Appendix K:
Guidance for Selection of Impact Resistant Constructed Wall and Roof Assemblies

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K.0 STRUCTURAL MISSILE IMPACT CRITERIA

The public shelter design criteria, which are also known as the EHPA criteria, require that exterior walls and roofs prevent perforation or penetration by windborne debris. Laboratory testing is the primary means of determining if a specific assembly (i.e., exterior and interior surface cladding, structural components and configurations, material properties, connections, etc.) is capable of satisfying the applicable performance criteria. Certain types of commonly used non-proprietary materials and constructed assemblies have been demonstrated through laboratory testing to satisfy the required debris impact performance criteria. Constructed assemblies that are approved for use without further testing by the authority having jurisdiction are commonly referred to as "deemed to comply." The deemed to comply method is recognized in section 1626.4, FBC—Building. Appendix K has been prepared to assist designers with selection of constructed wall and roof assemblies that have been tested and satisfy applicable large missile impact criteria.

Please note that the Department of Education has stated that roof assemblies must be tested and certified to meet SSTD 12 as an assembly. This applies to district school board and community college facilities. With the exception of code prescripted concrete deck assemblies, "deemed to comply" assemblies will not be approved by the Department of Education. Therefore, "deemed to comply" assemblies are only applicable to other state and local agency facilities.

The Florida Department of Education's list of approved roof decks can be found at the following web address:

http://www.fldoe.org/edfacil/formsplanreview.asp

K.1 METHODOLOGY

To begin the assembly selection process, it is critical to determine the design wind velocity of the EHPA. Higher windfield velocities impart higher velocities to entrained debris. Higher wind velocities can also lift and accelerate larger and heavier debris objects, as well as extend the distance downwind that an object can travel. As a planning guide, unanchored, inadequately anchored or poorly constructed large debris can be generated from sources within a distance of about 300 feet of proposed or constructed EHPA(s). Smaller debris down to the size of gravel can be generated from sources out to a range of possibly 1,500 feet. Research considered by the ICC storm shelter standard committee indicates that objects lifted by wind forces undergo rapid acceleration and achieve velocities of between 40 and 80 percent of the entraining windfield's velocity. Thus the lower bound for representative missiles require test velocities of at least 40 percent of the proposed design wind speed.

The industry-recognized straight wind (which include hurricane) large missile that is used for impact testing is a nine pound sawn lumber 2x4 (9 lb 2x4). The industry-recognized 9 lb 2x4 large missile is also the missile required to satisfy the EHPA code provisions. For those school districts that are interested in incorporating tornado protection into an EHPA construction project, national guidance currently recommends that the large missile be increased to a 15 pound sawn lumber 2x4 (15 lb 2x4). In addition to tornado applications, the Division also recommends increasing the large missile requirement to a 15 lb 2x4 for EHPA's that may be subjected to an unusual barrage of heavy debris (e.g., building materials and mechanical equipment).

Debris impact testing of wall and roof assemblies has generally been conducted using a limited number of specified conditions (e.g., 9 and 15 lb 2x4s propelled at 34, 50, 75 and 100 miles per hour). Many of the more robust materials and assemblies, such as reinforced concrete and solid-grouted masonry, have satisfied test requirements that are significantly more demanding than the EHPA code-required SSTD 12. Another factor considered by the Division is that current research indicates that an object's impact momentum, and not energy, provides the best correlation of test performance of a specified assembly when comparing missiles of different weights and velocities. Calculating the momentum associated with a published sample's impact test conditions permits the data to be converted to the industry standard straight wind 9 lb 2x4 missile. Impact momentum is calculated as follows: missile weight (lb) / acceleration of gravity (32.2 ft/sec^2) x missile velocity (ft/sec) = momentum (lb-sec). It should be noted that in addition to momentum values, Tables K-1 and K-2 provide corresponding impact energy values to assist with conversion when the impact energy of a test is known, but momentum is not calculated.

