ICC-ES Evaluation Report

ESR-2015P*

Reissued April 2014

This report is subject to renewal April 1, 2015.

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DIVISION: 07 00 00—THERMAL AND MOISTURE PROTECTION
Section: 07 32 13—Clay Roof Tiles

DIVISION: 07 00 00—THERMAL AND MOISTURE PROTECTION
Section: 07 32 16—Concrete Roof Tiles

REPORT HOLDER:

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EVALUATION SUBJECT

CONCRETE AND CLAY ROOF TILE INSTALLATION MANUAL FOR MODERATE CLIMATE REGIONS

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2012 and 2009 *International Building Code®* (IBC)
- 2012 and 2009 *International Residential Code®* (IRC)
- 1997 *Uniform Building Code®* (UBC)

Property evaluated:

Concrete and clay roof tile installation

2.0 USES

The Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions, published by the Tile Roofing Institute Inc. and the Western States Roofing Contractors Association, and dated March 2010 (the manual), describes a method for installation of concrete and clay roof tiles that is an alternative to IBC Section 1507.3.7, IRC Section R905.3.7 and UBC Tables 15-D-1 and 15-D-2. Copies of the manual are available on the ICC-ES web site at http://www.icc-es.org/reports/pdf_files/ES_Plans/ESR-2015plans.pdf or from the Tile Roofing Institute Inc. (web site at www.tileroofing.org).

The manual is applicable to concrete and clay roof tiles recognized in current ICC-ES evaluation reports that reference the manual.

3.0 INSTALLATION

Roof tiles must be installed in accordance with the Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions, for locations where the January mean temperature is greater than 25°F (-4°C) and where ice damming does not occur.

4.0 CONDITIONS OF USE

4.1 Roof tiles installed in accordance with the Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions comply with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following condition: The concrete or clay roof tiles must be recognized in a current ICC-ES evaluation report that specifically references the Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions.

4.2 Under the 2012 IBC and IRC (ASCE 7-10), see Figure 1 of this report for design considerations for high wind applications.

4.3 Under the 2009 IBC and IRC (ASCE 7-05), see Appendix B (pages 77-86) of the manual for design considerations for high wind applications.

5.0 EVIDENCE SUBMITTED

5.1 The Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions, dated March 2010.

5.2 A study on seismic performance of roof tile installations.

5.3 Calculations for batten spacing.

5.4 Calculations for aerodynamic uplift moments based on data in accordance with SSTD-11.

5.5 Example calculations for aerodynamic uplift moment.

5.6 Calculations for typical restoring gravity moments.

Revised examples to calculate required and allowable aerodynamic uplift moment.

***Corrected April 2014**

Design Considerations for High Wind Applications Under The 2012 IBC and IRC (ASCE 7-10)

Please Refer to Tile Manufacturer's ICC-ES Evaluation Report for Additional Wind Design Details.

The installation requirements provided in Table 1A and 1B (See pages 10-11 of the TRI/WSCRA Concrete and Clay Roof Tile Installation Manual for Moderate Climate Regions) provide the normal installation guidelines for concrete and clay tile to comply with the 2012 International Building Code (Section 1507.3.7). The installation of tile in the specific regions of the country that are identified by IBC as subjected to wind speeds in excess of 110 miles per hour (V_{asd}), may be required to have additional fastening options not found in Tables 1A or 1B.

The Tile Roofing Institute has derived various uplift resistance values for nails, screws and adhesive fastening systems. Some of these methods of installation may have limiting factors depending upon wind speed, roof slope and roof height. Please consult with your tile supplier or design professional for additional information about these optional systems for those unique installations.

IRC: On buildings located in areas where IRC wind speeds do not exceed 100 mph and having a maximum mean roof height of 40 feet (12.2 m), tile application must comply with 2012 IRC Section R905.3.7. For higher basic wind speeds or mean roof heights, installation must be in compliance with 2012 IBC Sections 1507.3.7 and 1609.5.3.

The following design aids are provided to the roof designer for consideration in determining the required aerodynamic uplift moment for roof tiles for wind applications beyond the prescriptive requirements in the IBC or IRC. These tables were developed based on the requirement of 2012 IBC Section 1609.5.3 and ASCE 7-10.

TABLE 5

Conversion from Nominal Design Wind Speed V_{asd} to Ultimate Design Wind Speed V_{ult} *shall be converted as* $V_{asd} = V_{ult} * \sqrt{0.6}$ *or from the following table:*

Design Wind Speed Conversion (mph)									
V_{ult}	110	120	130	140	150	160	170	180	190
V_{asd}	85	93	101	108	116	124	132	139	147

For SI: 1 mile per hour = 0.44 m/s A linear interpolation is permitted.

