

RESILIENT HOME BUILDING GUIDE

HIGH WIND WOOD FRAME CONSTRUCTION

Twenty six percent (approximately 30 million) of U.S. households are in wind zones with an expected wind speed of 110 mph (3-second gust) or greater. Homes in these high wind zones should be designed and built to be strong and weather resistant to improve safety and reduce costly repairs following severe weather. This guide illustrates high wind building design and construction practices, beyond code practices and recommendations for added resiliency.

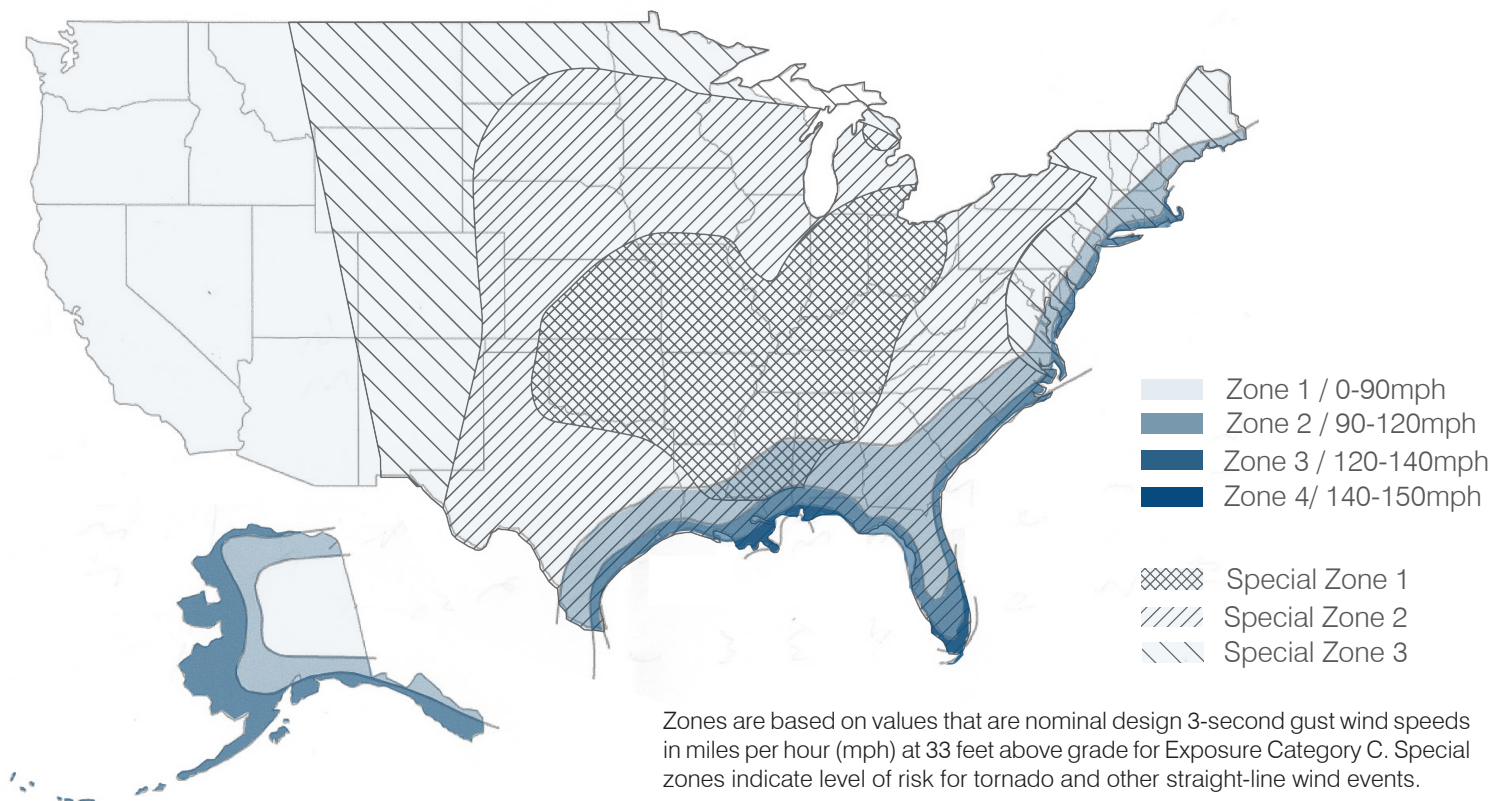
BUILDING CODES

The purpose of this guide is to provide information to designers and homebuilders about high wind construction while outlining options for enhanced resilience with affiliated costs and benefits. Building codes and practices vary throughout the U.S., so users of this guide should become familiar with local building codes and keep in mind that a home can be made more resilient by building beyond the building code. This guide will not detail all building code requirements, but will highlight beyond code and other proven ways to increase resilience.

WIND ZONES

Some building codes use different methods to calculate wind forces and the wind zone maps vary accordingly. For example the 3-second gust wind speed of 120 mph used in the International Building Code is equivalent to fastest mile wind speed of 104 mph used in other codes. The map used here is a general guide to wind zones. Detailed maps included with local building codes should be used for determining appropriate design wind speeds.

Wind Zone Map





The nonprofit Federal Alliance for Safe Homes (FLASH®) is the country's leading consumer advocate for strengthening homes and safeguarding families from natural and manmade disasters. The FLASH mission is to promote life safety, property protection and resilience by empowering the families with knowledge and resources for strengthening homes and safeguarding families from disasters of all kinds. www.flash.org

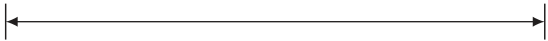
GCCDS

Gulf Coast Community Design Studio

Mississippi State University College of Architecture Art + Design

The Gulf Coast Community Design Studio (GCCDS) is a professional service and outreach program of Mississippi State University's College of Architecture, art + design. The GCCDS works through close, pragmatic partnerships with local organizations and communities, regional nonprofits, local governments, universities, developers and other partners across the country to help shape vibrant and resilient Gulf Coast communities. <http://www.gccds.org/>

architecture for humanity



Architecture for Humanity is a nonprofit design services firm founded in 1999. By building a more sustainable future through the power of professional design, Architecture for Humanity taps a network of more than 55,000 professionals willing to lend time and expertise to help those who would not otherwise be able to afford their services. They bring design, construction and development services where they are most critically needed. To learn more about Architecture for Humanity and support their work, go to www.architectureforhumanity.org

The purpose of this Resilient Design Guide is to provide architects, designers or even homeowners the information necessary to make any set of house plans useful for constructing a more wind resilient structure. The guide was developed during the course of a two-day charrette that brought together a cross-section of professionals from across the United States. The charrette allowed participants to tap into diverse knowledge and resources provided by professionals, including academics, architects, community outreach organizations, engineers, homebuilders, insurance professionals, manufacturers, product experts and other building professionals with practical experience before and after high wind disasters, including hurricanes and tornadoes. The group pooled their knowledge and experience to develop an outline for this guide with the goal to provide not only an overview of the "why," but the "how to" of resilient wind construction. The authors sincerely appreciate the many dedicated professionals that supported this guide.

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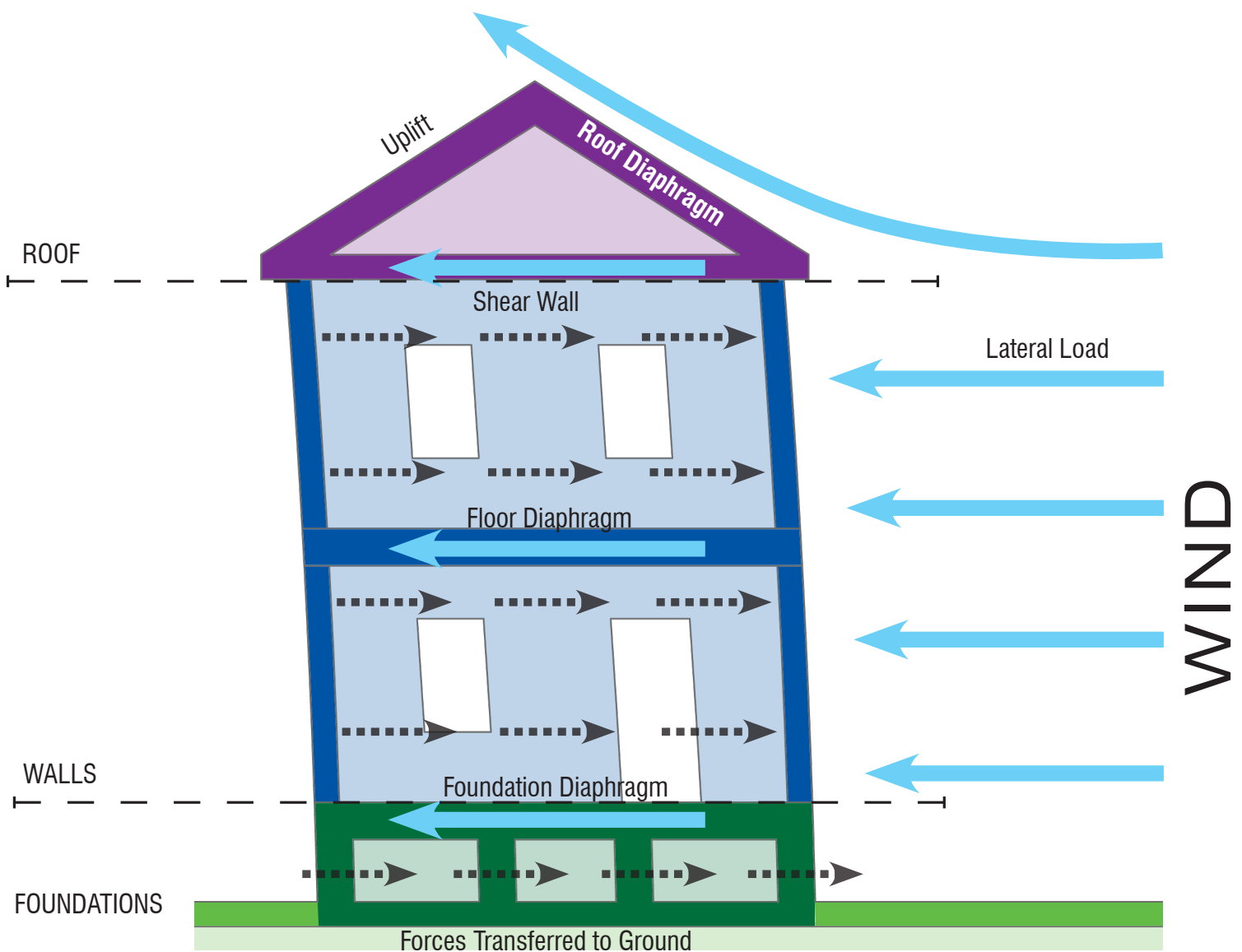
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House as a Whole System

Typically, the primary force from wind is lateral (sideways) force. For a wind of 150 mph, the wind force is approximately 42 pounds per square foot of wall area. If this load were equated to a roof load, it would compare to the weight of three feet of snow acting horizontally. Ordinary construction is designed to transfer the vertical loads of a house from the roof to the foundation and is typically inadequate to resist such high winds. Roof decking, shear walls, clips, straps, and anchor bolts work together to provide lateral support. In addition to lateral loads, winds produce uplift forces that act dynamically to pull off the components of a house apart. The structural system that transfers the force from the walls down to the ground is a set of connected diaphragms – the roof and the floor decks are stiff horizontal diaphragms that transfer wall loads into vertical shear wall diaphragms. In the roof, floor and wall diaphragms, sheathing strength and nailing, as well as strong continuous boundary conditions such as double top plates, blocking and rim joists are essential details.



Roof

Walls

Foundation

Site

Construction Types Used in this Guide

ORDINARY CONSTRUCTION

Common wood-frame house construction is typically strong enough for wind speeds less than 100 mph. Ordinary wind design construction is illustrated in this guide to give a reference for the typical components of wood frame construction.

HIGH WIND CONSTRUCTION

Wind speeds above 100 mph require lateral strength from the roof to the foundation not provided by ordinary wind construction. High wind construction is illustrated in the pages of this guide to help explain what is generally required by various building codes to meet lateral and uplift load requirements for high wind construction standards.

RESILIENT CONSTRUCTION

Houses can be made more resilient by designing for a higher wind load because the safety factor will be increased, making house components more resistant to wind and rain during storms. Increased resilience construction is illustrated in this guide with information regarding costs and expected benefits of making homes more resilient.



These markers are used throughout the guide to indicate whether a building material is considered typical in high wind construction or represents an “increased resilience” construction upgrade.



This icon indicates the cost implication of different components from 1 to 5 with 1 representative of baseline construction costs.



