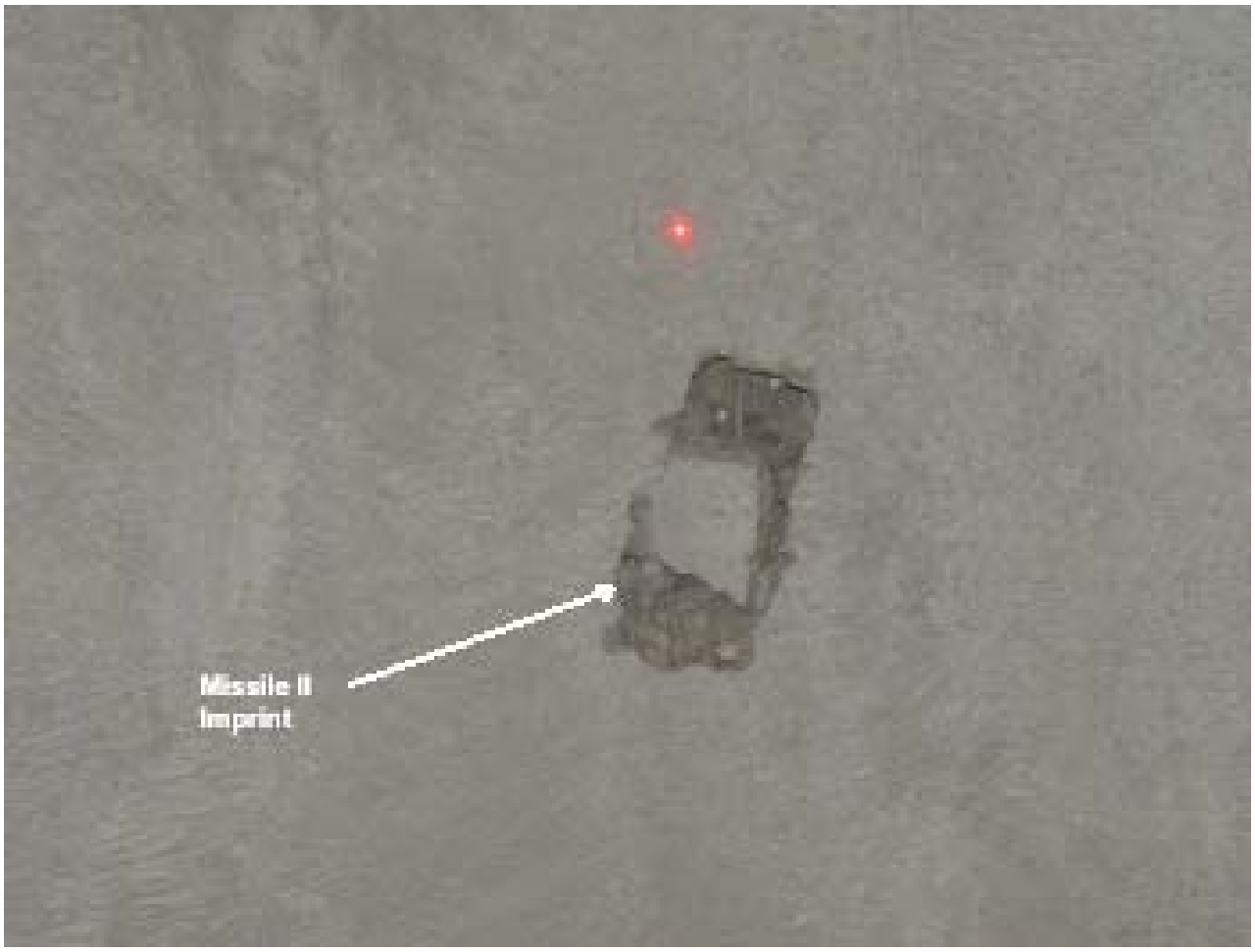


Series 1 Panel after Impact 1

Missile Shot II – 9-lb. 34 mph Hurricane Test Protocol

The Series 1 specimen was impacted by the hurricane missile left of the previous impact. The missile left a 2-in. x 4-in. imprint 1 ¼-in. deep. There was no remarkable damage to the backside of the panel.