Design of Attachment System:

Example 1:

A building is a low rise structure in an Exposure B region where the ultimate design wind speed is 180 mph. The building is a Category II structure. The mean height of the building is 30 feet. The roof is a gable roof with a roof slope of 3:12. The terrain around the building does not abruptly change so as to create any wind speed-up effects due to channeling, or shielding. The building is not located on a hill, ridge, or escarpment that would cause the wind to speed up. The roof tiles will be flat- or low-profile concrete roof tile with a total tile length of 16-½" and exposed width of 11". The roof tiles weigh 9 pounds each. The roof covering is installed direct to deck on solid sheathing.

Calculate the Required Aerodynamic Uplift Moment and use the Allowable Aerodynamic Uplift Resistance from Table 7. Risk Category from Table 1.5-1 (ASCE 7-10): Velocity pressure: $q_h = 0.00256*K_z*K_{zt}*K_d*V^2$

q_h = velocity pressure at height z (psf)

K_z = velocity pressure exposure coefficient at height z (ASCE-7-10 Table 30.3-1) K_z = 0.7 for example from Table 30.3-1)

K_{zt} = topographic factor: K_{zt} = 1.0 (ASCE 10-11, Section 26, 8.2)

K_d = wind directionality factor: ASCE 7-10, Table 26.6-1 (K_d = 0.85)

V = basic wind speed (mph) Fig. 26.5-1A (180 mph)

q_h = $.00256* K_z* K_{zt}* K_d* V^2$ = .00256 (0.7) (0.85) (1.0) ($180mph^2$)

q_h = 49.35 psf

Required Aerodynamic Uplift Moment

M_a = 0.6 q_h C_L b L L_a (1.0-GC)

b = Exposed width, feet of the roof tile = 11" = 0.917'

C_L = Lift Coefficient = 0.2 (IBC - Section 1609.5.3)

GCp = -2.6, Roof pressure coefficient for each applicable roof zone determined from Figure 30.4-2B in Chapter 30 of ASCE 7-10. Roof Coefficient shall not be adjusted for internal pressure.

L = Length, feet of the roof tile = 16.5" = 1.375'

L_a = moment arm for the roof tile = 0.76L (IBC Section 1609.5.3) = 0.76 (1.375') = 1.045'

M_a = Aerodynamic uplift moment, feet-pounds acting to raise the tail of the tile

q_h = Wind velocity pressure, psf determined from Chapter 30, ASCE 7-10.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS

$M_a = 0.6q_h C_L b L L_a (1-GC_p) = (0.6)49.35 (0.2) (.917) (1.375) (1.045) (1-(-2.6)$

M_a = 28.1 ft-lbf

Required Aerodynamic Uplift Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moments - A mechanical fastening system that is equal to or greater than 28.1 ft-lbf will be required.

From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Example 2

The building is the same as in example 1, except the flat/low concrete roof tile in this example is now within the combined maximum tile length and maximum exposed width listed in Table 6A (1.407 ft²) for the allowable tile length and tile's exposed width. This roof tile may be designed using the appropriate Table 5A and Table 5B. Based on the exposure and the roof pitch, the appropriate table is Table 5A, (Required Aerodynamic Uplift Moment for Tile). Exposure B Table 5A indicates that the required aerodynamic uplift moment for this roof covering, **M_a is 30.0 ft-lbf.**

Note: The difference between the M_a's in Example 1 and Example 2 is in the tile factor in Example 2. Table 5A and Table 5B are based on a tile factor of 1.407 ft² while the actual tile factor for this roof tile is 1.318 ft². (Tile Factor = b L L_a = (0.917) (1.375) (1.045) = 1.318 ft². See Table 6A for maximum dimensions to Satisfy Tile Factor of 1.407ft².

Required Aerodynamic Uplift Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moments - A mechanical fastening system that is equal to or greater than 30 ft-lbf will be required. From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Example 3

The same building as found in example 1, but design the Roof Tile Installation for a Lightweight Roof Tile. The roof tile installation is identical to the previous examples except that the lightweight roof tiles weigh 5 pounds each. The flat/low lightweight concrete roof tile is within the combined maximum tile length and maximum exposed width listed in Table 6A, Maximum Dimensions to Satisfy Tile Factor. This roof tile may be designed using the appropriate Table 5A or Table 5B.

