FLASH®
FEDERAL ALLIANCE FOR SAFE HOMES

Resilient Design Guide

CONCRETE CONSTRUCTION EDITION
AMENDED

RESILIENT DESIGN GUIDE

The purpose of the *Resilient Design Guide – Concrete Edition* is to provide information regarding the effective use of above- and below-grade concrete wall systems, as well as concrete floor systems to illustrate cost-effective, robust practices for residential construction.

This information reflects leading practices combining the strength and durability of reinforced concrete and concrete masonry with conventional systems to provide the most practical, high-performing residential construction available. Whether starter or custom, homes built to the specifications outlined in this guide will be more resistant to fire, flood, wind, and windborne debris than construction using wood or steel framing alone.

Throughout the guide, supplemental information describing the use of concrete products and systems offers additional insight into ways to enhance home safety and performance. Using the information in this guide will help home builders and design professionals provide families with not only more disaster-resilient homes, but enhanced peace of mind in the face of potential disasters.

This guide was developed during a charrette that brought together a cross section of concrete, building, and design professionals. The charrette allowed participants to integrate knowledge of subject matter experts in concrete systems, architecture, academics, engineering, products, and other building professionals with practical experience in building with concrete products. The group combined 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 residential concrete construction. The authors sincerely appreciate the many dedicated professionals that helped make this guide possible.

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+lab

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www.pluslabnyc.com

Concrete Construction

Many U.S. households are located in areas that are affected by flooding, high wind (either hurricane or tornado), and wildfires. Designing homes in these areas to be strong and disaster-resilient can enhance occupant safety, and reduce costly repairs following catastrophic events. As an inherently strong and disaster-resilient material, concrete not only delivers benefits in the face of disaster, it provides additional benefits, such as energy efficiency, ordinary (vs. catastrophic) fire resistance, low maintenance, and eligibility for financial incentives like insurance discounts.

The new guide illustrates use of leading concrete construction practices and prescriptive recommendations to create a higher level of resiliency than is possible with conventional construction alone.

Building Codes

This guide is intended to provide designers and homebuilders with information about concrete construction while outlining options for enhanced resilience with affiliated costs and benefits. As building codes and practices vary throughout the U.S., 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 minimum building code requirements, but will highlight beyond-code practices as well as other proven ways to increase resilience.

Construction Types Used in This Guide

Code Compliant Conventional Construction:
Roof and Foundation Construction

Common house construction is typically strong enough for wind speeds less than 100 mph, and it does not account for flooding. Ordinary wind design roof construction and flood resilient foundation components are illustrated in this guide to give a baseline reference for minimum, code-compliant construction in many locations.

Higher Local Hazard Construction:
Roof and Foundation Construction

Wind speeds above 100 mph and flowing flood waters require lateral strength from the roof to the foundation not provided by ordinary code compliant construction. Higher risk construction is illustrated in the pages of this guide to help explain how concrete wall systems can enhance performance to meet or exceed lateral and uplift load requirements for locations with higher potential hazard.

Resilient Construction: Roof, Above Grade Wall, Concrete Floor, and Foundation Construction

Houses can be made more resilient by designing for a higher lateral load because the safety factor will be increased, making house components more resistant to wind and flooding forces during storms, often significantly reducing potential for severe damage. Increased resilient concrete construction combining concrete walls and floors is illustrated in this guide with information regarding costs and expected benefits of making homes stronger and safer.

These markers are used throughout the guide to indicate whether a building material is considered typical in higher local hazard construction or represents an "increased resilience" construction upgrade.

This icon indicates the cost implication of different components from 1 to 5 with 1 (**$**) representing baseline construction costs and 5 (**$$$$$**) representing the most costly.

This icon indicates the construction implication and/or difficulty level from 1 to 5 scale with 1 (🔨) representing baseline for ease of construction, need for specialized installation, and ability for skilled labor to complete the work. Five (5) (🔨🔨🔨🔨🔨) represents a requirement for highly specialized and skilled labor.

Supplemental Information – Roof

HAZARDS

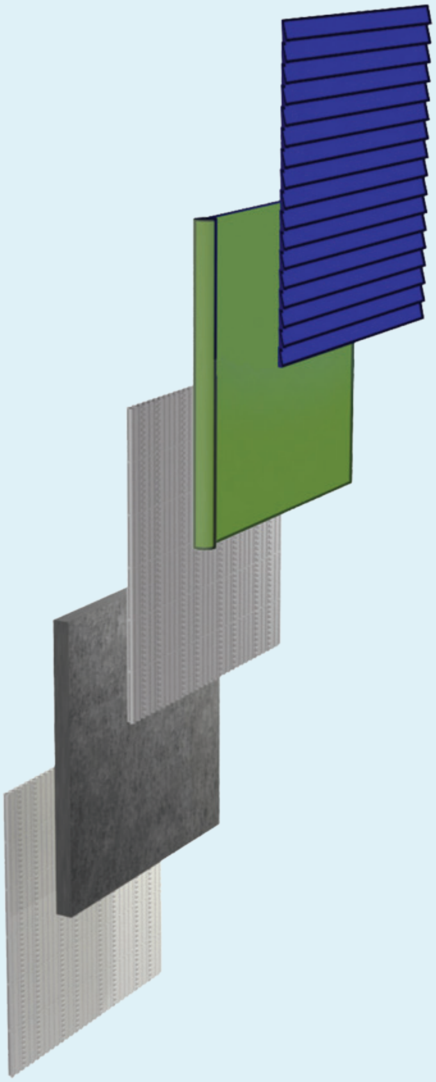
Roofs are the most susceptible component of houses exposed to severe wind forces. Typically, wind damage to roofs is caused by uplift forces (vertical), suction and torsional forces (twisting), and horizontal pressures. Wind damage effects vary depending on the roof height, slope, siting and style. Steep 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 documented by FEMA after major storms, the roof component damaged most often in high wind is the roof covering (shingle, tile, etc.). The second most common damage found is to sheathing (plywood or OSB decking). Roof covering failure usually follows use of the incorrect type of fasteners (e.g., nail too small or absence of mechanical attachment on concrete 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