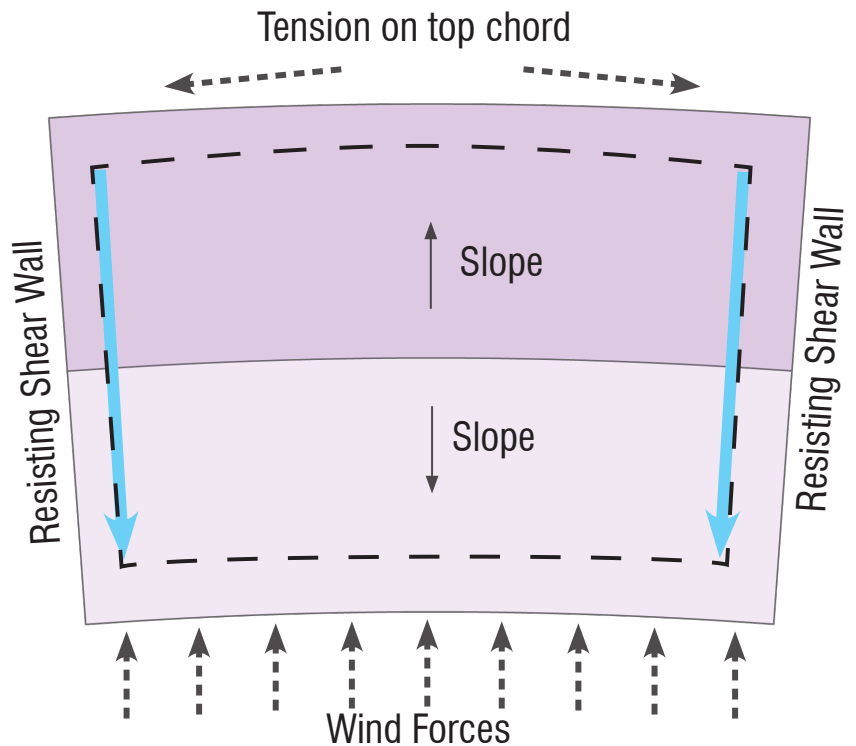
This icon indicates the construction implication and/or difficulty level from 1 to 5 scale with 1 representative of baseline for ease of construction need for specialized installation and ability for skilled labor to complete the work.

HOW A ROOF WORKS IN WIND

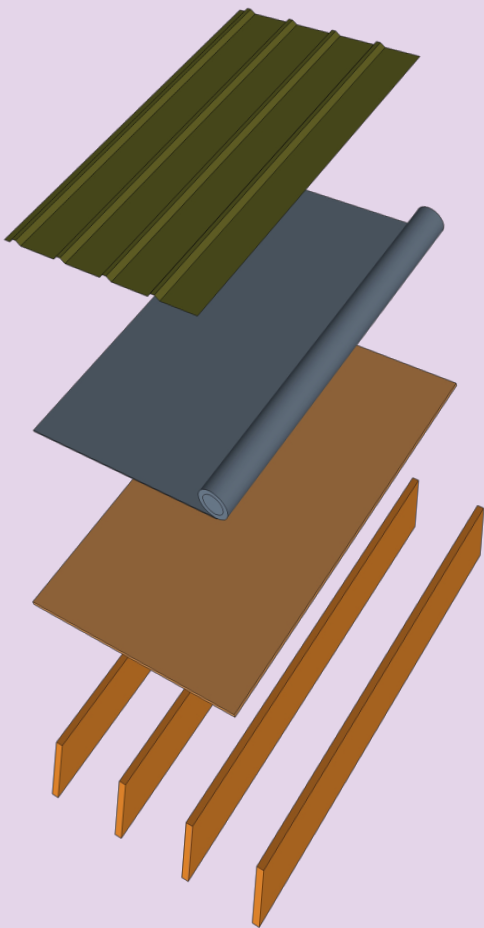
The roof is the primary structural element of the house, transferring the loads that act on the walls facing the wind into the walls that are parallel to the wind. The main structural components of a roof assembly include: 1) strong nailing of the roof deck to the framing, especially at the edges; 2) connection of the roof to shear walls with blocking; and 3) an unbroken double top plate on the shear walls that acts as a structural chord.

Roofs are highly exposed to wind and rain and need to be strong as an overall structural system as well as watertight at any given area on the roof. A resilient roof has two durable layers of protection designed for high winds that include roof covering and underlayment.

Overhead View of Roof



ROOF COMPONENTS



Coverings are the roof's first line of defense against wind and wind driven rain. Common residential coverings include asphalt shingles, concrete/clay tiles and metal panels.

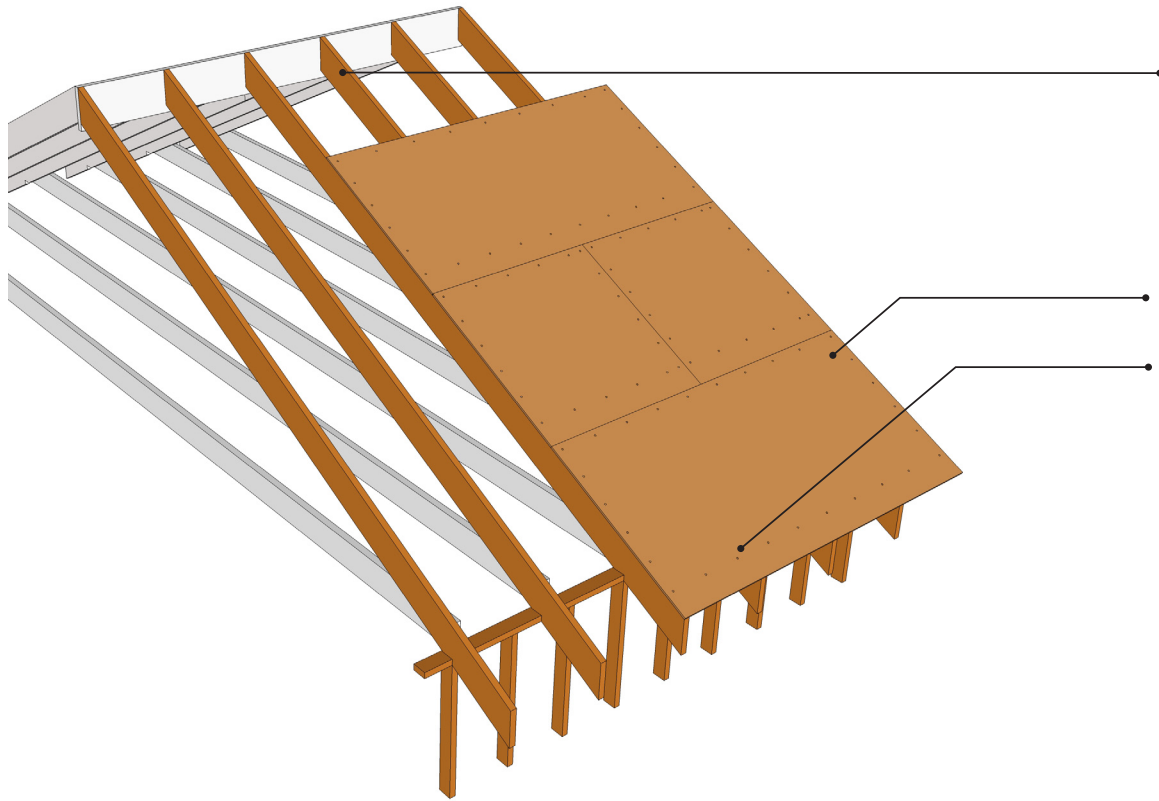
Underlayment is a secondary layer of roof covering designed to keep moisture from the decking. If a primary covering layer fails, properly installed underlayment will keep water from penetrating the roof and attic. Common underlayment includes 30 lb. felt or tar paper, self-adhesive membranes and membranes that are fully integrated into the decking.

Sheathing/decking is a structural component of a roof typically made of plywood or oriented strand board (OSB) panels. Decking is fastened to the top of the roof framing and makes the framing rigid, so it can transfer loads to the exterior walls.

Framing is the primary structural element of a roof. In this guide, residential framing is limited to wood rafters and wood trusses. Roof framing should be tied to the walls as part of a load path from the roof to the foundation.

ORDINARY CONSTRUCTION

Typical components of wood frame construction



Framing

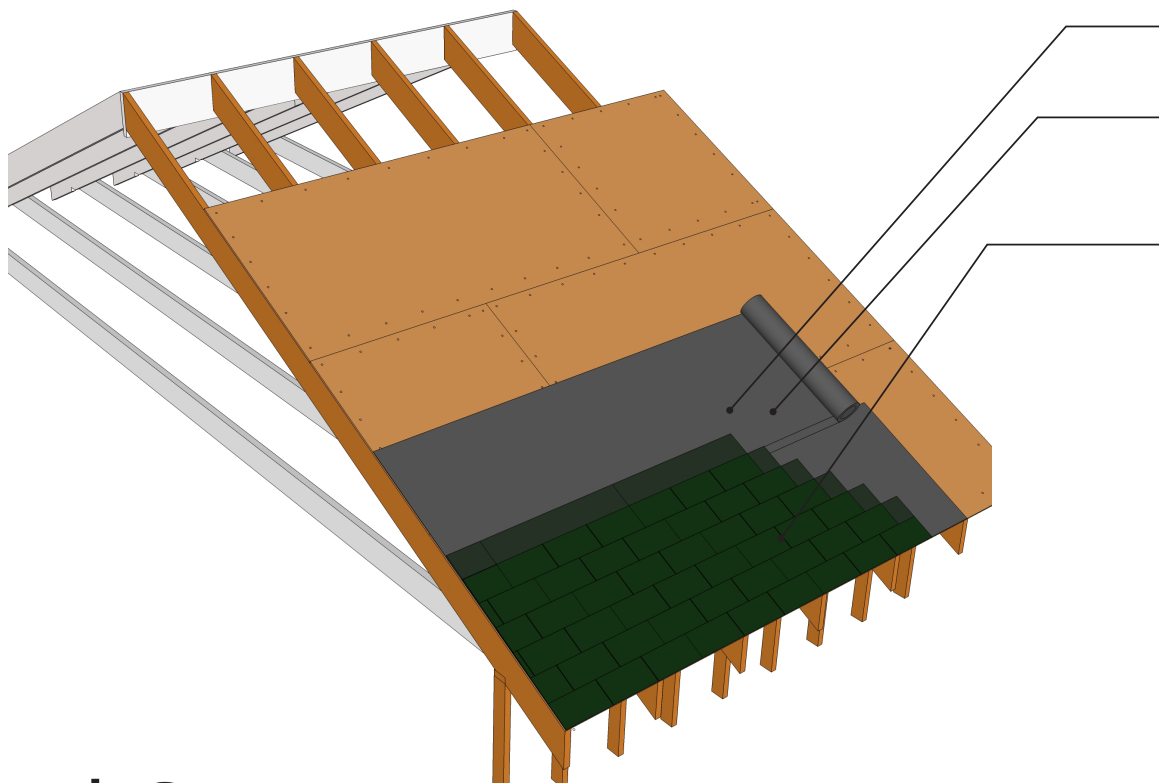
#2 grade 2x rafter & joist framing @ 24" O.C. or 2x engineered truss @ 24" O.C.

Decking

1/2" plywood/OSB decking

8d ring shank nails 6" O.C. edge 8" O.C. field

\$  Structure Detail



Underlayment

30# lb. felt building/tar paper

Staple fastener

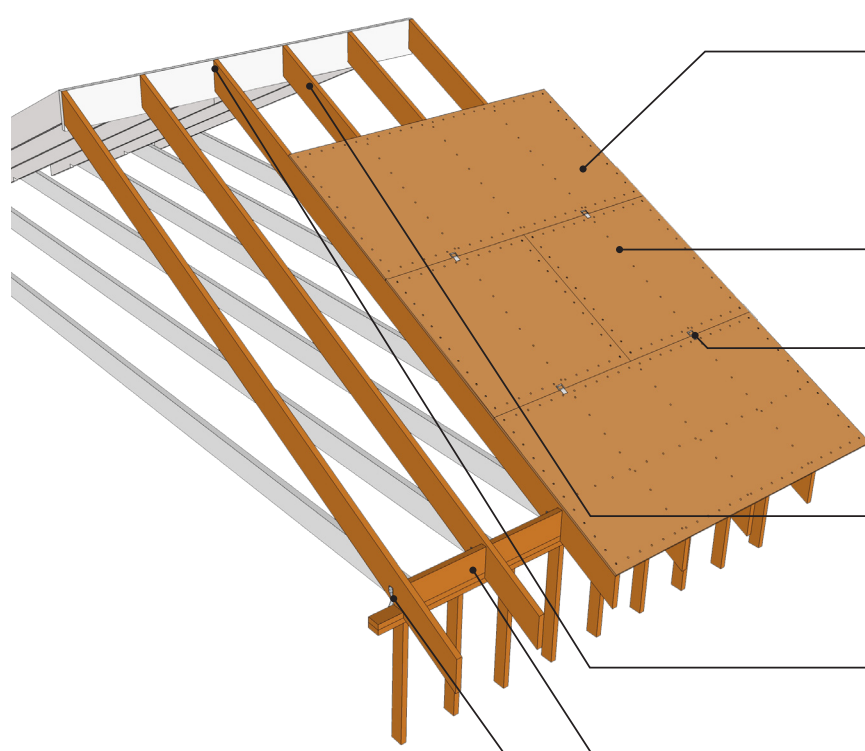
Coverings

Three tab shingle - 4 corrosion resistant nails per shingle

\$  Covering Detail

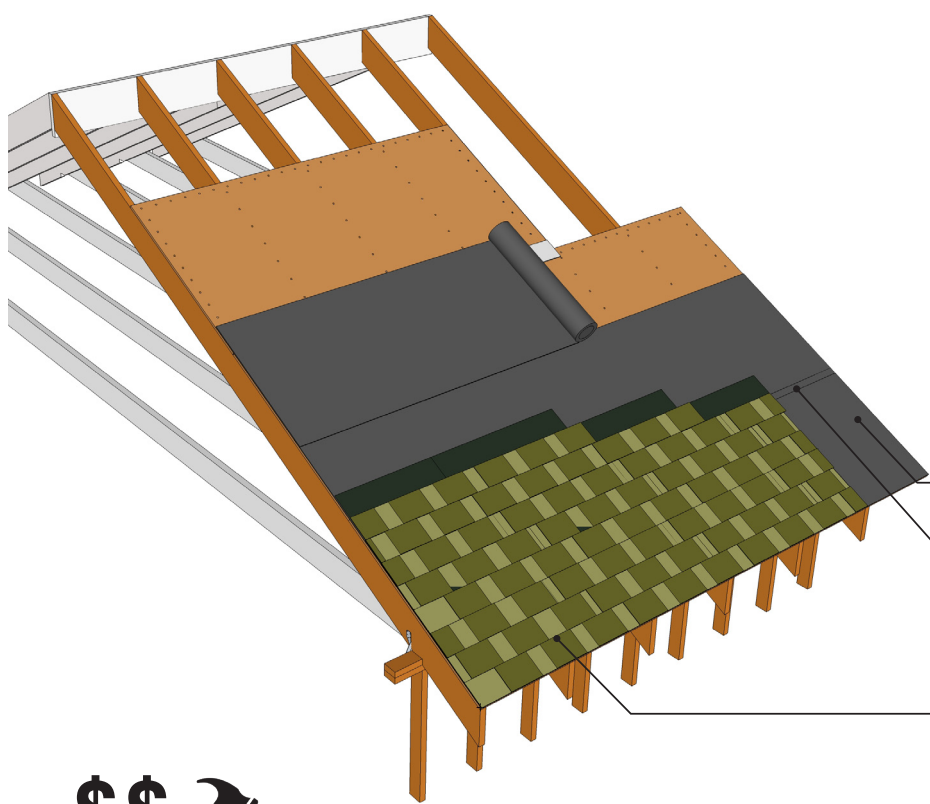
HIGH WIND CONSTRUCTION

Generally required by various high-wind building codes



- **Decking**
5/8" plywood/OSB decking (full sheet at eaves, ridges; no sheet narrower than 24" anywhere on the roof and no sheet shorter than 48" at rake edge)
- 10d ring shank fastener 4" O.C. at edge and eave blocking, 6" O.C. in field
- Panel edge "H" clip spaced between framing member attachment
- **Framing**
#2 grade 2x rafter & joist framing @ 24" O.C. or 2x engineered truss @ 24" O.C.
- Metal strap tie at ridge installed before decking
- 2x eave blocking cut to match roof slope, installed before roof deck
- Strap on every rafter/truss

