National Wind Institute
Debris Impact Facility- Texas Tech University
P.O. Box 43155
Lubbock, Texas 79409-1023

Report No. _20140604A
Specimen No. _____2 ____
Test Date: _June 4, 2014_

1.0 MANUFACTURER'S IDENTIFICATION

1.1 NAME OF APPLICANT: **International Masonry Institute**

1.2 CONTACT PERSON: **Ms. Diane Throop**
27 Worthington Court
Simpsonville, SC 29681

1.3 TEST LAB CERTIFICATION: Federal Emergency Management Agency (FEMA) and the ICC-500 Shelter Standard; ISO 17025 certified tests available.

2.0 TEST UNIT IDENTIFICATION

2.0 PRODUCT TYPE: **Series 1**-FEMA 320/361 & ICC 500, Utility Brick Veneer Wall
Series 2-FEMA 320/361 & ICC 500, Modular Brick Veneer Wall
2.1 MODEL NUMBER: **N/A**
2.2 CONFIGURATION: See Article 3.0 Test Unit Description
2.3 SAMPLE SIZE: See Article 3.0 Test Unit Description
2.4 DOOR ASSEMBLY: See Article 3.0 Test Unit Description, see installation photos, pages 5-14.
2.5 DRAWINGS: See Appendix B Drawings.

3.0 TEST UNIT DESCRIPTION

3.0 TEST FRAME UNIT CONSTRUCTION: N/A
3.1 ASSEMBLY CONSTRUCTION:

3.1.1 **Series 1**- FEMA 320/361 & ICC 500, Utility Brick Veneer wall (4-ft. 8-in. x 4-ft. tall) with partially grouted and reinforced 8-in. CMU backup. Clay brick utility-sized veneer units, 2-in. cavity, CMU back-up partially grouted and reinforced with 1- #5 at 32-in. on center vertically and horizontally in top bond beam. Joint reinforcement and tie system was wire bond tab lock adjustable ladder and tie system, extra heavy duty, installed at 16-in. on center vertically with tabs at 16-in. on center horizontally. #5 grade 60 reinforcement was welded to the steel base channel.

3.1.2 **Series 2** – FEMA 320/361 & ICC 500, Modular Brick Veneer wall (4-ft. x 4-ft. tall) with partially grouted and reinforced 8-in. CMU backup. Clay brick modular-sized veneer units, 2-in. cavity, CMU back-up partially grouted and reinforced with 1- #5 at 24-in. on center. Joint reinforcement and tie system was wire bond tab lock adjustable ladder and tie system, extra heavy duty, installed at 16-in. on center vertically with tabs at 16-in. on center horizontally. #5 grade 60 reinforcement was welded to the steel base channel.

4.0 TEST RESULTS

4.1 SCOPE: Conduct impact tests for two brick veneer wall configurations.

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4.2 SUMMARY OF RESULTS:

Test Method	Test Conditions	Test Conclusion
Impact Test FEMA 320/361 & ICC-500 – Tornado Protocol 4, See Appendix A	Impacts **Series 1** FEMA 320/361 & ICC-500 utility brick veneer wall. **Series 2** FEMA 320/361 & ICC-500 modular brick veneer wall. Test projectile 15 lb. wooden 2-in. x 4-in. propelled at 100 mph.	**Series 1** utility brick veneer wall passed the required three impacts. **Series 2** modular brick veneer wall passed the required three impacts. See Conclusions Article 5.0

4.3 OUTDOOR WEATHER CONDITIONS:

Temperature	101 degrees
Wind	5 mph
Relative Humidity	14%
Barometric Pressure	29.85 in Hg

4.4 IMPACTS

Impact Speed: **Series 1 & 2 -** 100mph

Impacts Test

Series/Impact	Velocity (mph)	Location	Results
1/1	100.0	Panel center.	Vertical crack from top to bottom and missile perforation of brick. No damage to CMU, front or back; see photos, pages 15-18.
1/2	100.2	Lower right over reinforced column.	Opening of vertical crack to ¾-in. and brick destruction at impact area. No penetration of CMU; see photos, pages 19-22.
1/3	101.0	Lower left beside grouted cell.	Failure of left lower corner brick. No backside damage; see photos, pages 23--27.
2/1	102.3	Panel center.	Brick perforation with diagonal shear cracks at 22-in.; see photos, pages 28-31.
2/2	101.0	Lower right over grouted cell.	Destruction of brick at impact point; see photos, pages 32-33.
2/3	103.3	Upper left beside grouted core.	Cracking of corner; see photos, pages 34-39.

5.0 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:

An impact test was conducted by NWI on two brick veneer on partially reinforced 8-in. CMU wall configurations produced by International Masonry Institute. The tested products included:

(1) Series 1- FEMA 320 & ICC-500**,** Utility Brick Veneer Wall
(2) Series 2- FEMA 320 & ICC-500, Modular Brick Veneer Wall

These tests were consistent with the guidelines of FEMA 320/361 (2008) and ICC-500 (2008) Standard for "The Design and Construction of Storm Shelters." The panels were tested with impacts per the Test Protocol 4, Tornado. These impacts relate to a 250 mph ground speed tornado.

The impact tests conducted on the **Series 1 & Series 2** wall panels meet the guidelines set forth by FEMA 320/361 and the ICC-500 standards.

