5E Elevation

One of the most common of all retrofitting techniques is to raise an entire existing superstructure above the DFE. When properly done, the elevation of a house places the living area above all but the most severe floods.

The steps required for elevating a building are essentially the same in all cases. A cradle of steel beams is inserted under (or through) the structure; jacks are used to raise both the beams and structure to the desired height; a new, elevated foundation for the house is constructed; utility systems are extended and modified; and the structure is lowered back onto the new foundation and reconnected.

While the same basic elevation techniques are used in all situations, the final siting and appearance of the house will depend on the final elevation and type of foundation used. However, the actual elevation process is only a small part of the whole operation in terms of planning, time, and expense. The most critical steps involve the preparation of the house for elevation and the construction of a new, adequately designed, and elevated foundation. The elevation process becomes even more complex with added weight, height, or complex design or shape of the house. Brick or stucco veneers may require removal prior to elevation. Building additions may need to be elevated independently from the main structure.

NOTE

FEMA strongly encourages that flood retrofits provide protection to the DFE (or BFE plus 1 foot, whichever is higher). However, in some situations, lower flood-protection levels may be appropriate. Homeowners and design professionals should meet with a local building official to discuss the selected retrofit measure and the elevation to which it will protect the home. The text and examples in this manual assume flood protection measures will be implemented to the DFE.

5E.1 Types of Residential Structures that Can Be Elevated

The elevation of houses over a crawlspace; houses with basements; houses on piers, columns, or piles; and houses on a slab-on-grade are examined here. In each of these situations, the designer must account for multiple (non-flood-related) hazards, such as wind and seismic forces. The various methods utilized to elevate different home types are illustrated in the pages that follow, providing the designer with an introduction to the design of these measures.

Houses that are elevated using solid foundation walls as opposed to piers, columns, or piles to raise the finished floor to or above the DFE must include openings to allow the automatic entry and exit of floodwater. Guidance on the design and installation of flood vents can be found in Section 5E.1.2.1.

NOTE

Figures 5E-1 through 5E-5 illustrate the elevation of a home on extended solid foundation walls. Subsequent figures for various elevation techniques will include only those illustrations unique to that technique.

5E.1.1 Houses Over a Crawlspace

These are generally the easiest and least expensive houses to elevate. They are usually one- or two-story houses built on a masonry crawlspace wall. This allows for access in placing the steel beams under the house for lifting. The added benefit is that, since most crawlspaces have low clearance, most utilities (heat pumps, water heaters, air conditioners, etc.) are not placed under the home; thus the need to relocate utilities may be limited. Houses over a crawlspace can be:

- elevated on extended solid foundation walls (see Figures 5E-1 through 5E-5); or
- elevated on an open foundation such as masonry piers (see Figures 5E-6 through 5E-8).

CROSS REFERENCE

Information on the design of foundation wall openings and adjustment of existing utility systems can be found in Chapter 5W.