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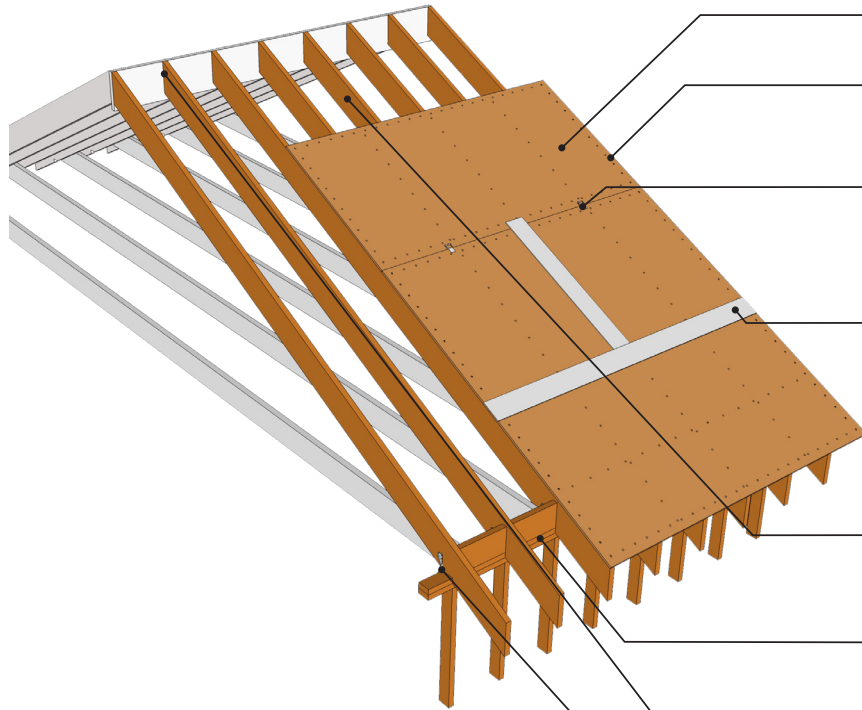


- **Underlayment**
30# lb. felt building/tar paper
- Button cap fastener 9" O.C. edge 18" O.C. field
- **Coverings**
High-Wind rated shingles
6 corrosion resistant nails per shingle

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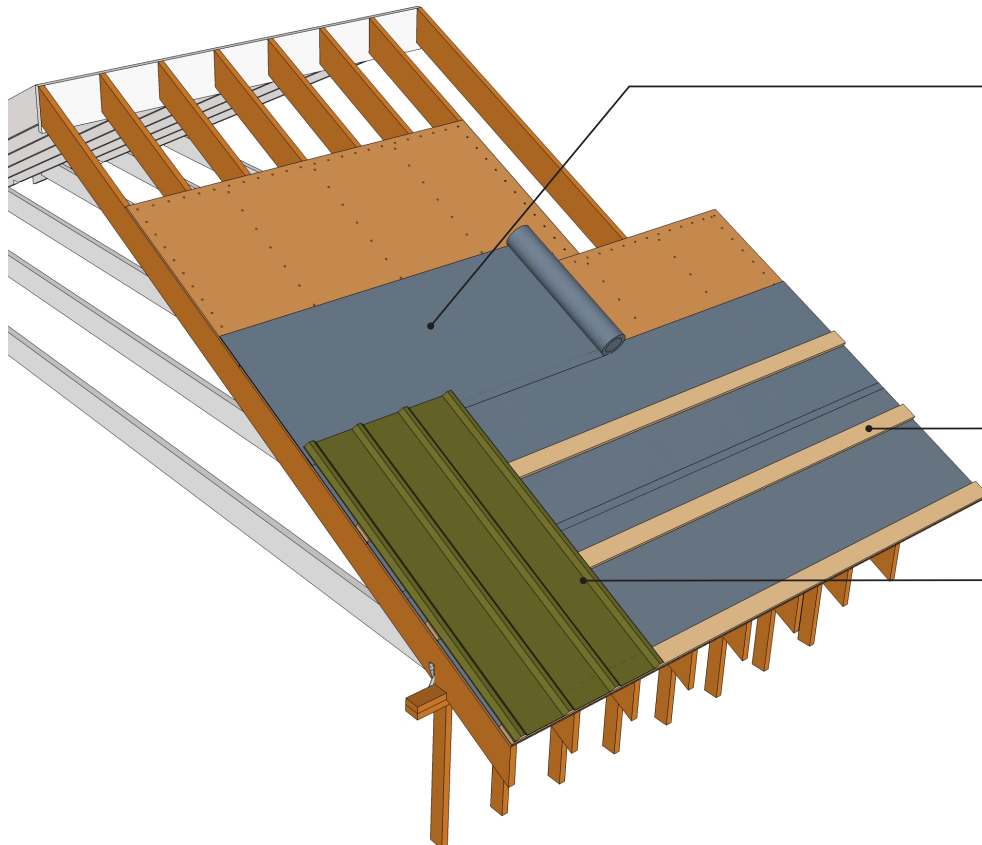
RESILIENT CONSTRUCTION

Reduces the damaging effects of a storm



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- Decking
 - 5/8" plywood/OSB decking
 - 10d ring shank fastener 4" O.C. at edge at eave blocking, 6" O.C. field
 - Panel edge "H" clip spaced between framing member attachment
 - 4" self-adhering polymer modified bitume flashing tape and polyurethane spray foam adhesive at underside of decking at all framing and joints attachments
- Framing
 - #2 grade 2x rafter & joist framing @ 16" O.C. or 2x engineered truss @ 16" O.C.
 - 2x eave blocking cut to match roof slope, installed before roof deck
 - Metal strap tie at ridge installed before decking
 - Strap on every rafter/truss



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- Underlayment
 - Self-adhering polymer modified bitumen membrane over entire roof deck or
 - Self-adhering polymer modified bitume flashing tape on all decking panel joints. 30# lb. felt building/tar paper. Button cap fastener 9" O.C. edge 12" O.C. field
- Coverings
 - On 1x4 wood (untreated) purlins fastened by 2 10d ring shank nails @ 12" O.C. into framing every other set
 - Metal Roof screw down panel
 - Per manufacturers' specification for increased wind load or
 - Metal Panel/Standing Seam Metal Roof System
 - Per manufacturers' specification for increased wind load
 - Concrete & Clay Tile Systems
 - Per manufacturers' specification for increased wind load

SUPPLEMENTAL INFORMATION - ROOF

Hazards

Roofs are the most susceptible component of houses exposed to hurricane force winds. Typically, wind damage to roofs is caused by uplift forces (vertical), suctional and torsional forces (twisting) and horizontal pressures. Wind damage effects vary depending on the roof height, slope, siting and style. Steep roof systems generally fail at the ridge or along gable ends where wind forces are the highest. Low slope roofs typically fail at roof corners. According to information gathered by FEMA after major storms, the roof component damaged most often in high wind is the roof covering (shingle, tile, etc.), and the second most common damage is sheathing (e.g. plywood or OSB decking). Covering failure usually follows use of the incorrect type of fasteners, e.g. nail too small or absence of mechanical attachment on clay tiles, etc. Sheathing damage is more often the result of insufficient attachment, e.g. not enough nails in the nailing pattern. Once the failures occur, they not only expose buildings to water penetration, but also generate windborne debris. When roof systems fail during a hurricane or other high wind events, the rest of the home is weakened and becomes vulnerable to significant, progressive damage.



credit: FEMA

Ridges, Valleys and Accessories

Roof ridges often experience covering loss in hurricanes or severe windstorms, and vented ridge caps should be properly fastened to ensure adequate resistance. Low profile ridge vents are a good choice as they are less vulnerable in high wind events. Roof valleys are vulnerable in severe weather because they experience significant water flow that can lead to water infiltration. Special care should be taken to follow manufacturers' specifications to attach all roof elements, including accessories, equipment, solar panels and/or turbine roof vents.

Underlayment & Coverings

Underlayment should be securely fastened to roof decking independently of the roof covering fasteners. Staples are sometimes used to fasten underlayment materials such as building paper or felt based on the assumption that fasteners used to apply roof shingles on top will secure the underlayment. Unfortunately, in a high wind zone, roof shingles are often lost and this leaves inadequately attached underlayment that cannot prevent water intrusion through deck joints or nail holes. Using a fastener such as a button cap to secure the underlayment will help prevent water intrusion should the coverings fail. Peel-and-stick membrane products also offer superior protection when coverings are lost. Shingles are more wind resistant overall when installed using six vs. four nails. Metal and clay tile roof systems should always be attached using manufacturers' specifications for an increased wind load.

Nail Patterns

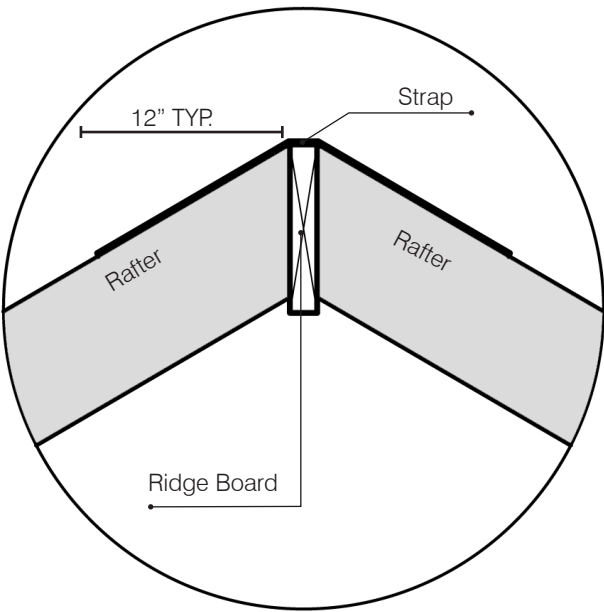
Nail patterns describe layout and spacing for a particular attachment of one component to another. Choose the type, size and amount of nails to achieve high wind resilience.

Gable End Wall

The rake is an overhang at the gable end wall that is particularly vulnerable to wind forces, so it should be adequately and properly attached to the rafters and top of the wall. Because the edge of the roof framing, decking, underlayment and coverings all meet at this location, it is critical to ensure the assembly is attached correctly to withstand wind forces. Gable end walls should be braced back into roof framing and must have a minimum of 7/16" structural sheathing.

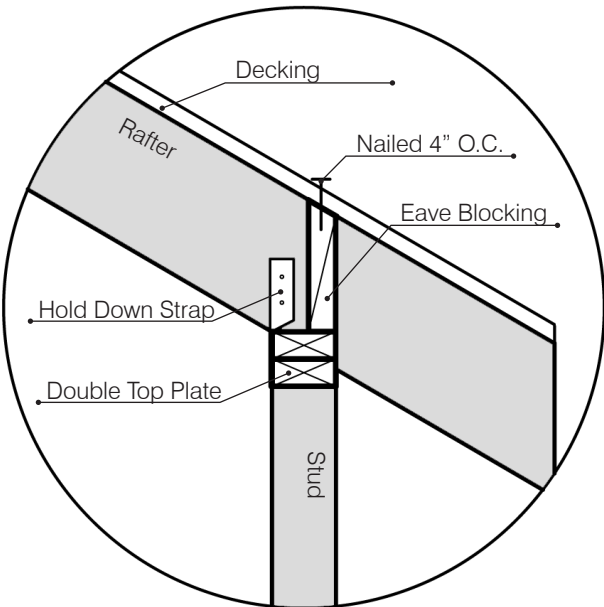
Rafter at Ridge Board

Typical construction practices include cutting out a ridge vent in the roof decking to allow for air to flow freely from inside the attic. This causes an unintended weakness while the vent allows air to flow, it also weakens the roof diaphragm at a critical location because the ridge board serves as a boundary of the roof diaphragm. When the decking is cut away for the vent, the decking is no longer connected between the rafters. Installing a strap or straps will strengthen the connection between rafters while still allowing for roof venting at the ridge.