Series 1 Specimen Impacted by Hurricane Protocol Missile II



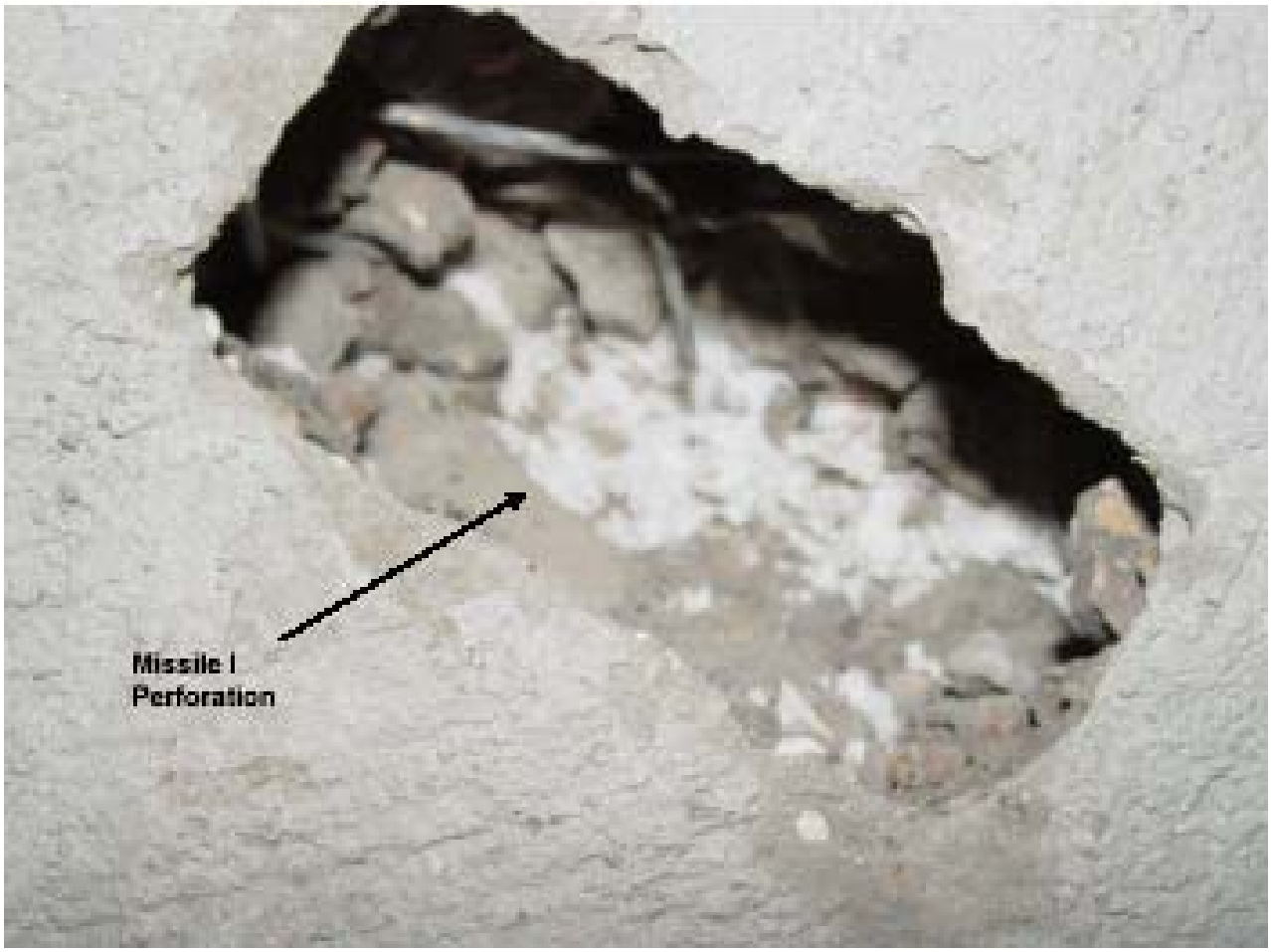
Impact Face of Series 1 Panel after Missile II

Series 2 Testing, Protocol 2

Missile Shot I – 15-lb. 66 mph Hurricane Shelter Protocol

The missile impacted the Series 2 PSM 80 specimen in the left center of the panel penetrating the panel 4 ½-in. The exterior face wire reinforcing was failed by the impact and the polystyrene insulation was compressed against the backside layer. The backside of the panel exhibited radial cracking ranging in width from hairline to .002-in. in thickness. Cracking radials extended from the impact point to the top, bottom, left edge and near the panel center. The cracked plaster was not spalled or propelled into the safe compartment.

