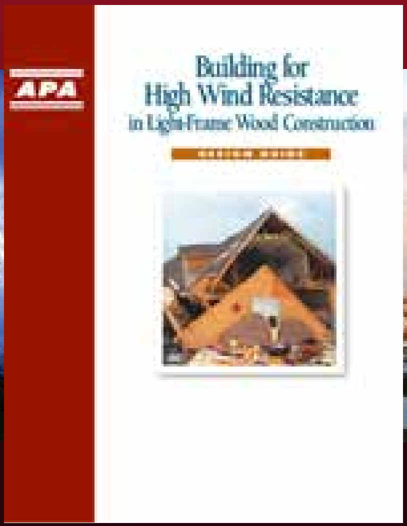
APA

Before the Storm

Building for High Wind Resistance

Presented by: Cathy Scarince, P.E.



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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

This session will examine structural failures observed during storm damage assessments and the behavior of wood structures during high-wind events. Discussion will include an overview of how high wind forces work, the importance of a complete load path to building resiliency, and how good design and construction practices can improve the storm resistance of buildings. Both code requirements and APA's above-code recommendations, which contribute to improved overall performance in the structural shell, will be reviewed. These recommendations focus on good connection details and common failure modes seen in storm-damage assessments, and can help builders to cost-effectively build safer structures. By understanding key code requirements and lateral-load concepts, building damage in storms can be minimized.

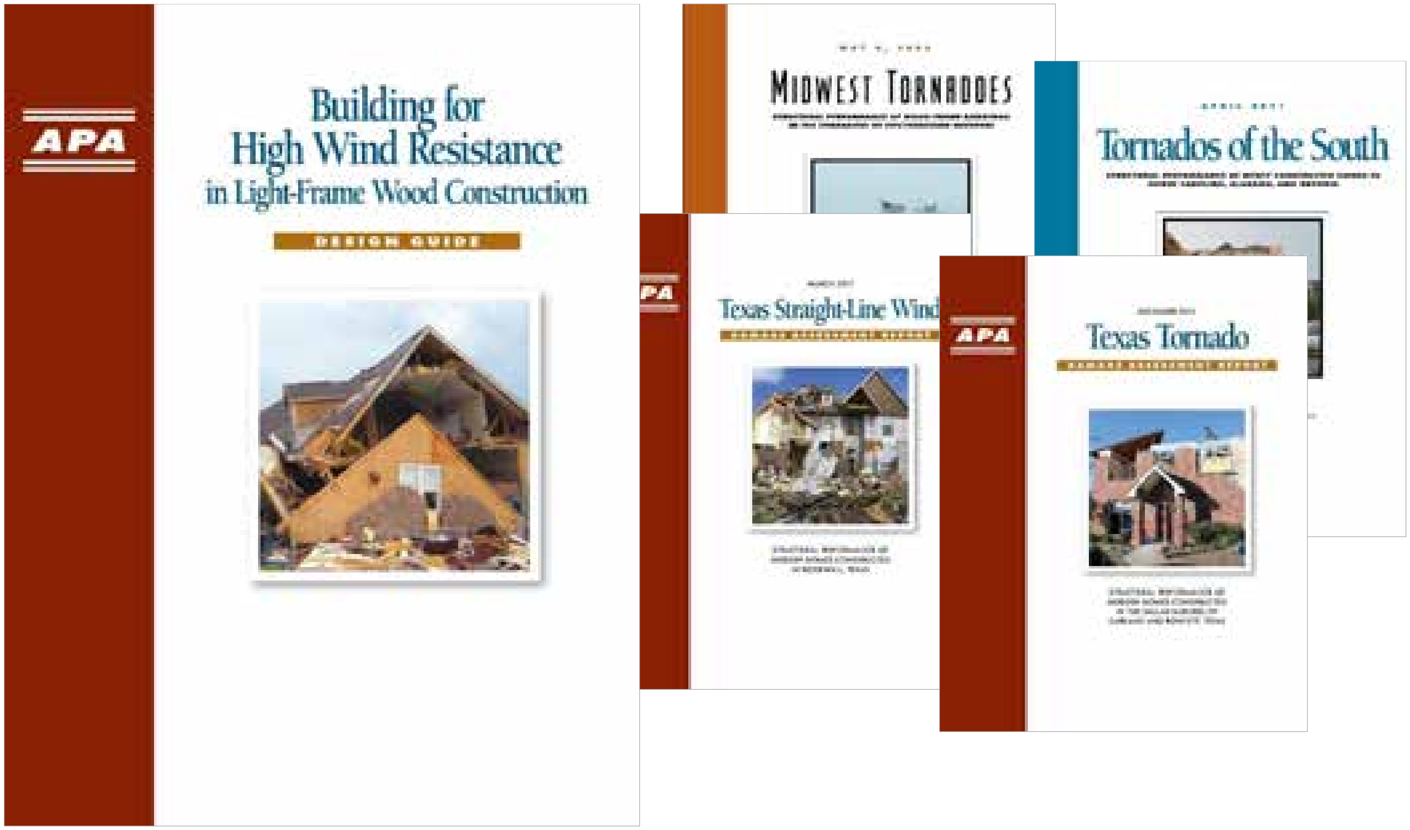
Learning Objectives

1. Identify common failure modes using photographs from post-disaster evaluations.
2. Understand the importance of a complete load path when designing and building for resiliency.
3. Recognize the fundamental behavior of wood structures especially as it pertains to lateral loads from high-wind events.
4. Discusses preventive methods that can reduce the damage that occurs during high-wind events utilizing additional connection detailing.

Agenda

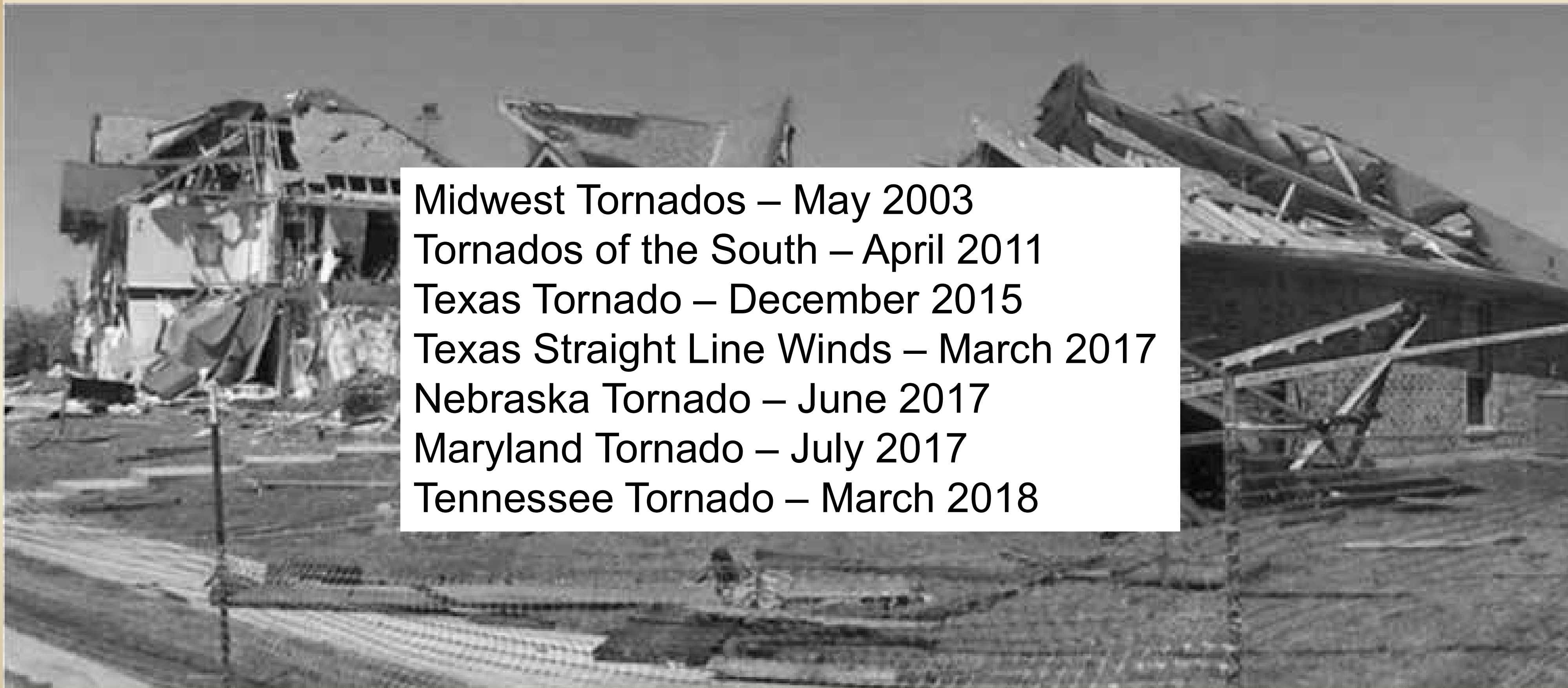
1. Understand high wind events and classifications
2. Discuss complete load paths.
3. Identify common failure modes.
4. Review APA suggested methods that can reduce damage due to high winds.