The manufacturer is advised to install warning signs inside the shelter that warns the occupants to not come in contact with the surfaces of the shelter and to wear hearing protection during a storm event. Any alterations made to the panel design or construction must be approved or retested by NWI at Texas Tech University.

All testing was in strict accordance to FEMA 320/361 (2008), and ICC-500 (2008).

Engineer of Record
Larry J. Tanner, P.E.

National Wind Institute
Debris Impact Facility- Texas Tech University
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Series 1 Utility Brick Veneer Wall

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Series 1 Utility Brick Veneer Wall Side View

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Series 1 Utility Brick Veneer Wall Backside View

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Series 1 Utility Brick Veneer Wall Close Up and Top View

Series 1 Utility Brick Veneer Wall Side View

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Series 2 Modular Brick Veneer Wall

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Series 2 Modular Brick Veneer Wall Side View

Series 2 Modular Brick Veneer Wall Backside View

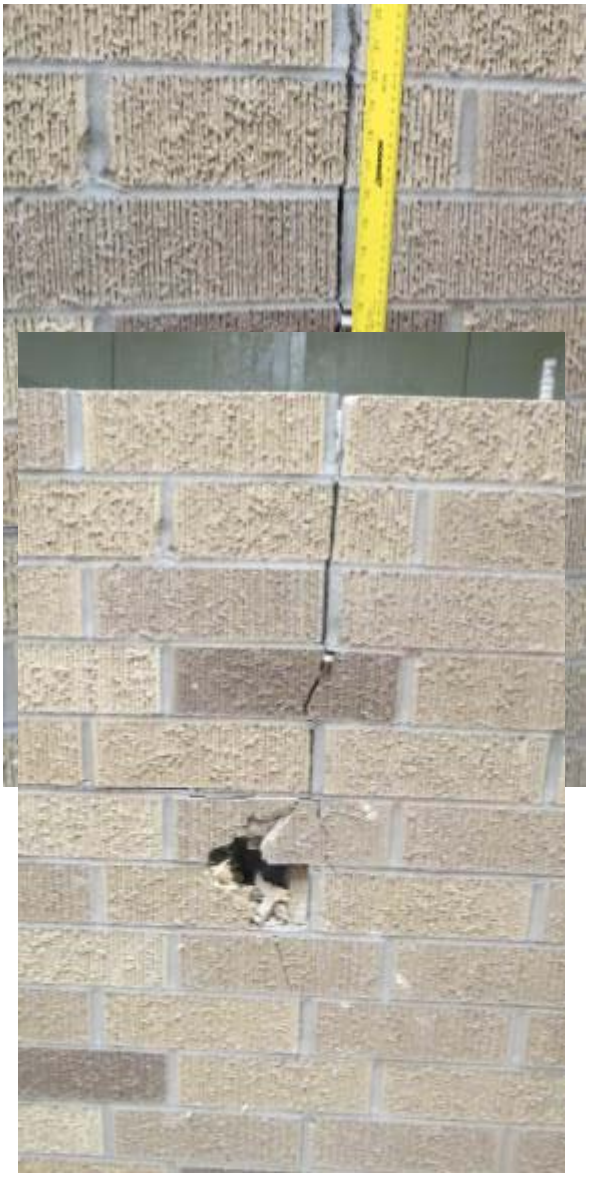
Series 2 Modular Brick Veneer Wall Cavity View

Series 2 Modular Brick Veneer Wall Cavity View

Series 1 Impact 1

Series 1 Impact 1 Horizontal Width of Impact

Series 1 Impact 1 Vertical Crack



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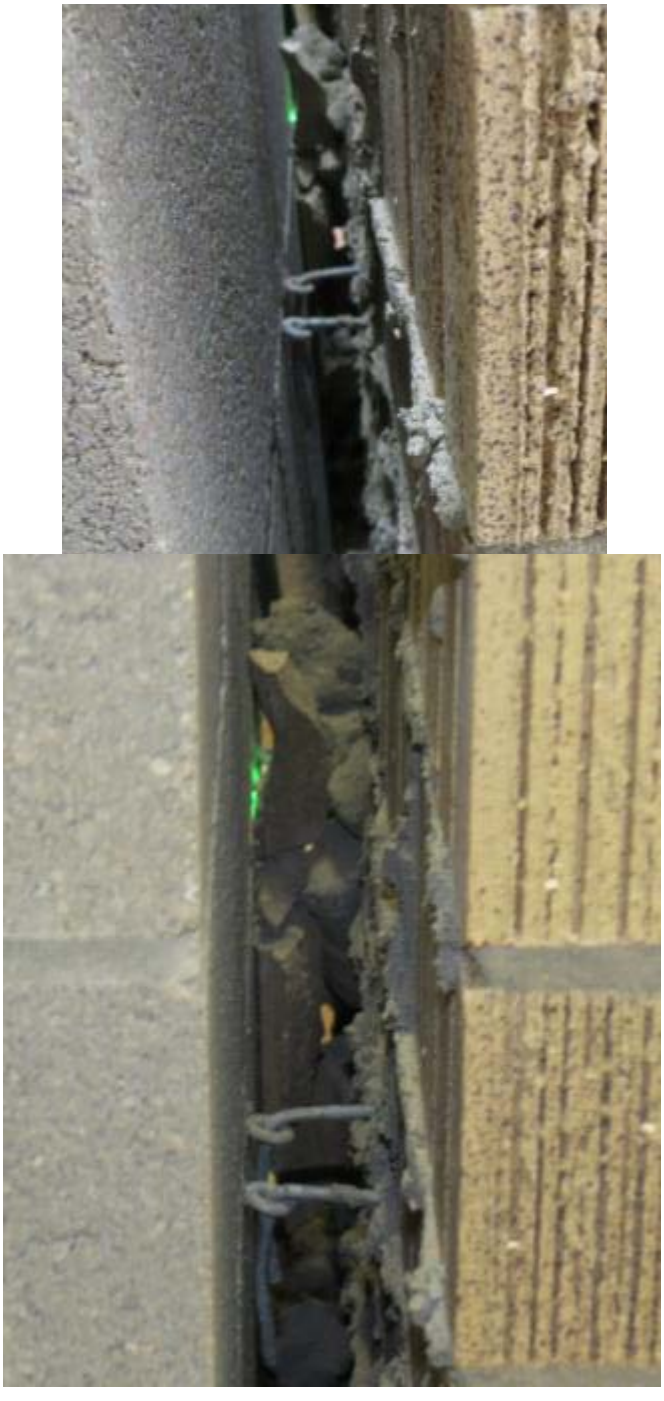
Series 1 Impact 1 Cavity View