Hurricane Shelter Impact on Series 2 Specimen



Impact Side of Series 2 Panel after Impact I by Hurricane Shelter Missile

Series 2 Testing, Protocol 2

Missile Shot II – 15-lb. 66 mph Hurricane Shelter Protocol

The missile impacted the Series 2 PSM 80 specimen in the center of the panel penetrating the panel 4-in. The exterior face wire reinforcing was failed by the impact and the polystyrene insulation was compressed against the backside layer. The backside of the panel exhibited similar radial cracking as Impact I. The cracked plaster was not spalled or propelled into the safe compartment.

Series 2 Panel Impacted by the Second Hurricane Shelter Missile

Impact Hole from Series 2 Hurricane Shelter Missile

Series 2 Testing, Protocol 2

Missile Shot III – 15-lb. 66 mph Hurricane Protocol

The missile impacted the Series 2 PSM 80 specimen on the right center of the panel penetrating the panel 4-in. The exterior face wire reinforcing was failed by the impact and the polystyrene insulation was compressed against the backside layer. The backside of the panel exhibited further radial cracking ranging in width from hairline to .002-in. in thickness. Cracking radials extended to the panel edges and connected with the cracks from the previous impacts. The cracked plaster was not spalled or propelled into the safe compartment.

Series 2 Protocol 2 Hurricane Shelter Impact III

Impact Damage from Missile III on Series 2 Protocol 2

Series 3 Testing, Protocol 3

Missile Shot I – 15-lb. 103 mph Tornado Protocol

The Series 3 PDME100 specimen was impacted on the right corner by the tornado missile. The missile penetrated the panel 2 ¾-in. stopping at the concrete core. There was no remarkable damage to the backside of the panel.

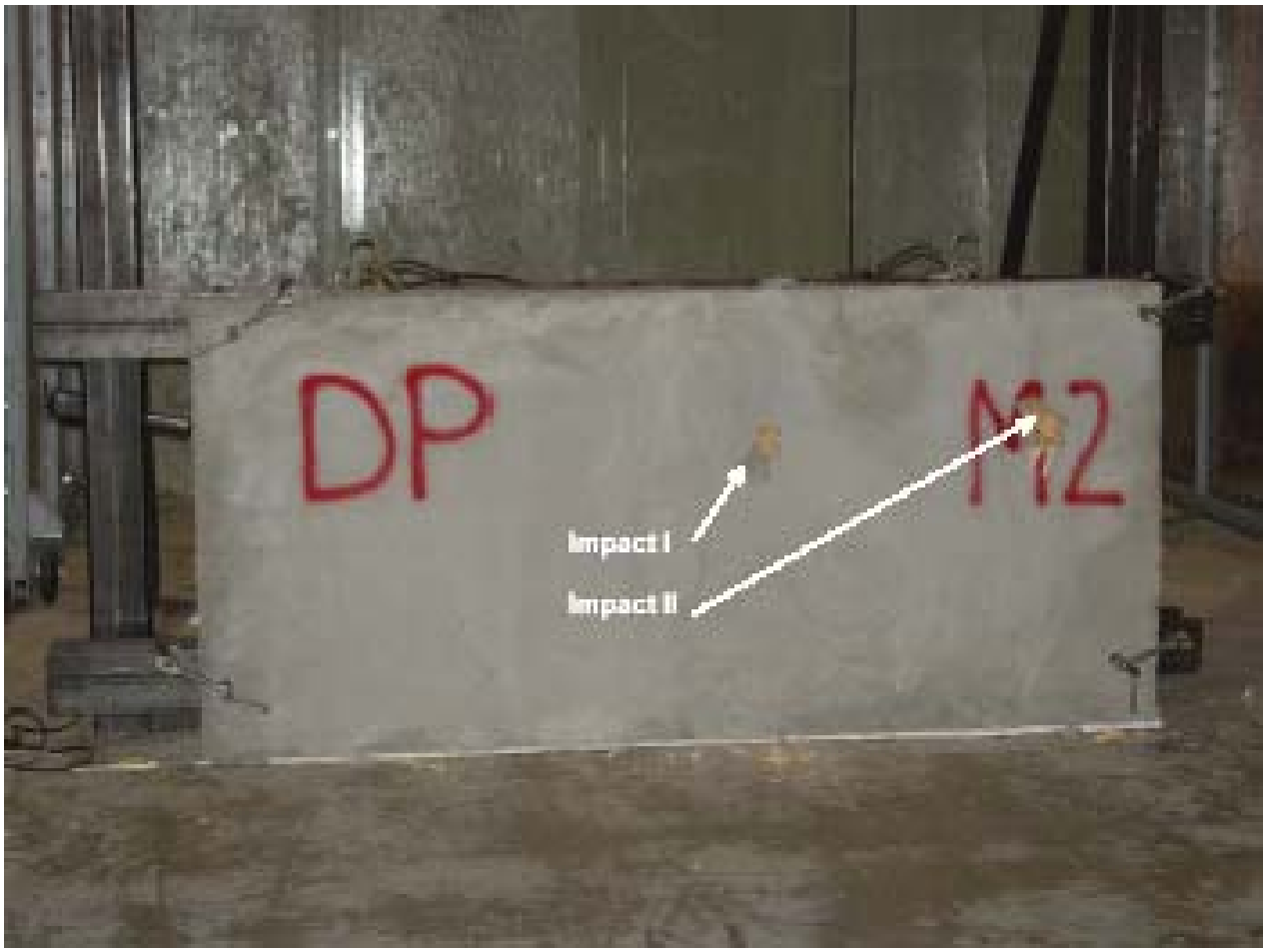
Series 3 Panel Impacted by Tornado Missile I