APA Publications



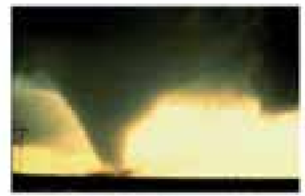
Publications from Others

High Wind Events



Midwest Tornados – May 2003
Tornados of the South – April 2011
Texas Tornado – December 2015
Texas Straight Line Winds – March 2017
Nebraska Tornado – June 2017
Maryland Tornado – July 2017
Tennessee Tornado – March 2018

How are hurricanes different from tornadoes?



	Hurricanes	Tornadoes
Where they form	Hurricanes form over warm water in the tropical oceans and develop best when far from the jet stream.	Tornadoes form over land and form within storms that are often very close to the jet stream
How big they are	Can be up to several hundred miles wide	Usually no more than [illegible] mile wide
How long they last	Can last up to 3 weeks	Usually last no more than an hour
How strong the winds are	Usually less than 180 mph	The most severe ones can be up to 300 mph
Occurrences per year	An average of 10 tropical storms in the Atlantic Ocean	In the United States, 800-1000
Advance warning from forecasters	Several days	Usually no more than 15-30 minutes

HIGH WIND EVENTS

The Saffir-Simpson Hurricane Wind Scale

Category	Wind Speed (peak 1-min.)	Description of Expected Damage
1	74-95	Very dangerous winds will produce some damage. People, livestock, and pets struck by flying or falling debris could be injured or killed…
2	96-110	Extremely dangerous winds will cause extensive damage. There is a substantial risk of injury or death to people, livestock, and pets due to flying and falling debris…
3	111-129	Devastating damage will occur. There is a high risk of injury or death to people, livestock, and pets due to flying and falling debris…
4	130-156	Catastrophic damage will occur. There is a very high risk of injury or death to people, livestock, and pets due to flying and falling debris...
5	157+	Catastrophic damage will occur. People, livestock, and pets are at very high risk of injury or death from flying or falling debris, even if indoors in mobile homes or framed homes...

Hurricane Facts

- 90% of hurricanes on US mainland are Cat. 3 or below (max. wind speed = 129 mph)
- The winds around the eye of a hurricane are usually the strongest.
- The eye of a hurricane is usually around 30 miles wide.
  - Can range from 2 miles – over 200 miles
- The Saffir-Simpson Hurricane Wind Scale provides examples of the type of damage and impacts to expect based on measured wind speed
  - Damage rises by about a factor of four for every category increase.

Enhanced Fujita Scale

EF-Scale	Tornado description	Wind Speed (3-sec gust)	Description of Expected Damage
EF-0	Gale tornado	65-85	Minor or no damage. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over.
EF-1	Moderate tornado	86-110	Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF-2	Significant tornado	$\boxed{111\text{-}135}$	Considerable damage. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
EF-3	Severe tornado	136-165	Severe damage. Entire stories of well-constructed houses destroyed; trains overturned; trees debarked; heavy cars lifted off the ground and thrown.
EF-4	Devastating tornado	166-200	Extreme damage. Well-constructed and whole frame houses completely leveled; cars and other large objects thrown and small missiles generated.
EF-5	Incredible tornado	>200	Total Destruction. Strong framed, well built houses leveled off foundations and swept away;

Tornado Facts

- 96% of all tornados are EF2 and below (max wind speed = 135 mph)
- Unrealistic to protect against EF4, EF5, and some EF3
- Winds outside vortex are slower than maximum winds
- The Enhanced F-scale still is a set of wind estimates (not measurements) based on damage.
- Safe rooms are not a universal remedy
  - There is often little warning to those who are in the tornado path
  - Need recommendations to protect building shell

Damage Indicators

- Group of objects that can be used to evaluate a tornado severity
- EF scale currently has 28 damage indicators (DI) or types of structures and vegetation, each with varying number of degrees of damage (DoD)
- The larger the degree of damage, the higher the wind speed and corresponding tornado ratings
- Primary Damage Indicators used in this report
  - One- or two-family residences
  - Hardwood trees

Damage Indicator #2 (FR12)

One- And Two-Family Residences (FR12)
(1000 – 5000 sq. ft.)

- **Typical Construction**
  - **Roof coverings**
  - **Roof sheathing and framing**
  - **Roof geometry**
  - **Wall claddings**
  - **Wall sheathing and framing**
  - **Wall geometry and openings, including attached garages**

Damage Indicator #2 (FR12)

DOD	Damage Description	EXP	LB	UB
1	Threshold of visible damage	65	53	80
2	Loss of roof covering material (<20%), gutters and/or awning; loss of vinyl or metal siding	79	63	97
3	Broken glass in doors and windows	96	79	114
4	Uplift of roof deck and loss of significant roof covering material (>20%); collapse of chimney; garage doors collapse inward; failure of porch of carport	97	81	116
5	Entire house shifts off foundation	121	103	141
6	Large sections of roof structure removed; most walls remain standing	122	104	142
7	Exterior walls collapsed	132	113	153
8	Most walls collapsed, except small interior rooms	152	127	178
9	All walls EF-3 to EF-4	170	142	198
10	Destruction of engineered and/or well constructed residence; slab swept clean	200	165	220

DOD = Degree of Damage
EXP = Expected Wind Speed
LB = Lower Bound Wind Speed
UB = Upper Bound Wind Speed

****Well Constructed Home****

Damage Indicator #27 (TH)

Hardwood: Oak, Maple, Birch, Ash

DOD	Damage Description		EXP	LB	UB
1	Small limbs broken (up to 1” diameter)	EF-0	60	48	72
2	Large branches broken (1”-3” diameter)		74	61	88
3	Trees uprooted		91	76	118
4	Trunks snapped		110	93	134
5	Trees debarked with only stubs of largest branches remaining	EF-3	143	123	167

DOD = Degree of Damage
EXP = Expected Wind Speed
LB = Lower Bound Wind Speed
UB = Upper Bound Wind Speed

EF-3 Severe damage. Entire stories of well-constructed houses destroyed; trains overturned; trees debarked; heavy cars lifted off the ground and thrown.

Texas Tornado – December 2015

EF-1 Moderate damage. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.