Required Aerodynamic Uplift Moment

Based on the exposure and the roof pitch the appropriate table is Table 5A, Exposure B - Required Aerodynamic Uplift Moment. Aerodynamic uplift moment for this roof covering indicates that the required aerodynamic uplift moment for this roof covering, **M_a, is 30.0 ft-lbf.**

Mechanical Attachment Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moment-Mechanical Fastening Systems select an attachment resistance that is equal to or greater than 30.0 ft-lbf.

From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Attachment Resistance

Determine the attachment resistance with the generic restoring gravity moment used in Table 7. Footnote 11 for Table 7 states that the table is based on a generic restoring gravity moment of 6.5 ft-lbf for a direct deck installation and 5.5 ft-lbf for a batten installation. Based on a direct deck installation the attachment resistance for 1-#8 screw is 32.6 ft-lbf.

M_f = 39.1 ft-lbf - 6.5 ft-lbf = 32.6 ft-lbf

Restoring Gravity Moment:

From Table 6B, the restoring gravity moment for a roof tile weighing 5 lbs. is 3.17 ft-lbf.
M_s = 3.17 ft-lbf (Table 6B)

Allowable Aerodynamic Uplift Resistance

The allowable aerodynamic uplift resistance for the flat/low lightweight concrete roof tile is the sum of the attachment resistance plus the restoring gravity moment of the flat/low lightweight concrete roof tile. See Table 6B for Restoring Gravity Moment for various tile weights.

Allowable Aerodynamic Uplift Resistance, $M_{all} = M_f + M_g$ = 32.6 ft-lbf + 3.17 ft-lbf = 35.77 ft-lbf

M_{all} = 35.8 ft-lbf M_a = 30.0 ft-lbf

The use of 1-#8 screw to install each lightweight roof tile complies with the code for uplift resistance.

Note: For consideration of attachment of underlayments in high winds areas under the 2012 IBC and 2012 IRC, see Section 1507.3.3.3 of the 2012 IBC and Section R905.3.3.3 of the 2012 IRC. Attachment of underlayments must comply with the above mentioned sections.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

$M_a = 0.6q_h C_L b L L_a (1-GC_p) = (0.6)49.35 (0.2) (.917) (1.375) (1.045) (1-(-2.6)$

M_a = 28.1 ft-lbf

Required Aerodynamic Uplift Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moments - A mechanical fastening system that is equal to or greater than 28.1 ft-lbf will be required.

From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Example 2

The building is the same as in example 1, except the flat/low concrete roof tile in this example is now within the combined maximum tile length and maximum exposed width listed in Table 6A (1.407 ft²) for the allowable tile length and tile's exposed width. This roof tile may be designed using the appropriate Table 5A and Table 5B. Based on the exposure and the roof pitch, the appropriate table is Table 5A, (Required Aerodynamic Uplift Moment for Tile). Exposure B Table 5A indicates that the required aerodynamic uplift moment for this roof covering, **M_a is 30.0 ft-lbf.**

Note: The difference between the M_a's in Example 1 and Example 2 is in the tile factor in Example 2. Table 5A and Table 5B are based on a tile factor of 1.407 ft² while the actual tile factor for this roof tile is 1.318 ft². (Tile Factor = b L L_a = (0.917) (1.375) (1.045) = 1.318 ft². See Table 6A for maximum dimensions to Satisfy Tile Factor of 1.407ft².

Required Aerodynamic Uplift Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moments - A mechanical fastening system that is equal to or greater than 30 ft-lbf will be required. From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Example 3

The same building as found in example 1, but design the Roof Tile Installation for a Lightweight Roof Tile. The roof tile installation is identical to the previous examples except that the lightweight roof tiles weigh 5 pounds each. The flat/low lightweight concrete roof tile is within the combined maximum tile length and maximum exposed width listed in Table 6A, Maximum Dimensions to Satisfy Tile Factor. This roof tile may be designed using the appropriate Table 5A or Table 5B.

Required Aerodynamic Uplift Moment

Based on the exposure and the roof pitch the appropriate table is Table 5A, Exposure B - Required Aerodynamic Uplift Moment. Aerodynamic uplift moment for this roof covering indicates that the required aerodynamic uplift moment for this roof covering, **M_a, is 30.0 ft-lbf.**

Mechanical Attachment Resistance

For a direct deck installation select a fastening system from Table 7, Allowable Aerodynamic Uplift Moment-Mechanical Fastening Systems select an attachment resistance that is equal to or greater than 30.0 ft-lbf.

From Table 7 a 2-10d ring shank nail or 1 #8 screw at 39.1 ft-lbf would be selected.