Series 1 Impact 2

National Wind Institute
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P.O. Box 43155
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Report No. _20140604A
Specimen No. _____2 ____
Test Date: _June 4, 2014_

Series 1 Impact 2 Side View

Series 1 Impact 2 Close Up

Series 1 Impact 2 Vertical Crack Separation

Series 1 Impact 3

Series 1 Impact 3 Side View

Series 1 Impact 3 Close of Cavity and Impact Point

Series 1 Wall Backside View after Impacts

National Wind Institute
Debris Impact Facility- Texas Tech University
P.O. Box 43155
Lubbock, Texas 79409-1023

Report No. _20140604A
Specimen No. _____2 ____
Test Date: _June 4, 2014_

Series 1 Wall Holes Drilled to Prove Interior Reinforcement

National Wind Institute
Debris Impact Facility- Texas Tech University
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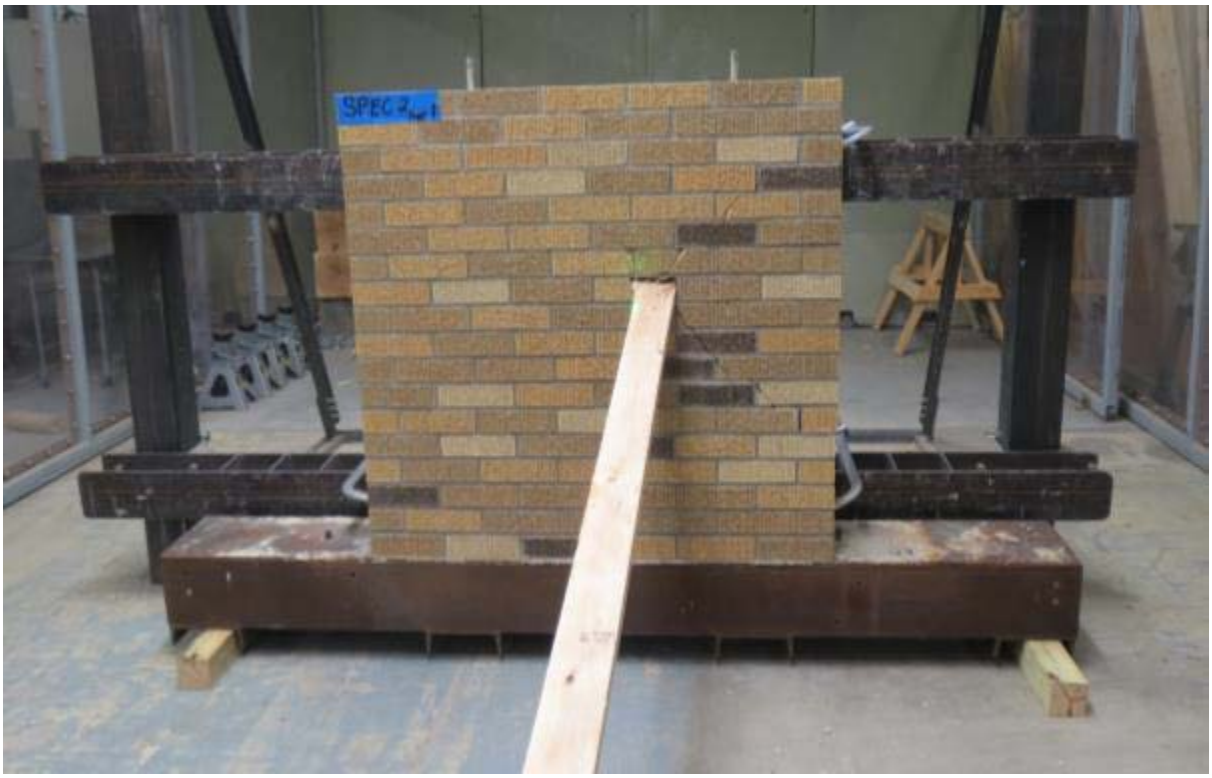
Lubbock, Texas 79409-1023