Texas Tornado – December 2015

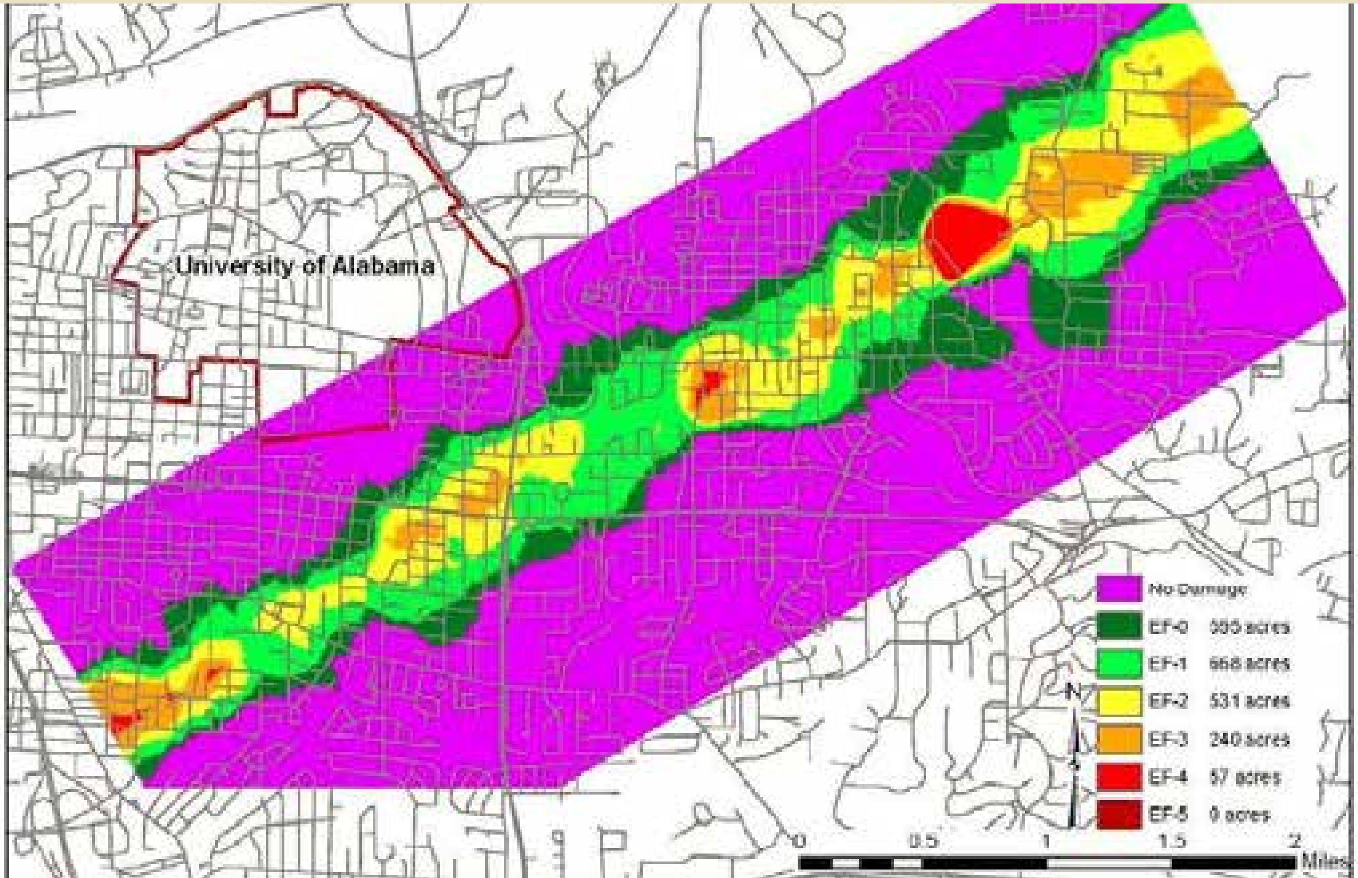
Damage Indicators

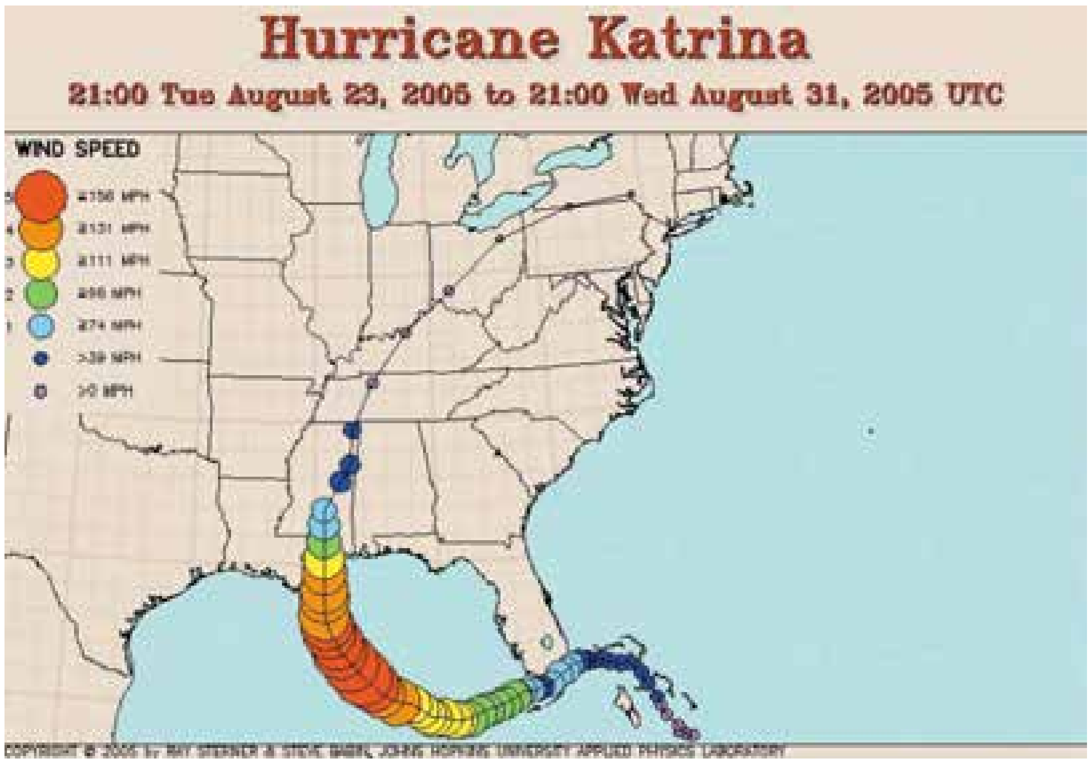
Texas Tornado – December 2015

Nebraska Tornado – June 2017

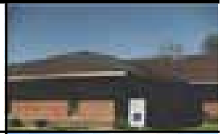
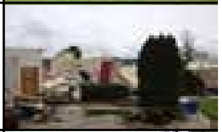
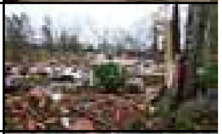
Nebraska Tornado – June 2017

Tornado Intensity Along Path




Hurricane Katrina
21:00 Tue August 23, 2005 to 21:00 Wed August 31, 2005 UTC
WIND SPEED

Percentage of Occurrence

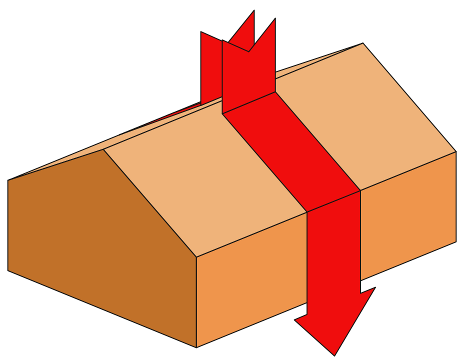
EF-Scale	Wind Speed (3-sec gust)	Relative Frequency	Cumulative Percentage	Examples of Damage
EF-0	65-85	53.5 %	53.5 %	
EF-1	86-110	31.6 %	85.1	
EF-2	111-135	10.7 %	$\boxed{95.8}$	
EF-3	136-165	3.4 %	99.2	
EF-4	166-200	0.7 %	99.9	
EF-5	>200	< 0.1	100	

LOAD PATH

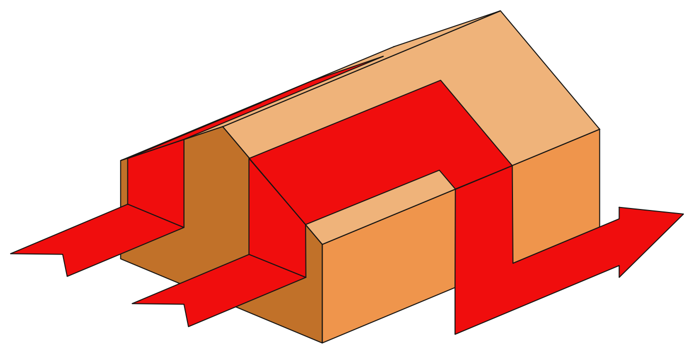
Load Path

A load path takes a load on the structure from the point of origin to the foundation.