Wall Systems



WALL COVERING

Wall covering, also known as cladding, is the outermost layer of the assembly. Unlike roofs, wall cladding is not sealed from moisture. Instead, cladding protects the water barrier layer beneath from damage. All claddings can provide weather protection, but more durable concrete and masonry materials are preferred for resilient construction by providing better resistance and reduced damage from windborne debris. Common residential wall coverings include brick, fiber cement siding, stucco, vinyl, and wood.

HOUSE WRAP
(Code Compliant Conventional Construction)

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

SOLID CONCRETE WALL ASSEMBLY

Use of concrete systems for above-grade walls eliminates the need for separate sheathing and framing components, reduces complexity, and simplifies the required labor. Finishes inside and out are solidly backed and more easily installed over continuous concrete or concrete masonry substrate, and this enhances structural integrity while greatly reducing gaps, seams, and potential for air infiltration.

INSULATION

Insulation runs continuously within concrete wall assemblies. There is no framing to create thermal shorts and undermine thermal effectiveness, or any requirements for additional layers of continuous insulation that could complicate installation of exterior finishes and/or window and door trim. Virtually all types of rigid insulations can be effectively incorporated into concrete wall assemblies, and polystyrene is the most prevalent. Some systems can incorporate field or factory-injected foams as well.

Wall Systems

TYPES OF CONCRETE WALL SYSTEMS

There are four major concrete wall systems that are commonly used for above-grade wall construction: concrete masonry, conventionally-formed, insulating concrete forms, and precast systems. In addition to resilience, all of these systems can provide the following general sustainability and energy efficiency advantages.

One of the most appealing attributes of above-grade concrete and concrete masonry walls is that they require less energy to heat and cool the building. Insulation, thermal mass, and low air infiltration all contribute to the energy savings. Further, large quantities of insulation can be easily incorporated into the concrete assemblies.

In addition to added insulation, the thermal mass properties of concrete construction enhance energy efficiency. Concrete holds heat from its surroundings and releases it slowly when temperatures moderate, functioning like a thermal storage battery. Incorporating lightweight aggregates, such as shale and clay, can also improve thermal efficiency.

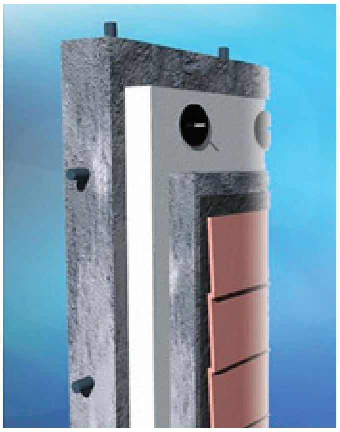
Concrete walls typically have 10 to 30 percent better air tightness than comparable framed walls because the concrete envelope has fewer parts and pieces, and is nearly continuous with fewer joints. In addition to saving energy and costs associated with heating and cooling, concrete walls provide more consistent interior temperatures that provide increased occupant comfort.

Concrete systems are well suited to the use of recycled materials. For example, concrete can be mixed with supplementary cementitious materials like fly ash or slag to replace a portion of the traditional cement. Recycled aggregates like crushed concrete can also be used to reduce the need for virgin aggregate. Most steel used for reinforcement is recycled, and concrete components are typically sourced from local materials and shipped short distances to a project.

This combination of energy efficiency features and environmental benefits help projects earn credits toward certification under green rating systems like LEED®.

Wall Systems

CONVENTIONALLY FORMED CONCRETE



Cast-in-place (CIP) concrete walls are made with ready-mix concrete delivered from a local concrete producer, placed into removable forms that are erected on site. Historically, this has been one of the most common forms of building basement walls. The same below-grade techniques can be repeated with above-grade walls to form the first floor and upper levels of homes.

Early forays into this technology were done more than 100 years ago by Thomas Edison who saw the benefit of building homes with concrete well before it was widely understood. As technology developed, improvements in forming systems and insulation materials increased the ease and appeal of using removable forms for single-family construction.