The following reference data sources were used to compile the list of assemblies given in Table K-3. Windborne Debris Impact Resistant Wall Assemblies, and Table K-4. Windborne Debris Impact Resistant Roof Assemblies:

1. *Large Wind Missile Impact Performance of Public and Commercial Building Assemblies*, Florida Agricultural and Mechanical University-Florida State University (FAMU-FSU) in cooperation with the University of Florida (UF), 2004
2. *Summary Report on Debris Impact Testing at Texas Tech University*, Texas Tech University (TTU), 2003
3. *Design and Construction Guidance for Community Shelters* (FEMA 361), Federal Emergency Management Agency, 2000

These reference sources can provide additional guidance on selection of suitable wall and roof assemblies for both hurricane and tornado shelters.

To match the existing data sources' test conditions with a practical range of corresponding design wind speeds, the Division consolidated the data into categories defined as "Levels of Protection." The test performance required to satisfy each level of protection category is bounded by the respective category's highest hurricane design

wind speed. As an example, Enhanced-B's design wind speed range is 165 to 200 miles per hour (mph), therefore the assembly must satisfy a laboratory missile test equal to a 9 lb 2x4 propelled at 80 mph (200 x 0.40 = 80).

The lowest level of protection, which is referred to by the Division as "Basic-D," is equal to the large missile test requirements of SSTD 12 and ASTM E 1996 Missile Level D (i.e., 9 lb 2x4 propelled at 34 mph). Basic-D is the minimum code requirement for EHPA walls and roofs. ASTM E 1996 also establishes an "Enhanced Protection" requirement for essential facilities, which includes designated hurricane shelters. ASTM E 1996's enhanced missile is defined as Missile Level E and increases the test velocity of the 9 lb 2x4 to 55 mph. For the purposes of this appendix, ASTM E 1996's Missile Level E is referred to as "Basic-E." The reference sources used by the Division for preparation of this appendix do not provide test data specific to ASTM E 1996's Missile Level E.

The Division's Enhanced-A level of protection corresponds to design wind speeds of 141 to 160 mph (3-second gust), which is consistent for EHPA's that are designed to include the code recommended addition of 40 mph to ASCE 7's basic design wind speed, and proposed to be located in ASTM E-1996's Wind Zones 1, 2 and 3 (i.e., basic wind speeds < 141 mph). The Enhanced-A missile requirement is equal to a 9 lb 2x4 propelled at 65 mph. The 141 to 160 mph design wind speed range is also consistent with a Saffir-Simpson Scale hurricane Category 3 (i.e., 135 mph to 159 mph, 3-second gust).

The Division's Enhanced-B level of protection corresponds to design wind speeds of 161 to 200 mph (3-second gust), which is consistent for EHPA's that are designed to include the code recommended addition of 40 mph to ASCE 7's basic design wind speed, and proposed to be located in ASTM E-1996's Wind Zone 4 (i.e., basic wind speeds > 140 mph). The Enhanced-B missile requirement is equal to a 9 lb 2x4 propelled at 80 mph. Conveniently, the 9 lb 2x4 propelled at 80 mph test missile has approximately the same impact momentum as the Department of Energy's recommended straight wind missile criteria, which is a 15 lb 2x4 propelled at 50 mph (15 lb 2x4 @ 50 mph). The 15 lb 2x4 @ 50 mph is a commonly used test so there are several wall and roof assemblies that have been demonstrated to satisfy its performance requirements. The 161 to 200 mph design wind speed range is also consistent with a Saffir-Simpson Scale hurricane Category 4 (i.e., 160 mph to 189 mph, 3-second gust).

The Enhanced-C level of protection exceeds the EHPA's design wind speed range, and includes hurricane design wind speeds of 201 to 250 mph. Design wind speeds in this range are consistent with a Saffir-Simpson Scale hurricane Category 5 and are provided for comparison purposes only. Enhanced-D and Enhanced-E levels of protection are consistent with tornado missile test criteria established in ICC 500, FEMA 361 and other national guidance publications for EF3 and EF4&5 tornadoes respectively.

It should be noted that Tables K-1 and K-3 provide criteria for exterior envelope vertical surfaces, such as walls. Exterior envelope surfaces that are inclined less than 30 degrees from horizontal are considered horizontal surfaces, and Tables K-2 and K-4 apply. For the purposes of this appendix, the missile velocity requirement for horizontal

surfaces is assumed to be 67 percent of that required for the respective vertical surface. This is consistent with tornado missile test criteria found in ICC 500, FEMA 361 and other national guidance publications. This is conservative since hurricane missile requirements for horizontal surfaces may only be 25 percent of that required for vertical surfaces, but negligible data is available for such low impact criteria. Also, weak to moderate tornadoes and other isolated wind disturbances can be embedded in hurricanes, which can cause severe local impacts. Therefore, the use of the tornado missile requirement for horizontal surfaces of hurricane shelters is not exceptionally conservative.