There are 2 types of load paths:



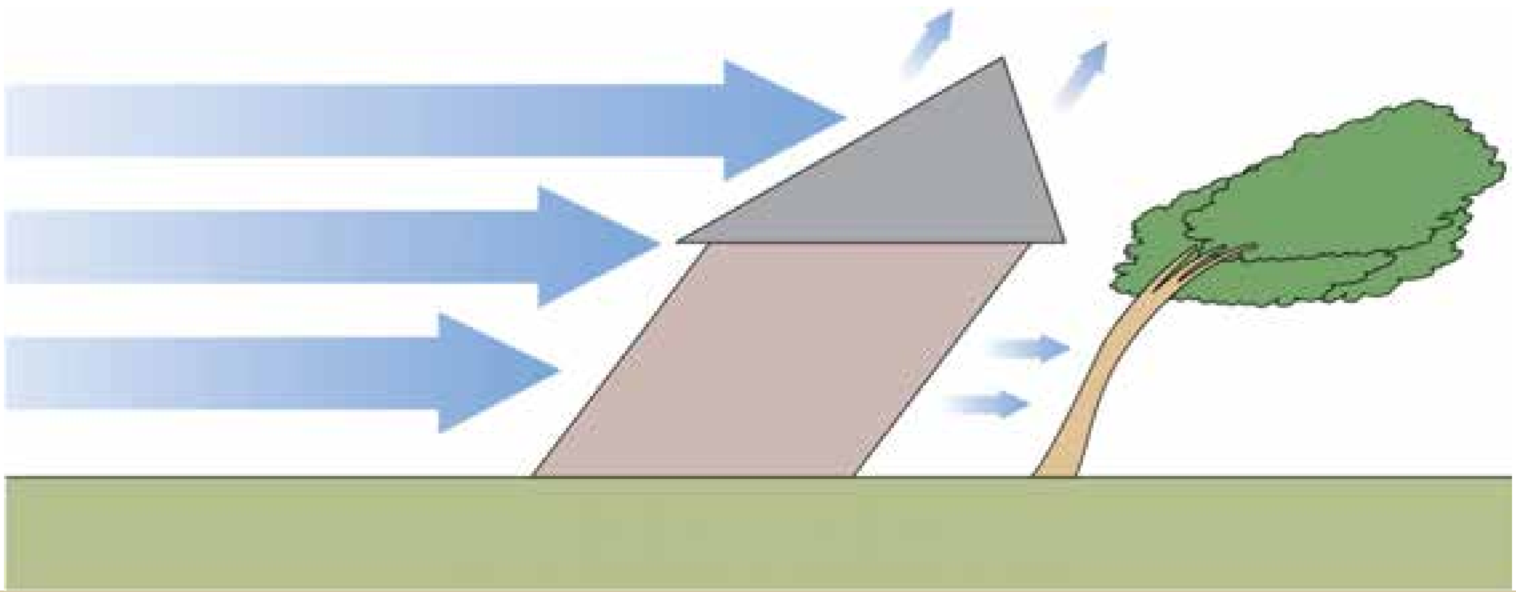
Vertical Load Path
- fairly intuitive



Lateral Load Path
- not as intuitive

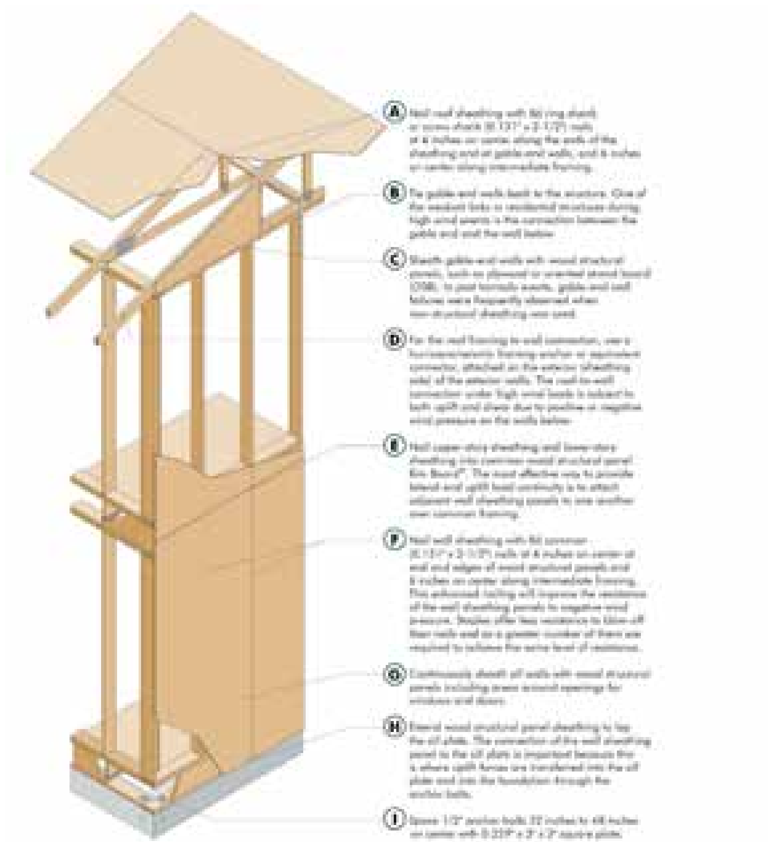
Load Path

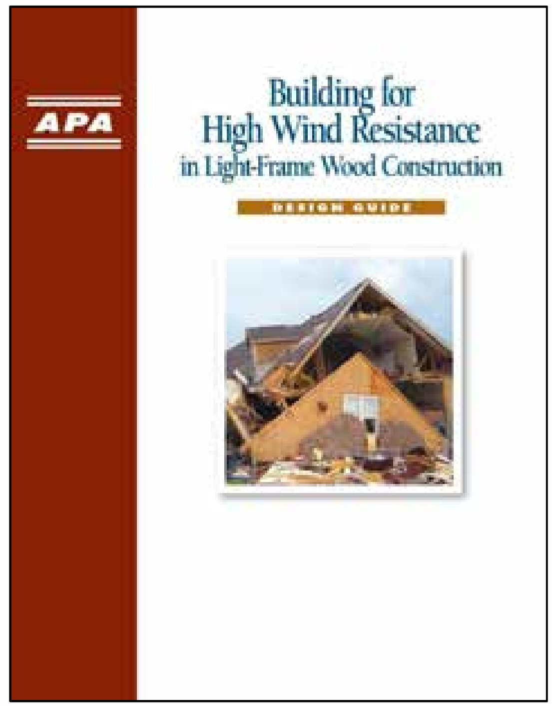
Wind is a complex load…



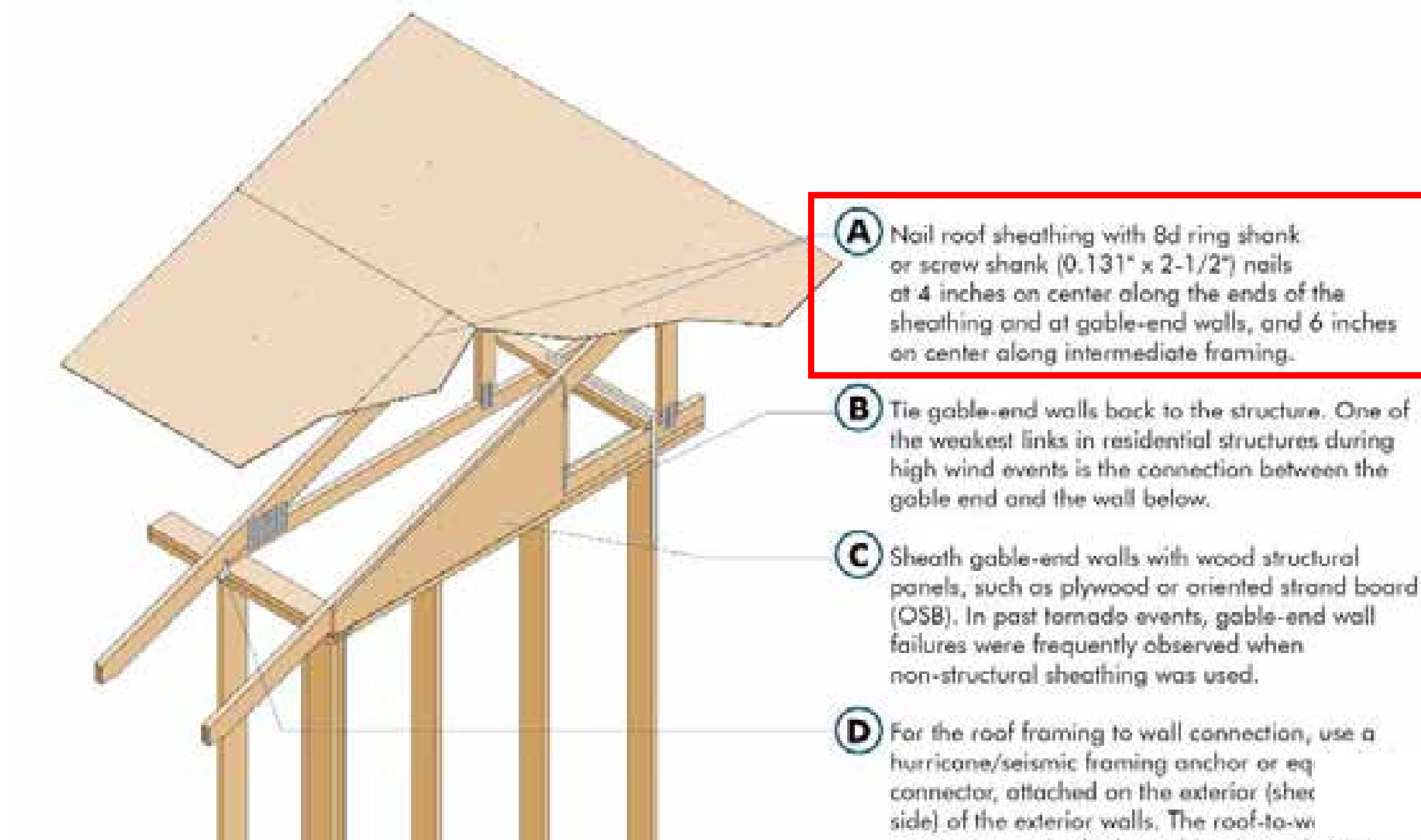
BUILDING FOR HIGH WIND RESISTANCE

Building for High Wind Resistance





A - Roof Sheathing Connection



A - Roof Sheathing Connection

Texas Tornado – December 2015

Springfield, IL
March 16, 2006

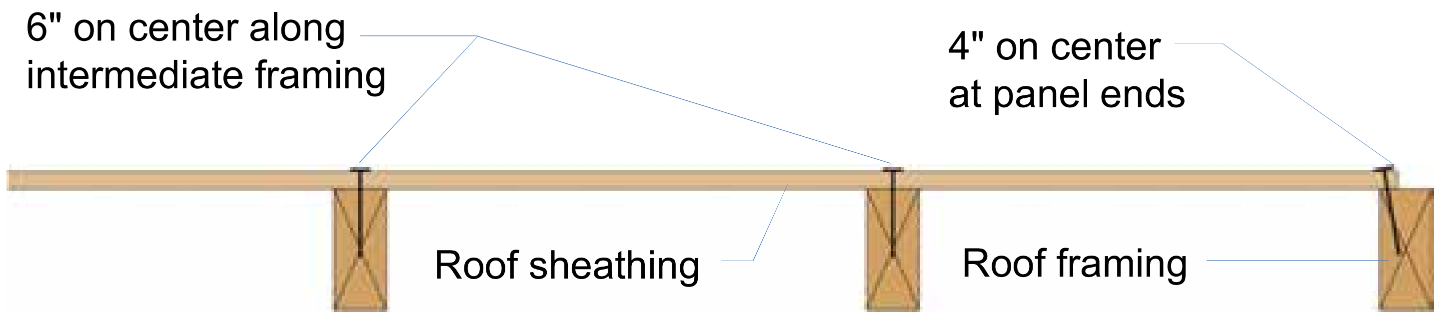
Hartford, WI – Multi-Family Garage Structure – 2006

Texas Tornado – December 2015

Nebraska Tornado – June 2017

A - Roof Sheathing Attachment

Nail roof sheathing with at 4" on center at panel ends and edges and 6" on center in the intermediate framing

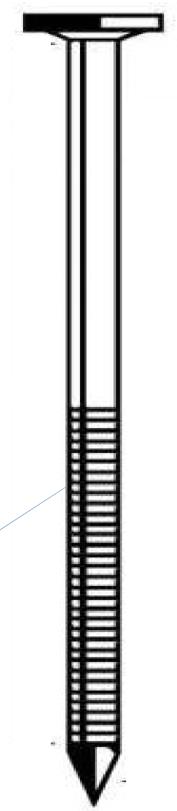


2015 IRC Code Minimum: 6" on center at panel ends and edges and 12" on center in the intermediate framing

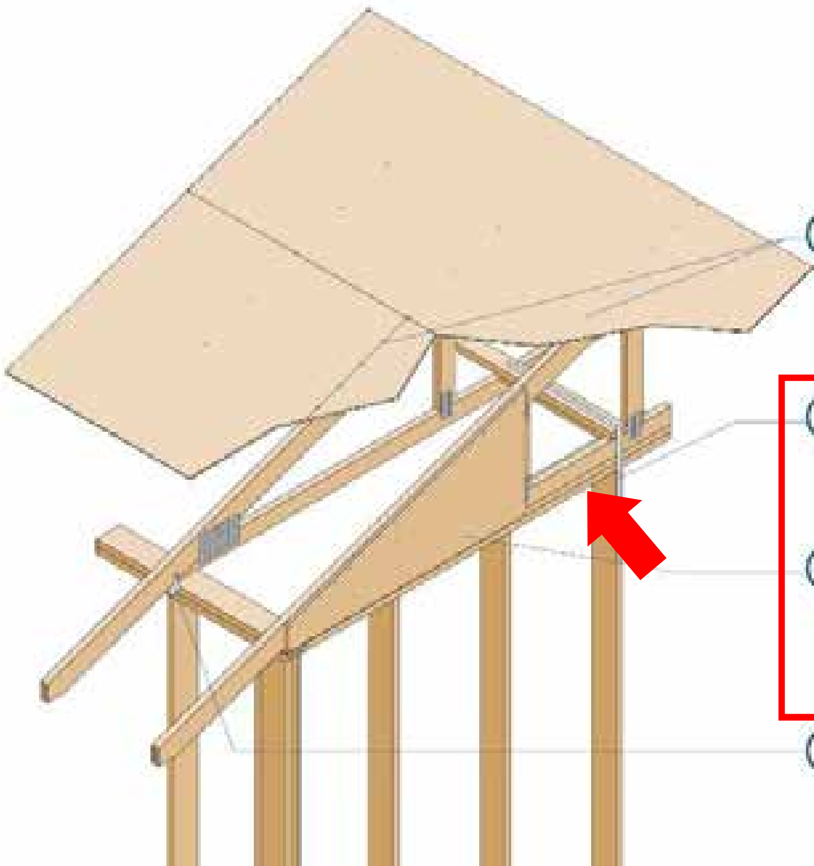
A - Roof Sheathing Attachment

