Test Report

INVESTIGATION OF WIND PROJECTILE RESISTANCE OF EMMEDUE M2 PANELS

Submitted to

Mr. Angelo Candiracci, Chairman
EMMEDUE S.p.A. —*Advanced Building System*
Via Toniolo *39/B* - Z.I. Bellocchi
61032 Fano (PU) Italy

Investigators

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Larry J. Tanner, P.E.

Date Submitted

July 22, 2005

Wind Science and Engineering
Texas Tech University
Lubbock, Texas 79409

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Testing Performed by

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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. Previous tests were conducted on May 2nd, 2005. The specifics about each test, results, and conclusions follow.

Five series of tests were conducted on M2 panels – PSME100, PSM100HP overlapped reinforcement, PSM100HP offset reinforcement, and two PDME120 samples with increasing reinforcement schedules. The goals of the tests were 1) to determine the ability of the PSME100 panel to comply with the Hurricane Shelter Test Protocol 3 (15-lb., 2-in. x 4-in. wood missile propelled at 80 mph) 2) to determine the ability of the PSM100HP with overlapped reinforced to resist the 15-lb., 2-in. x 4-in. tornado missile propelled at 100 mph, 3) to determine the ability of the maximum reinforced PDME120 panel to resist the Nuclear Regulatory Agency 75-lb steel pipe missile propelled at 70 mph 4) to determine the ability of the minimum reinforced PDME120 panel to resist the Nuclear Regulatory Agency 75-lb steel pipe missile propelled at 50 mph and 5) to determine ability of the PSM100HP offset reinforced panel to resist the 15-lb., 2-in. x 4-in. tornado missile propelled at 100 mph.

Series 1: The test panel consisted of a 4-ft. x 8-ft. M2 PSME100 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 Hurricane Shelter test protocol 3 was utilized.

Series 2: The test panel consisted of a 4-ft. x 8-ft. M2 PSM100HP 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 Tornado Shelter test protocol 4 was utilized.

Series 3: The test panel consisted of a 4-ft. x 8-ft. M2 PDME120, see **Figure 1,** with maximum

reinforcement schedule as follows: 7/32-in. reinforcing wire on 3-in. by 4 ¾-in. grid spacing with an additional 7/32-in. vertical reinforcement wire in the field. 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 Nuclear Regulatory Agency Test for containment vessels, protocol 5b.

Series 4: The test panel consisted of a 4-ft. x 8-ft. M2 PDME120, see **Figure 1,** with minimum

reinforcement schedule as follows: 7/32-in. reinforcing wire on 3-in. by 4 ¾-in. grid spacing. 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 Nuclear Regulatory Agency Test for containment vessels, protocol 5a.

Series 5: The test panel consisted of a 4-ft. x 8-ft. M2 PSM100HP panel, see **Figure 1**, with modification to the reinforcement as follows: double reinforcement wires on Series 5 were offset versus in-line to increase reinforcement coverage. 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 missile, protocol 4.

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.

