The Development of the City of Moore - New Building Code for Tornado Resistance

Lessons Learned from the May 20th, 2013 Tornado

NSF Evaluation - A quick review

NSF RAPID Team
- University of Oklahoma
- Oklahoma State
- Mississippi State
- Florida State
- University of Alabama

Statistics
- 1400 homes involved
  - 29 EF5
  - 403+ EF4
- 25 fatalities
  - 13 in homes
  - 1 in travel trailer
  - 7 in elementary school
- Estimated roughly $2,000,000,000 in damages

http://esridev.caps.ua.edu/MooreTornado/MooreTornado.html
ENHANCED FUJITA (EF) SCALE

EF3: Roofs and Walls Torn Off
Estimated Wind Speed 136 - 165 mph (3 sec gust)

EF4: Homes Leveled
Estimated Wind Speed 166 - 200 mph (3 sec gust)
EF5: Foundation Wiped Clean
Estimated Wind Speed >200 mph (3 sec gust)

THE STORY BEGINS

PROGRESSION OF COLLAPSE
(TYPICAL - LOW ROOF SLOPES)
PROGRESSION OF COLLAPSE
(TYPICAL - HIGH ROOF SLOPES)
Wind flow around a building

Wind pressure
Into the roof

Wind suction
Away from the roof

Loss of these connections due to wind
Uplift causes:
1. Rafter effectively becomes twice as long.
2. Over stresses the rafter
3. Leading to failure
Key Area:
Interface of
• Sill Plate
&
• Stem Wall
Bolt Breakout

Due to Torsion

WALL TO FOUNDATION CONNECTION ISSUES

Wall system
- Discrete bracing system

ANCHOR BOLT ISSUES

Wall system
- Continuous bracing system
Bolt Yielding
Bolt Pullout
Bolt Breakout

DEBRIS IMPACT
DEBRIS FLOW
INTERESTING
Improved construction methods can narrow the damage path of a tornado, increasing the safety of occupants and reducing financial loss due to property damage.

Intermittent bracing resulted in early wall failure at the stud to sill plate connection.

Continuous sheathing bracing resulted in a wall system that can sustain a higher ultimate load capacity.

Failure of a home with a low slope roof system tends to begin in the garage.

Homes with high pitch roofs are prone to failures in the roofing system due to tension failure of the connection.

Anchorage failures where noted with continuously sheathed homes, but these occurred after the walls had failed.
Lessons Learned
Conclusions

- It is possible for an economical residential structure to provide shelter close to a EF5 tornado.
- Data suggests that impact resistant window are not warranted.
- Everyone in a storm shelter survived.
- Vehicles are not storm shelters
- It’s about the details - load path

City of Moore

- Has asked us to provide our recommendations for a rational approach to high wind design.
- Approximately EF3 or 135 mph

Why 135 mph?

Tornadoes by F-Scale 2000-2011

- ~90-95% of tornadoes are F2 or less

80 - 85% of damage area is < EF3
Residential Code Recommendations
For City of Moore
Residential Construction for High Wind Resistance

#1 Roof Sheathing
Nail roof sheathing (OSB or Plywood) with 8d ring shank (0.131” x 2.5”) or 10d (0.148” x 3”) nails on 4” on center along the edges and 6” on center in the field. Dimensional lumber decking is not allowed.

#2 Roof Framing
Max spacing for roof framing is 16 inches on center. Minimum nominal sheathing panel size is 7/16 Minimum wood Structural panel span rating 24/16. (wall framing to be 16 inches on center)
#3 Roof Connections

Improved connections for roof framing to be designed for both compression and tension. Nail plates or steel connection plates work well. This includes improved connections on rafters, web members, purlins, kickers and bracing connections. Including the connections to interior brace wall top plates or ceiling joists.

#4 Gable End Walls Connections

Tie gable end walls to structure. Steel connection plates or straps work well. Make sure the improved connections are included at the top and bottom of the gable end wall.
#5 Gable End Wall Construction
Structural sheathing panel (OSB or plywood) for gable end walls with 8d ring shank (0.131" x 2.5") or 10d (0.148" x 3") nails on 4" on center along the edges and 6" on center in the field.

#6 Roof Framing Anchors
Hurricane clip or framing anchor on all rafter to wall connections.

Detailing when using WSP sheathing to resist uplift

#7 Two Story Detailing
Nail upper and lower story wall sheathing to common rim board.
#8 Wall Sheathing
Continuously sheath all walls with structural sheathing (OSB or plywood) using the CS-WSP method. Garage doors to be framed using the sheathed portal frame method CS-PF. No form of intermittent bracing is allowed on an outer wall. Intermittent bracing may only be used for interior braced wall lines.

#9 Increased Nailing for Sheathing
Increased nailing of wall sheathing (OSB or plywood) with 8d ring shank (0.131” x 2.5”) or 10d (0.148” x 3”) nails on 4” on center along the edges and 6” on center in the field.

#10 Sheathing Detailing
Extend structural wood sheathing to lap the sill plate. Nail to sill plate using a 4” on center along the edges. Nail to rim board if present with 8d ring shank (0.131” x 2.5”) or 10d (0.148” x 3”) nails on 4” on center along both the top and bottom edges of the rim board.
Wind rated garage doors required.

Selecting a Rated Garage Door

www.dasma.com

ICC-500 Design Windspeed for Tornado Shelters
Going Forward....
- Oklahoma Uniform Building Code Commission
  - Presently reviewing the IRC- 2015
  - Will probably add High Wind Resistance to the appendix

What will the Insurance Industry do?
Active support.....
- Provide premium incentives
  - Decreases income
- Reduce $$$ exposure

What and see.....
- Same old, same old
  - Income remains as it is
- Same $$$ exposure

Did $2,000,000 in losses feel good?

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Probability of increased adoption
- High
- Low

Why Not ?
Become the agents of change?
- Factory Mutual - an example?

Questions ?
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