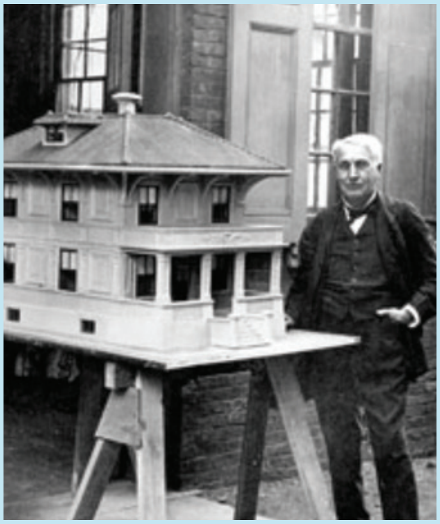
CIP systems are strong. Additionally, their inherent thermal mass, coupled with appropriate insulation, makes them very energy efficient. While CIP walls are usually thicker, traditional finishes can be applied to interior and exterior faces, so that the buildings look similar to frame construction.

HISTORY

The technology for casting concrete in removable forms dates back to the 1850's—the beginning of the reinforced concrete construction industry. Since that time, advancements in forming and placing technology, concrete mixtures, and insulation strategies have made construction of concrete homes using removable forms a well-accepted building technique.

ADVANTAGES

Cast-in-place provides benefits to builders and building owners alike.



Thomas Edison with model of a concrete house (circa 1910). Photo courtesy of U.S. Department of the Interior, National Park Service, Edison National Historic Site.

Wall Systems

OWNERS APPRECIATE:

- Strong walls
- Safety and disaster-resistance
- Mold, rot, mildew, and insect-resistance
- Sound-blocking ability
- Energy efficiency and cost savings (with an insulated system)

BUILDERS AND CONTRACTORS LIKE:

- Expand business to include more than basements
- Cost-effective and familiar building technology

COMPONENTS, INCLUDING INSULATION

The most common formwork materials for casting concrete in place are steel, aluminum, and wood. Many wood systems are custom manufactured and may be used only once or a few times. Steel and aluminum forming systems, on the other hand, are designed for multiple reuses, saving on costs. Metal panel forms are usually two to three feet wide and come in various heights to match the wall. Most common are eight and nine-foot-tall panels.

Cast-in-place (CIP) concrete is the second major component required for these systems. Although it is possible to batch concrete on site, ready mixed concrete is widely available and is usually delivered by a ready mix supplier. By 2011, the average distance to most project sites from a ready mix plant was approximately 14 miles.

Combining concrete with steel reinforcement results in unsurpassed structural strength for residential and light commercial structures.

INSTALLATION, CONNECTIONS, FINISHES

Casting concrete in place involves a few distinct steps: placing formwork, placing reinforcement, incorporating insulation, and pouring concrete. Builders usually place forms at the corners first and then fill in between the corners. This helps with proper alignment of forms and, therefore, walls. After one side of the formwork is installed, steel reinforcement bars (rebar) can be installed individually or as a prefabricated cage.

Reinforcement in both directions maintains the wall strength. Vertically, bars are usually placed at one to four feet on center, and tied to dowels extending up from a footing or basement slab for structural integrity. Horizontally, bars are typically placed at about four-foot spacing in residential applications. Additional bars are placed at corners and around openings (doors, windows) to help control cracking and provide additional strength.

Insulation can be incorporated entirely within the concrete assembly or exposed on one

Wall Systems

face, and special components are available to hold the insulation in the desired location within the forms. Specially-engineered connectors can be used to interconnect the two wythes of concrete that separate a layer of insulation so they act together structurally. Alternatively, insulation can be installed on one or both sides of the wall after the concrete has been placed and formwork stripped. Foam is the most typical insulation used with either expanded polystyrene (EPS), or extruded polystyrene (XPS). XPS is stronger, but also costlier.

Once both form faces are tied together and braced and insulation has been installed, concrete is then placed in the forms via a chute extended directly from the concrete truck, a craned bucket, or concrete pump. Forms should always be filled at a steady, appropriate rate based on formwork manufacturer recommendations to prevent problems, including a breach or blowout. And, although blowouts are uncommon with metal and wood forms, misalignment can occur if they do.

For single-family residential construction, wall thicknesses will typically range from 4 to 12 inches. Uninsulated walls are typically 6 or 8 inches thick. Walls with insulation are generally thicker to accommodate the insulation while still maintaining adequate thickness of the structural portion of the assembly. For residential construction, insulated cast-in-place walls will generally add at least 6 inches to the overall thickness of exterior walls compared to conventional construction.

Openings for doors and windows require bucks to surround the opening, to hold back the fresh concrete during placement, and provide suitable material for fastening window or door frames.

Floors and roofs can be concrete or wood, or light-gauge steel. Ledgers to support floor systems are anchored with bolts or brackets embedded into the concrete. For heavy steel floors, weld plates are installed inside the formwork so they become embedded in the fresh concrete. This provides an attachment for steel joists, trusses, or angle irons. Floors and roof systems can also be formed with conventional forming systems to create flat or ribbed decks that can span 12 to 16 feet.