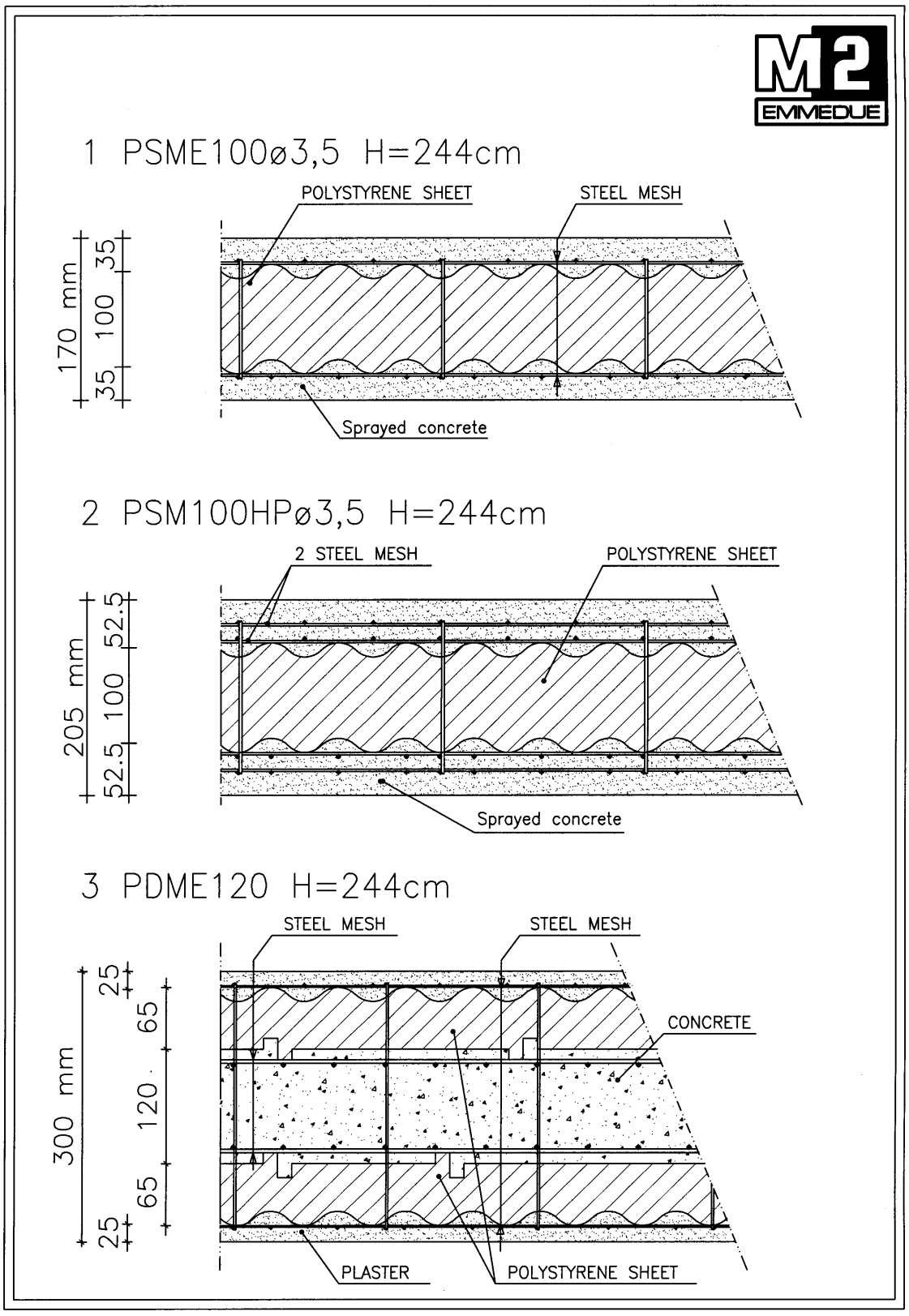