**Fastener Recommendation:
8d (0.131" x 2-1/2") screw or
ring shank nails**

Enhanced withdrawal strength is achieved with the deformed shank



B and C - Gable Ends



A Nail roof sheathing with 8d ring shank or screw shank (0.131" x 2-1/2") nails at 4 inches on center along the ends of the sheathing and at gable-end walls, and 6 inches on center along intermediate framing.

B Tie gable-end walls back to the structure. One of the weakest links in residential structures during high wind events is the connection between the gable end and the wall below.

C Sheath gable-end walls with wood structural panels, such as plywood or oriented strand board (OSB). In past tornado events, gable-end wall failures were frequently observed when non-structural sheathing was used.

D For the roof framing to wall connection, use a hurricane/seismic framing anchor or equivalent connector, attached on the exterior (sheathing side) of the exterior walls. The roof-to-wall

Nebraska Tornado – June 2017

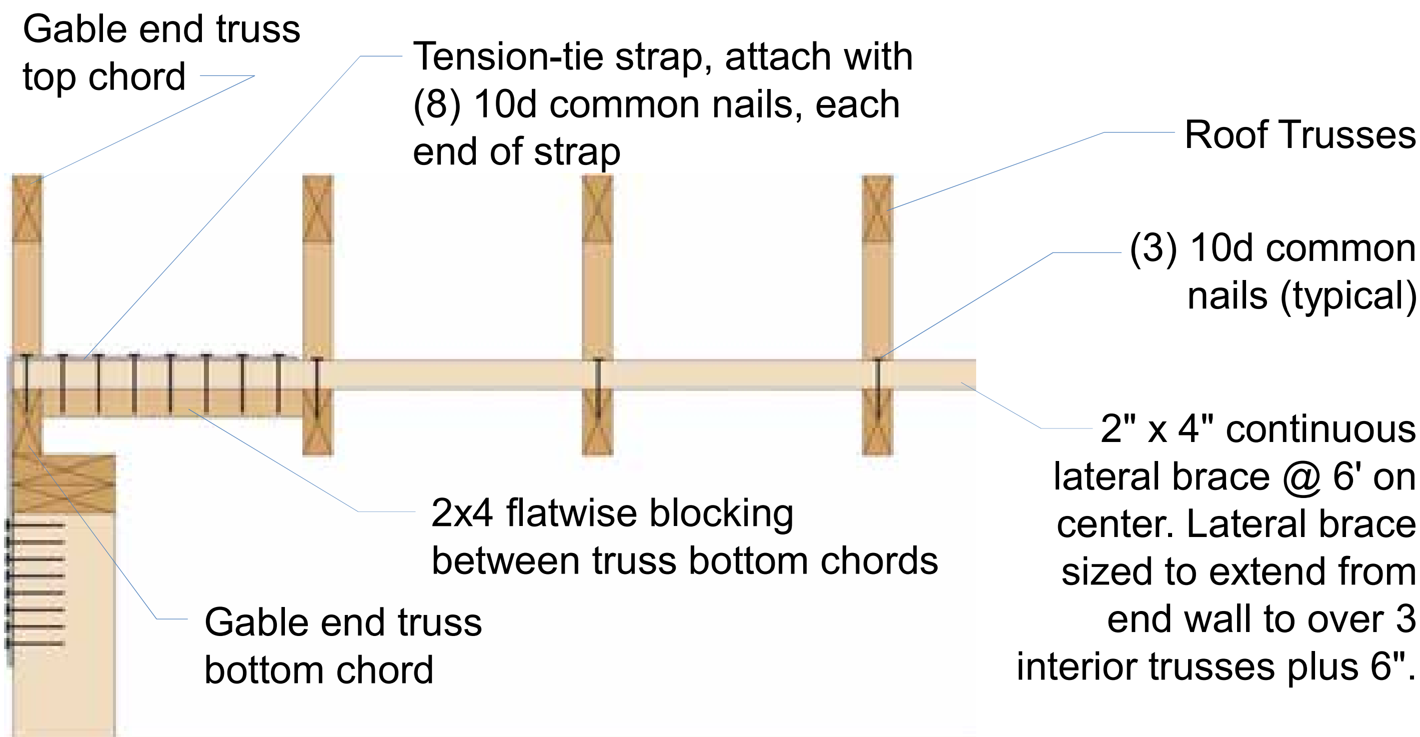
Fayetteville, North Carolina – 2011 Tornados