Virtually any type of traditional applied finishes can be attached with furring strips. Wallboard remains the most common interior finish. Exterior finishes are much more varied, depend on customer preference, and can including siding, as well as traditional masonry.

Integral finishes cast into the face of the walls are a second popular option. Form liners attached to the exterior form face can impart any type of texture. The look and feel of masonry, siding, stucco, and stone can all be created as the wall is formed. Paint or stain often completes this treatment, leaving a finish that appears very much like real masonry, siding, stucco or stone.

Wall Systems

BUILDING CODES

Model building codes like the International Building Code (IBC), International Residential Code (IRC) and others address masonry construction, including references to relevant standards.

CONVENTIONALLY FORMED WALL SYSTEMS	
Category	**Attributes**
Performance	• Noncombustible • Integral insulation, thermal mass, and reduced air infiltration combine to reduce mechanical loads • Durable integral finishes eliminate need for additional site applied finishes/integral insulation • Thermal mass and reduced air infiltration combine to reduce mechanical loads • Solid monolithic reinforced concrete for exceptional wind and debris impact resistance • Formwork for floor and roof structures as well • Mass of walls provide exceptional acoustic performance • Somewhat thicker wall assembly than conventional systems
Availability	• Readily available nationwide • Commonly used and well understood
Labor	• Upfront investment in specialized formwork for above grade walls with architectural details • Forms must be stripped after concrete sets • Somewhat more specialized installation labor requirements • Design aids available for one and two family dwellings
Sustainability and Energy	• Can contain recycled content • Mold, rot, mildew, and insect resistant • Panelized construction with virtually no site waste

Supplemental Information – Walls

HAZARDS

Cladding/Coverings Loss

Siding of any type (wood, vinyl or fiber cement) can blow off a house and become damaging windborne debris. However, the solid concrete behind those finishes will continue to provide weather and impact protection.

Impact from Windborne Debris

Windborne debris impacts are difficult to anticipate; however, the concrete wall assembly will help protect occupants from flying debris.

Wind-Driven Water

A well attached weather resistive barrier can help to minimize moisture and water infiltration.

When cladding is lost, the concrete wall assemblies are far less vulnerable to wind-driven water while also providing a strong backing to help maintain the integrity of secondary weather barriers.

Openings & Penetrations

Door and window openings are commonly damaged by wind and wind-driven water. There are vital steps that make doors and windows wind resistant, including following specified installation instructions, using flashing, and deploying locking mechanisms.

credit: FEMA

HOUSE SHAPE

The shape of a house impacts how it handles lateral loads. For instance, a square house has the same load in every direction because the size of the ends and sides are uniform. Conversely, a long narrow house 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.

Supplemental Information – Walls

CLADDING AND COVERING

Brick Veneer

Brick veneer is popular as home cladding because it provides for low maintenance and windborne debris protection; however, it can be vulnerable to wind and wind-driven water in high wind areas. This is less of a problem with concrete walls. Because they are stiffer continuous assemblies, they reduce movement that can open veneer joints supported by conventional substrates. Common brick veneers are secured with masonry ties attached to the concrete or concrete masonry substrate; however, problems can occur when not enough ties are used, ties are not fastened securely or corrosion sets in. In high wind zones, ties should be spaced closer together and securely anchored. 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

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.

Fiber Cement Siding

Fiber cement siding is popular as home cladding because it provides for low maintenance and windborne debris protection. 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 securely anchored to the supporting concrete wall.

Supplemental Information – Walls

DESIGN PRESSURE (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 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 and 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 50 feet per second
Small Missile
30 pieces of roof gravel fired at 80 feet per second

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 that can work in place of, or supplement the strength of, impact-resistant windows. Rated hurricane shutters decrease the chance of breaking glass.

Supplemental Information – Windows

INSTALLATION

Window installation is critical to window performance in the wall, so using the correct Design Pressure 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. Stiffer concrete wall assemblies help to reduce flexing of the window frames and joints, to better maintain weather tightness.

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 Design Pressure and impact ratings although they are similar to windows ratings. Common areas where doors fail are outlined on the following pages.

Supplemental Information – Doors

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. Stiffer concrete wall assemblies help to reduce flexing of the door frames and joints, to better maintain weather tightness and function.

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.

Supplemental Information – Doors

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 concrete wall assemblies will enhance the overall performance of the garage door assembly. Thresholds poured into the concrete 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. Stiffer concrete wall surrounds will help to reduce flexing of the joints to better maintain weather tightness.

Thresholds

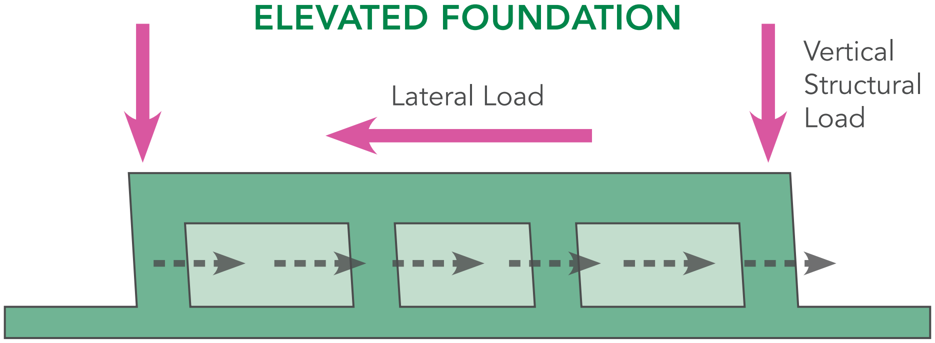
The threshold is the bottom of the door frame and provides transition from outside to inside. Thresholds can be particularly vulnerable to wind-driven water. Sealing the bottom of the threshold to the door frame is important and is often overlooked at the time of installation.

