Tornado Resistant Construction: Design Issues Plus Pros and Cons of Various Building Systems

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Who is IBHS

Insurer-Funded Non-Profit
Promotes Resilient Construction
Research & Communications

Tornado Protection Terminology

“Tornado Proof”
“Near Ultimate Protection”
“Tornado Resistant”

“Tornado Proof”
You could live in a cave or . . .
. . . you could live in a bunker.

Tornado Protection Issues

Wind Loads
Debris Impact
Atmospheric Pressure Drop
Tornado Simulator Results

Wind Pressures
Plus
Full Atmospheric Pressure Drop

Practical Issues

Must survive high winds and debris field before exposed to highest pressure drop

Pressure equalization will reduce effects of pressure drop

Practical Issues

Exceptions:
• nuclear containment vessels;
• tornado smaller than structure

Wind and Pressure

Atmospheric pressure drop equalization does not require large openings

Pressure Equalization

Current Design Guidance for Wind Loads

• Select target tornado wind speed
• Assume partially enclosed structure
• Assume open terrain exposure
• Directionality factor = 1.0, not 0.85
• Gust effect factor = 0.90, not 0.85
• Use/adjust ASCE 7 pressure coefficients
ASCE 7-Based Pressure Coefficients

MWFRS pressure coefficients from DIRECTIONAL METHOD

Reduce Component & Cladding GCp values by 10% because of short storm duration

Design Wind Speed Targets: Top of Range

| EF1  | 100 mph |
| EF2  | 135 mph |
| EF3  | 165 mph |
| EF4  | 200 mph |
| EF5  | >200 mph |
(Safe Room: 250 mph)

Typical Tornado Design Wind Load Increases

Miami-Dade - 170 mph Design for Enclosed Building

<table>
<thead>
<tr>
<th>Tornado Category</th>
<th>MWFRS Increase</th>
<th>C&amp;C Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF2 (135 mph)</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>EF3 (165 mph)</td>
<td>60%</td>
<td>20%</td>
</tr>
<tr>
<td>EF4 (200 mph)</td>
<td>140%</td>
<td>80%</td>
</tr>
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Charleston, Melbourne, New Orleans - 150 mph Design for Enclosed Building in Open Exposure

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<th>MWFRS Increase</th>
<th>C&amp;C Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF2 (135 mph)</td>
<td>40%</td>
<td>10%</td>
</tr>
<tr>
<td>EF3 (165 mph)</td>
<td>110%</td>
<td>60%</td>
</tr>
<tr>
<td>EF4 (200 mph)</td>
<td>210%</td>
<td>130%</td>
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Oklahoma - 115 mph Design for Enclosed Building in Open Exposure

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</thead>
<tbody>
<tr>
<td>EF2 (135 mph)</td>
<td>140%</td>
<td>80%</td>
</tr>
<tr>
<td>EF3 (165 mph)</td>
<td>260%</td>
<td>170%</td>
</tr>
<tr>
<td>EF4 (200 mph)</td>
<td>430%</td>
<td>290%</td>
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Key to Wind Resistance

Connections

Connections

Connections
Importance of Connections & Internal Pressure

Video of Wood Frame Building Goes Here

Importance of Connections & Internal Pressure

Video of Masonry Building Goes Here

Can Manufactured (HUD Code) Homes be Tornado Resistant? At Least to Moore, OK Standards?

Meeting Moore, OK Tornado Requirements is Possible!

• Zone III exposure D manufactured home (open water exposure wind design) = site-built home design for ~140 mph in open exposure

• Permanent foundations or anchorage conditions that severely limit displacement are required

Foundation Requirements are Critical - No Dry Stack Allowed -

Windborne Debris Protection
Windborne Debris Protection Requirements

- Hurricane shutter residential – 9-lb 2x4 @ 34 mph
- Hurricane shutter essential facility – 9-lb 2x4 @ 54 mph
- Tornado shelter – 15-lb 2x4 @ 100 mph

Examples of Materials that stop a 15-lb 2x4 impacting at 100 mph

- 5 layers of ¾” plywood
- 4” thick concrete w/ 2-way reinforcing (vertical & horizontal)
- 6” thick concrete with vertical reinforcing
- 6” thick Insulating Concrete Form (ICF)
- 6” CMU with all cells reinforced & grouted
- 12 ga. steel plate
- 16 ga. steel plate & 2 layers ¾” plywood

Impact Resistance of Typical Wall Materials

Plywood has About 30% Better Impact Resistance than OSB

Resistance to Tornado Missiles

Video of Debris Impact Tests Goes Here

Windborne Debris Impact Resistance – Rigid Debris on Double T with Light Reinforcing in Deck
Windborne Debris Impact Resistance – Rigid Debris on Heavily Reinforced Deck

Use Metal Deck Below to Prevent Injuries from Spalling Concrete

Thank you for your attention.

Questions?

Web site: www.disastersafety.org