K.2 SELECTION OF WALL OR ROOF ASSEMBLIES

With the type of wind event (straight or tornado wind) and design wind speed established, the designer or specifying authority can select an appropriate windborne debris impact level of protection that best suits performance expectations. The levels of protection categories simplify the selection of appropriate wall and roof assemblies to match the EHPA's design wind speed. As an example, for an EHPA with a hurricane design wind speed of 140 mph the representative missile's lower bound velocity is equal to 40 percent of the design wind speed, or 56 mph (170 x 0.40 = 68). Instead of searching for test results specific to a 9 lb 2x4 propelled at 68 mph (9 lb 2x4 @ 68 mph), the designer or specifying authority can select the level of protection applicable to 170 mph from Table K-1 (for vertical surfaces), which is an "Enhanced-B" level of protection; i.e., design wind speed between 161 and 200 mph. The Enhanced-B determination will also concurrently apply to the building's horizontal surfaces, such as roofs.

With the level of protection determined for both vertical and horizontal surfaces, the designer or specifying authority then selects a wall and roof assembly from Tables K-3 and K-4, respectively, that satisfies the minimum required impact momentum resistance criteria. Tables K-3 and K-4 provide the following information:

Column 1 (left-most column) – A wall/roof number for reference purposes

Column 2 – Assembly Type, such as wood, metal, CMU/masonry, reinforced concrete, etc; light wood and metal stud framing is included under wood assembly type, and brick masonry over sheathing material and light wood or metal framing is also included under wood assembly type

Column 3 – Assembly description, which includes inside and outside sheathing materials (if any) and nominal dimensions, reinforcement and connections as applicable

Column 4 – Data source, which can be used as reference for additional information; the data sources are:

1. *Large Wind Missile Impact Performance of Public and Commercial Building Assemblies,* Florida Agricultural and Mechanical University-Florida State University (FAMU-FSU) in cooperation with the University of Florida (UF), 2004
2. *Summary Report on Debris Impact Testing at Texas Tech University,* Texas Tech University (TTU), 2003
3. *Design and Construction Guidance for Community Shelters* (FEMA 361), Federal Emergency Management Agency, 2000

Column 5 – Level of Protection, which is subdivided into Basic-D (9 lb 2x4 @ 34 mph) and Enhanced-A (9 lb 2x4 @ 65 mph) through Enhanced-D/Tornado EF2 (15 lb 2x4 @ 85 mph); Column 5 also lists the respective impact momentum associated with each level of protection

Under the listed levels of protection in Column 5, the specified test performance results are given as "Satisfied the Test Criteria" (S); "Failed the Test Criteria" (F); or "No Data/Not Determined" (ND). For assemblies that fail at a given level of protection, the higher performance requirements are listed as "---."

All dimensions are subject to conventional industry tolerances unless noted otherwise. The order of materials given in each assembly description is listed from the outside/outer most surface material (opposite the occupied shelter space), then inwards toward the inside finish surface material (if any). The missile impact is assumed to be on the outside surface. The order of installation is important, since some of the assemblies rely on flexure to resist (or absorb) the impact forces (e.g., for Wall No. 7, the 14 ga. expanded steel sheeting must be located between the double 2x4 wood stud supports on the inside of the assembly, and the two layers of 3/4 inch plywood located at the outer most surface).

Tables K-3 and K-4 provide nominal reinforcement and connection information. The building designer of record is responsible for determining all design loads and specifying all structural elements and connections in accordance with applicable material design standards, codes, rules, regulations and manufacturer's instructions. The Division strongly recommends that design wind pressures for components and cladding be calculated with directionality factor (K_d) = 1.0 and wind exposure category = C.

Note that there is insufficient data available to establish a stand-alone Basic-E level of protection category. Therefore, in the absence of specific tests performed to satisfy Basic-E, the Division recommends use of the Enhanced-A level of protection category for design wind speeds that are less than 140 mph.