Nebraska Tornado – June 2017

Nebraska Tornado – June 2017

B and C - Gable Ends

Tie gable end walls back to the structure



B and C - Gable Ends

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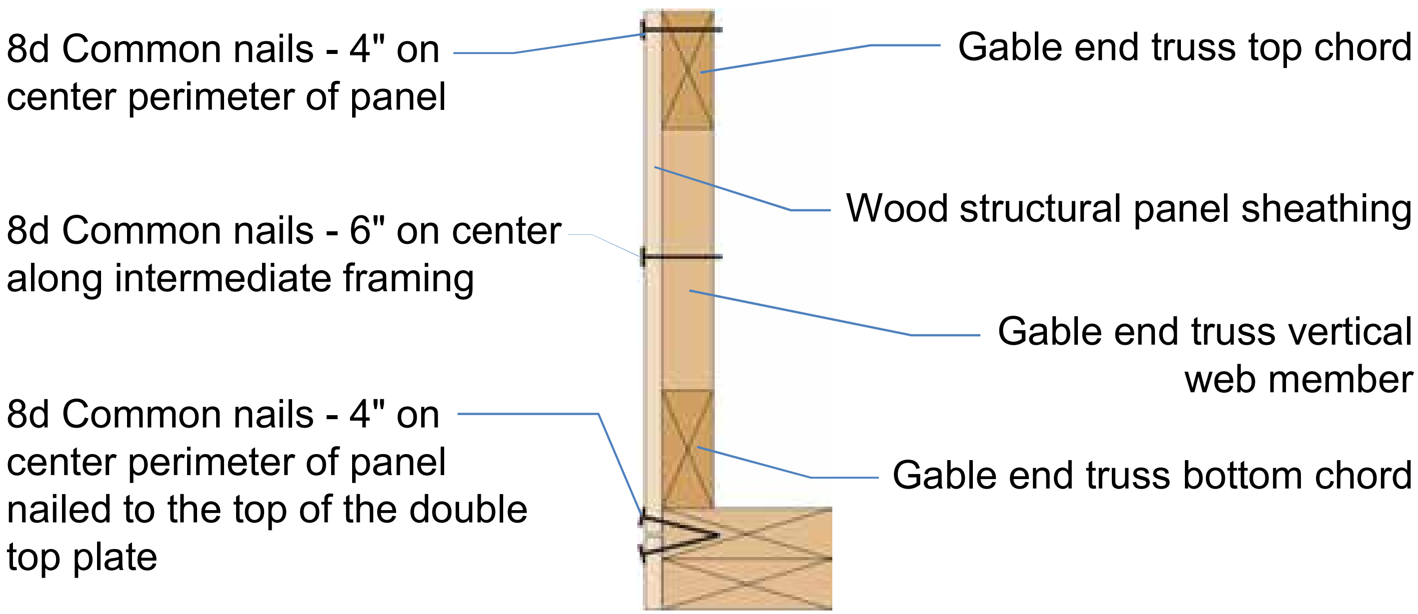
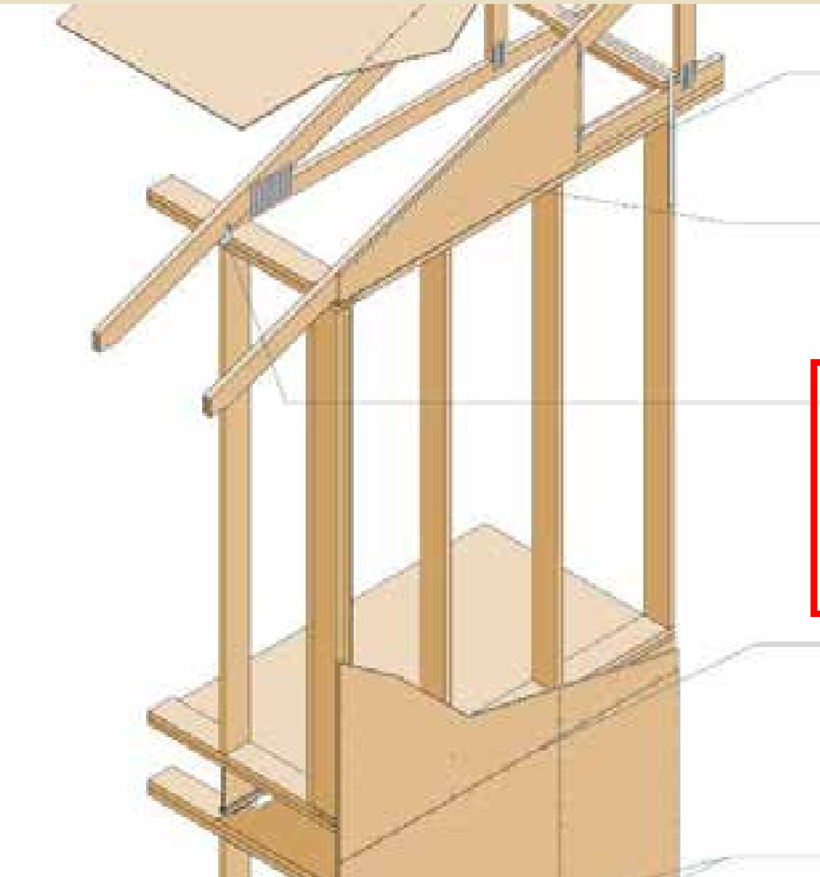
Resisting Pressure on Components and Cladding: Sheath gable end walls with wood structural panels such as plywood or oriented strand board (OSB)



D - Top Plates



on center along intermediate framing.

B Tie gable-end walls back to the structure. One of the weakest links in residential structures during high wind events is the connection between the gable end and the wall below.

C Sheath gable-end walls with wood structural panels, such as plywood or oriented strand board (OSB). In past tornado events, gable-end wall failures were frequently observed when non-structural sheathing was used.

D For the roof framing to wall connection, use a hurricane/seismic framing anchor or equivalent connector, attached on the exterior (sheathing side) of the exterior walls. The roof-to-wall connection under high wind loads is subject to both uplift and shear due to positive or negative wind pressure on the walls below.

E Nail upper-story sheathing and lower-story sheathing into common wood structural panel Rim Board®. The most effective way to provide lateral and uplift load continuity is to attach adjacent wall sheathing panels to one another over common framing.