Attachment Resistance

Determine the attachment resistance with the generic restoring gravity moment used in Table 7. Footnote 11 for Table 7 states that the table is based on a generic restoring gravity moment of 6.5 ft-lbf for a direct deck installation and 5.5 ft-lbf for a batten installation. Based on a direct deck installation the attachment resistance for 1-#8 screw is 32.6 ft-lbf.

M_f = 39.1 ft-lbf - 6.5 ft-lbf = 32.6 ft-lbf

Restoring Gravity Moment:

From Table 6B, the restoring gravity moment for a roof tile weighing 5 lbs. is 3.17 ft-lbf.
M_s = 3.17 ft-lbf (Table 6B)

Allowable Aerodynamic Uplift Resistance

The allowable aerodynamic uplift resistance for the flat/low lightweight concrete roof tile is the sum of the attachment resistance plus the restoring gravity moment of the flat/low lightweight concrete roof tile. See Table 6B for Restoring Gravity Moment for various tile weights.

Allowable Aerodynamic Uplift Resistance, $M_{all} = M_f + M_g$ = 32.6 ft-lbf + 3.17 ft-lbf = 35.77 ft-lbf

M_{all} = 35.8 ft-lbf M_a = 30.0 ft-lbf

The use of 1-#8 screw to install each lightweight roof tile complies with the code for uplift resistance.

Note: For consideration of attachment of underlayments in high winds areas under the 2012 IBC and 2012 IRC, see Section 1507.3.3.3 of the 2012 IBC and Section R905.3.3.3 of the 2012 IRC. Attachment of underlayments must comply with the above mentioned sections.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 5A
Required Aerodynamic Uplift Moment For Tile, Zone 3
Ma (ft-lbf) *For Roof Pitches 6:12 and Less*
Gable Roof 2 ½:12 < ϴ < 6:12 (12° < ϴ < 27°)
Hip Roof 5 ½:12 < ϴ < 6:12 (25° < ϴ < 27°)

Exposure B	Ultimate Design Wind Speed in MPH								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	11.2	13.3	15.6	18.1	20.8	23.7	26.8	30.0	33.4
20	11.2	13.3	15.6	18.1	20.8	23.7	26.8	30.0	33.4
25	11.2	13.3	15.6	18.1	20.8	23.7	26.8	30.0	33.4
30	11.2	13.3	15.6	18.1	20.8	23.7	26.8	30.0	33.4
35	11.7	13.9	16.3	18.9	21.7	24.7	27.9	31.3	34.9
40	12.2	14.5	17.0	19.7	22.6	25.7	29.1	32.6	36.3
45	12.5	14.9	17.4	20.2	23.2	26.4	29.8	33.4	37.2
50	12.9	15.4	18.1	21.0	24.1	27.4	31.0	34.7	38.7
55	13.3	15.8	18.6	21.5	24.7	28.1	31.7	35.6	39.6
60	13.6	16.2	19.0	22.0	25.3	28.8	32.5	36.4	40.6
Exposure C	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	13.6	16.2	19.0	22.0	25.3	28.8	32.5	36.4	40.6
20	14.4	17.1	20.1	23.3	26.8	30.5	34.4	38.6	43.0
25	15.0	17.9	21.0	24.4	28.0	31.8	35.9	40.3	44.9
30	15.7	18.7	21.9	25.4	29.2	33.2	37.5	42.0	46.8
35	16.1	19.2	22.6	26.2	30.1	34.2	38.6	43.3	48.2
40	16.6	19.8	23.2	27.0	30.9	35.2	39.8	44.6	49.7
45	17.0	20.2	23.7	27.5	31.5	35.9	40.5	45.4	50.6
50	17.5	20.8	24.4	28.3	32.4	36.9	41.7	46.7	52.0
55	17.7	21.1	24.8	28.8	33.0	37.6	42.4	47.6	53.0
60	18.1	21.5	25.3	29.3	33.6	38.3	43.2	48.4	54.0
Exposure D	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	16.5	19.6	23.0	26.7	30.7	34.9	39.4	44.1	49.2
20	17.3	20.6	24.1	28.0	32.1	36.6	41.3	46.2	51.6
25	19.9	21.3	25.0	29.0	33.3	37.9	42.8	48.0	53.5
30	18.6	22.1	25.9	30.1	34.5	39.3	44.3	49.7	55.4
35	19.1	22.7	26.6	30.8	35.4	40.3	45.5	51.0	56.8
40	19.5	23.2	27.3	31.6	36.3	41.3	46.6	52.2	58.3
45	20.0	23.8	27.9	32.4	37.2	42.3	47.8	53.5	59.7
50	20.3	24.2	28.4	32.9	37.8	43.0	48.5	54.4	60.6
55	20.7	24.6	28.8	33.4	38.4	43.7	49.3	55.2	61.6
60	20.9	24.9	29.3	34.0	39.0	44.4	50.1	56.1	62.5