How Foundations Work

The primary structural role of the floor and foundation is to support the structure and transfer the lateral loads into the ground. The accumulated forces from high winds or flood waters are significant at foundations 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.

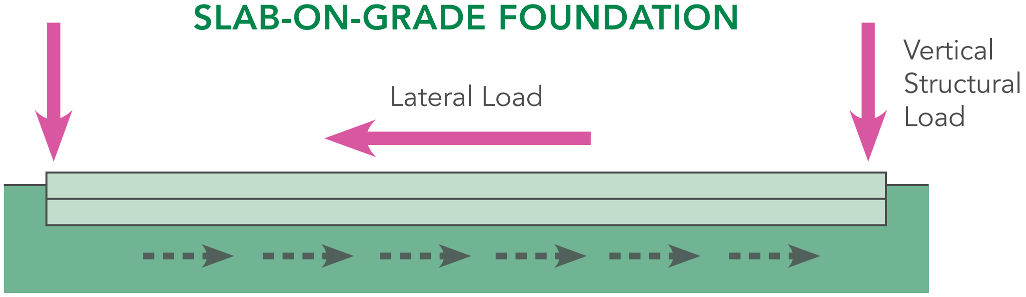
In a two-story home, the second floor deck is a stiff horizontal diaphragm that transfers the loads on the walls facing the wind to the wall parallel to the wind. Whether the foundation is a slab-on-grade or a framed floor, the attachment of the walls to the floor is one of the most important structural details as this anchor condition transfers the lateral and uplift wind loads from the wall to the floor.

ELEVATED FOUNDATION



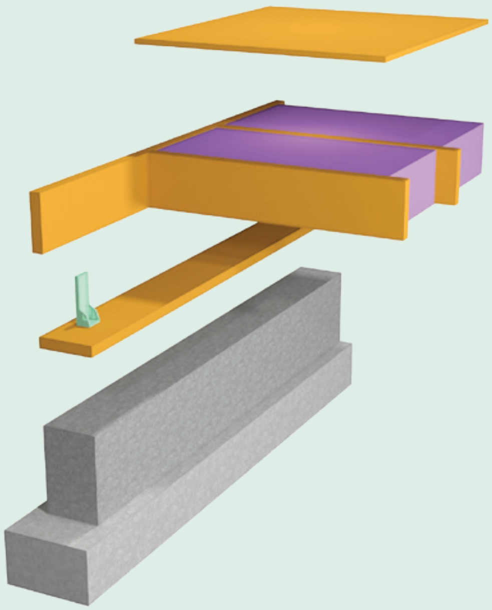
Forces Transferred to Ground

SLAB-ON-GRADE FOUNDATION



Forces Transferred to Ground

Foundation Components



SUBFLOOR

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 and fastened to the floor framing.

FLOOR FRAMING

Floor framing is typically 2 x 10, 2 x 12 or engineered lumber. The size of the framing is determined by the spans and floor loads.

INSULATION

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 as these two types of applications deliver energy-efficiency, water resistance, and structural strength as opposed to batt and blown in insulation that only provide energy-efficiency.

SILL PLATES AND ANCHORS

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.

CONCRETE FLOOR SYSTEMS

For greatest resilience substituting reinforced or precast decking, insulated as required, replaces subfloor framing, sill plates, and anchors. See pages 47-48.

FOUNDATIONS

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 spread footings under each pier, continuous spread footings for a stem wall or combined piers, or deep foundations such as concrete piers or driven piles.