F Nail wall sheathing with 8d common

D - Top Plates

Garland, Texas – 2015

Battlefield, MO Fire Station – 2003

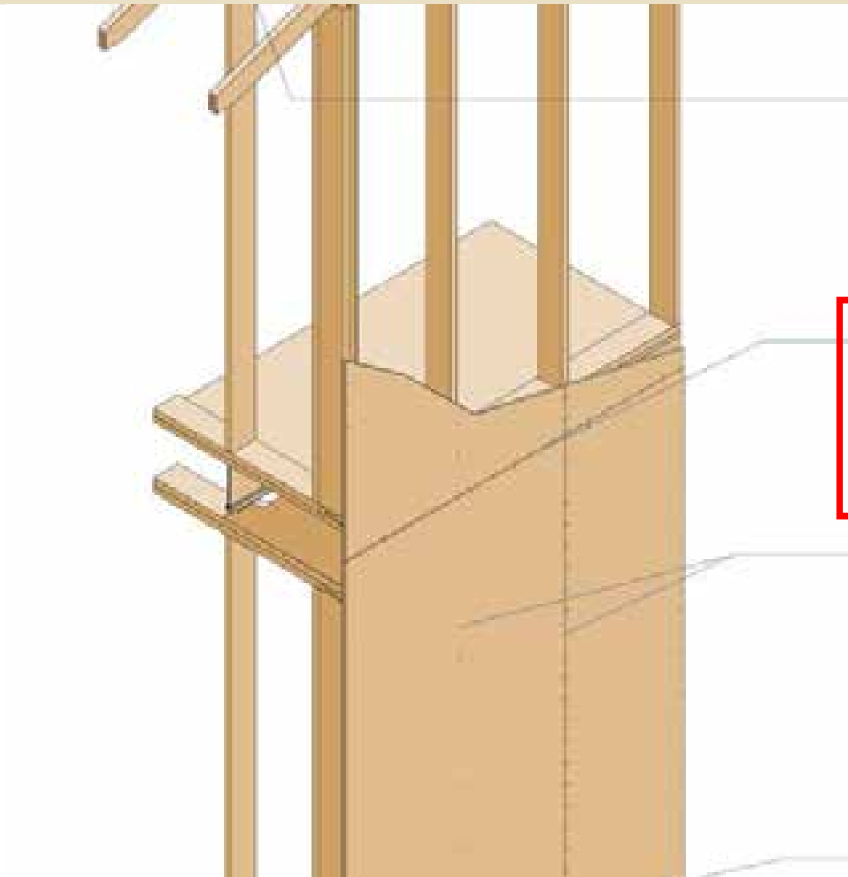
Missouri Tornado – 2003

Missouri Tornado – 2003

D - Top Plates

Pre-engineered Connectors

E - Rim Board Connections



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F Nail wall sheathing with 8d common (0.131" x 2-1/2") nails at 4 inches on center at end and edges of wood structural panels and 6 inches on center along intermediate framing. This enhanced nailing will improve the resistance of the wall sheathing panels to negative wind pressure. Staples offer less resistance to blow-off than nails and so a greater number of them are required to achieve the same level of resistance.

G Continuously sheath all walls with wood structural

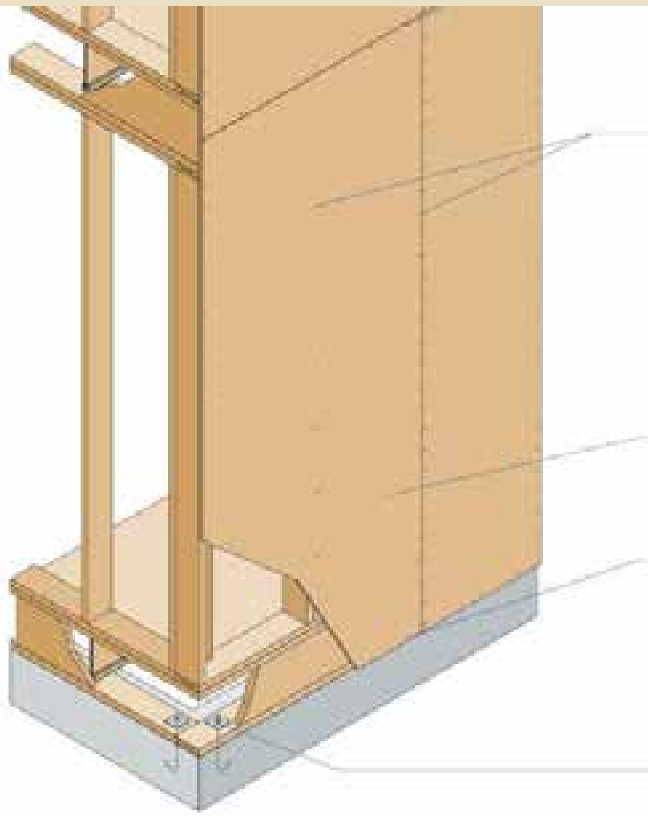
Texas Tornado – December 2015

Nebraska Tornado – June 2017

E - Rim Board Connections

E - Rim Board Connections

F and G - Wall Sheathing



lateral and uplift load continuity is to attach adjacent wall sheathing panels to one another over common framing.

(F) Nail wall sheathing with 8d common (0.131" x 2-1/2") nails at 4 inches on center at end and edges of wood structural panels and 6 inches on center along intermediate framing. This enhanced nailing will improve the resistance of the wall sheathing panels to negative wind pressure. Staples offer less resistance to blow-off than nails and so a greater number of them are required to achieve the same level of resistance.

(G) Continuously sheath all walls with wood structural panels including areas around openings for windows and doors.

(H) Extend wood structural panel sheathing to lap the sill plate. The connection of the wall sheathing panel to the sill plate is important because this is where uplift forces are transferred into the sill plate and into the foundation through the anchor bolts.

(I) Space 1/2" anchor bolts 32 inches to 48 inches on center with 0.229" x 3" x 3" square plate.

Springfield, IL – Fairfield Inn – 2006

Missouri Tornado – 2003

Missouri Tornado – 2003

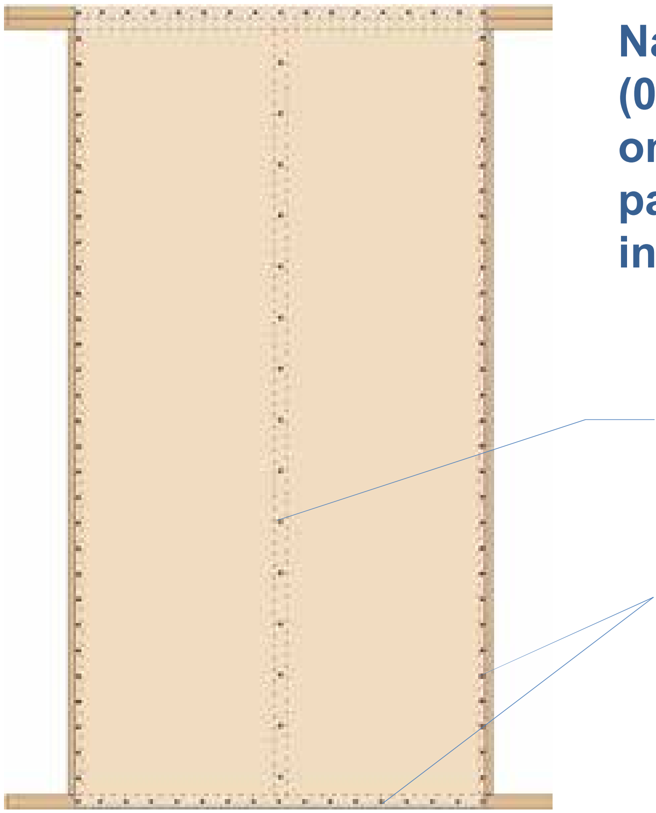
Nebraska Tornado – June 2017

Missouri Tornado – 2003

F and G - Wall Sheathing

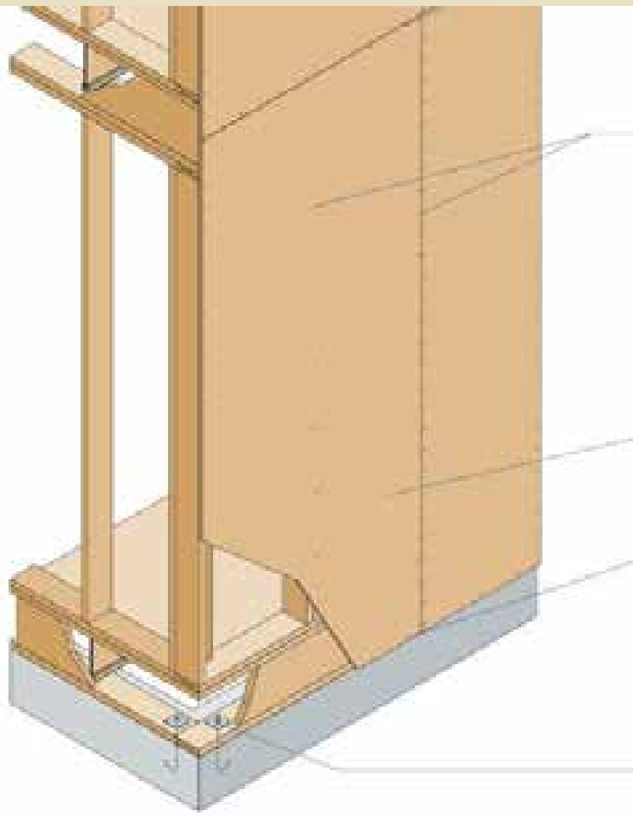
Texas Straight Line Wind – March 2017

F and G - Wall Sheathing Attachment



Nail wall sheathing with 8d common (0.131" x 2-1/2") nails at 4" on center on the perimeter of wood structural panel wall sheathing and 6" on center in the field