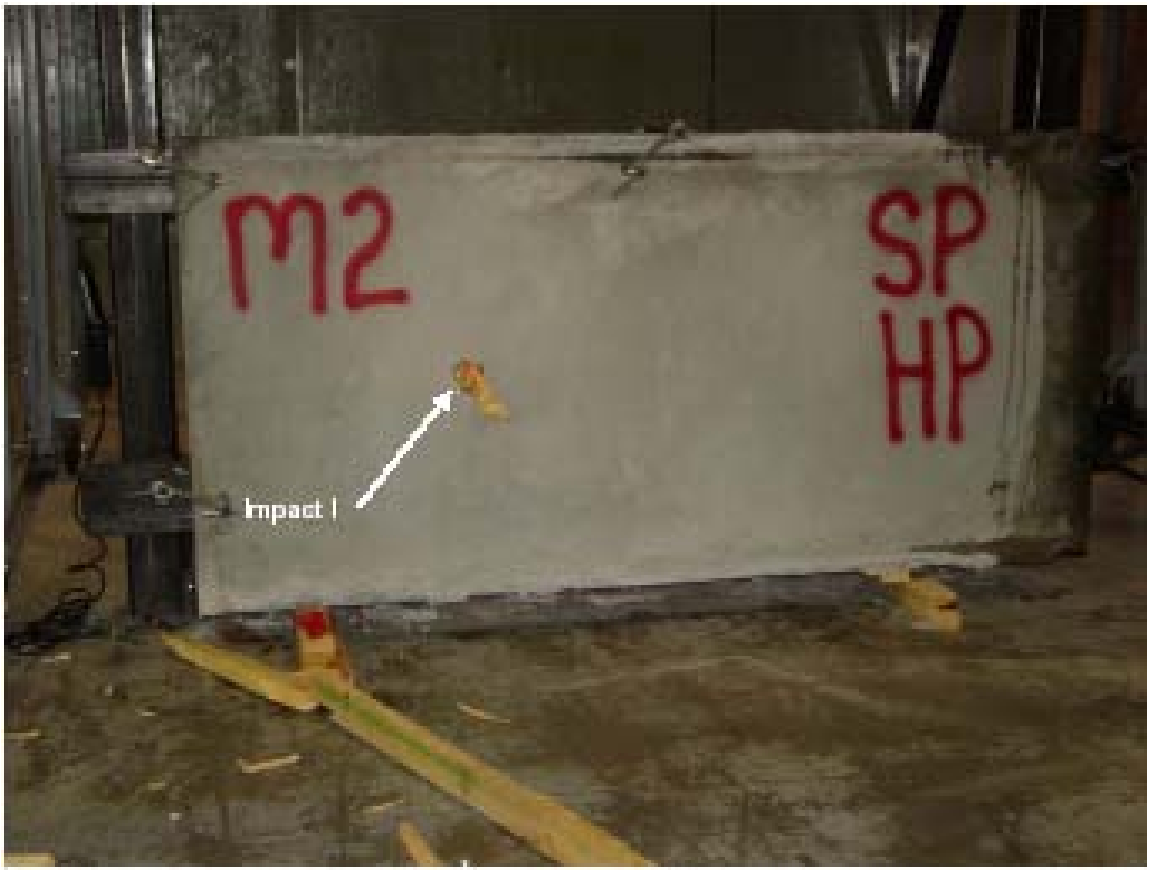