Foundation Component Comparison

FOUNDATION COMPONENTS	Code Compliant Conventional Construction	Higher Local Hazard Construction	Resilient Construction
Raised Floor – Subfloor	3/4" tongue and groove (glued and nailed)	3/4" tongue and groove (glued and nailed)	
Raised Floor – Joists	2x (depth is span dependent on load)	2x (depth is span dependent load)	Precast concrete planks, or formed reinforced concrete slab
Raised Floor – Supporting Structure	2x double rim joist	2x double rim joist	Integral concrete beam or concrete beam supporting underside of planks or slab
Raised Floor – Foundation Connection	Sill plate with anchor bolts	Sill plate with anchor bolts, include hold down bolted through bottom plate into foundation	Steel reinforcement to connect concrete floor system to foundation
Raised Floor – Foundation	Reinforced concrete masonry or cast-in-place piers or continuous foundation wall designed by engineer to local code	Reinforced concrete masonry or cast-in-place piers or continuous foundation wall designed by engineer to local code	Reinforced concrete masonry or cast-in-place piers or continuous foundation wall designed by engineer to local code
Raised Floor – Footings	Reinforced concrete footings sized and designed by engineer based on local soil conditions	Reinforced concrete footings sized and designed by engineer based on local soil conditions	Reinforced concrete footings sized and designed by engineer based on local soil conditions
Raised Floor – Underside		Batt insulation covered with vapor barrier attached with button caps	Exposed concrete or fiber cement panels over ICF form foam
Slab-on-grade – Connection	Anchor bolts into bottom plate, 1/2" "J" bolts 48" O.C., plus 1 "J" bolt within 12" of corners	Vertical steel reinforcement dowels extending from foundation into concrete exterior wall supported above	Vertical steel reinforcement dowels extending from foundation into concrete exterior wall supported above
Slab-on-grade	Reinforced slab and grade beams sized and designed by engineer	Reinforced slab and grade beams sized and designed by engineer	Reinforced slab and grade beams sized and designed by engineer

Supplemental Information – Floors & Foundations

CONCRETE FLOOR SYSTEMS

Concrete floor systems have been popular for use in multi-family and commercial construction for a very long time. Today, similar systems derived from these larger scale projects are now available for use in one- and two-family dwellings. There are three types of concrete floor systems most typically used in housing: precast planks, conventionally formed, and insulating concrete form floor systems. Composite steel joist and concrete or steel deck and concrete systems are also available, but they are beyond the scope of this publication.

PRECAST CONCRETE FLOOR PLANKS

Precast concrete floor planks are pre-ordered from a local precast producer, and typically cast offsite. They arrive at the site formed to length and already reinforced. Cranes set them into position, allowing for floor decks to be in place in only several hours. There is literally no site waste. These become particularly economical when combined with precast wall systems permitting floors and walls to be erected with one visit of a crane. They can also be supported by other types of concrete wall systems. The planks can have hollow cores that can function as utility chases for some ductwork, plumbing, and electrical wiring. Finish coatings are typically installed directly to the underside of the planks, or final finishes are installed over furring strips secured to the bottom of the assembly.

CONVENTIONALLY FORMED CONCRETE FLOORS

Formwork similar to the removable forming used for wall construction can be assembled to allow for the construction of reinforced concrete floors. Very often the walls and floors are cast at the same time. Once the concrete has cured adequately to allow the floors to support themselves, the formwork and supporting shoring can be removed. Again, there is minimal waste. The forms are designed to be used multiple times and are particularly economical on projects with a series of similar houses. Spans are determined by the thickness of the slab and reinforcement design. Electrical conduit can be installed to permit electrical systems to run within the slabs.

Supplemental Information – Floors & Foundations

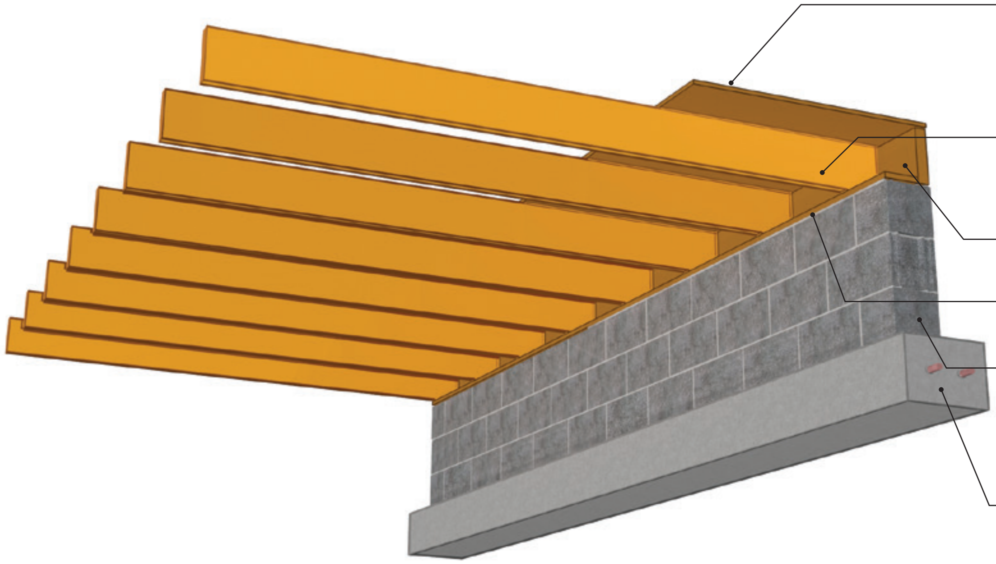
INSULATING CONCRETE FLOOR FORMING

Like all other concrete floor systems, insulating concrete form, or ICF, floor forming systems can be supported by all of the popular concrete wall assembles. They feature polystyrene foam, designed to form up the underside of the concrete floor and remain in place after the pour, just like ICF wall systems. The systems typically have steel rails or channels that help support the forms during concrete placement. Shoring is installed to support the system when concrete is placed, and then removed when the floor can support itself. Finishes can typically be fastened to the integral support channels to complete the installation. Utilities can be cut into the foam after concrete is placed.