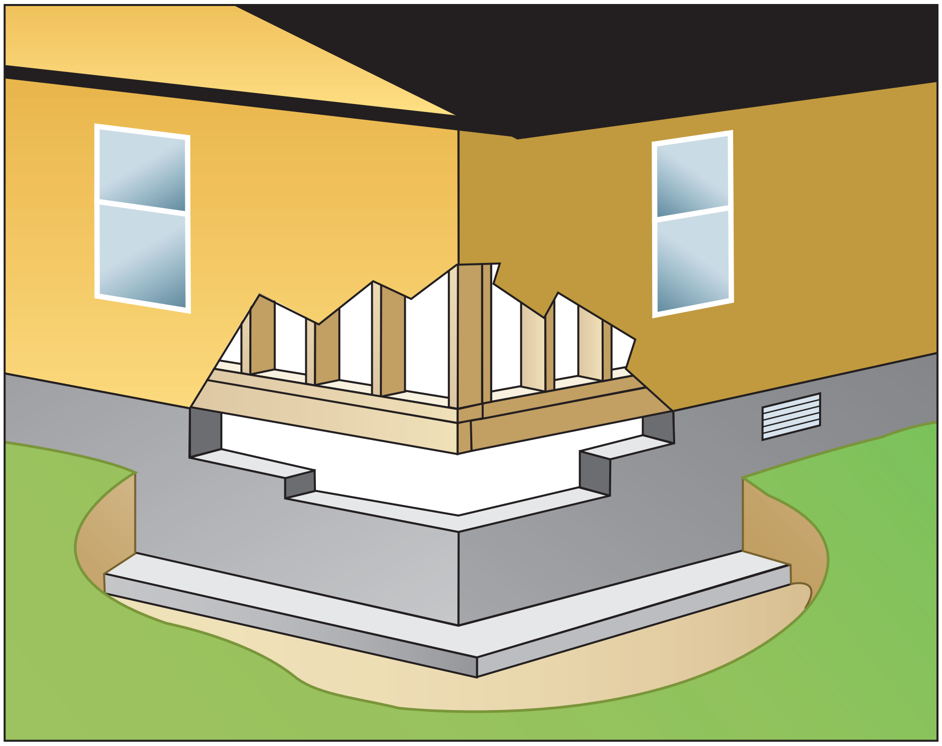


Figure 5E-1.
Existing wood-frame house on crawlspace foundation to be elevated with extended walls and piers

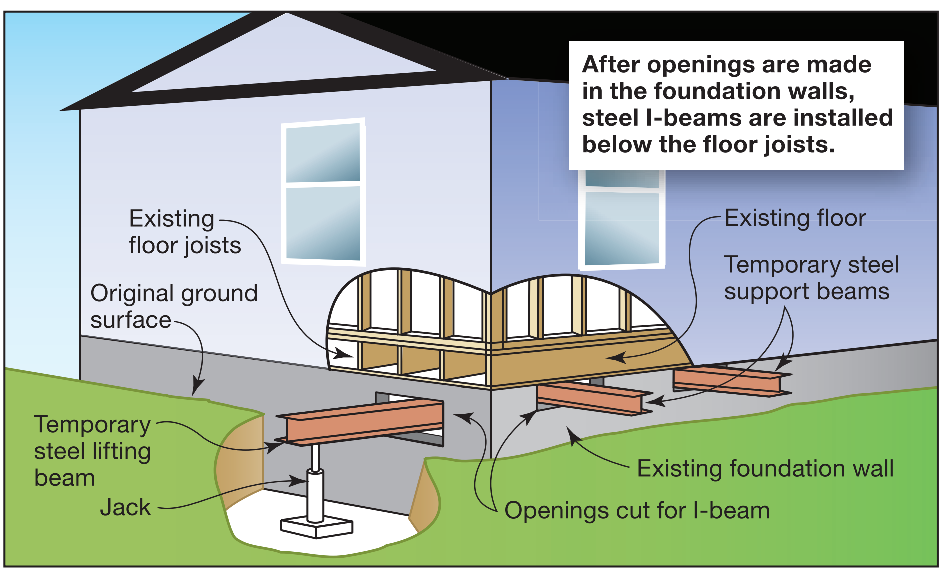


Figure 5E-2.
Step 1 of elevating an existing wood-frame house on extended foundation walls and piers: Install network of steel I-beams

Figure 5E-3.
Step 2 of elevating an existing wood-frame house on extended foundation walls and piers: Lift house and extend foundation walls and piers (reinforce as needed); relocate utility and mechanical equipment above flood level

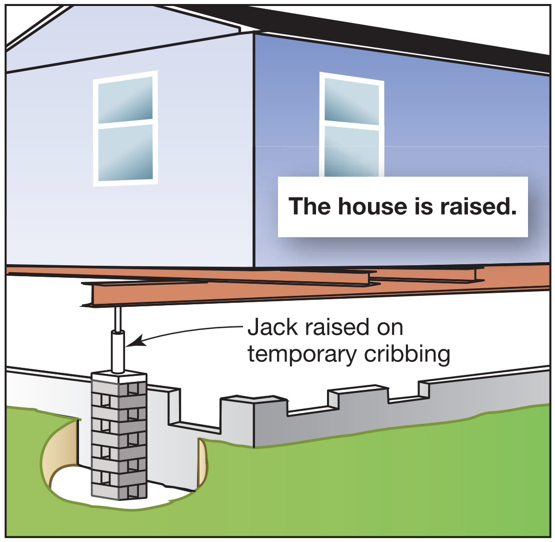
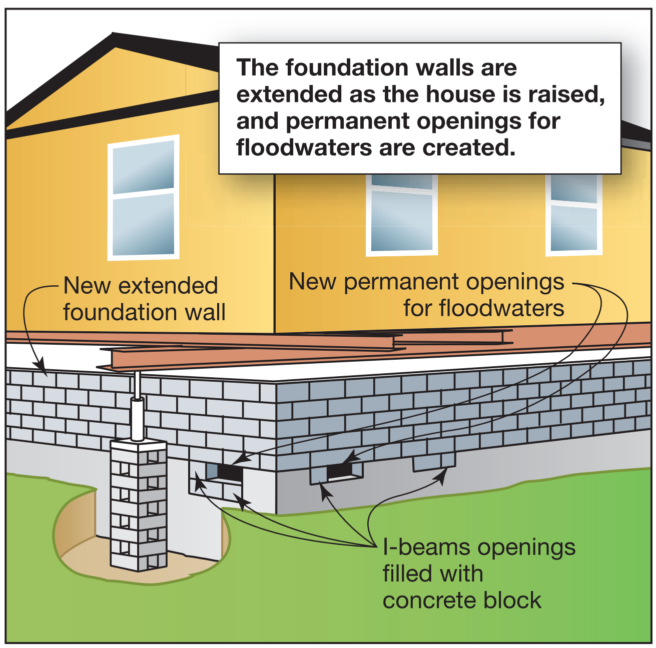