Wind Speeds are per ASCE 7-10 for Ultimate Design Wind Speed at 33 ft above ground. MRH=Mean Roof Height in Feet For Roof Pitches 6:12 and Less Equates to Roof Slopes 12 deg <ϴ< 27 deg for Zone 3.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 5B
REQUIRED AERODYNAMIC UPLIFT MOMENT FOR TILE, ZONE 3
Ma (ft-lbf) for Roof Pitches $5^1/_2$:12 and Less
Hip Roof $2^1/_2$:12 < ϴ < 51/2:12 < ϴ < 25°

Exposure B	Ultimate Design Wind Speed in MPH								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	8.4	10.0	11.7	13.6	15.6	17.8	20.1	22.5	25.1
20	8.4	10.0	11.7	13.6	15.6	17.8	20.1	22.5	25.1
25	8.4	10.0	11.7	13.6	15.6	17.8	20.1	22.5	25.1
30	8.4	10.0	11.7	13.6	15.6	17.8	20.1	22.5	25.1
35	8.8	10.4	12.2	14.2	16.3	18.5	20.9	23.5	26.1
40	9.1	10.9	12.7	14.8	17.0	19.3	21.8	24.4	27.2
45	9.4	11.1	13.1	15.2	17.4	19.8	22.4	25.1	27.9
50	9.7	11.6	13.6	15.7	18.1	20.6	23.2	26.0	29.0
55	10.0	11.9	13.9	16.1	18.5	21.2	23.8	26.7	29.7
60	10.2	12.1	14.2	16.5	19.0	21.6	24.4	27.3	30.4
Exposure C	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	10.2	12.1	14.2	16.5	19.0	21.6	24.4	27.3	30.4
20	10.8	12.9	15.1	17.5	20.1	22.9	25.8	28.9	32.2
25	11.3	13.4	15.8	18.3	21.0	23.9	26.9	30.2	33.7
30	11.8	14.0	16.4	19.1	21.9	24.9	28.1	31.5	35.1
35	12.1	14.4	16.9	19.5	22.5	25.6	29.0	32.5	36.2
40	12.5	14.9	17.4	20.2	23.2	26.4	29.8	33.4	37.2
45	12.7	15.1	17.8	20.6	23.7	26.9	30.4	34.1	38.0
50	13.1	15.6	18.3	21.2	24.3	27.7	31.2	35.0	39.0
55	13.3	15.9	18.6	21.6	24.8	28.2	31.8	35.7	39.7
60	13.6	16.1	18.9	22.0	25.2	28.7	32.4	36.2	40.5
Exposure D	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	12.4	14.7	17.3	20.0	23.0	26.2	29.5	33.1	36.9
20	13.0	15.4	18.1	21.0	24.1	27.4	31.0	34.7	38.7
25	13.4	16.0	18.8	21.8	25.0	28.4	32.1	36.0	40.1
30	13.9	16.6	19.4	22.6	25.9	29.5	33.3	37.3	41.5
35	14.3	17.0	19.9	23.1	26.6	30.2	34.1	38.2	42.6
40	14.6	17.4	20.5	23.7	27.2	31.0	35.0	39.2	43.7
45	15.0	17.9	21.0	24.3	27.9	31.7	35.8	40.2	44.8
50	15.2	18.1	21.3	24.7	28.3	32.3	36.4	40.8	45.5
55	15.5	18.4	21.6	25.1	28.8	32.8	37.0	41.5	46.2
60	15.7	18.7	22.0	25.5	29.2	33.3	37.6	42.1	46.9

Wind Speeds are per ASCE 7-10 for Ultimate Design Wind Speed at 33 ft above ground. MRH=Mean Roof Height in Feet For Roof Pitches Less Than 5½:12 Equates to Roof Slopes 12 deg < ϴ < 25 deg for Zone 3.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 5C
Required Aerodynamic Uplift Moment For Tile, Zone 3
Ma (ft-lbf) *For Roof Pitches Greater Than 6:12*
Gable Roof 6:12 < Θ <12:12 (27° <Θ< 45°)