Table K-1. Windborne Debris Impact Criteria Comparisons for Vertical Surfaces

Level of Protection, Vertical Surface	Hurricane Design Wind Speed, mph (3-sec. gust)	Missile Weight, lbs	Missile Velocity, mph	Missile Velocity, ft/sec	Energy, ft-lb	Momentum, lb-sec
Basic-D	85 or less	9	34	50	349	14
Basic-E	86-140	9	50	74	765	21
Basic-E	86-140	9	55	80	894	22
Enhanced-A	141-160	9	60	88	1,082	25
Enhanced-A*	**141-160**	**9**	**65**	**95**	**1,261**	**27**
Enhanced-B	161-200	9	70	103	1,483	29
Enhanced-B	161-200	9	75	110	1,691	31
Enhanced-B*	**161-200**	**9**	**80**	**117**	**1,913**	**33**
Enhanced-C	201-250	9	85	125	2,184	35
Enhanced-C	201-250	9	90	132	2,435	37
Enhanced-C	201-250	9	95	139	2,700	39
Enhanced-C*	**201-250**	**9**	**100**	**147**	**3,020**	**41**
Enhanced-B	161-200	15	50	74	1,275	34
Enhanced-C	201-250	15	55	80	1,491	37
Enhanced-C	201-250	15	60	88	1,804	41
Enhanced-D*	**EF3 Tornado**	**15**	**85**	**125**	**3,639**	**58**
Enhanced-E*	**EF4 & 5 Tornado**	**15**	**100**	**147**	**5,033**	**68**

*-Denotes missile impact criteria (weight and velocity) selected to represent the specified level of protection.

Table K-2. Windborne Debris Impact Criteria Comparisons for Horizontal Surfaces

Level of Protection, Horizontal Surface**	Hurricane Design Wind Speed, mph (3-sec. gust)	Missile Weight, lbs	Missile Velocity, mph	Missile Velocity, ft/sec	Energy, ft-lb	Momentum, lb-sec
Basic-D***	85 or less	9	23	34	162	10
Basic-E***	86-140	9	33	48	322	13
Basic-E***	86-140	9	37	54	408	15
Enhanced-A	141-160	9	40	57	454	16
Enhanced-A*	**141-160**	**9**	**44**	**65**	**590**	**18**
Enhanced-B	161-200	9	47	69	665	19
Enhanced-B	161-200	9	50	74	765	21
Enhanced-B*	**161-200**	**9**	**54**	**79**	**872**	**22**
Enhanced-C	201-250	9	57	84	986	23
Enhanced-C	201-250	9	60	88	1,082	25
Enhanced-C	201-250	9	64	94	1,235	26
Enhanced-C*	**201-250**	**9**	**67**	**98**	**1,342**	**27**
Enhanced-B	161-200	15	33	48	537	22
Enhanced-C	201-250	15	37	54	679	25
Enhanced-C	201-250	15	40	57	757	27
Enhanced-D*	**EF3 Tornado**	**15**	**57**	**84**	**1,643**	**39**
Enhanced-E*	**EF4 & 5 Tornado**	**15**	**67**	**98**	**2,237**	**46**

*-Denotes missile impact criteria (weight and velocity) selected to represent the specified level of protection.
**-Horizontal surface impact loading velocity is based on tornado factor of 0.67 of vertical surface velocity.
***-SSTD 12, ASTM E 1886 and E 1996 and the structural requirements of Section 423.25.4, FBC do not permit a reduction in basic missile test velocity due to an assembly's horizontal surface orientation.

Table K-3. Windborne Debris Impact Resistant Wall Assemblies

Wall No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
1	Wood	One layer 1/2 inch CD grade plywood on metal or 2”x4” wood studs	1	F	---	---	---	---
2	Wood	Stucco veneer on one layer 1/2 inch CD grade plywood, OSB, GWB or rigid insulation on metal or 2”x4” wood studs	1	F	---	---	---	---
3	Wood	One layer 3/4 inch CD grade plywood on double 2”x4” wood studs (4”x4”)	2	S	F	---	---	---
4	Wood	Two layers 3/4 inch CD grade plywood on double 2”x4” wood studs (4”x4”)	2	S	S	F	---	---
5	Wood	One layer 1/2 inch CD grade plywood with masonite siding on 2”x4” wood studs	2	ND	ND	F	---	---
6	Wood	One layer 1/2 inch CD grade plywood with 5/16 inch hardiboard siding, metal or 2”x4” wood studs	1	F	---	---	---	---