Figure 5E-4.
Step 3 of elevating an existing wood-frame house on extended foundation walls and piers: Set house on new extended foundation and remove I-beams



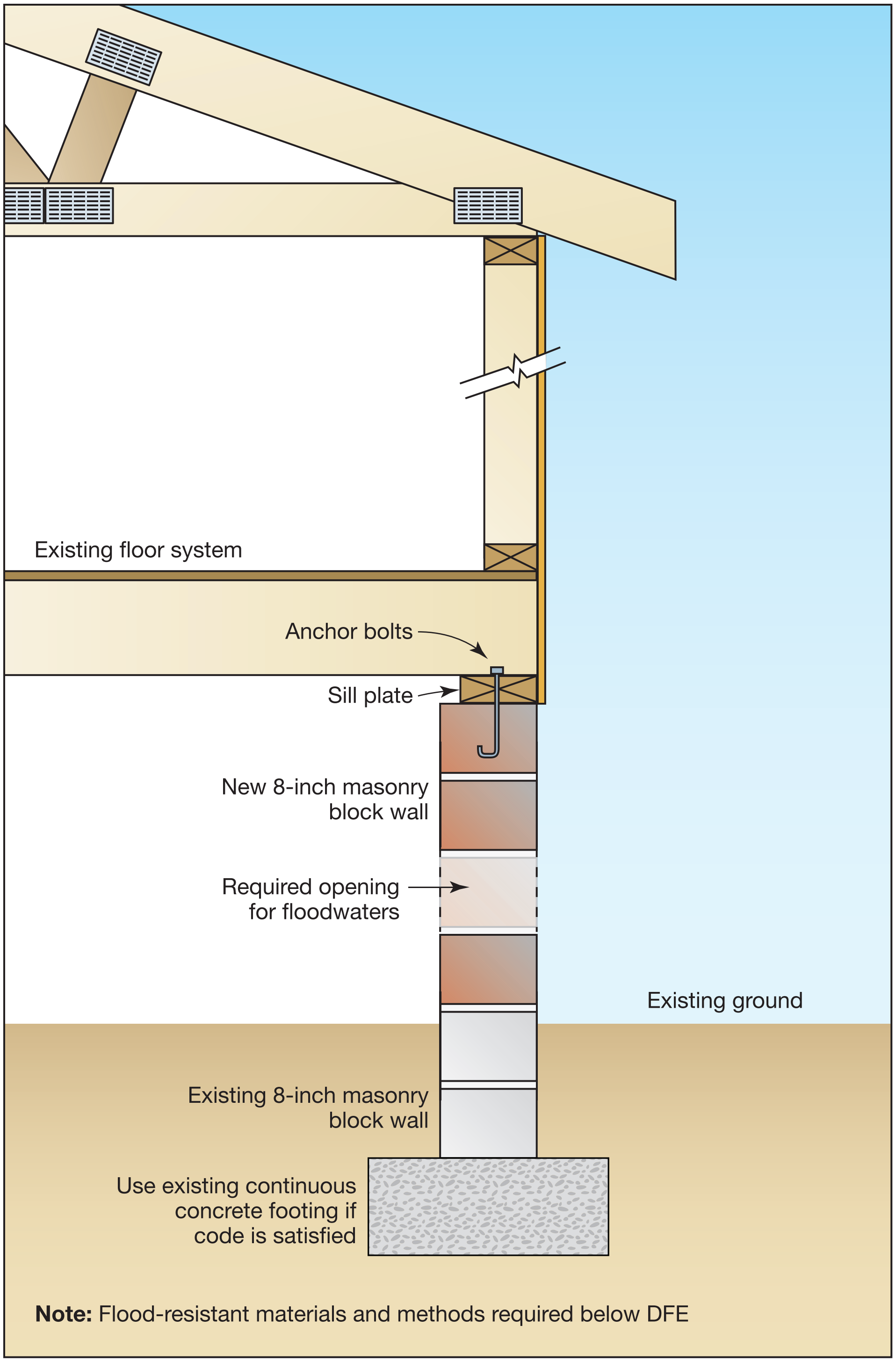


Figure 5E-5. Cross-section of elevated wood-frame house on extended piers and crawlspace walls

Figure 5E-6.
Step 1 of elevating an existing wood frame house on new or extended pier foundations: Install network of steel I-beams. Step 2 (not shown): Lift house, rebuilding or extending (reinforce as needed) piers; relocate utility and mechanical equipment above flood level.

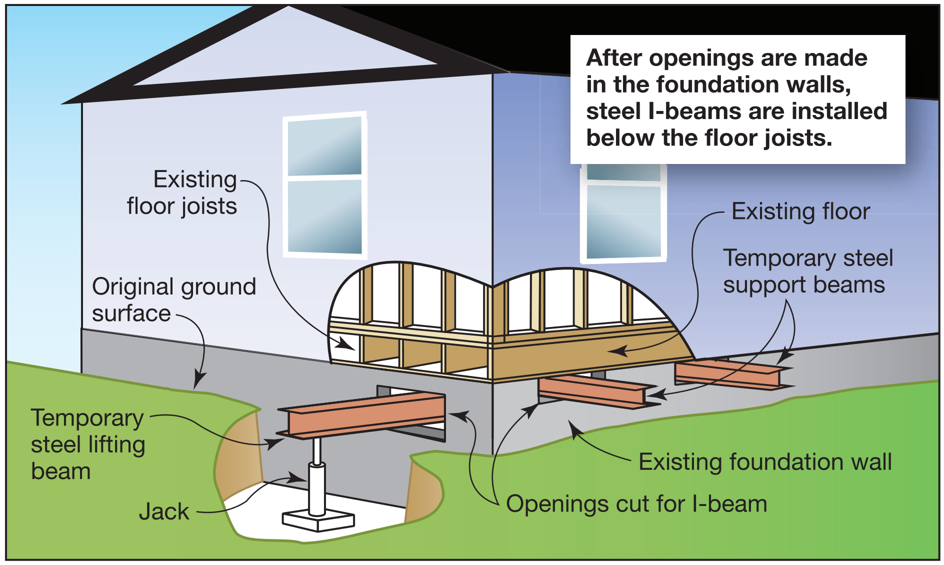
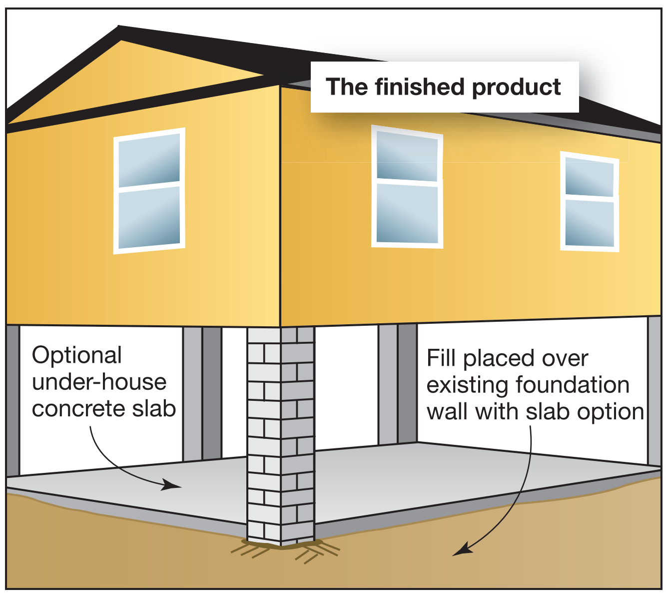