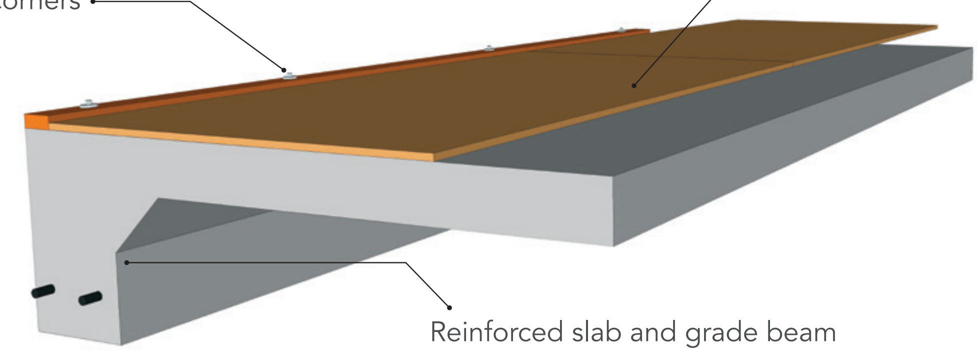
All concrete floor systems offer exceptional durability and fire resistance. They are also more dimensionally stable and are far less likely to be impacted by rot, rust, or insects. These systems provide thermal mass for improved energy efficiency which can be enhanced even more when combined with radiant heat systems. Concrete also provides a more effective sound barrier between floors. Longer spans than conventional framing allow for creation of more open spaces. All of these systems typically prefabricated or assembled with removable forms on site to greatly reduce site waste. Finally, from a resilience perspective, these assemblies create a strong and rigid diaphragm, transferring lateral loading extremely well.

Code Compliant Conventional Construction

Typical Components



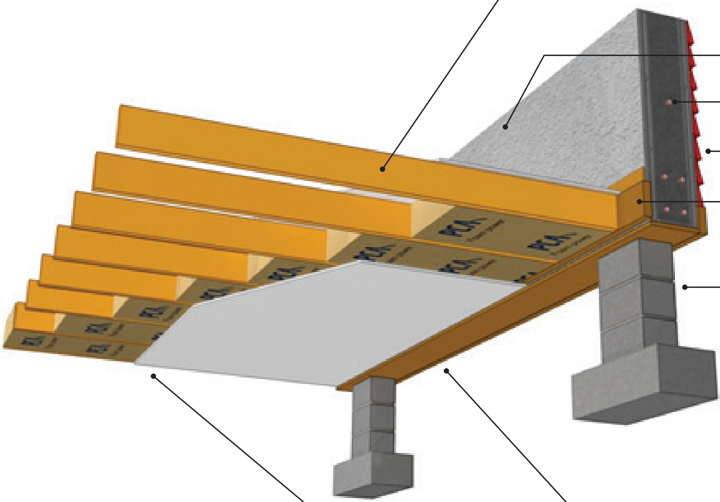
$$$ Raised Floor



$ Slab-on-grade

Higher Local Hazard Construction

Generally required by beyond-code programs



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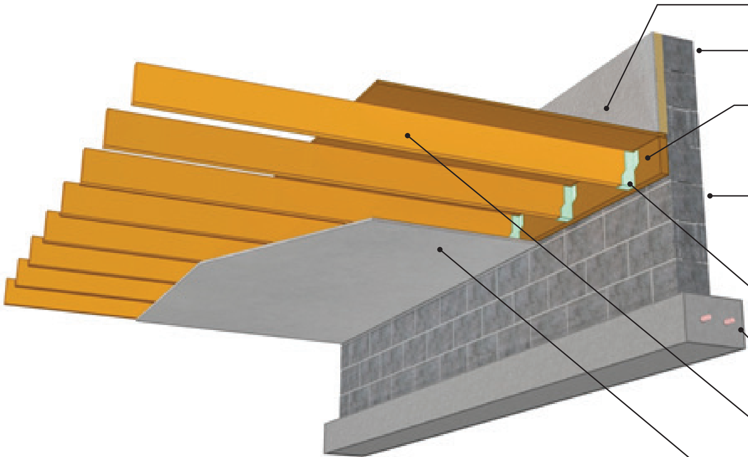