Figure 1. Series 1 – 5 M2 Panels

Series 2 Testing, Protocol 4

Missile Shot 1 – 15lb. 102 mph Tornado Test Protocol

The Series 2 PSM100HP specimen was impacted by the tornado missile left of center. The missile left a rough 2-in. x 4-in. imprint 1-in. deep. There was no remarkable damage to the backside of the panel.



Series 2 Panel Impacted by Missile 1

Shattered Remains of Impact I Tornado Missile

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

The Series 2 PSM100HP specimen was impacted by the tornado shelter protocol test missile in the center of the wall sample. ¾-in. of penetration was of penetration was observed in the rough 3 ¼-in.
imprint area on the exterior surface. There was no remarkable damage to the backside of the target.

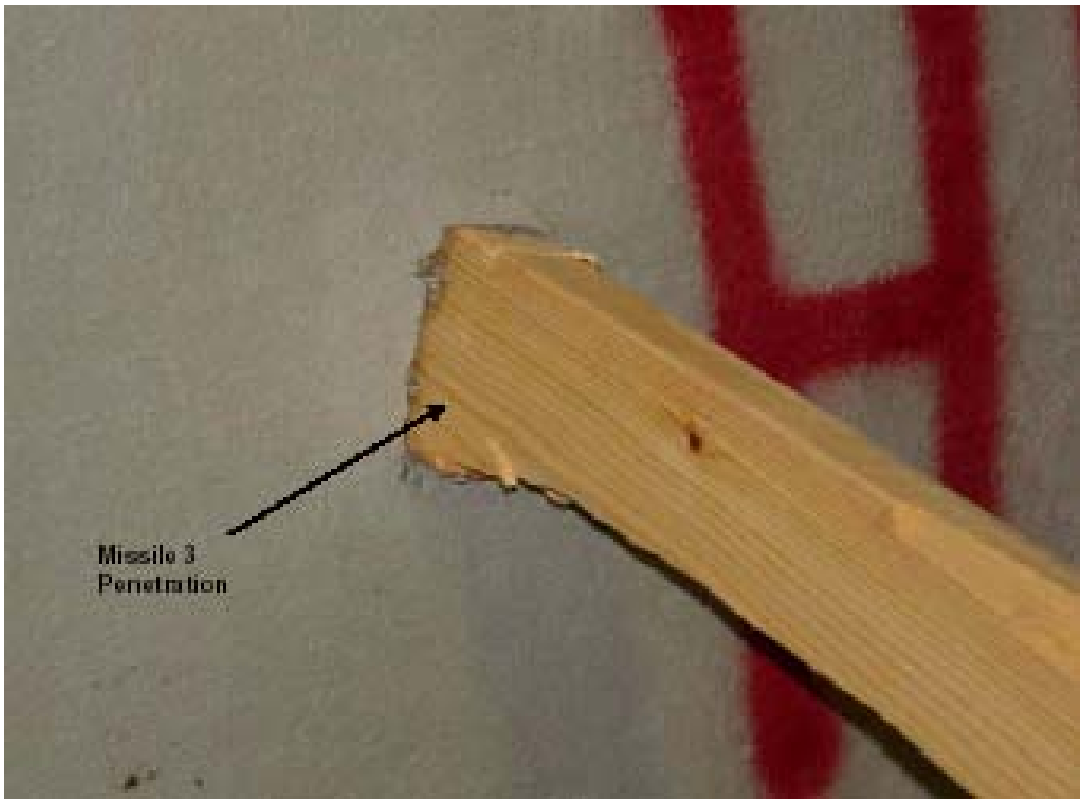
Series 2 Impact by Tornado Shelter Missile II

Specimen after Series 2 Impact II

Missile Shot III – 15-lb. 100 mph Tornado Shelter Protocol

The missile impacted the Series 2 PSM100HP specimen right of impact 2. The exterior plaster layer was perforated as the missile displaced the reinforcement wires, stopping at the backside plaster layer for a total of 4 1/4-in. of penetration. There was no remarkable interior damage to the backside of the specimen.

Tornado Shelter Impact on Series 2 Specimen



Impact Side of Series 2 Panel after Impact 3 by Tornado Shelter Missile

Series 3 Testing, Protocol 5b

Missile Shot 1 – 75-lb. Pipe Impact at 74 mph Nuclear Regulatory Test for Containment Vessels

The missile impacted the Series 3 PDME 120 specimen right of center of the panel. The missile penetrated 5 3/8-in. into the panel, perforating the 1st plaster layer, foam core, and concrete center until reaching the first layer of reinforcing bars. The backside exhibited radial cracking extending from the impact point to the wall edges, no spalling was observed.

Series 3 Panel Impacted by the Nuclear Regulatory Missile

Impact Crater from Series 2 Nuclear Regulatory Missile

Radial Cracking on Backside of Series 3 Impact Specimen

Series 4 Testing, Protocol 5a

<u>Missile Shot I – 75-lb. pipe missile at 52 mph – Nuclear Regulatory Test for Containment Vessels</u>

The missile impacted the Series 4 PDME120 specimen right of center of the panel, penetrating the panel 4 5/8-in. The exterior face plaster and foam core failed but the missile was contained by the center concrete layer. Radial cracking was observed on the backside of the target with cracks extending to the adjacent wall edges.