Figure 5E-7.
Step 3 of elevating an existing wood-frame house on new or extended pier foundation: Set house on new or extended piers



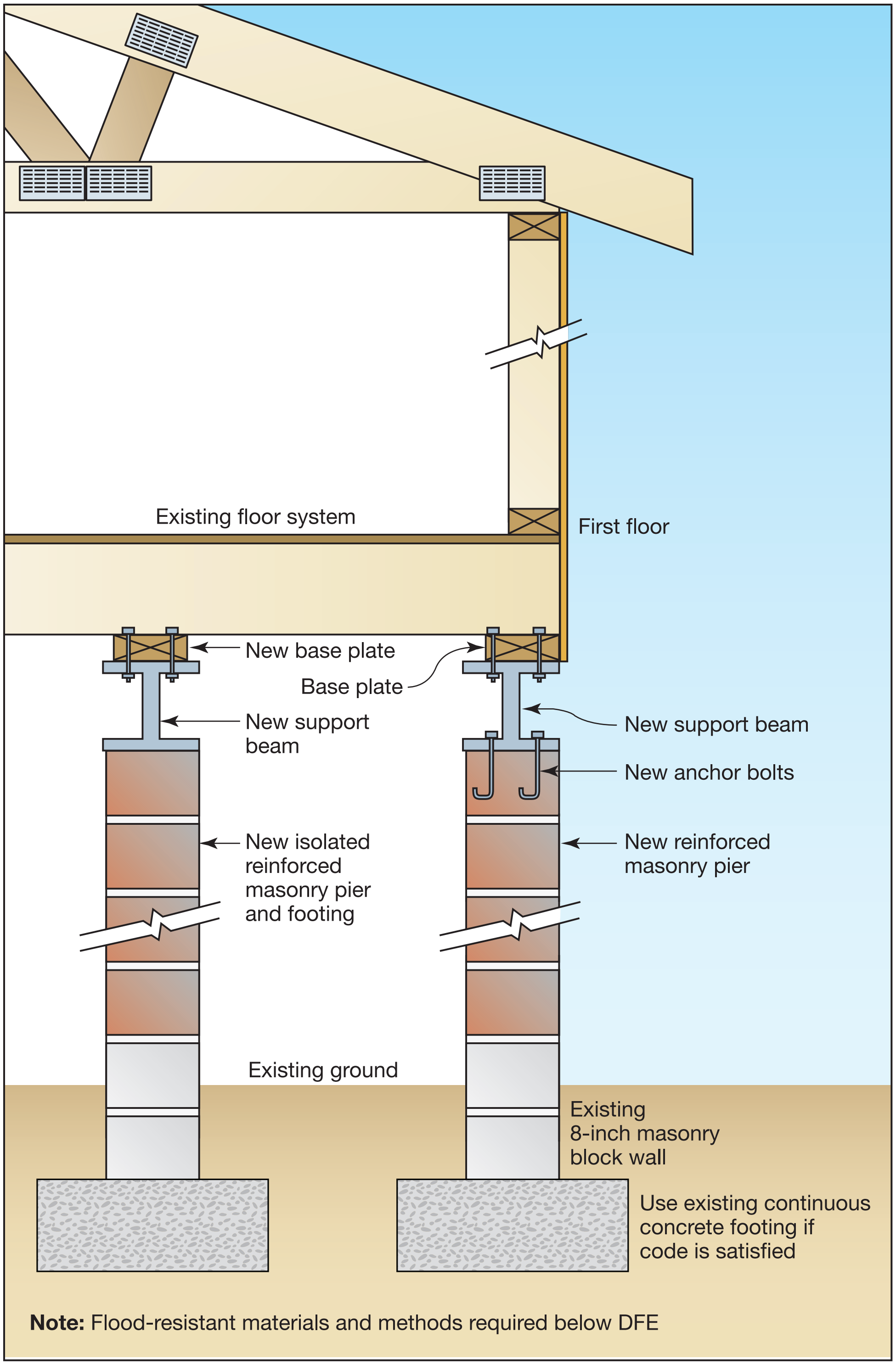


Figure 5E-8. Cross-section of elevated wood-frame house on new or extended pier foundation

5E.1.2 Houses Over Basements

These houses are slightly more difficult to elevate because their mechanical and HVAC equipment is usually in the basement. In addition, basement walls may already have been extended to the point where they cannot structurally withstand flood forces. Houses over basements can be:

- elevated on solid foundation walls by creating a new masonry-enclosed area on top of an abandoned and filled-in basement (see Figures 5E-9 and 5E-10); or
- elevated on an open foundation, such as masonry piers, by filling in the old basement (see Figures 5E-11 and 5E-12).