Table K-3. Windborne Debris Impact Resistant Wall Assemblies

Wall No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
7	Wood	Two layers 3/4 inch CD grade plywood, 14 ga. sheet steel liner and double 2”x4” wood studs (4”x4”)	2	S	S	S	S	S
8	Wood	4 inch brick veneer, 1/2 inch CD grade plywood sheathing and 2”x4” wood studs at 24 in oc	1	S	S	F	---	---
9	Wood	4 inch brick veneer, 7/16 inch OSB sheathing on 2”x4” wood studs at 24 in oc	1	S	S	F	---	---
10	Wood	24 ga. or 26 ga. galv. metal siding on 1/2 inch CD grade plywood and 2”x4” wood stud	1	S	F	---	---	---
11	Wood	24 ga. or 26 ga. galv. metal siding on 7/16 inch OSB and 2”x4” wood stud	1	S	F	---	---	---
12	Metal	24 ga. or 26 ga. (50 ksi) galv. metal panels on Z 8.25, 14 ga. girts @ 5 feet oc	1	S	ND	ND	ND	ND
13	Metal	24 ga. (50 ksi) galv. metal panels on Z 8.0, 16 ga. girts @ 3 feet oc	1	S	S	S	ND	ND
14	Metal	24 ga. (80 ksi) galv. metal panels on Z 8.0, 16 ga. girts @ 3 feet oc	1	S	S	S	ND	ND

Table K-3. Windborne Debris Impact Resistant Wall Assemblies								
Wall No.	**Assembly Type**	**Assembly Description**	**Data Source**	**Level of Protection**				
				Basic D	**Enhanced A**	**Enhanced B**	**Enhanced C**	**Enhanced D**
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
15	Metal	20 ga. or 22 ga. (50 ksi) metal panels on Z 8.25, 16 ga. girts @ 3 feet oc	1	S	S	S	ND	ND
16	CMU	8, 10 and 12 inch hollow cell CMU with #4 or larger rebar vertical reinforcement in grout filled cells as required for wind design; truss-type horizontal reinforcement in joints @ 16 inches oc	1,2	S	F	---	---	---
17	CMU	8 inch structural pea-gravel grout filled CMU reinforced with #4 or larger rebar as required for wind design; truss-type horizontal reinforcement in joints @ 16 inches oc	2	S	S	S	S	ND
18	CMU	4 inch brick veneer with 8, 10 or 12 inch hollow cell CMU back-up reinforced with #4 or larger rebar as required for wind design; truss-type horizontal reinforcement in joints @ 16 inches oc	1	S	S	ND	ND	ND

Table K-3. Windborne Debris Impact Resistant Wall Assemblies

Wall No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
19	CMU	6 inch structural pea-gravel grout filled CMU reinforced with #4 or larger rebar in every cell; truss-type horizontal reinforcement in joints @ 16 inches oc	2,3	S	S	S	S	S
20	CMU	8, 10 or 12 inch structural pea-gravel grout filled CMU reinforced with #4 or larger rebar in every cell; truss-type horizontal reinforcement in joints @ 16 inches oc	2,3	S	S	S	S	S
21	RC	2 inch pea-gravel concrete with #4 rebar at 12 inches oc each way	2	S	F	---	---	---
22	RC	3 inch pea-gravel concrete with #4 rebar at 12 inches oc each way	2	S	S	S	S	S
23	RC	4 inch to 6 inch pea-gravel concrete reinforced with #4 rebar at 12 inches oc each way	2	S	S	S	S	S
24	RC	5 inch pea-gravel concrete tilt-up wall panel reinforced with #5 rebar at 12 inches oc longitudinal and #3 rebar at 12 inches oc temperature reinforcement	1	S	S	ND	ND	ND