Series 4 Protocol 5a Nuclear Regulatory Impact I

Impact Damage from Missile I on Series 4 Protocol 5a

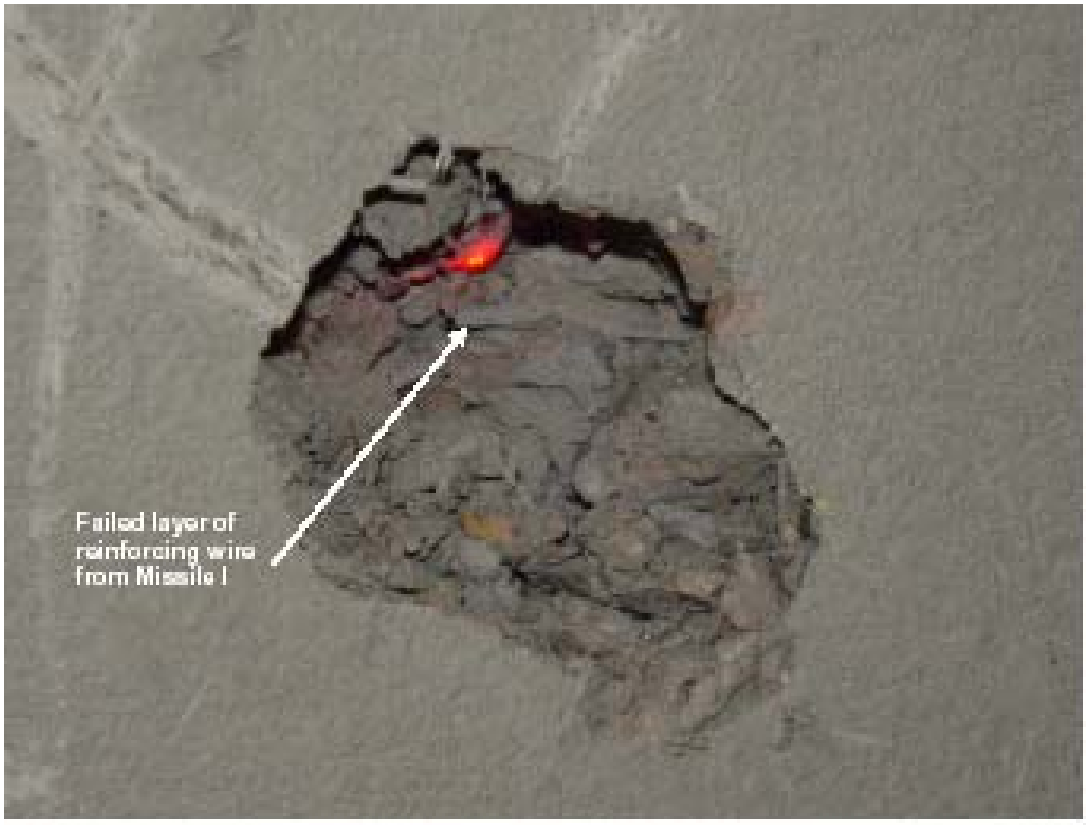
Radial Cracking of Backside of Series 4 Specimen

Series 5 Testing, Protocol 4

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

The missile impacted the Series 5 PSM100HP specimen at the center of the panel. The missile penetrated the panel 3 ½-in. and failed the first wire reinforcement layer. There was no remarkable damaged to the backside of the specimen.