CROSS REFERENCE

FEMA's post- and pre-FIRM requirements do not allow basements below the BFE for substantially damaged/improved and post-FIRM applications. For more information on what retrofitting measures are allowable under FEMA guidelines, refer to Chapter 2, Regulatory Requirements.

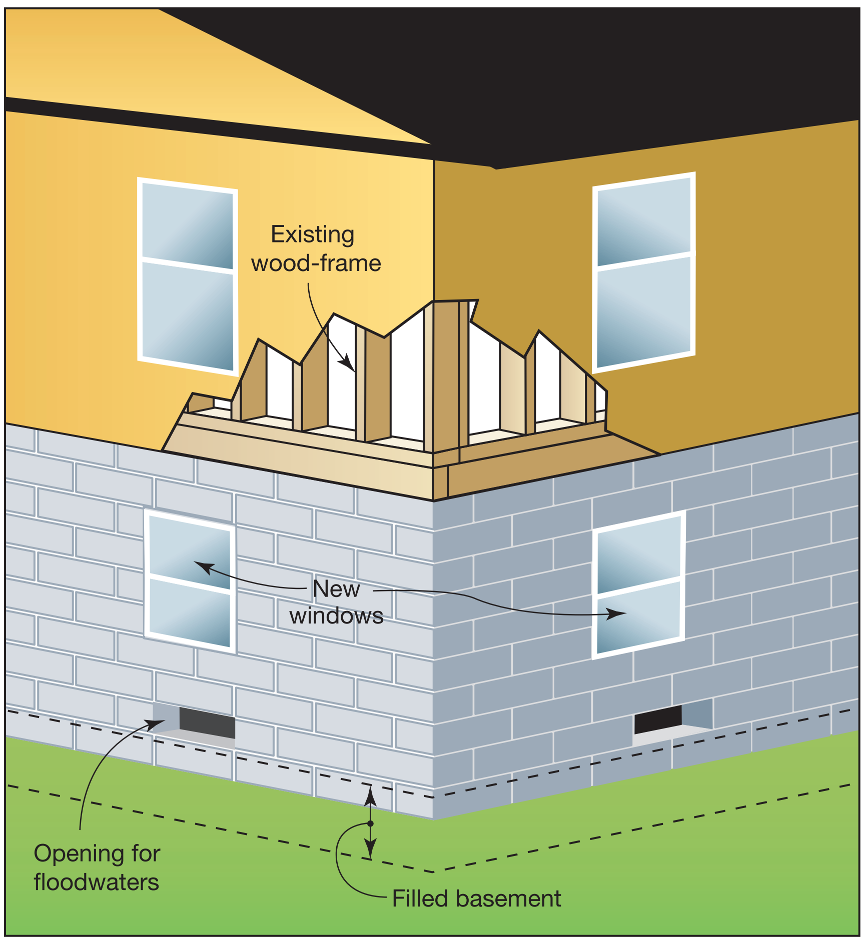


Figure 5E-9. Elevated wood-frame house with new masonry-enclosed area on top of an abandoned and filled-in basement; utility and mechanical equipment must be relocated above the flood level