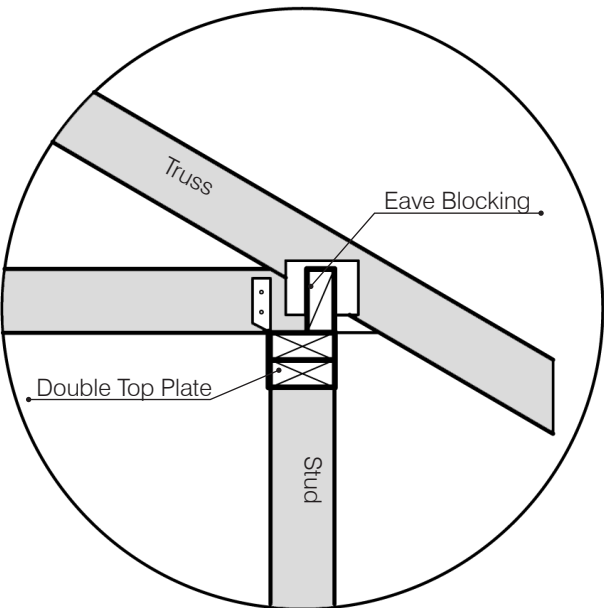
Rafter at Top of Wall

Rafters attached to the top of a wall in a high wind zone should be fastened to the top plates of the wall with more than just framing nails. Typically, metal connectors, straps or clips, are specified to hold down the rafter. Eave blocking between the rafters in high winds does more than keep the birds out of the attic; it helps tie the roof diaphragm to the walls and keep the rafters from rolling due to lateral loads.



Truss at Top of Wall

When a truss attaches to the top of the wall, it is similar to a rafter in the hold down connection. A metal strap or clip is specified to hold down the truss in the same way a rafter is held down. The eave blocking detail is somewhat different. In most places, it is not required by code to have full eave blocking when trusses are used for the roof structure, however 2x4 blocks should be installed to help resist lateral loading.

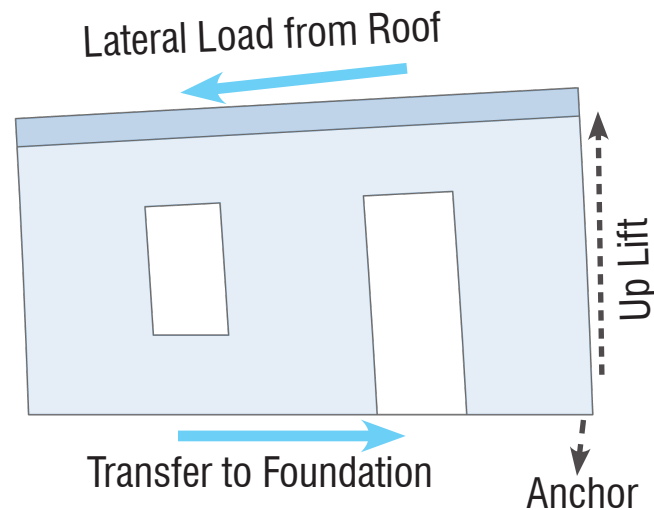


HOW A WALL WORKS IN WIND

Three types of wind forces act on walls--wind pressure perpendicular to the wall, lateral loads transferred from the roof to the foundation parallel to the wall, and uplift forces from the roof being lifted from the wall.

The **perpendicular wind force** acts as either positive or negative pressure and is greatest at the corners. The largest wind load is the **parallel lateral load**. This load comes from the roof diaphragm transferred to a shear wall. A shear wall is sheathed with structural panels such as plywood and has critical attachment requirements to the roof and floor framing. Window openings and parts of the wall at corners and between windows that have a length less than 30% of the wall height are not considered part of the shear wall. As a result, windows spaced closely together and windows located closer than 3 feet from corners reduce the shear wall capacity and may require special engineering. The end walls of long, narrow homes are often inadequate shear walls. In such cases, one or multiple interior partitions must be built as shear walls.

High wind zone construction requires use of metal anchors, clips and straps to create a “continuous load path” from the roof to foundation. The well connected load path allows the structure to resist **uplift forces** because the attachments prevent the roof, wall framing and foundation from separating under uplift and lateral loads.



WALL COMPONENTS

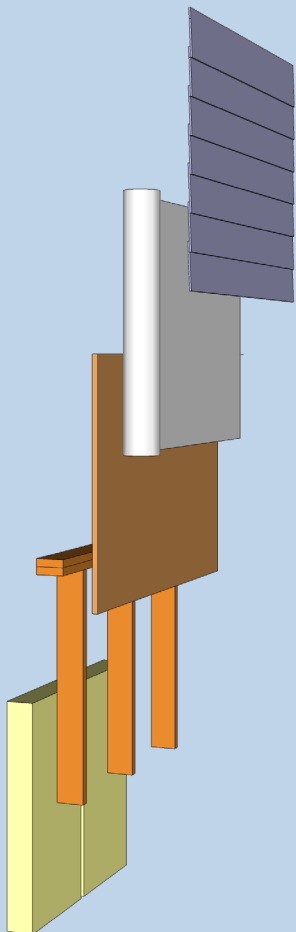
Wall covering, also known as cladding, is the outermost layer of the assembly. Unlike roofs, wall cladding is not sealed to moisture. Instead, cladding protects the water barrier layer beneath from damage. Common residential wall coverings include brick, cement fiber siding, stucco, vinyl and wood.

House wrap also known as weather resistive barrier (WRB) has the unique ability to stop water from penetrating to the sheathing while still allowing the wall to ventilate.

Sheathing provides lateral strength and serves as the base for the house wrap and flashing; and is part of the wall's thermal barrier. In high wind zones, sheathing is usually plywood or OSB. Following the specified nail pattern for the sheathing is critical to gain the proper strength.

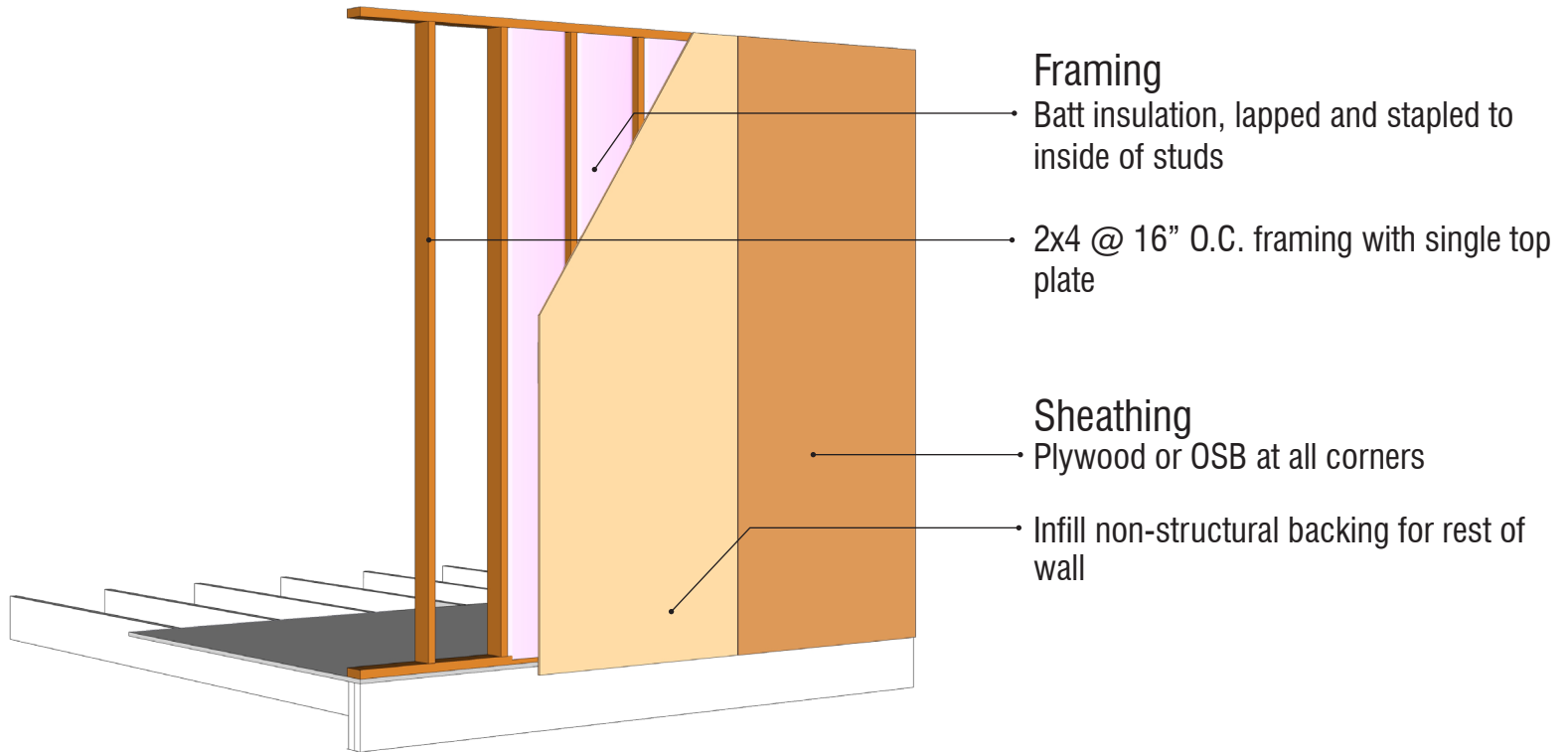
Framing is the primary structural element of a wall and is most often 2x4 wood studs spaced at 16 inches. Some homes are built using advanced framing which uses 2x6 studs aligned with the roof rafters spaced at 24 inches. Advanced framing offers the advantages of energy and material conservation.

Insulation typically fills space between studs. There are three types of insulation used in homes, including batt, blown, or spray foam. All three types can achieve the thermal performance required by code; however, spray foam has structural and sealing advantages that add to resiliency of the home.