Report No. _20140604A
Specimen No. _____2 ____
Test Date: _June 4, 2014_

Series 2 Impact 1

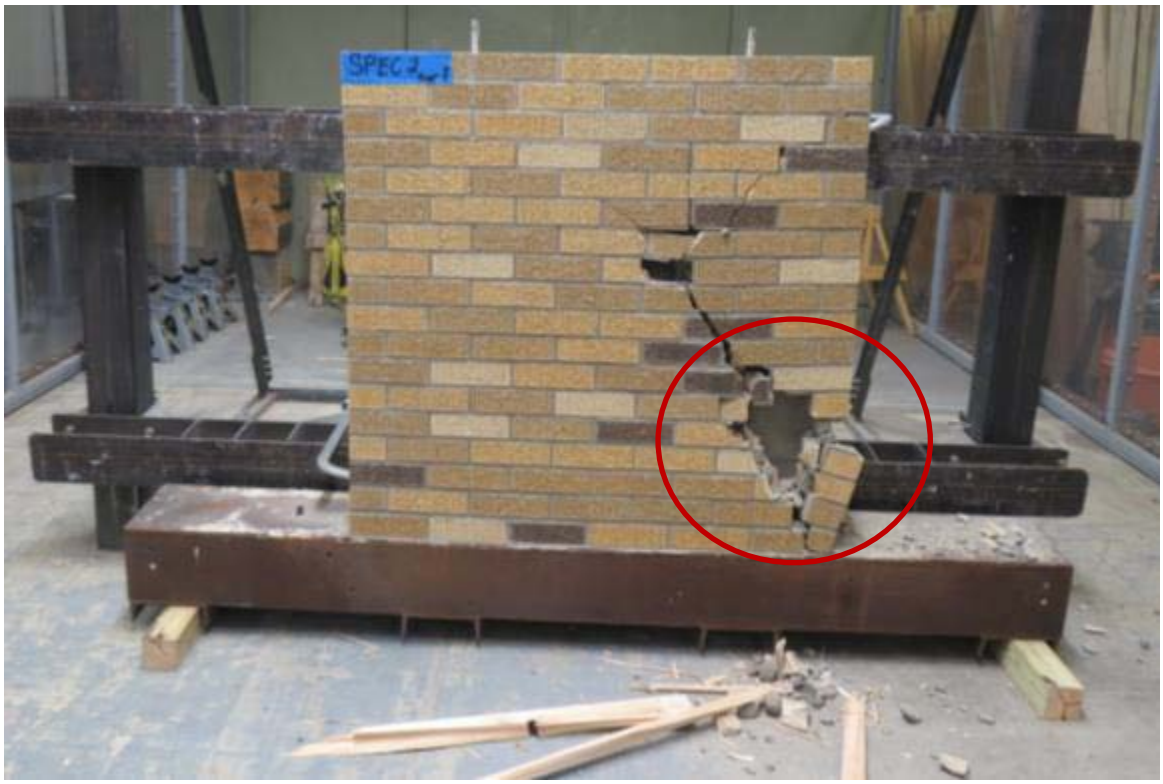


Series 2 Impact 1 Side Crack and Close Up

Series 2 Impact 1 Close Up of Diagonal Crack

Series 2 Impact 1 Close Up of Diagonal Crack

Series 2 Impact 2



Series 2 Impact 2 Close Up of Impact Point and Side View

Series 2 Impact 3

Series 2 Impact 3 Close Up of Impact Point

Series 2 Impact 3 Side View

Series 2 Impact 3 Separation and Top View

Series 2 Impact 3 Cavity View

Series 2 Impact 3 Cavity View

APPENDIX A.1 – TEST PROTOCOLS

The National Wind Institute, Debris Impact Test Facility (TTU NWI - DIF) at Texas Tech University (TTU) performs debris impact tests on storms shelters, shelter components, and building materials to evaluate their ability to resist various types of projectiles propelled at different speeds in accordance to accepted and proposed test protocols as follows:

A.1.1 - Protocols for Debris Impact Testing

Protocol 1	Hurricane envelope impact by a 9 lb. wood 2"x4" propelled at 34 mph, in accordance with the Florida Building Code, the International Code Council, and the Texas Dept. of Insurance windstorm Resistant Construction Guide.
Protocol 2	Hurricane shelter speed impact by a 9 lb. wood 2"x4" propelled at 0.40 x the design wind speed (mph) for horizontal impacts and 0.10 x the design wind speed (mph) for vertical impacts, in accordance to the proposed ICC 500[1] – ICC/NSSA Standard for the Design and Construction of Storm Shelters.
Protocol 3	Hurricane shelter speed impact by a 9 lb. wood 2"x4" propelled at 0.50 x the design wind speed (mph) for horizontal impacts and 0.33 x the design wind speed (mph) for vertical impacts, in accordance with FEMA 320, "Taking Shelter from the Storm," 2008 Edition and FEMA 361, "Design and Construction Guidance for Community Safe Rooms," 2008 Edition.
Protocol 4	Tornado shelter speed impact by a 15 lb. wood 2"x4" propelled at 100 mph for horizontal impacts and 67 mph for vertical impacts, in accordance with FEMA 320, "Taking Shelter from the Storm," 2008 Edition and FEMA 361, "Design and Construction Guidance for Community Safe Rooms," 2008 Edition, and the ICC-500 Standard for "The Design and Construction of Storm Shelters," 2008 Edition.[1]
Protocol 5	Department of Energy (DOE) Impact Standards