Exposure B	Ultimate Design Wind Speed in MPH								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	6.8	8.1	9.6	11.1	12.7	14.5	16.4	18.3	20.4
20	6.8	8.1	9.6	11.1	12.7	14.5	16.4	18.3	20.4
25	6.8	8.1	9.6	11.1	12.7	14.5	16.4	18.3	20.4
30	6.8	8.1	9.6	11.1	12.7	14.5	16.4	18.3	20.4
35	7.1	8.5	10.0	11.6	13.3	15. 1	17. 1	19. 1	21.3
40	7.4	8.8	10.4	12.0	13.8	15.7	17.8	19.9	22.2
45	7.6	9.1	10.7	12.4	14.2	16.1	18.2	20.4	22.8
50	7.9	9.4	1 1.1	12.8	14.7	16.8	18.9	21.2	23.6
55	8.2	9.7	11.3	13.1	15.1	17.2	19.4	21.7	24.2
60	8.3	9.9	11.6	13.5	15.5	17.6	19.9	22.3	24.8
Exposure C	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	8.3	9.9	11.6	13.5	15.5	17.6	19.9	22.3	24.8
20	8.8	10.5	12.3	14.3	16.4	18.6	21.0	23.6	26.3
25	9.2	10.9	12.8	14.9	17.1	19.5	22.0	24.6	27.4
30	9.6	11.4	13.4	15.5	17.8	20.3	22.9	25.7	28.6
35	9.9	11.8	13.8	16.0	18.4	20.9	23.6	26.4	29.5
40	10.2	12.1	14.2	16.5	18.9	21.5	24.3	27.2	30.3
45	10.3	12.3	14.5	16.8	19.3	21.9	24.8	27.8	30.9
50	10.7	12.7	14.9	17.3	19.8	22.6	25.5	28.5	31.8
55	10.8	12.9	15.2	17.6	20.2	23.0	25.9	29.1	32.4
60	11.1	13.2	15.4	17.9	20.6	23.4	26.4	29.6	33.0
Exposure D	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	10.1	12.0	14.1	16.3	18.7	21.3	24.1	27.0	30.1
20	10.6	12.6	14.8	17.1	19.6	22.3	25.2	28.3	31.5
25	10.9	13.0	15.3	17.7	20.4	23.2	26.2	29.3	32.7
30	11.3	13.5	15.8	18.4	21.1	24.0	27.1	30.4	33.8
35	11.7	13.9	16.3	18.9	21.6	24.6	27.8	31 .2	34.7
40	11.9	14.2	16.7	19.3	22.2	25.2	28.5	31.9	35.6
45	12.2	14.5	17.1	19.8	22.7	25.9	29.2	32.7	36.5
50	12.4	14.8	17.3	20.1	23.1	26.3	29.7	33.3	37.1
55	12.6	15.0	17.6	20.4	23.5	26.7	30.1	33.8	37.6
60	12.8	15.2	17.9	20.8	23.8	27.1	30.6	34.3	38.2

Wind Speeds are per ASCE 7-10 for Ultimate Design Wind Speed at 33 ft above ground. MRH=Mean Roof Height in Feet For Roof Pitches Greater Than 6:12 Equates to Roof Slopes 27 deg <Θ< 45 deg for Zone 3.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 5D
Required Aerodynamic Uplift Moment For Tile, Zone 3, Ma (ft-lbf)
For Monoslope Pitches 2 1/2:12 < Θ <6 3/4:12 (12° < Θ < 30°)