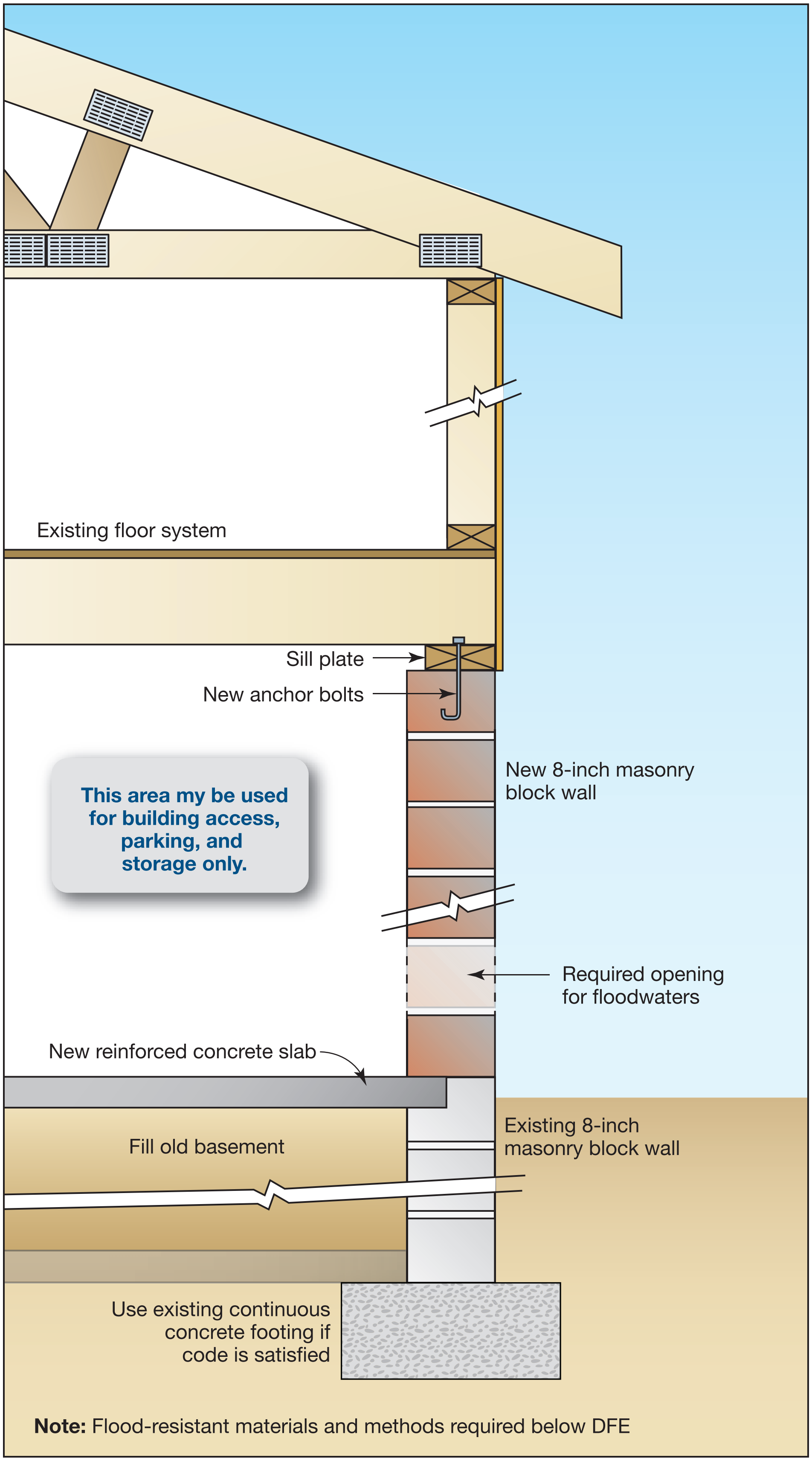