[1]The ICC 500 – ICC/NSSA Standard for the Design and Construction of Storm Shelters is a referenced standard in the 2009 editions of the International Residential Code and the International Business Code. This is a Life Safety Standard for protection from tornadoes and hurricanes. For hurricanes the Standard uses an Extreme Wind Map with wind speeds starting at 225 mph and with contours along the Atlantic and Gulf Coast stepping inland in 10 mph increments to 160 mph. Doors are required by ICC-500 to withstand design pressures + a design safety factor of 1.2.

A.1.2 - Introduction

All testing is conducted by a registered professional engineer (Engineer of Record). 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.

A.1.3 - 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 1886-05 & ASTM E 1996-06 "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;" FM 4473, "specification Test Standard for Impact Resistance Testing of Rigid Roofing Materials by Impacting with Freezer Ice Balls, July 2005; ICC 500 – "ICC/NSSA Standard for the Design and Construction of Storm Shelters;" and Texas Tech University, National Wind Institute'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 is addressed in Article A.1.1, Protocols 1-3 and uses a 9-lb. 2x4-in. wood board, called a missile. The missile speed therein described is a function of the guideline selected and the hurricane wind speed chosen from the guideline. The tornado test criterion found in Article A.1.1, Protocol 4, 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 250 mph tornado is a 15-lb. 2x4-in. board traveling at 67-mph (two-thirds the horizontal speed), striking perpendicular to the surface. The one-third criterion is used for surfaces horizontal to the ground and inclined less than 30-degrees. Lesser tornado missile impact speeds for decreased tornado wind speeds are included in the test regimen and are addressed in FEMA 361. Additional factors of safety are inherent in all of 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.

A.1.4 - Test Procedure

Shelter impacts are conducted in accordance to the Guidelines. Shelter appurtenances, vents, louvers, windows, or installed electrical equipment, shelving seats, etc., are impacted by a single missile if they are perceived by the Test Engineer of Record as vulnerable with regard to Life Safety.

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 A.1.3 - Test Criteria. Pressure tests are required for swinging door assemblies constructed to the Standards of The Steel Door Institute (SDI) and the Door and Hardware Institute (DHI). In accordance to FEMA 320, the residential shelter guideline, swinging door assemblies should be pressure tested away from the frame stops (soffits). In accordance to FEMA 361, the community shelter guideline, swinging door assemblies swing in the direction of egress and therefore normally tested away from the door stops (soffits). All pressure tests are conducted in accordance to ASTM E-330. Test pressures are dependent upon the storm wind speed selected and the location of the door in the building envelope and the wall height. A 1.20 safety factor must be included in the design pressures to meet the requirements of ICC-500.

A.1.5 - Pass/Fail Criteria

A.1.5.1 The criterion for the shelter/shell/panel test pass/fail is as follows:

A.1.5.1.1 The test subject must be impacted by a minimum of three missiles in the areas as described in Articles A.1.3 and A.14;

A.1.5.1.2 The missile may penetrate that test subject, but may not perforate the safe side (back face) of the subject;

A.1.5.1.3 The test subject's permanent deflection after impact must be less than 3-in.;

A.1.5.1.4 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

A.1.5.1.5 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.

A.1.5.2 Passage of the shelter door tests requires:

A.1.5.2.1 The door assembly must hold the required test pressures,

A.1.5.2.2 Resist perforation by the missiles,

A.1.5.2.3 Exhibit permanent deflection less than 3-inches,

A.1.5.2.4 Prevent disassociation of door components or shelter wall materials into the safe compartment,

A.1.5.2.5 Maintain locked and firmly attached, two door points of locking and hinging. FEMA 320/361 recognizes that one test missile can destroy or otherwise disengage one locking point or one hinge. The guideline therefore requires that at least two locking points remained engaged and doors with only two points of locking must have both locks remain engaged and locked at the conclusion of the impact tests. Doors do not have to be operable at the conclusion of the impact or pressure tests.

A.1.5.2.6 Pass/fail rating of the door relates to the full door assembly, including door, locking hardware, hinge, hinge screws, and door frame. Commonly specified frame-to-wall anchors must be equal to or greater than the shear strength of the total connectors used in the test.

A.1.6 - Test Equipment

A.1.6.1 Debris Impact Air Cannon:

A.1.6.1.1 Air Tank – 30 gallon, Manchester Model Number 301853.

A.1.6.1.2 Electric Over Air Valve – Matryx Model Number MX200 – 600501.

A.1.6.1.3 4-in. aluminum quick coupler to connect barrel to valve.

A.1.6.1.4 4-in. x 20-ft. long schedule 40 PVC barrel.

A.1.6.1.5 Pair Optical Timing Sensors – Keyence Model Number PZ251R and PZ125T 12/24-volt.

A.1.6.1.6 National Instruments (NI) Data Acquisition Card (DAC) with custom software installed on control panel computer.