Series 5 Protocol 1 Tornado Missile I Impact on Panel



Missile I Penetration of the Series 5 Panel with the Tornado Missile

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

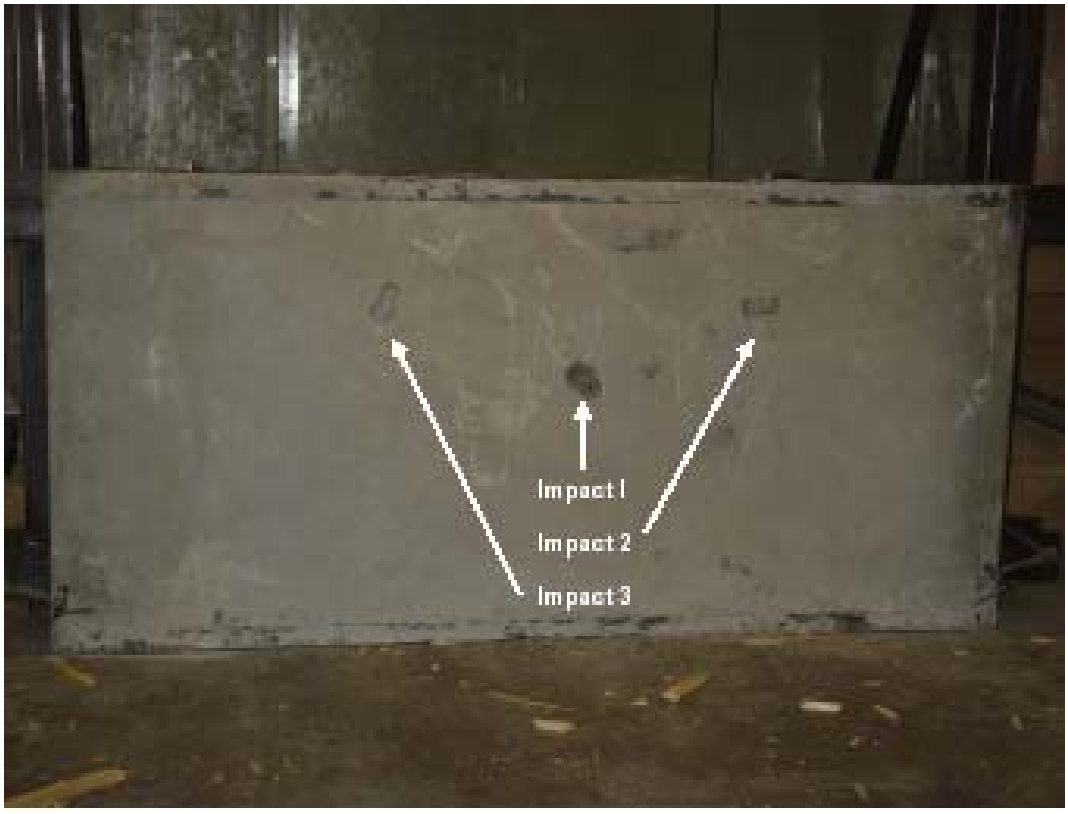
The Series 5 PSM100HP specimen was impacted right of center by the tornado missile. The missile penetrated the panel 1-in. stopping at the 1st layer of reinforcing which remained intact. There was no remarkable damage to the backside of the panel.

Series 5 Panel Impacted by Tornado Missile II

Series 5 Panel Impacted by the Tornado Missile II

Missile Shot III – 15-lb. 101 mph Tornado Protocol

The Series 5 PSM100HP specimen was impacted left of center by the tornado missile. The missile penetrated the panel ¾-in. stopping at the 1st reinforcement layer which remained intact. There was no remarkable damage to the backside of the panel.



Series 5 Panel Impacted by the Tornado Missile I, II, and III

Series 5 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 80 mph as recommended for hurricane shelters.
Protocol 4 - 15-lb. 2-in. x 4-in. wood missile propelled at 100 mph, required by the guidelines of FEMA 320/361 for tornado shelters.
Protocol 5a - 75 –lb. steel pipe missile propelled at 50 mph, required by the United States Nuclear Regulatory Agency
Protocol 5b - 75 –lb. steel pipe missile propelled at 70 mph, required by the United States Nuclear Regulatory Agency.

Series	**Protocol 1**	**Protocol 2**	**Protocol 3**	**Protocol 4**	**Protocol 5.a**	**Protocol 5.b**
Series 1 PSME100	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested
Series 2 PSM100HP	Not Tested	Not Tested	Not Tested	Passed	Not Tested	Not Tested
Series 3 PDME120 – maximum reinforcement	Not Tested	Not Tested	Not Tested	Not Tested	Not Tested	Passed
Series 4 PDME 120 – light reinforcement	Not Tested	Not Tested	Not Tested	Not Tested	Passed	Not Tested
Series 5 PSM100HP Offset reinforcement	Not Tested	Not Tested	Not Tested	Passed	Not Tested	Not Tested

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I. The Texas Tech University Wind Engineering logo may not be so prominent as to mislead the public or unduly play upon the Texas Tech University Wind Engineering name.

II. Whenever the logo is used one of the two alternative statements below is to be employed
in the text:

Alternate 1 – whole shelter
The use of the Texas Tech University Wind Engineering logo signifies that the complete shelter structure was tested and successfully passed missile impact resistance tests at Texas Tech University.

Alternate 2 - shelter component
The use of the Texas Tech University Wind Engineering logo does not signify that the entire shelter structure was tested at Texas Tech, but rather only [shelter component – name explicitly] was tested and successfully passed missile impact resistance tests at Texas Tech University.

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