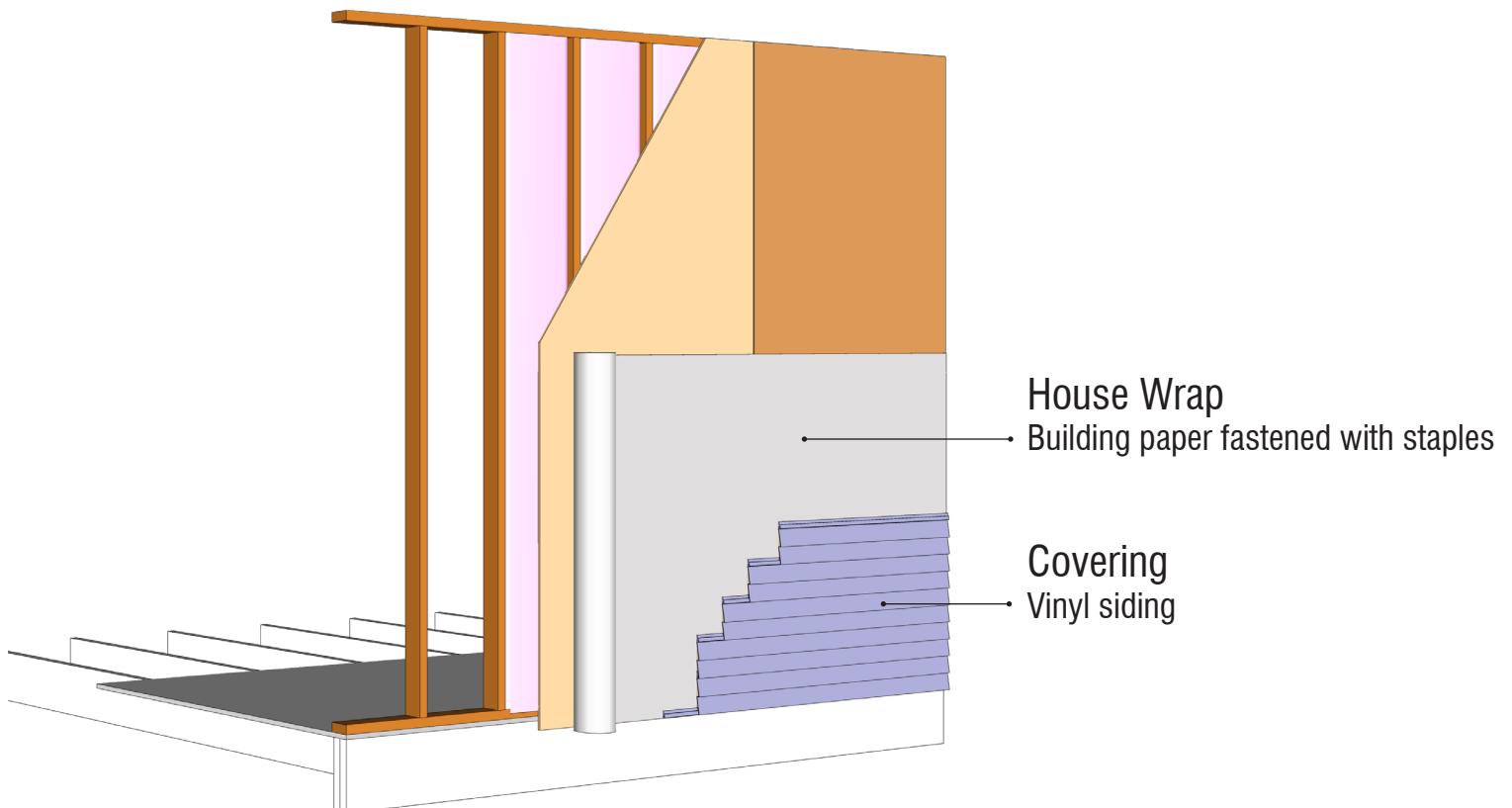


ORDINARY CONSTRUCTION

Typical components of wood frame construction



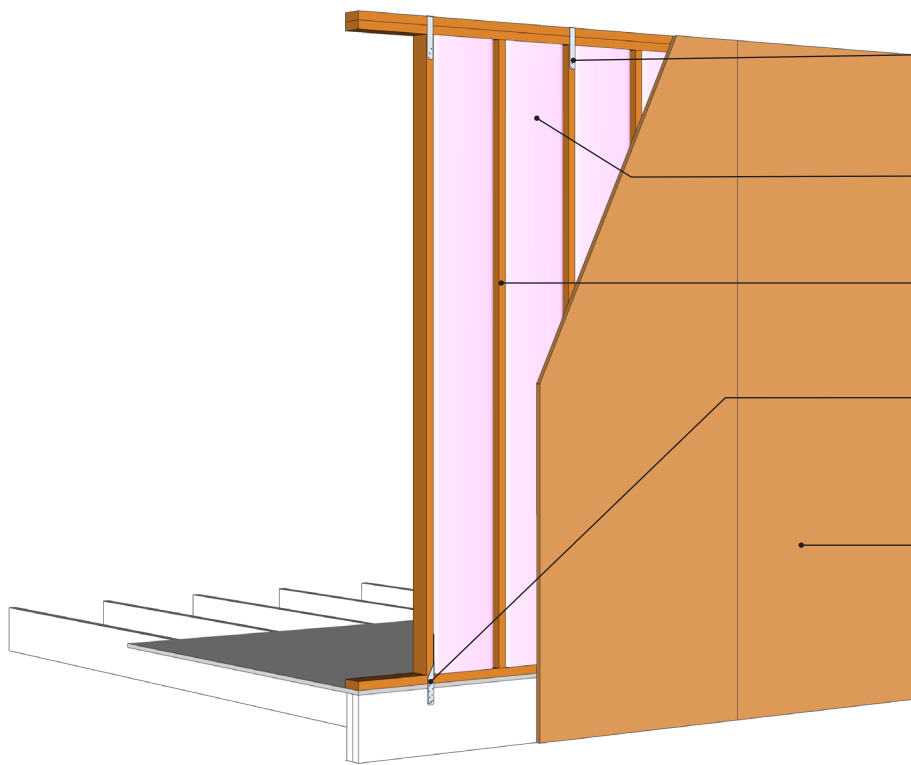
\$ 🛠️ Structure Detail



\$ 🛠️ Covering Detail

HIGH WIND CONSTRUCTION

Generally required by various high-wind building codes



Framing

- Top plate strap every other stud and every king stud

Batt insulation, lapped and stapled to inside of studs

- 2x4 @ 16" O.C. framing with double top plate

- Stud to floor strap every other stud and every king stud.

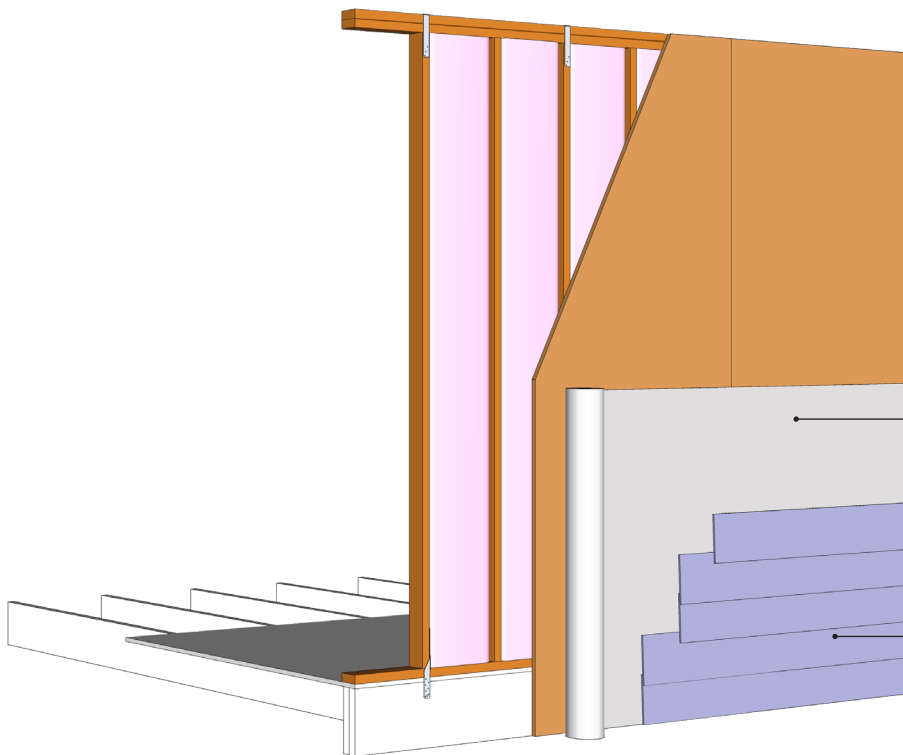
Sheathing

- 7/16 OSB long length sheathing, attached to bottom plate for slab and rim joist for raised floor

Nail Pattern:

4" at edges of sheet , 6" in field, 4" at boundary. Use 8d hot dipped galvanized ring or box shanked nails

\$ 🛠 Structure Detail



House Wrap

- Vapor permeable WRB attached with 1" button cap @ 32" O.C. in each direction

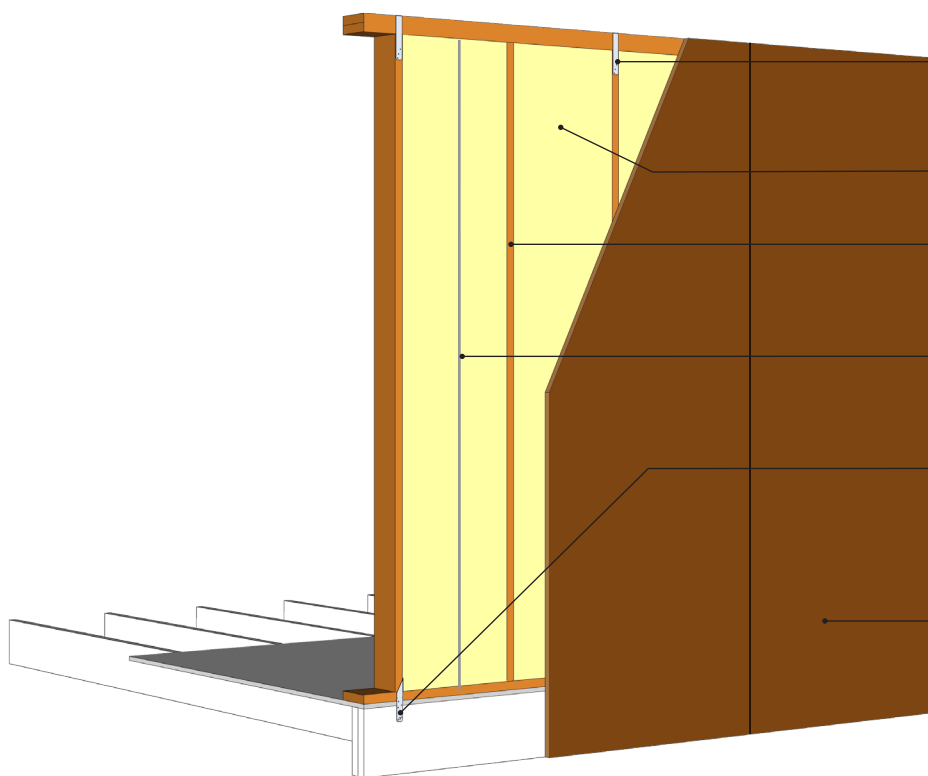
Covering

- Cement fiber board siding attached per manufacturers' specifications for high-wind zones and blind nailed

\$ 🛠 Covering Detail

RESILIENT CONSTRUCTION

Reduces the damaging effects of a storm



Framing

- Top plate to stud strap every other stud and every king stud
- Spray foam insulation in wall cavity
- 2x6 @ 24" O.C. framing with double top plate
- Continuous anchor tie downs (through bolt from top plate to foundation)
- Strap stud to bottom plate strap other stud and every king stud

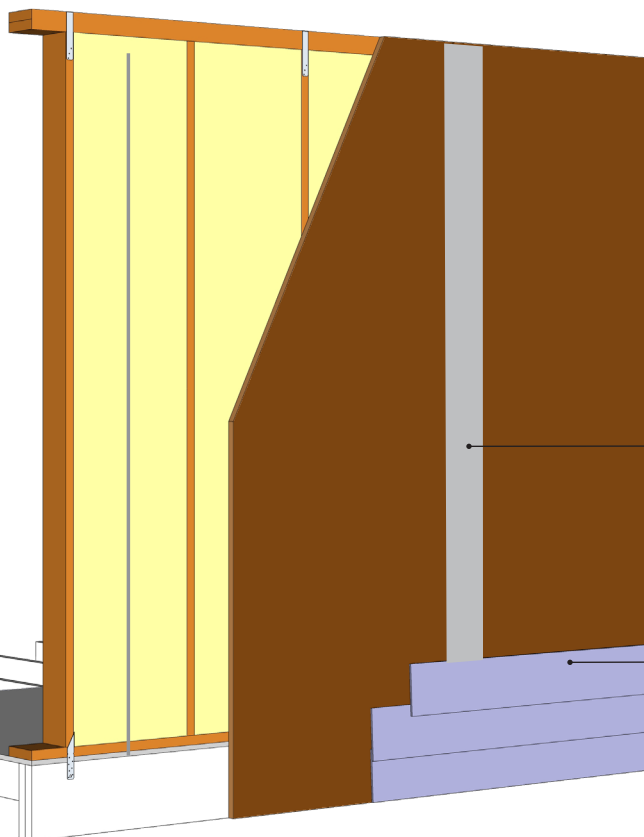
Sheathing

- 7/16 OSB long length sheathing, attached to floor system, overlap bottom plate by ~12" with WRB fully integrated into sheathing.

Nail Pattern:

4" at edges of sheet , 6" in field, 4" at boundary. Use 8d hot dipped galvanized ring or box shanked nails

\$\$ 🛠️ Structure Detail



House Wrap

- 4" self-adhering polymer modified bitume flashing tape on all sheathing panel joints

Covering

- Cement fiber board siding attached per manufacturers' spec for high-wind zones exposed nailing

\$\$\$ 🛠️ Covering Detail

SUPPLEMENTAL INFORMATION - WALLS

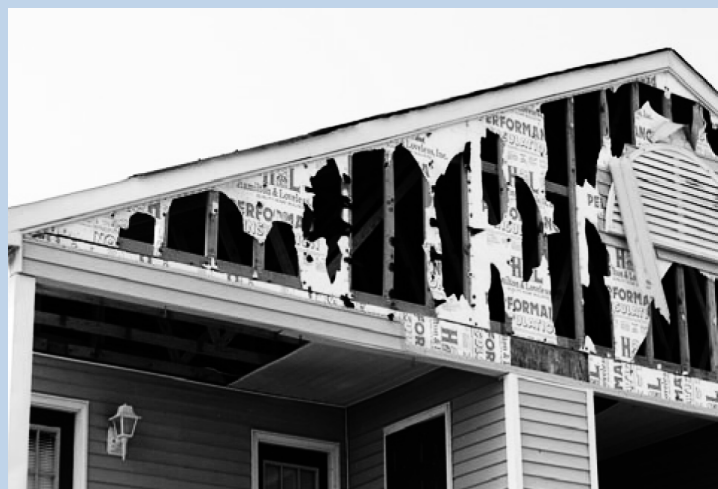
Hazards

CLADDING/COVERINGS LOSS – Siding of any type (wood, vinyl or cement fiber) can blow off a house and become damaging windborne debris. Once siding is blown off, vulnerable house wrap is quickly destroyed exposing the untreated wood sheathing that can suffer damage from wind driven rain.

IMPACT FROM WINDBORNE DEBRIS - Windborne debris impacts are difficult to anticipate, however, a well-constructed assembly with the proper sheathing and cladding attachments will help protect walls from flying debris.

WIND DRIVEN WATER - When cladding is lost, the walls are vulnerable to wind driven water. A well attached weather resistive barrier can help to minimize moisture and water infiltration.

OPENINGS & PENETRATIONS – Door and window openings are commonly damaged by wind and wind driven water. Following specified installation instructions, using flashing and deploying locking mechanisms are all vital steps to make doors and windows wind resistant.



credit: FEMA

House Shape

The shape of a home is material to how it handles lateral loads. For instance, a square home has the same load in every direction because the size of the ends and sides are uniform. Conversely, a long narrow home will experience a much larger load on the long sides than on the short sides. Walls parallel to the lateral load need to be designed and built in a way that anticipates and handles this loading.

Shear Walls

Shear walls are structural walls that resist lateral forces acting on a house, and structural panels and framing are the primary components of a shear wall. In high wind zones, exterior walls are typically shear walls. In some cases, interior walls are designed as shear walls if the configuration of the home or size of openings requires more rigidity. Openings create weak points in shear walls and the shear wall strength is discounted for openings. Shear wall design is based on the height and length of a wall, the number and size of openings and the calculated lateral loads based on the specific wind zone location of the home. Shear walls have typical diaphragm nail patterns, e.g. 4" O.C. at edges and 6" O.C. in field. The shear walls must be properly attached to the roof and floor structure in order to properly transfer the loads to the foundation. Interior shear walls should attach to floor/foundation systems much like exterior walls attach to floor/foundation systems.