H and I - Sill Plates and Anchor Bolts



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H and I - Sill Plates and Anchor Bolts

Garland, Texas – 2015

H and I - Sill Plates and Anchor Bolts

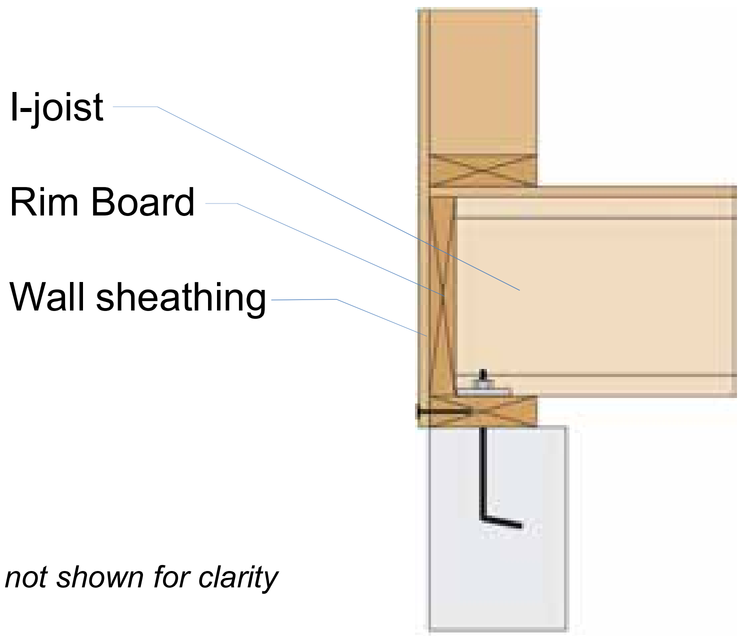
Nebraska Tornado – June 2017

H and I - Sill Plates and Anchor Bolts

Tennessee Tornado – March 2017

Wall Framing to Sill Plate Connection

Extend wood structural panel sheathing at bottom of wall to sill plate intersection



Other connections are not shown for clarity

Tennessee - 2018

Missouri Tornado – 2003

H and I - Sill Plates and Anchor Bolts

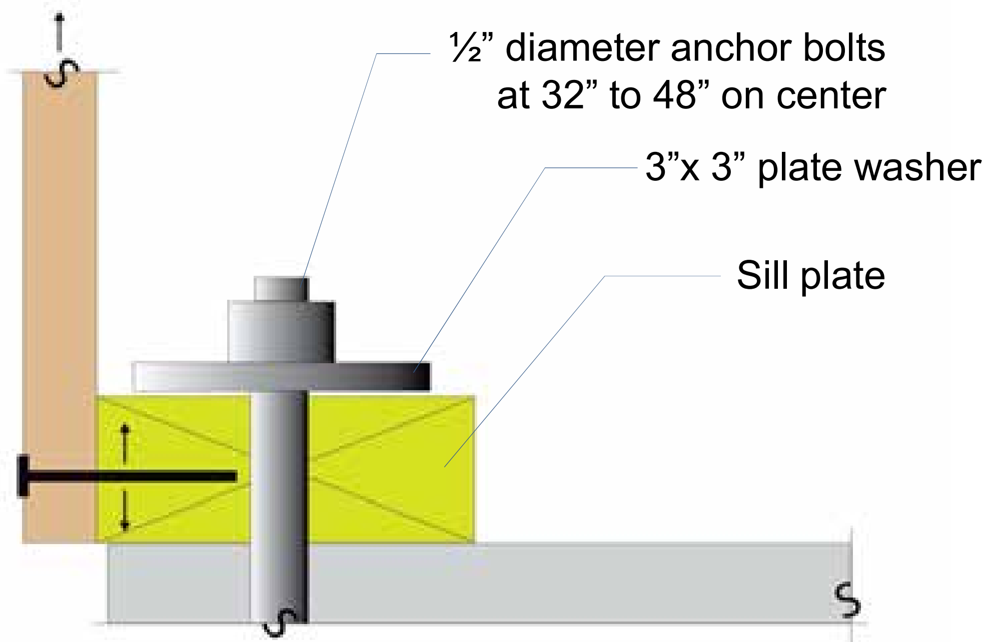
Texas Tornado – December 2015

H and I - Sill Plates and Anchor Bolts

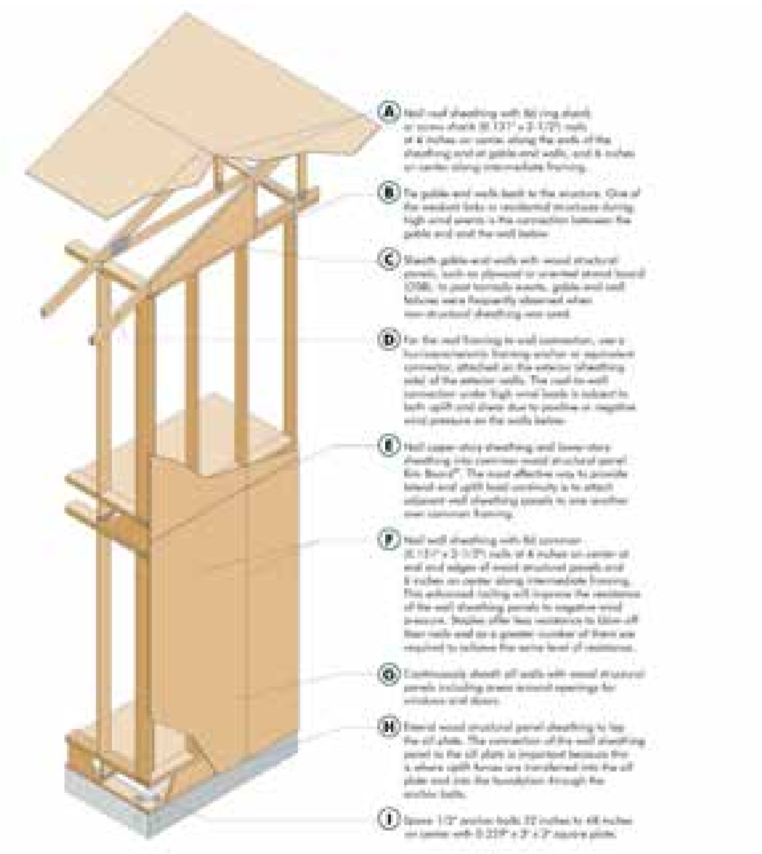
Texas Tornado – December 2015

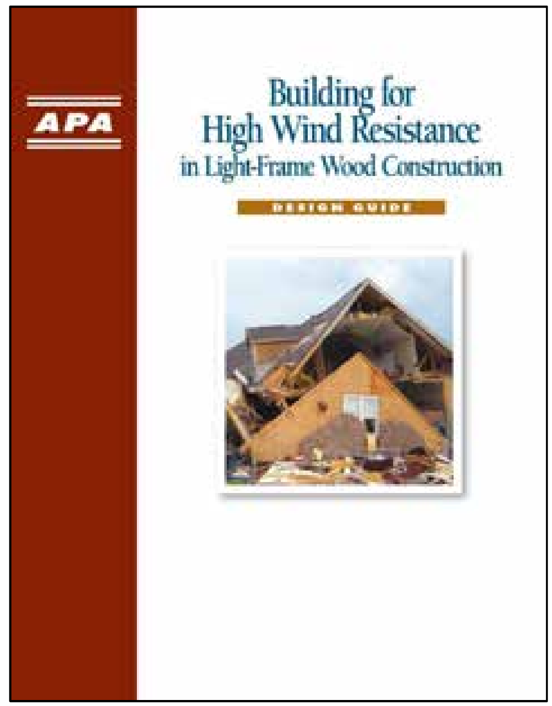
Anchor Bolt Installation

Large plate washers (3”x3”x0.229”) prevent pull through of sill plate



Building for High Wind Resistance





www.apawood.org/wind-weather-seismic

Thanks for Attending!