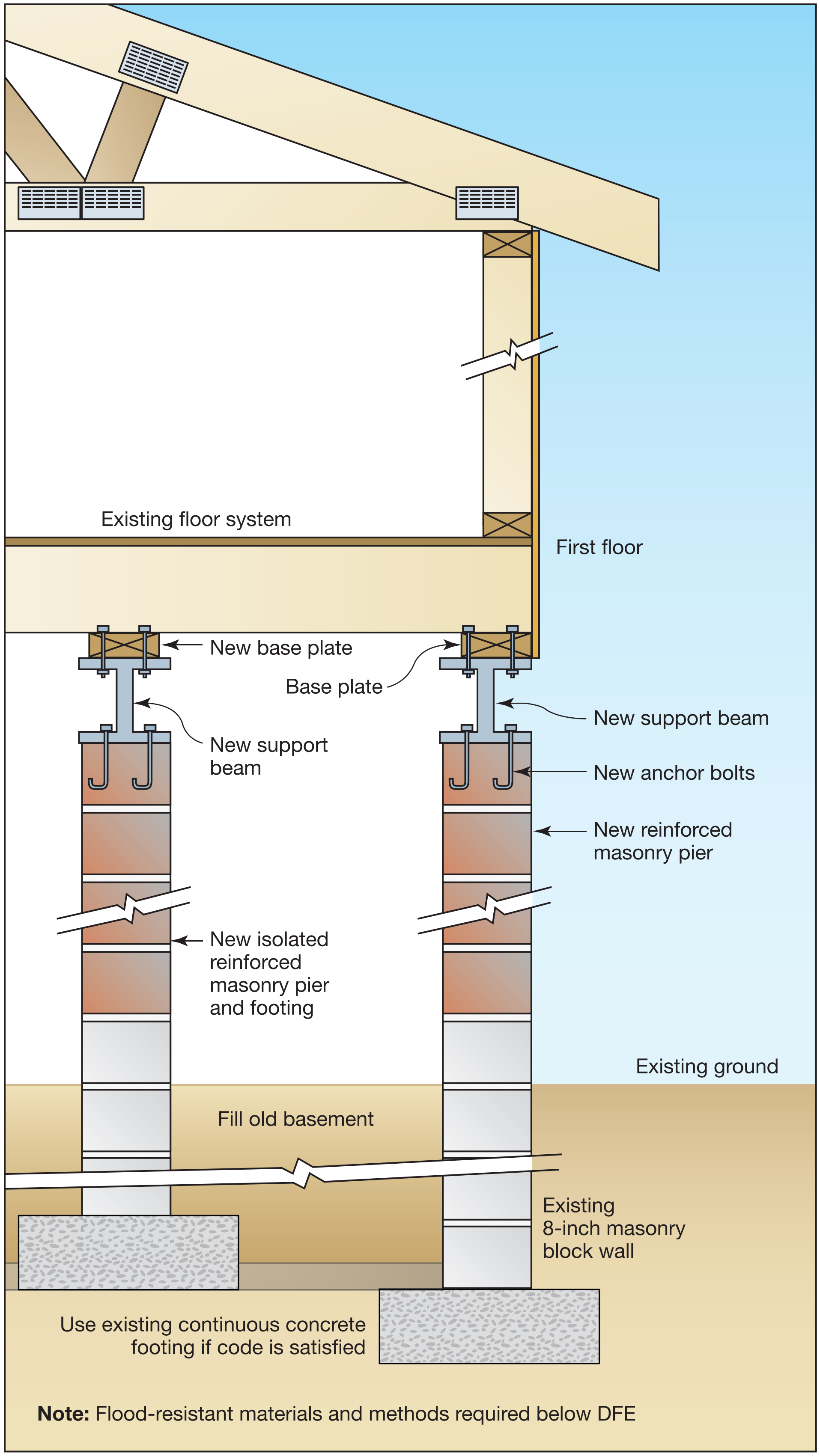