A.1.6.1.7 Control panel with laser sighting and a three stage firing system.

A.1.6.1.8 Horizontal articulating cannon carriage with DC motor drive and variable speed controller.

A.1.6.1.9 Cannon carriage mounted to a hydraulic scissor lift on wheels - Autoquip Model Number 84B16F20.

A.1.6.1.10 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.

A.1.6.2 Testing Equipment Calibration

A.1.6.2.1 Digital scales, pressure gages, micrometers, and caliper are ISO 17025 calibrated and certified by an ISO 17025 calibration laboratory.

A.1.6.2.2 Projectile speed calibrated with Olympus iSpeed 3 HD 16 GB camera, 1280 x 1024 resolution @ 2,000 fps, maximum 150,000 fps..

A.1.7 - Use of Testing Report, TTU and NWI Logos

The written report and supplemental photos and/or videos may be referenced or distributed by your company. Texas Tech University (TTU) cannot endorse products. The name of the University or any of its units or personnel may only be used to identify the University unit responsible for the successful tests. Misuse or misrepresentation of the report, pictures, or logos will result in action being taken by the University against the responsible parties.

Storm shelter manufacturers or producers that have had products tested at Texas Tech University can use the Texas Tech University National Wind Institute (NWI) logo provided they conform to the following:

A.1.7.1 The Texas Tech University NWI logo may not be so prominent as to mislead the public or unduly play upon the Texas Tech University NWI name.

A.1.7.2 Whenever the logo is used, one of the two alternative statements below is to be employed in the text:

A.1.7.2.1 Tested – whole shelter:
The use of the Texas Tech University NWI logo signifies that the complete shelter structure was tested and successfully passed missile impact resistance tests at Texas Tech University.

A.1.7.2.2 Tested shelter component/product component:
The use of the Texas Tech University NWI logo does not signify that the entire shelter structure/entire product assembly was tested at Texas Tech, but rather only [shelter component/product component – name explicitly] was tested and successfully passed missile impact resistance tests at Texas Tech University.

A.1.7.3 Prominent use of the Texas Tech University NWI logo in advertising and promotional texts must be presented to the Texas Tech University Office of Technology Transfer and Intellectual Property for review and approval before distribution.

Texas Tech University will challenge any use of the Texas Tech University National Wind Institute logo that does not conform to the above standards.

APPENDIX B

Manufactures Drawings

MASONRY CAVITY WALL TORNADO MISSILE TESTING SPECIMEN 1 & SPECIMEN 2 SPECIFICATION

GENERAL:

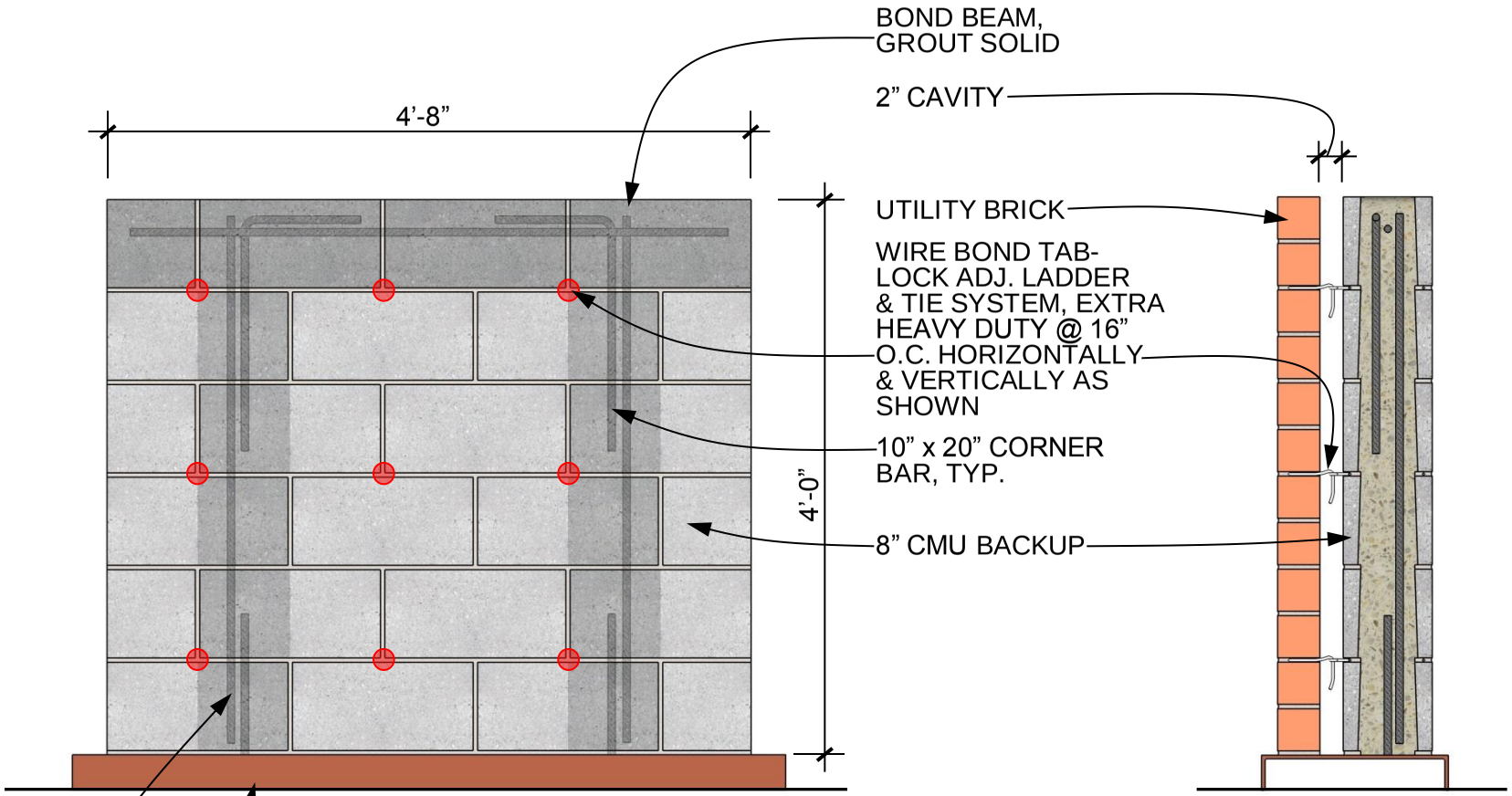
1. THE PROJECT CONSISTS OF TWO DIFFERENT CONFIGURATIONS OF MASONRY BRICK/CMU CAVITY WALLS AS SHOWN ON THE ATTACHED DRAWINGS AS SPECIMEN 1 AND SPECIMEN 2. CONSTRUCT 2 PANELS OF EACH SPECIMEN (TOTAL OF 4 SPECIMENS).
2. SPECIMEN 1 TO BE CLAY BRICK UTILITY-SIZED UNITS VENEER, 2-INCH CAVITY, CMU BACK-UP PARTIALLY GROUTED AND REINFORCED AT 32" C/C. REINFORCING & TIES AS SPECIFIED BELOW AND SHOWN ON DRAWINGS. (DO NOT GROUT THE SPECIMEN SOLID).
3. SPECIMEN 2 TO BE CLAY BRICK MODULAR-SIZED UNITS VENEER, 2-INCH CAVITY, CMU BACK-UP PARTIALLY GROUTED AND REINFORCED AT 24" C/C. REINFORCING & TIES AS SPECIFIED BELOW AND SHOWN ON DRAWINGS. (DO NOT GROUT THE SPECIMEN SOLID).
4. MASONRY CONSTRUCTION AND MATERIALS SHALL CONFORM TO THE REQUIREMENTS OF "SPECIFICATION FOR MASONRY STRUCTURES (TMS 602-11/ACI 530.1-11/ASCE 6-11)" PUBLISHED BY THE MASONRY SOCIETY, LONGMONT, COLORADO; THE AMERICAN CONCRETE INSTITUTE, FARMINGTON HILLS, MICHIGAN; AND THE AMERICAN SOCIETY OF CIVIL ENGINEERS, RESTON, VIRGINIA.

MATERIALS:

5. CONCRETE MASONRY UNITS TO MEET ASTM C-90, NORMAL-WEIGHT UNITS. PROVIDE BOND BEAM UNITS AS REQUIRED.
6. CLAY BRICK UNITS TO MEET ASTM C216, TYPE SW UNITS. SPECIMEN 1 TO HAVE UTILITY-SIZED UNITS. SPECIMEN 2 TO HAVE MODULAR-SIZED UNITS.
7. MORTAR TO MEET ASTM C270 TYPE S MORTAR – EITHER MASONRY CEMENT OR PORTLAND CEMENT-LIME ARE ACCEPTABLE.
8. SAND FOR MORTAR TO MEET ASTM C144 AND TO BE MEASURED IN LOOSE, DAMP CONDITION.
9. GROUT TO MEET THE PROPORTION REQUIREMENTS OF ASTM C 476 – FINE OR COARSE - WITH SLUMP BETWEEN 8" – 11".
10. JOINT REINFORCEMENT & TIE SYSTEM TO BE WIRE BOND TAB LOCK ADJUSTABLE LADDER & TIE SYSTEM, EXTRA HEAVY DUTY, INSTALLED AT 16" ON CENTER VERTICALLY WITH TABS AT 16"C/C HORIZONTALLY AS NOTED ON THE DRAWINGS.
11. ALL STEEL REINFORCEMENT SHALL BE DEFORMED BARS CONFORMING TO ASTM A-615 GRADE 60. BENT BARS TO BE FABRICATED NOT FIELD-FORMED.