Eave Blocking

The method of eave blocking is a significant difference between typical construction and high wind zone construction. Typical eave blocking is commonly referred to as "bird blocking". However, proper blocking between joists performs an essential function as it transfers lateral loads from the roof deck to the shear walls. Eave blocking should be installed during framing before the roof decking is in place. Roof decking should be nailed to the blocking before underlayment is installed.

Cladding and Covering

BRICK VENEER is popular as home cladding because it provides for low maintenance, however, it can be vulnerable to wind and wind driven water in high wind areas. Common brick veneers are secured with masonry ties tied back to the wood frame, however, problems can occur when not enough ties are used, ties are not fastened to the wood frame securely or corrosion sets in. In high wind zones, ties should be spaced closer together and attached through the sheathing to the framing. Also, using proper drainage and drying space will keep the ties and back side of the brick dry and less susceptible to moisture and corrosion.

VINYL SIDING is lightweight and susceptible to high wind damage. However, some manufacturers produce vinyl siding systems designed for high winds. Before using vinyl, ask local building suppliers for detailed product information and investigate the past product performance in your area.

FIBERCEMENTSIDING manufacturers provide for high wind by providing details for enhanced attachment with higher grade fasteners and closer placement. Roofing nails with larger heads are often specified in place of specialized “siding” nails. And, like masonry ties, fasteners should be attached to the wood frame behind the sheathing.

DP Ratings

Design Pressure (DP) Ratings on windows should not be confused with impact ratings as they are based solely on the wind load the windows are designed to withstand. DP Ratings and requirements vary by the home’s wind zone location as well as window location in the wall. For example, DP rating requirements in the middle of the wall where pressure is lower are lower than those near the edges where pressure is greater. Refer to your local building authority to identify appropriate DP Ratings.

Impact Windows

Impact-resistant windows are tested and rated with large & small missile impacts. Windows are required to remain intact after impact, however glass breakage is allowed as long as the glass does not fall out of the window.

Large Missile = 6’ nine lb. 2x4 fired at 50FT/S

Small Missile = 30 pieces of roof gravel fired at 80FT/S

When local building codes in high wind zones require impact-resistant windows, they often allow for product substitutions due to cost considerations.

Shutters, Panels, Etc.

Many products are available to work in place of, or supplement the strength of impact windows. Shutters or other protection decreases the chance of breaking glass.

Installation

Window installation is critical to window performance in the wall, so using the correct DP rating and impact resistance attributes will not matter if the installation is not correct. All window manufacturers specify the correct means of installation, and high wind resilience can be achieved by following the manufacturers’ installation guidelines for increased wind load.

Self-adhered Flashing

Self-adhered flashing, commonly called “window tape,” is vital to securely seal window openings. Tape should be installed after the window is secured in place from the bottom sections first and up to the top. Each section above should overlap the section below to create an effective drainage path.

SUPPLEMENTAL INFORMATION - DOORS

Doors are weak parts of the wall and must be detailed correctly to keep wind and wind driven rain out of the home. During a 130 mph wind (Category 4 hurricane), a typical 3' wide door will experience approximately 580 pounds of pressure. As with windows, the glass sections in doors are the most vulnerable. Door glass panels have their own DP and impact ratings although they are similar to windows ratings. Common areas where doors fail are outlined below:

Door to Jamb and Frame

Latch - A common weak point is the latch and lock because high winds can concentrate large forces on that single point. Many new door models have three and five point latching as opposed to the traditional single point at the latch and handle, which creates a stronger door to door frame connection.

Hinges - The hinge side of the door is also a major concern. Door hinges need specific attachments to the door frame and door to ensure proper connection.

Jamb and Frame to wall - If the door jamb and frame are not properly attached to the structure, the door system will fail. All door manufacturers provide detailed specifications on how to attach the system to the structure of the home.

French Double Doors

Double doors often fail in high winds because they are weak where they come together, especially if they swing inward. Some units use a center post to create a stronger latch point, however, the post somewhat defeats the purpose of a double door configuration. More manufacturers are offering out-swinging double door models, and they are sometimes required by local building codes.

Garage Doors

Like doors and windows, garage doors are a weak part of the wall, especially because most garages are designed to make the door opening as wide as possible. This wide opening requires a strong door frame that is commonly referred to as a "moment frame". The wind load on a garage door is substantial. A typical 10'x10', single car garage door is subject to more than 6000 lbs. of pressure in 130 mph winds. Garage doors must be rated for pressures associated with the site design wind speed and exposure category. Garage doors are commonly made of thin sheet metal, fiberglass or similar materials so that they are lightweight for efficient lifting. As a result, they are vulnerable to damage by wind forces and windborne debris. Glass panels in garage doors are not recommended because they introduce additional weakness and glass panel, wind rated garage doors are expensive options for typical residential construction. Roll up doors are often connected at only a few critical points. The concentrated loads on the edges must be accounted for when attaching garage doors. Anchoring into the wall is vital just as it is for windows and doors. Thresholds poured into the garage slab or installed onto the garage floor help keep out wind driven water.

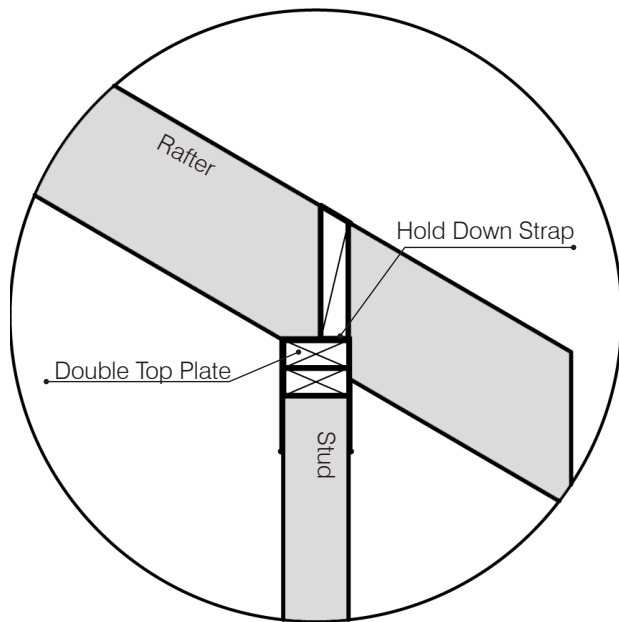
Wind-Driven Water

Seal - Doors should be properly flashed and sealed for both wind and wind driven water. All four sides of the door should seal tight to the frame, and all four sides of the frame should be sealed tight to the structure. A combination of flashing and sealers such as caulking, foam and silicone should be used.

Thresholds -The threshold is the bottom of the door frame and provides transition from outside to inside. Thresholds can be particularly vulnerable to wind driven water. Sealing the bottom of the threshold to the door frame is important and is often overlooked at the time of installation.

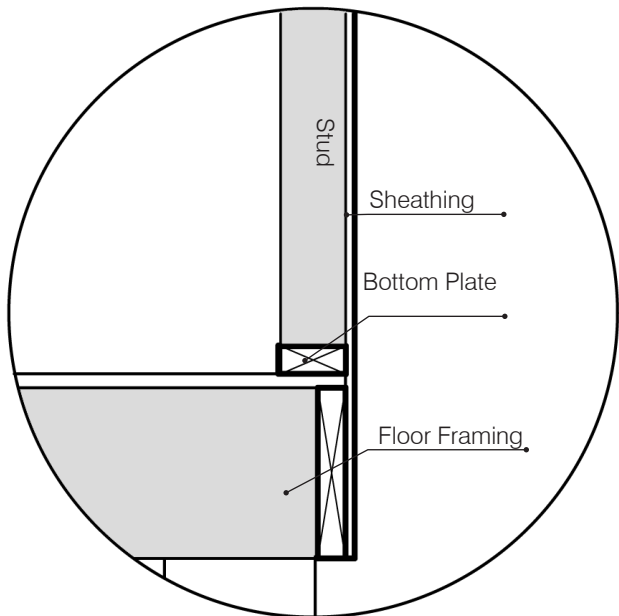
Top of Wall

The top chord of the wall is made of two 2x4 framing members. The top plate is doubled so that the strength of the chord is not lost at splices. Wind forces on the face of the wall pull the top plate from the stud. Hold down straps keep the top plate from overturning when an uplift force is acting on the roof structure. A hold down strap that wraps over the top and connects to both sides of the stud is recommended.



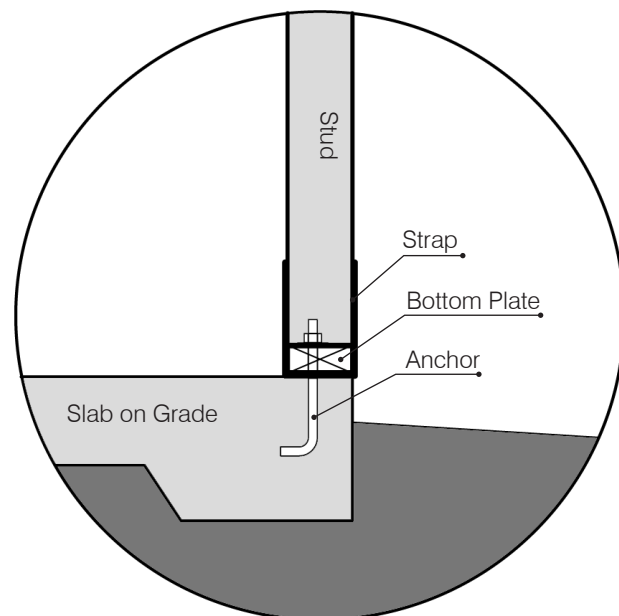
Wall at Raised Floor

The wall at a raised floor should use longer sheathing, known as a combined use wood structural panel, to overlap the bottom plate and attach to the floor framing members. This creates a connection from the top of the wall to the bottom of the floor framing. Additional straps can be used to strengthen the connection of the wall to the floor framing.



Wall at Slab on Grade

Just like the double top plate, the bottom plate, or sole plate, needs to be attached to the wall studs so they act as one structural element. There are metal straps and clips that help with this. The other major connection point is the bottom plate to the slab or grade beam. This connection is made with an anchor bolt that usually is embedded in the concrete when it is poured. Epoxy-set anchors can be used as retrofits if the concrete slab has already been poured or if there is a missing or misaligned anchor.

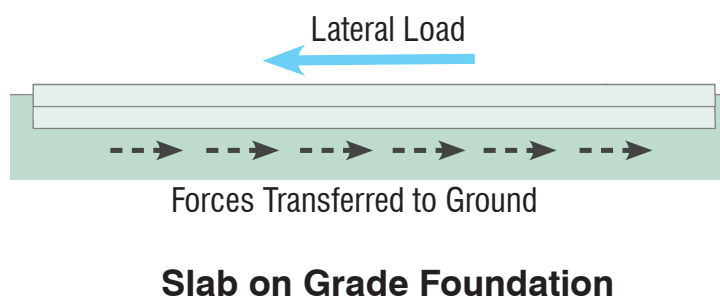
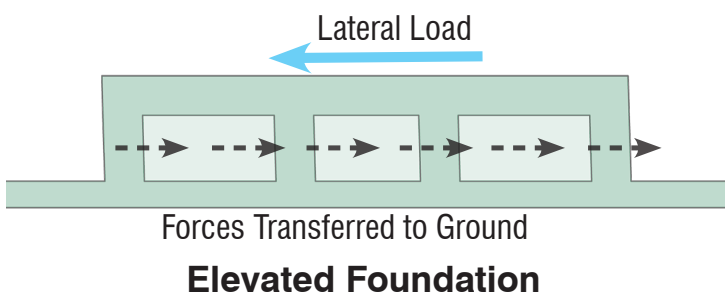


HOW FOUNDATIONS WORK IN WIND

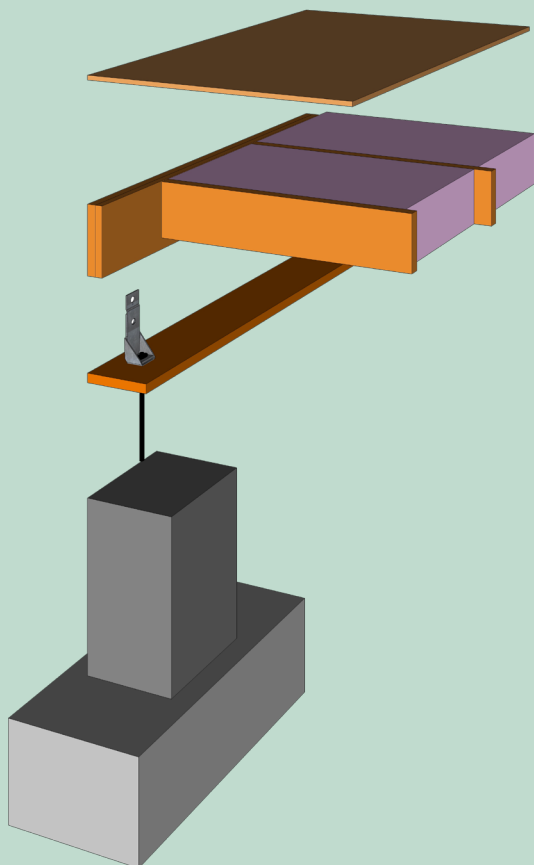
The primary structural role of the floor and foundation is to transfer the lateral loads into the ground. The accumulated forces at foundations from high winds are significant and the effects of such forces are increased in homes that are built on tall piers, a common practice in coastal flood zones. Elevated piers, which are built in the ground, or piles, which are driven into the ground, are generally eight or more feet deep depending on the soil capacity and should be designed by an engineer.