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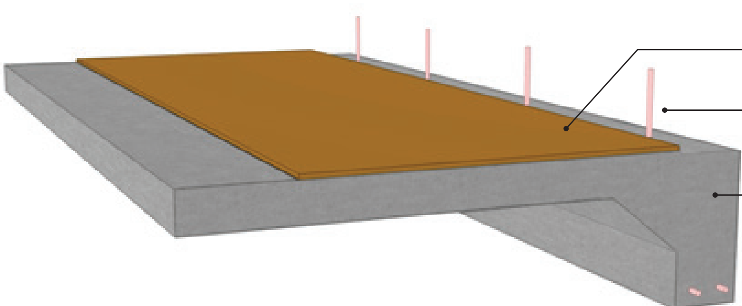
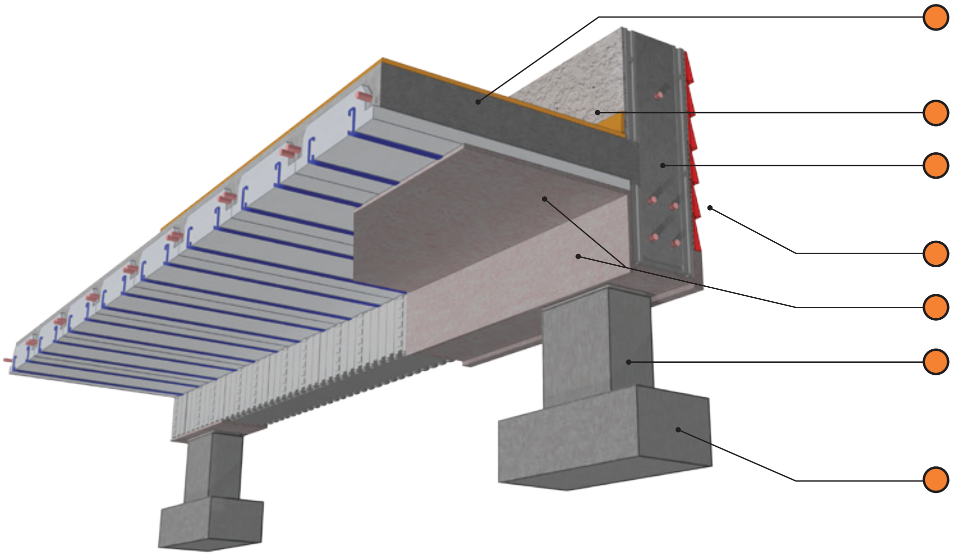


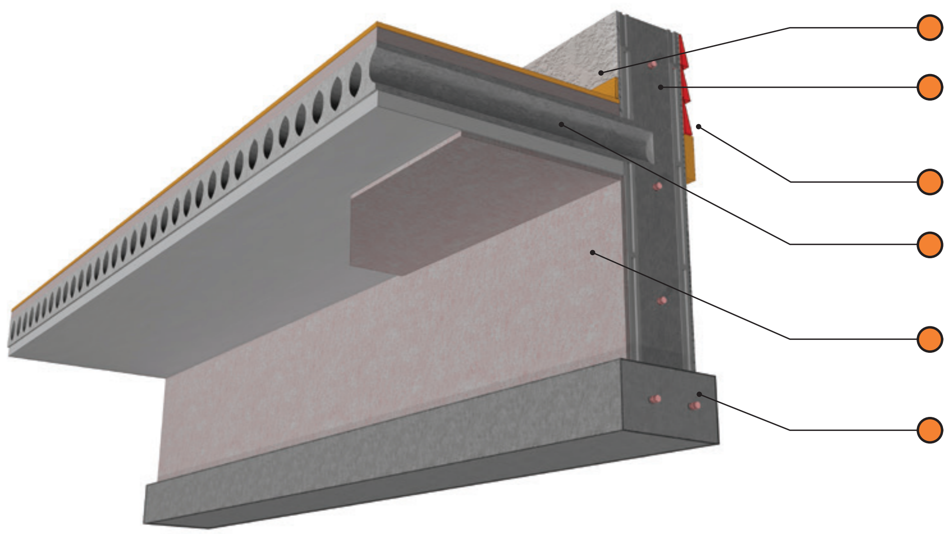
$ Slab-on-grade

Resilient Construction

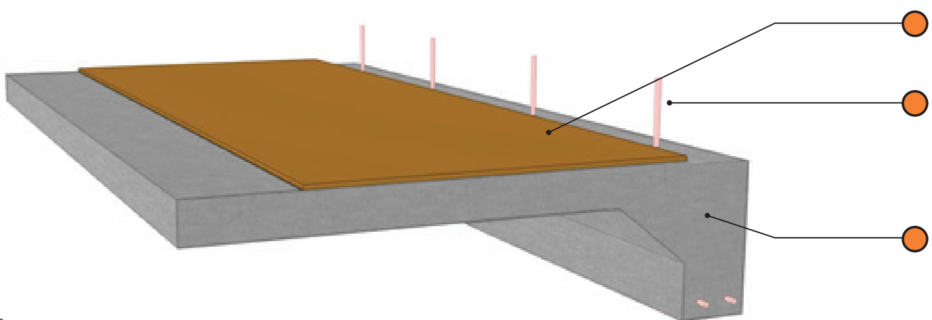
Reduces the damaging effects of a storm



$$$ Raised Floor



$$$ Raised Floor



$ Slab-on-grade

Resilient Landscape

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 are run underground as this reduces risk of power outages; and communities benefit from these types of efforts to invest in more resilient power infrastructure. For the individual homeowner, loss of electrical power is not only inconvenient in hot climates, but the lack of air conditioning allows mold growth inside the home. In cold locations, lack of heat can lead to frozen pipes and water damage. A resilient home is prepared for loss of power with good natural ventilation and a standby generator to provide power for a minimal amount of air conditioning and interior finishes that don't support mold growth.

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.

Notes

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