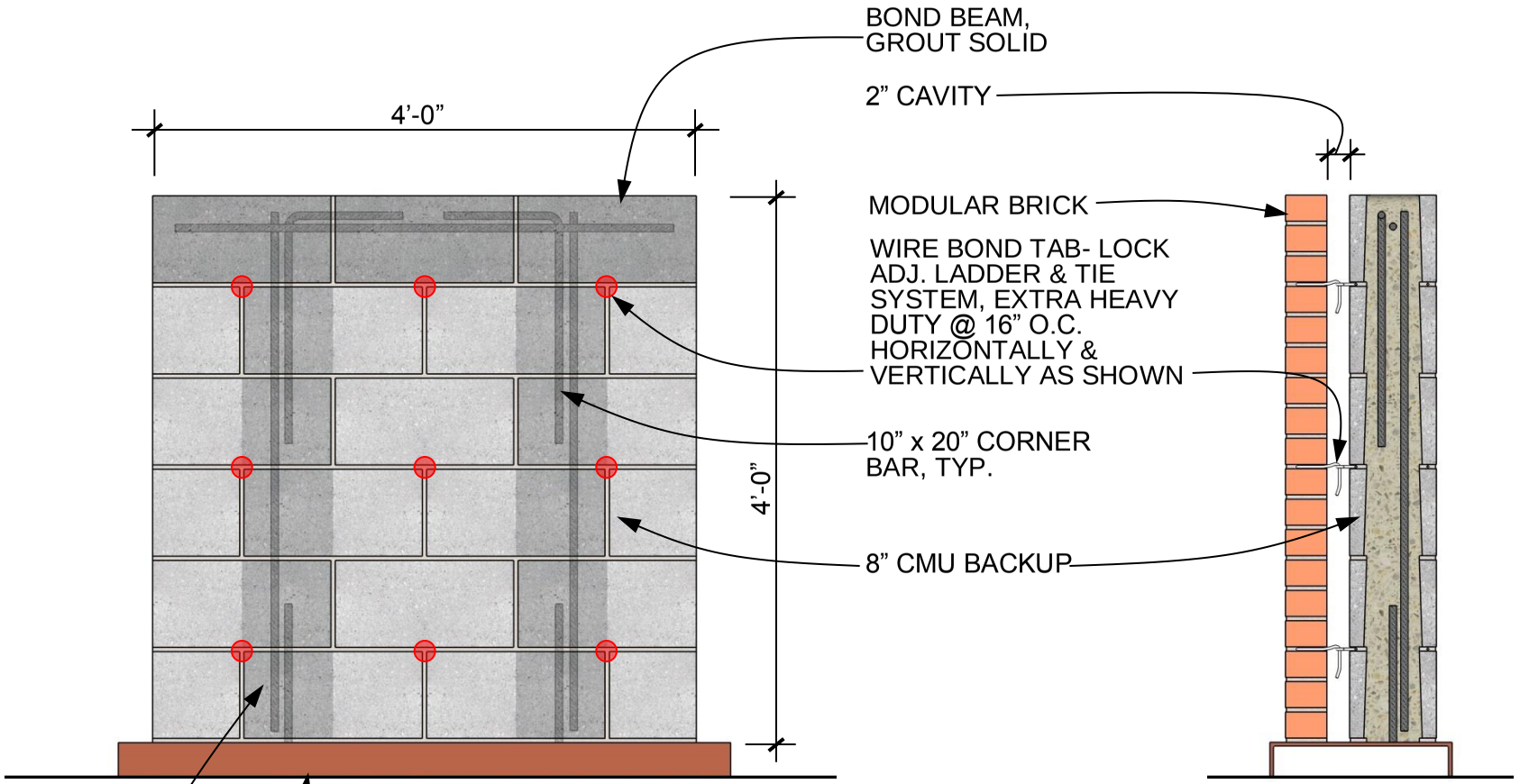
WORKMANSHIP:

12. ALL MASONRY WORK TO BE LAID IN RUNNING BOND.
13. CLAY BRICK UNITS TO BE LAID IN FULL HEAD AND BED JOINTS WITH TOOLED HEAD AND BED JOINTS ON THE EXTERIOR FACE.
14. CMU UNITS TO BE FACE SHELL BEDDED WITH HEAD JOINT DEPTH EQUAL TO THE FACE SHELL OR GREATER. TOOLED HEAD AND BED JOINTS ON THE INTERIOR FACE.
15. ISOLATE CELLS TO RECEIVE GROUT PRIOR TO GROUT PLACEMENT. SPECIMEN 1 HAS VERTICAL REINFORCEMENT AT 32" ON CENTER AS SHOWN ON DRAWING. SPECIMEN 2 HAS VERTICAL REINFORCMENT AT 24" ON CENTER AS SHOWN ON DRAWING.
16. GROUT PLACEMENT AND CONSOLIDATION SHALL CONFORM TO TMS 602/ACI 530.1/ASCE 6.
17. SOLIDLY GROUT BOND BEAM FILLING FULL AND TOPPING, IF REQUIRED, AFTER CONSOLIDATION BUT BEFORE GROUT ACHIEVES INITIAL SET.
18. ALL WORK SHALL BE LAID TRUE TO A LINE, PLUMB AND LEVEL IN KEEPING WITH THE TOLERANCES GIVEN IN "SPECIFICATIONS FOR MASONRY STRUCTURES (TMS 602-11/ACI 530.1-11/ASCE 6-11)".



SPECIMEN 1 UTILITY BRICK VENEER W/ PARTIALLY GROUTED & REINFORCED CMU BACKUP

REV. 5/19/14 N.T.S.



NOTES: ALL REINFORCEMENT #5 GRADE 60.
GROUT AT SHADED AREAS ONLY.
● = TAB-LOCK LOCATIONS.

SPECIMEN 2 MODULAR BRICK VENEER W/ PARTIALLY GROUTED & REINFORCED CMU BACKUP

REV. 5/19/14 N.T.S.