In a two-story home, the second floor deck is a stiff horizontal diaphragm that transfers the loads on the walls facing the wind to the wall parallel to the wind.

Whether the foundation is a slab-on-grade or a framed floor, the attachment of the walls to the floor is one of the most important structural details as this anchor condition transfers the lateral and uplift wind loads from the wall to the floor.



FOUNDATION COMPONENTS



The **subfloor** is a horizontal diaphragm for either a ground floor or upper floor. As with the roof and wall sheathing, the strength of the plywood or OSB and the strength of the attachments are important. Floor decking is often glued as well as fastened to the floor framing.

Floor framing is typically 2x10, 2x12 or engineered lumber. The size of the framing is determined by the spans and floor loads.

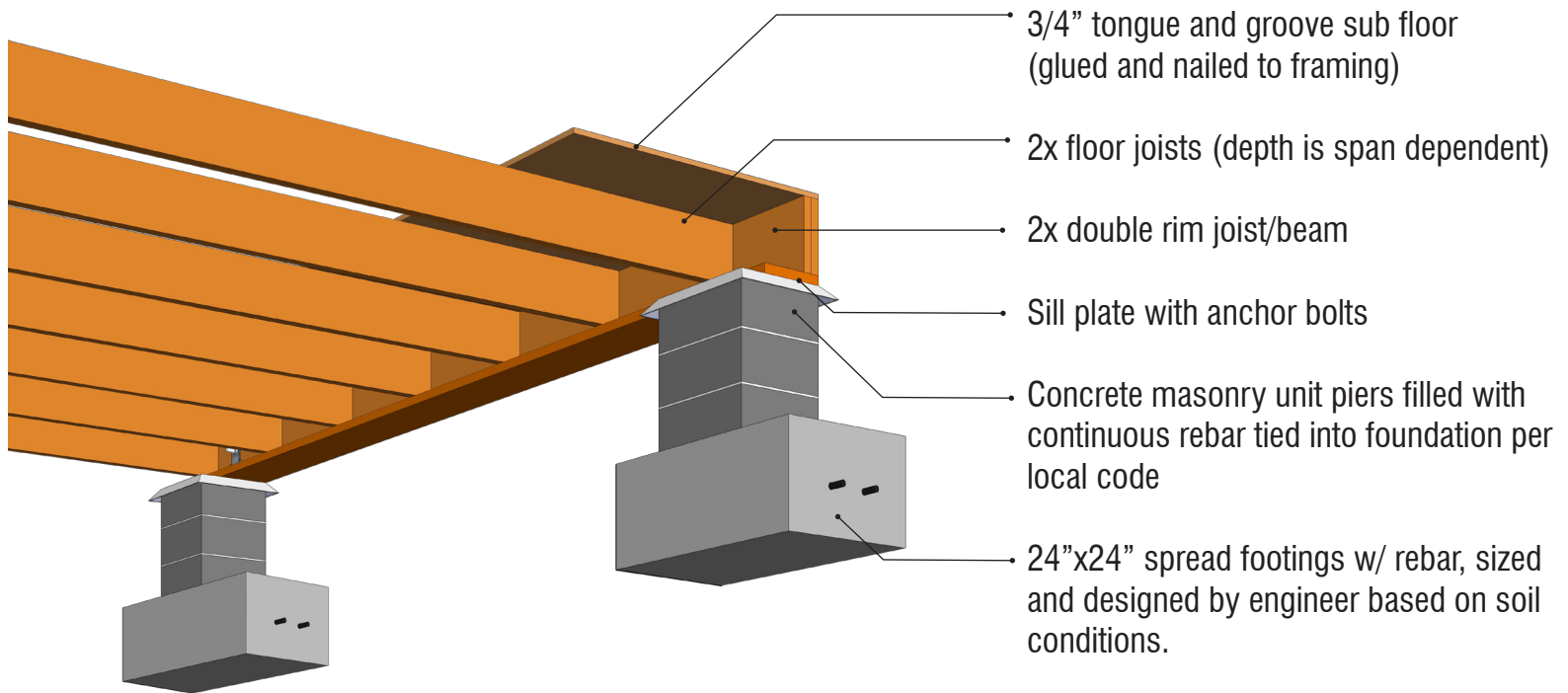
Insulation in raised floors should be tight to the underside of the decking unless another "air barrier" is created at a different location, e.g. the bottom of the framing members. Rigid insulation and spray foam insulation are recommended in high wind zones to secure insulation as these two types of applications are less vulnerable than batt and blown-in insulation.

Sill Plates are **anchored** to the foundation with anchor bolts cast into the foundation. The spacing and size of the anchor bolts are determined by the lateral loads.

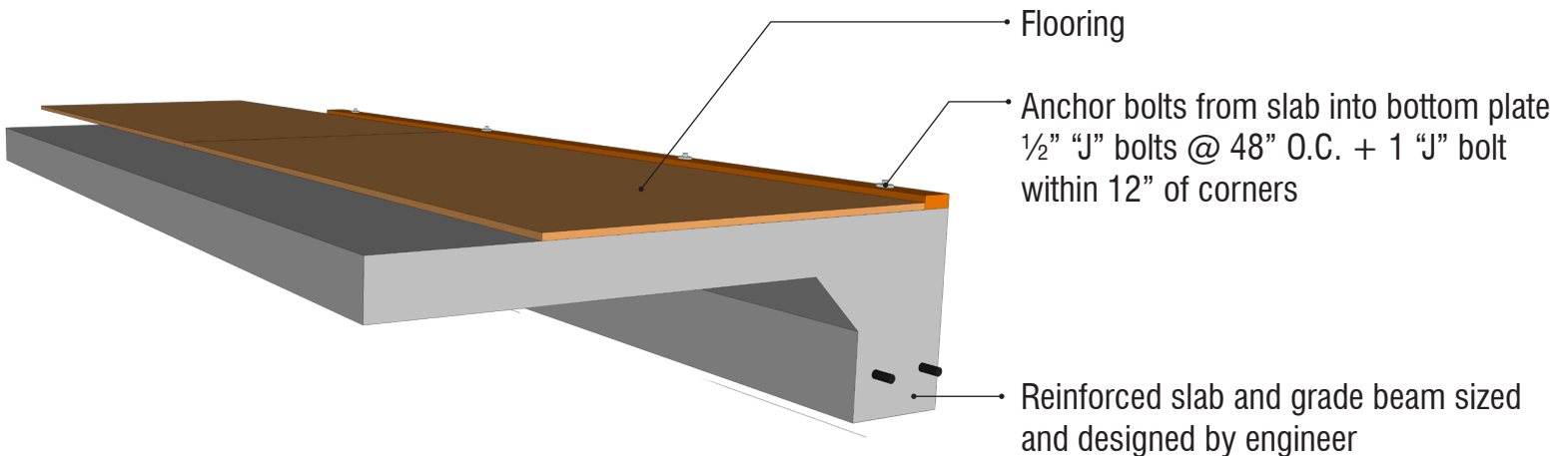
Houses have various **foundation** systems. A slab-on-grade is the floor and the foundation when it is used. If the floor is elevated or has a crawl space, the foundation consists of a vertical member and a footing. The vertical member is either a stem wall or a pier, which is typically reinforced concrete block or cast-in-place concrete. The footing type depends upon the soil strength and whether the home is elevated. Typical footings are either spot footings under each pier, continuous spread footings for a stem wall or combined piers, or deep foundations such as concrete piers or driven piles.