Table K-3. Windborne Debris Impact Resistant Wall Assemblies

Wall No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
25	RC	6 inch pea-gravel concrete panel reinforced with #4 rebar at 12 inches oc each way	2,3	S	S	S	S	S
26	RC	6 inch pea-gravel concrete panel reinforced with #4 rebar at 24 inches oc each way	2	S	S	S	S	S
27	RC	8 inch to 10 inch pea-gravel concrete reinforced with #4 rebar at 12 inches oc each way, placed 1-1/2 inches from each face	2	S	S	S	S	S
28	RC	11 inch brick cavity masonry wall with cavity filled with pea-gravel concrete and reinforced with #4 rebar at 12 inches oc each way	2	S	S	S	S	S
29	ICF	6 inch (or thicker) ICF wall panels with concrete at least 4 inches thick and reinforced with #4 rebar at 12 inches oc each way	1,2	S	S	S	S	ND
30	ICF	6 inch (or thicker) ICF waffle-grid wall section reinforced with #5 rebar every 12 inches vertically and #4 rebar every 16 inches horizontally	1,2	S	S	S	S	ND

Table K-3. Windborne Debris Impact Resistant Wall Assemblies

Wall No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				14	27	33	41	58
31	AAC	8x8x24 Autoclaved Aerated Concrete wall panel	1	S	F	---	---	---

S = Satisfied the Test Criteria
F = Failed the Test Criteria
ND = No Data/Not Determined

Table K-4. Windborne Debris Impact Resistant Roof Assemblies

Roof No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				10	18	22	27	39
1	Wood	One layer 1/2 inch CD grade plywood or 7/16 inch OSB on metal or wood joist or truss with wood, clay or asphalt shingle roof cover	1	F	---	---	---	---
2	Wood	One layer 19/32 inch or thicker CD grade plywood on metal or wood joist or truss with wood, clay or asphalt shingle roof cover	1	S	F	---	---	---
3	Wood	24 ga. or 26 ga. galv. metal roof cover on 1/2 inch or thicker CD grade plywood on metal or wood joist or truss	1	S	ND	ND	ND	F
4	Metal	24 ga. or 26 ga. (50 ksi) galv. metal panels on 16 ga. purlins @ 2 feet oc	1	S	S	S	ND	ND
5	Metal	20 ga. or 22 ga. (50 ksi) metal panels on Z 8.25, 16 ga. purlins @ 2 feet oc	1	S	S	S	ND	ND
6	Metal	1-1/2 inch 20 ga. or 22 ga. Type B, Grade 33 structural metal deck over Z 8.25 girt supports @ 5 feet oc with 26 ga. galv. metal roof cover	1	S	S	S	S	S

Table K-4. Windborne Debris Impact Resistant Roof Assemblies

Roof No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				10	18	22	27	39
7	Metal	1-1/2 inch 20 ga. or 22 ga. Type B, Grade 33 structural metal deck over supports @ 4 feet oc with 26 ga. galv. metal roof cover	1	S	S	S	S	S
8	Metal	3 inch 22 ga. structural metal deck	1	S	S	S	S	F
9	RC	CIP 2 inch pea-gravel concrete with #4 rebar at 12 inches oc each way	2	S	S	F	---	---
10	RC	CIP 3 inch pea-gravel concrete with #4 rebar at 12 inches oc each way	2	S	S	S	S	S
11	RC	CIP 4 inch to 6 inch pea-gravel concrete reinforced with #4 rebar at 12 inches oc each way	2	S	S	S	S	S
12	RC	CIP 8 inch to 10 inch pea-gravel concrete reinforced with #4 rebar at 12 inches oc each way, placed 1-1/2 inches from each face	2	S	S	S	S	S
13	RC	4 inch or thicker concrete panel reinforced with #4 rebar at 12 inches oc each way	1,2	S	S	ND	ND	ND
14	RC	Precast 6 inch reinforced concrete hollow core slab	1	S	S	S	S	ND

Table K-4. Windborne Debris Impact Resistant Roof Assemblies

Roof No.	Assembly Type	Assembly Description	Data Source	Level of Protection				
				Basic D	Enhanced A	Enhanced B	Enhanced C	Enhanced D
				Minimum Required Impact Momentum Resistance, lb-sec				
				10	18	22	27	39
15	RC	Precast 8, 10 or 12 inch reinforced concrete hollow core slab	1	S	S	S	S	S

S = Satisfied the Test Criteria
F = Failed the Test Criteria
ND = No Data/Not Determined