Series 3 Panel Impacted by the Tornado Missile I

Series 3 Testing, Protocol 3

Missile Shot II – 15-lb. 100 mph Tornado Protocol

The Series 3 PDME100 specimen was impacted one foot from the right edge by the tornado missile. The missile penetrated the panel 2 ¾-in. stopping at the concrete core. There was no remarkable damage to the backside of the panel.



Series 3 Panel Impacted by the Second Tornado Missile

Series 3 Testing, Protocol 3

Missile Shot III – 15-lb. 102 mph Tornado Protocol

The Series 3 PDME100 specimen was impacted between the two previous impacts by the tornado missile. The missile penetrated the panel 2 ¾-in. stopping at the concrete core. There was no remarkable damage to the backside of the panel.

Series 3 Panel Impacted by the Third Tornado Missile

Conclusions

Within the bounds of reasonable engineering and technical certainty, and subject to change if additional information becomes available, the following is my professional opinion:

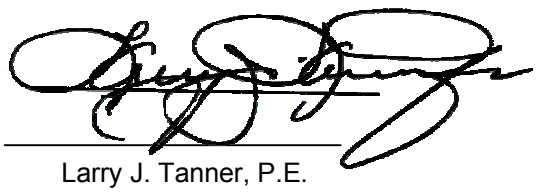
The following are the results of debris impact testing conducted by the Debris Impact Test Facility at Texas Tech University on insulated concrete panels produced by EMMEDUE M2 – *Advanced Building System* of Fano, Italy. Tests were consistent with the requirements of four separate protocols:

Protocol 1 - 9-lb. 2-in. x 4-in. wood missile propelled at 34 mph as required by the South Florida Building Code for hurricane envelope protection.

Protocol 2 - 15-lb., 2-in. x 4-in. wood missile propelled at 66 mph as recommended for hurricane shelters.

Protocol 3 - 15-lb. 2-in. x 4-in. wood missile propelled at 100 mph, required by the guidelines of FEMA 320/361 for tornado shelters.

Series	Protocol 1	Protocol 2	Protocol 3
Series 1 PSME80	Passed	Not tested	Not Tested
Series 2 PSM80HP	Not tested	Passed	Not Tested
Series 3 PDME100	Not tested	Not Tested	Passed



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