ORDINARY CONSTRUCTION

Typical components of wood frame construction



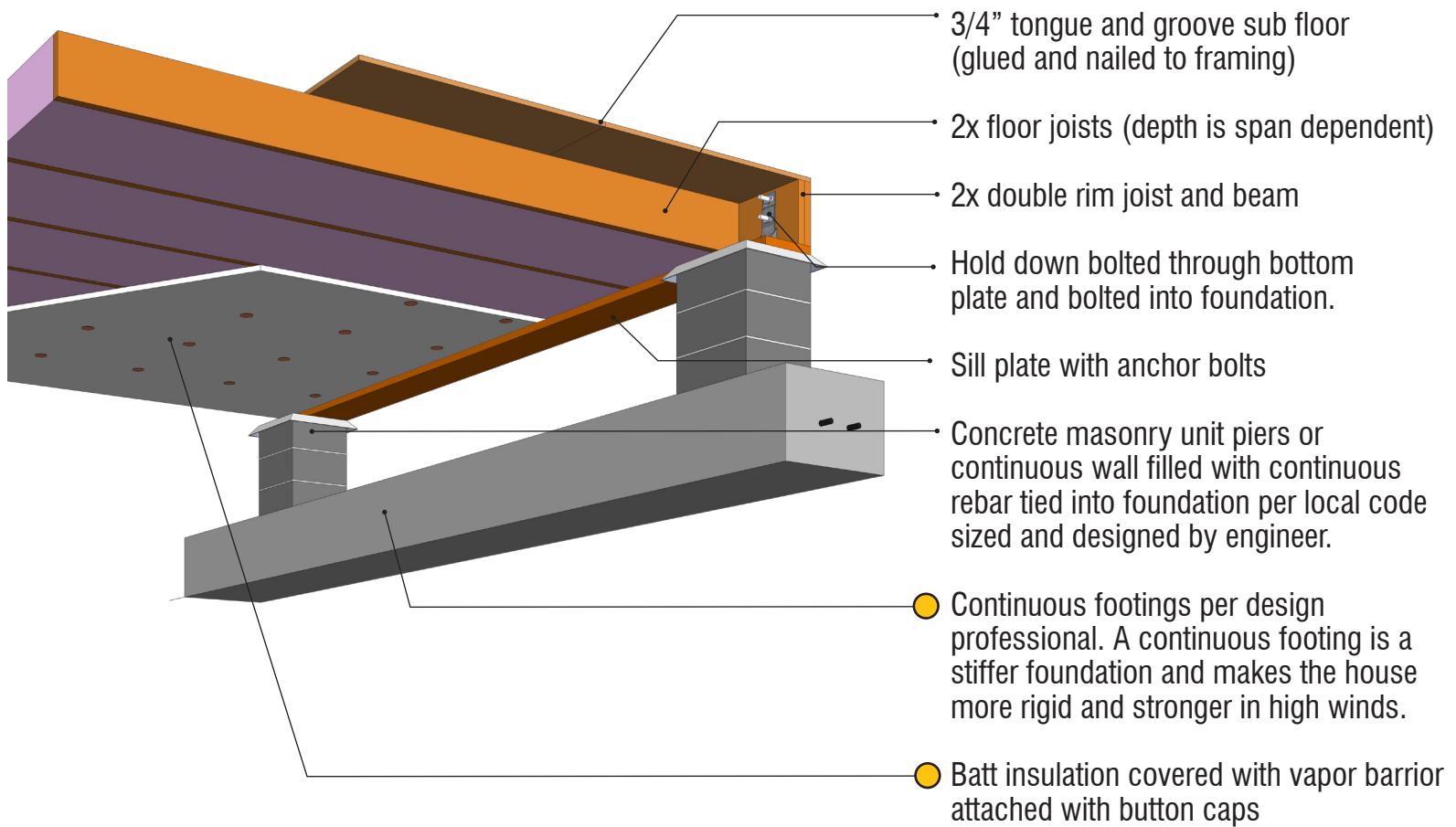
\$ 🛠️ Raised Floor



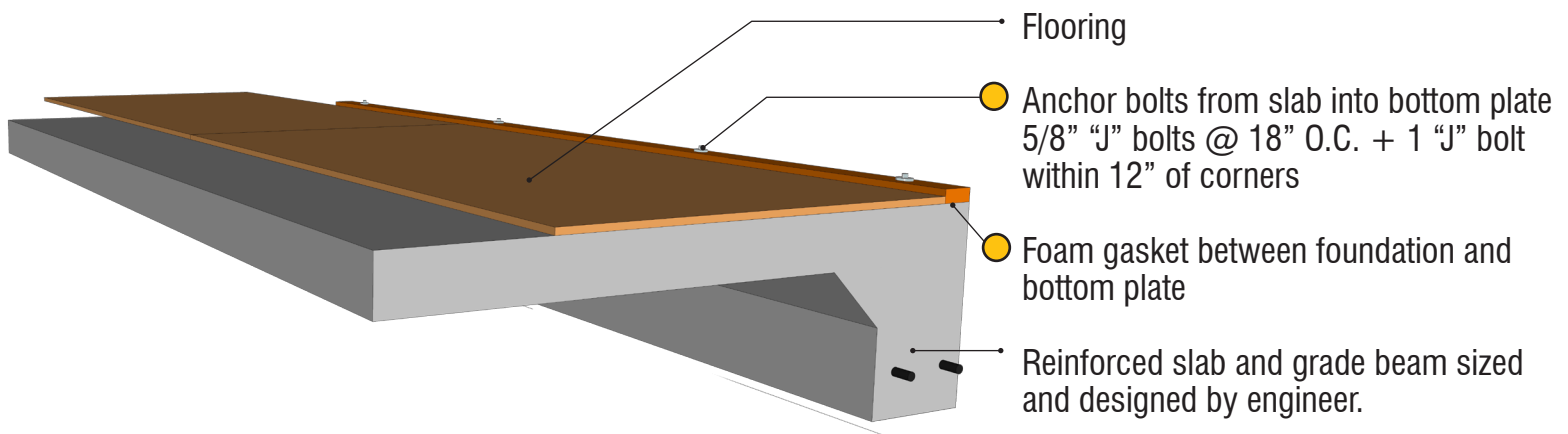
\$ 🛠️ Slab on Grade

HIGH WIND CONSTRUCTION

Generally required by various high-wind building codes



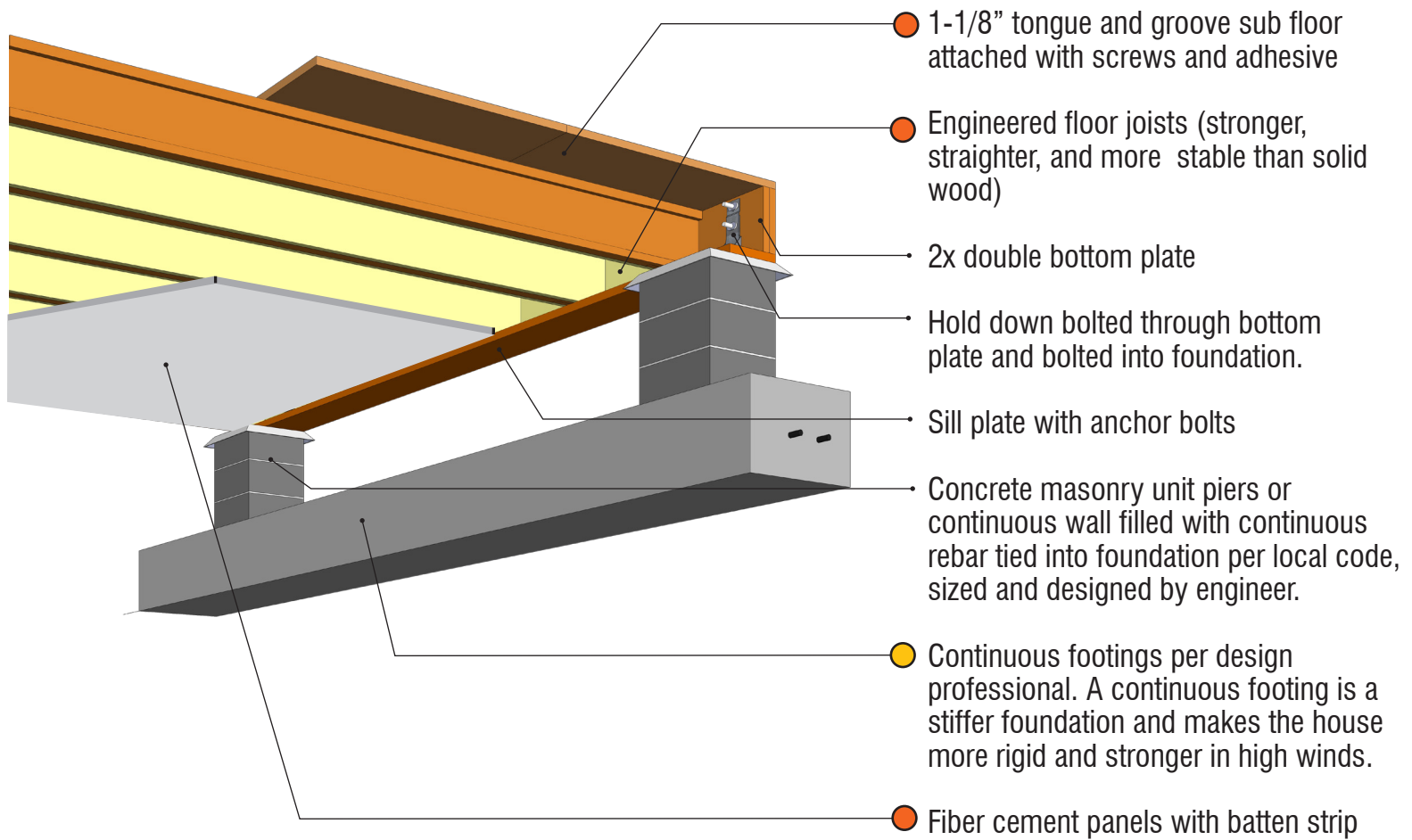
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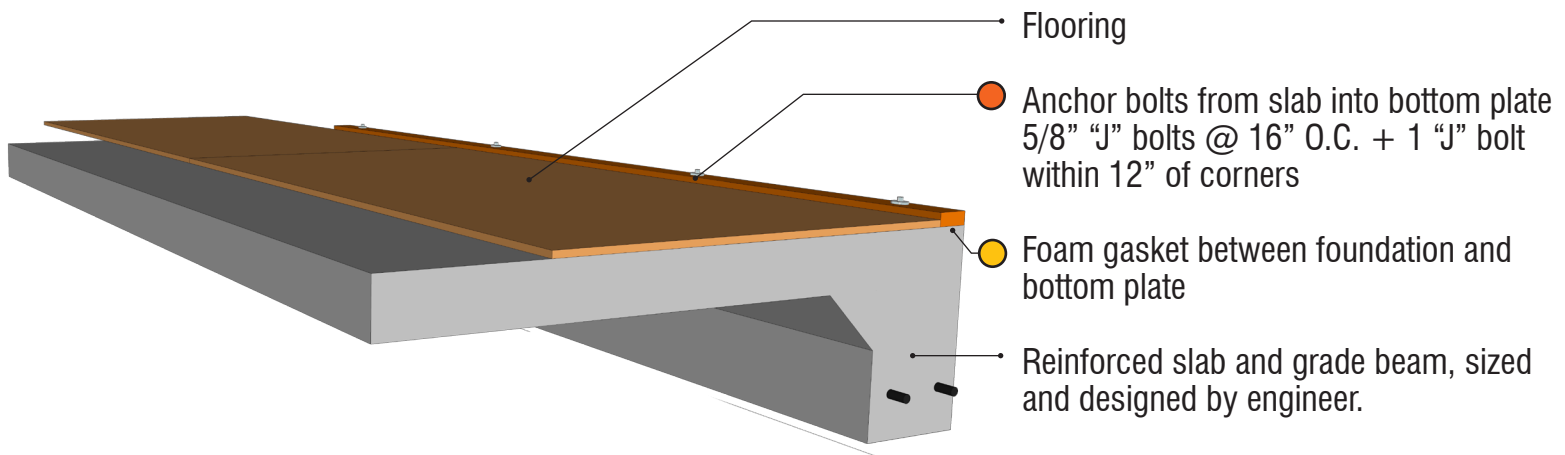
\$ 🛠️ Slab on Grade

RESILIENT CONSTRUCTION

Reduces the damaging effects of a storm



\$\$\$ 🛠️ Raised Floor



\$ 🛠️ Slab on Grade

Hazards

Floors and foundations are generally more susceptible to flood damage than from wind damage during storms. Many high wind locations are also coastal flood zones, and those zones require elevated homes. Unfortunately, elevated foundations significantly increase the wind hazard of a home because the lateral loads acting on the home cause a substantial overturn when forces exert pressure on piers. Added foundation height increases the load exponentially. Thus, the connection from the wall to the foundation is critical to resist overturning.



credit: FEMA

Flooring

Subfloors for raised floors are typically plywood and OSB panels. They are typically between $\frac{3}{4}$ " and 1 $\frac{1}{8}$ " thick and attached with a polyurethane construction sub-floor adhesive.

Nailing Patterns

Recommended floor sheathing nail patterns are 4" at edges of exterior walls, 6" at panel edges and 8" in the field

Slab on Grade Foundations

Slab on grade floors and foundations are poured at the same time and form a monolithic structure. Walls are anchored into the foundation at the edges and thickened slabs or grade beams can be installed where extra structure is needed.

In high wind zones, anchor bolts are typically required at 18" O.C., however since 18" spacing is out of sync with typical 16" spaced studs, 16" anchor bolt spacing is recommended.

Interior Shear Walls

Interior shear walls should be fastened to the floor or foundation. If on a slab, the interior shear walls should have anchor bolts in the slab similar to the exterior walls. If on a raised foundation, hold down straps help to connect the wall to the floor and roof framing.

Hazards

Falling trees account for most of the major wind damage to houses in hurricanes. In storms like Hurricane Katrina with wind speed more than 120 MPH, approximately 20% of the urban trees toppled. In Hurricane Andrew, 38% of the affected trees toppled. Beyond wind intensity, other storm factors influencing tree damage include:

- **Amount and duration of rain**
- **Tree species, age and condition**
- **Soil characteristics**

Even though it is not possible to build a home strong enough to withstand the impact of a large tree, it is possible to plan and maintain landscapes that reduce the risk of trees falling on a home. Certain species are more vulnerable to wind damage such as various southern pine, pecan, red oak and water oak. Moreover, as every tree has an inherent life span, older trees of species with shorter life spans are most susceptible to storm damage.



Landscaping

Trees benefit homeowners by beautifying the yard, attracting songbirds, providing protection from wind and noise and by shading the yard and home. However, falling trees and limbs are often the source of storm damage to homes. Three factors regarding trees should be considered, including condition, location and species. Limbs on healthy trees that hang over the roof should be trimmed back and any unhealthy or unstable trees should be removed.

In addition to trees, a resilient landscape takes into account manmade elements that might cause damage from wind such as fences, flag poles, lawn furniture and light fixtures. These elements, as well as building components such as gutters, downspouts and exterior air conditioning equipment, should be secured.

Auxiliary Structures (Gazebos, Pavilions, Pergolas)

Outdoor covered structures are usually supported by horizontal beam members sitting on vertical columns which must be correctly connected to the foundation to prevent uplift and wind damage.

Resilient Home Systems - Standby Generators

The most common result of wind storms is loss of electrical power due to trees and limbs falling on power lines. Ideally, electrical services run underground to reduce risk of power outages and communities benefit from efforts to invest in more resilient power infrastructure. For the individual homeowner, loss of electrical power is not only inconvenient, but the lack of air conditioning allows mold growth inside the home. A resilient home is prepared for loss of power with interior finishes that don't support mold growth, good natural ventilation, and a standby generator to provide power for a minimal amount of air conditioning.

Loss of electrical power in a neighborhood can also affect the water and sewage system. Sewage check valves and back flow preventers can be used on homes to guard against contamination from systems that might not operate normally after a disaster.

Placement Details

Install the generator set

- Outdoors
- Near the incoming gas service
- Near the main electrical panel(s)
- On a flat, level mounting area

Important placement guidelines

- The recommended distance from a structure is dependent on state and local codes.
- Locate the generator set so that the hot exhaust does not blow on plants or other combustible materials. No plants, shrubs, or other combustible materials are allowed within 1.2 m (4 ft.) of the exhaust end of the generator set.
- Do not install the generator set where exhaust gas could accumulate and seep inside or be drawn into a potentially occupied building. Furnace and other similar intakes must be at least 3 m (10 ft.) from the exhaust end of the generator set.
- Do not locate the generator set near patios, decks, play areas, or animal shelters.
- Do not install the composite mounting pad directly on grass, wood, or other combustible materials. Clear all combustible materials, including plants and shrubs, building materials, and lawn furniture, from an area at least 1.2 m (4 ft.) beyond the exhaust end of the generator.
- In flood hazard areas, locate the generator and its control systems above the highest expected flood level.
- In high wind areas, the generator should be securely mounted to a concrete pad according to the mounting instructions in the installation manual.

Roof

Spray Foam

When applied to the underside of the roof deck, closed-cell spray polyurethane foam insulation had various characteristics to provide a sealed roof deck and secondary water barrier performance.

Properly applied spray foam can be considered as an impermeable insulation. Controlled air permeability helps to prevent and control bulk water entry which created a sealed roof deck. Spray foam can also be considered a water/secondary resistive barrier and also provide support against wind uplift and racking.

For resilient construction consider applying a 3” minimum full insulating layer between roof rafters/trusses.

For more information and product resources please visit www.flash.org/basf/rdghouse.pdf

Metal Roofing Options

For further information on the different types of metal roofing systems visit:

www.facilitiesnet.com/roofing/article/Metal-Roofs-Compare-the-Different-Systems--9806#

www.unioncorrugating.com/all_products.html

www.metalroofing.com/v2/content/metal-roofing/index.cfm?

www.metalroofing.com/v2/content/guide/types/

Walls

Connectors and Straps

For information how to choose metal connectors and fasteners, visit www.strongtie.com.

Alternate Construction Methods

This guide focuses on standard wood frame construction methods. For more information about alternative construction methods such as masonry, steel frame, factory-assembled or panelized construction systems, visit:

LTH Steel Structures www.lthsteelstructures.com/building-types/steel-framing-kits-custom-homes

National Association of Home Builders www.nahb.org

Manufacturers Home Institute www.manufacturedhousing.org

Structural Insulated Panel Association www.sips.org

Residential Advantage Building Systems www.resadvan.com

ICFA - Insulating Concrete Form Association www.forms.org

NCMA - National Concrete Masonry Association www.ncma.org

PCI - Precast/Prestressed Concrete Institute www.pci.org

Floors and Foundation

Engineered Floor Framing Systems

For more information about engineered floor framing systems visit:

www.buildgp.com/engineered-lumber

Concrete and Rebar

For further information about concrete construction and to find out more about alternative construction methods using concrete please visit:

Portland Cement Association www.cement.org

Concrete Reinforcing Steel Institute www.crsi.org

Landscape

Auxiliary Structures

These covered structures are usually supported by horizontal beam members sitting on vertical columns, which must be correctly connect to the foundation to prevent uplift and wind damage.

Standby Power Generation

For more information visit www.kohlergenerators.com

References

Home Builders Guide to Coastal Construction

Technical Fact Sheet Series

FEMA P-499/ December 2012

www.fema.gov/media-library/assets/documents/6131

Mitigation Assessment Team Report

Hurricane Katrina in the Gulf Coast

Building Performance Observations, Recommendations, and Technical Guidance

FEMA 549 / July 2006

www.fema.gov/media-library/assets/documents/4069

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