Exposure B	Ultimate Design Wind Speed in MPH								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	12.1	14.4	17.0	19.7	22.6	25.7	29.0	32.5	36.2
20	12.1	14.4	17.0	19.7	22.6	25.7	29.0	32.5	36.2
25	12.1	14.4	17.0	19.7	22.6	25.7	29.0	32.5	36.2
30	12.1	14.4	17.0	19.7	22.6	25.7	29.0	32.5	36.2
35	12.7	15.1	17.7	20.5	23.5	26.8	30.2	33.9	37.8
40	13.2	15.7	18.4	21.3	24.5	27.9	31.5	35.3	39.3
45	13.5	16.1	18.9	21.9	25.1	28.6	32.3	36.2	40.3
50	14.0	16.7	19.6	22.7	26.1	29.7	33.5	37.6	41.9
55	14.4	17.1	20.1	23.3	26.8	30.4	34.4	38.5	42.9
60	14.7	17.5	20.6	23.9	27.4	31.2	35.2	39.5	44.0
Exposure C	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	14.7	17.5	20.6	23.9	27.4	31.2	35.2	39.5	44.0
20	15.6	18.6	21.8	25.3	29.0	33.0	37.3	41.8	46.6
25	16.3	19.4	22.8	26.4	30.3	34.5	38.9	43.6	48.6
30	17.0	20.2	23.7	27.5	31.6	35.9	40.6	45.5	50.7
35	17.5	20.8	24.5	28.4	32.6	37.0	41.8	46.9	52.2
40	18.0	21.5	25.2	29.2	33.5	38.1	43.1	48.3	53.8
45	18.4	21.9	25.7	29.8	34.2	38.9	43.9	49.2	54.8
50	18.9	22.5	26.4	30.6	35.1	40.0	45.1	50.6	56.4
55	19.2	22.9	26.9	31.2	35.8	40.7	46.0	51.5	57.4
60	19.6	23.3	27.4	31.7	36.4	41.4	46.8	52.5	58.4
Exposure D	**Ultimate Design Wind Speed in MPH**								
MRH	**110**	**120**	**130**	**140**	**150**	**160**	**170**	**180**	**190**
0-15	17.9	21.3	24.9	28.9	33.2	37.8	42.7	47.8	53.3
20	18.7	22.3	26.2	30.3	34.8	39.6	44.7	50.1	55.9
25	19.4	23.1	27.1	31.5	36.1	41.1	46.4	52.0	57.9
30	20.1	23.9	28.1	32.6	37.4	42.5	48.0	53.9	60.0
35	20.6	24.6	28.8	33.4	38.4	43.7	49.3	55.2	61.6
40	21.2	25.2	29.5	34.3	39.3	44.8	50.5	56.6	63.1
45	21.7	25.8	30.3	35.1	40.3	45.9	51.8	58.0	64.7
50	22.0	26.2	30.8	35.7	40.9	46.6	52.6	59.0	65.7
55	22.4	26.6	31.2	36.2	41.6	47.3	53.4	59.9	66.7
60	22.7	27.0	31.7	36.8	42.2	48.1	54.2	60.8	67.8

Wind Speeds are per ASCE 7-10 for Ultimate Design Wind Speed at 33 ft above ground. MRH=Mean Roof Height in Feet For Roof Pitches 6 3/4:12 and Less Equates to Roof Slopes 12 deg < Θ < 30 deg for Zone 3.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 6A
MAXIMUM DIMENSIONS TO SATISFY TILE FACTOR OF 1.407 ft^3

Maximum Combination of Tile Length and Tile's Exposed Width										
Maximum Tile Length (inches)	20	18-1/2	18	17-1/2	16-1/2	16	15-1/2	15	14-1/2	14
Maximum Exposed Width (inches)	8	9-1/4	9-3/4	10-1/4	11-3/4	12-1/2	13-1/4	13-3/4	14	15

TABLE 6B
RESTORING GRAVITY MOMENT

Maximum Combination of Tile Length and Tile's Exposed Width						
Tile Weight (lbs)	5	6	7	8	9	10
Mg (ft-lbf)	3.17	3.80	4.43	5.06	5.7	6.33

Notes for Tables 5A through 6B:

1. Roof tiles shall comply with the following dimensions:
   (1) The total length of the roof tile shall be between 1.0 foot and 1.75 feet.
   (2) The exposed width of the roof tile shall be between 0.67 feet and 1.25 feet.
   (3) The maximum thickness of the tail of the roof tile shall not exceed 1.3 inches.
2. The required aerodynamic uplift moments in these tables are based on a roof tile that has a Tile Factor of 1.407 ft^3. The required aerodynamic uplift moment for roof tiles with a Tile Factor other than 1.407 ft^3 may be determined by using the following procedure. These tables are conservative for roof tiles with a Tile Factor less than 1.407 ft^3.
   (1) Calculate the Tile Factor for the desired roof tile.
   Tile Factor = b (L) (L_a)
   b = exposed width of the roof tile (ft)
   L = total length of roof tile (ft)
   L_a = moment between point of rotation and the theoretical location of the resultant of the wind uplift force.
   For the standard roof tiles the moment arm = 0.76 L (See IBC - Section 1609.5.3)
   (2) Based on exposure, roof style, roof pitch, ultimate design wind speed, and mean roof height, select the appropriate required aerodynamic uplift moment from the tables for the desired roof tile.
   (3) Multiply the selected required aerodynamic uplift moment by the ratio of the tile factor for the desired roof tile and 1.407 ft^3.
   (4) Select an attachment system that is equal to or greater than the calculated required aerodynamic uplift moment in step 3.
3. Table 6A provides a combination of exposed widths and total lengths that generate a Tile Factor of 1.407 ft^3. The table "Maximum Combination of Tile Length and Tile's Exposed Width" provides a listing of tiles that fit this Tile Factor.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)

TABLE 7
MECHANICAL ROOF TILE RESISTANCE VALUES (ft-lbf) for Tile

Deck Thickness	Method	Fastener Type	Low	Medium	High
15/32"	Direct Deck	1-10d smooth or screw shank nail, with clip	25.2	25.2	35.5
		2-10d, smooth or screw shank nail, with clip	38.1	38.1	44.3
		2- 10d ring shank nail	39.1	36.1	28.6
		2- 10d ring shank nail, with 4" head lap	50.3	43.0	33.1
		1- #8 Screw	39.1	33.2	28.7
		2- #8 screw	50.2	55.5	51.3
	Batten	1-10d smooth or screw shank nail, with clip	27.5	27.5	29.4
		2-10d smooth or screw shank nail, with clip	37.6	37.6	47.2
		2- 10d ring shank nail	34.6	36.4	26.8
		1- # 8 screw	25.6	30.1	25.5
		2- #8 screw	36.1	41.9	37.1
19/32"	Direct Deck	2- 10d ring shank nail	46.4	45.5	41.2

SS = Smooth Shank Nail or Screw Shank RS = Ring Shank
C = Clip HL = Head Lap

For mean roof heights over 60 ft, engineering calculations must be submitted for permitting.

Notes for Table 7:

1. For attachment systems not listed in the table for $^{19}/_{32}$" sheathing use the allowable aerodynamic uplift resistance from the table for $^{15}/_{32}$" sheathing.
2. Fasteners shall have a minimum edge distance of 1-½ inches from the head of the tile and located in the pan of the tile to obtain the values in Table 7. Consult the tile manufacturer for additional limitations or restrictions.
3. Ring shank nails shall be 10d ring shank corrosion resistant steel nails with the following minimum dimensions: (3 inches long, 0.283 inch flat head diameter, 0.120 inch undeformed shank diameter or 0.131 inch screw diameter).
4. Smooth or screw shank nails shall be 10d corrosion resistant steel (with the following minimum dimension. 3 inch long, 0.283 inch flat head diameter, 0.120 inch undeformed shank diameter or 0.131 inch screw diameter).
5. Screws are #8 course threaded, 2.5 inches long corrosion-resistant steel wood screws conforming to ANSI/ASME B 18.6.1.
6. The fastener hole nearest the overlock shall be used when a single nail or screw is required. The fastener hole nearest the underlock and the fastener hole nearest the overlock shall be used when two nails or screws are required.
7. When using eave and field clips, attachment of the tiles is accomplished by a combination of nails and clips. Tiles are nailed to the sheathing or through the battens to the sheathing with one or two 10d corrosion resistant nails (Note 2 and 3 above) as required by Tables 5 and 6. Additionally, each tile is secured with a 0.060 inch thick and 0.5 inch wide clip which is secured to the plywood sheathing or eave fascia, as appropriate, with a single nail per clip. The nail shall be placed in the hole closest to the tile for clips having more than one nail hole. The following clip/nail combinations are permitted: (1) Aluminum alloy clip with 1.25 inch HD galvanized roofing nail (0.128 inch shank diameter). (2) Galvanized steel deck clip with 1.25 inch HD galvanized roofing nail (0.128 inch shank diameter). (3) Stainless steel clip with 1.25 inch HD galvanized roofing nail (0.128 inch shank diameter).
8. Field clips and eave clips are to be located along the tile where the clip's preformed height and the tile's height above the underlayment are identical.
9. Counter batten values not included.
10. For attachment systems not listed in table for $^{15}/_{32}$" sheathing, use allowable aerodynamic uplift moment from table for $^{15}/_{32}$" sheathing.
11. The allowable aerodynamic uplift moments include a generic restoring gravity moment of 6.5 ft-lbf for a direct deck installation and a generic restoring gravity moment of 5.5 ft-lbf for a batten installation.

Additional Notes [outside the scope of ICC-ES report (ERS-2015P) on this manual]

Allowable Aerodynamic Uplift Moments Adhesive Fastening Systems

Refer to the adhesive manufacturer for the allowable aerodynamic uplift moment for the installation method used to comply with the applicable code requirements. Installation of roof tiles using the adhesive system should be done by technicians trained and having a current certification by the adhesive manufacturer to comply with the applicable code requirements.

Allowable Aerodynamic Uplift Moments
Mortar Fastening Systems

Refer to the pre-bagged mortar mix manufacturer for the allowable aerodynamic uplift moment for the installation method used to comply with the applicable code requirements. Mixing of mortar at the jobsite is not a recommended practice. Installation of roof tiles using the mortar system should be done by technicians trained and having a current certification by the mortar mix manufacturer to comply with the applicable code requirements.

FIGURE 1—DESIGN CONSIDERATIONS FOR HIGH WIND APPLICATIONS (continued)