Figure 5E-10.
Cross-section of elevated wood-frame house with extended masonry-enclosed area on top of an abandoned and filled-in basement

Figure 5E-11.
Cross-section of elevated wood-frame house on new reinforced piers on top of the existing filled-in basement



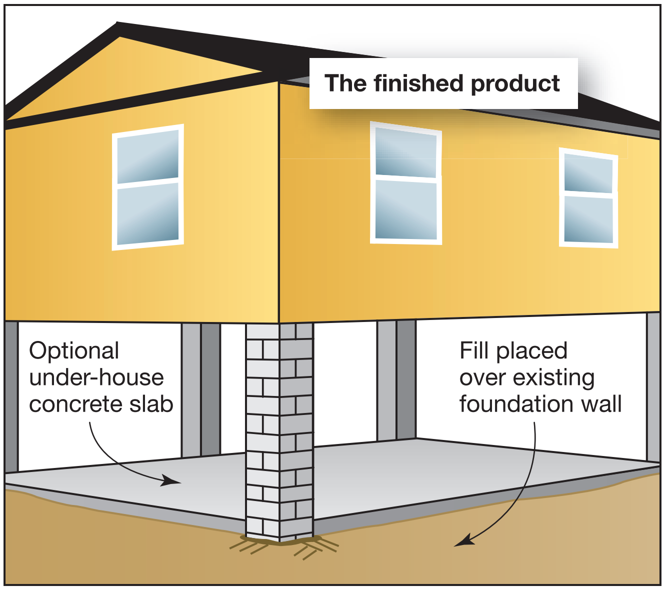


Figure 5E-12. Elevated wood-frame house set on new reinforced piers on top of the existing filled-in basement

5E.1.2.1 Design of Openings in Foundation Walls for Intentional Flooding of Enclosed Areas Below the DFE

It is important that the foundation walls contain openings that will permit the automatic entry and exit of floodwater for buildings that are constructed on extended solid foundation walls or that have other enclosures below the DFE (see Figure 5E-13).

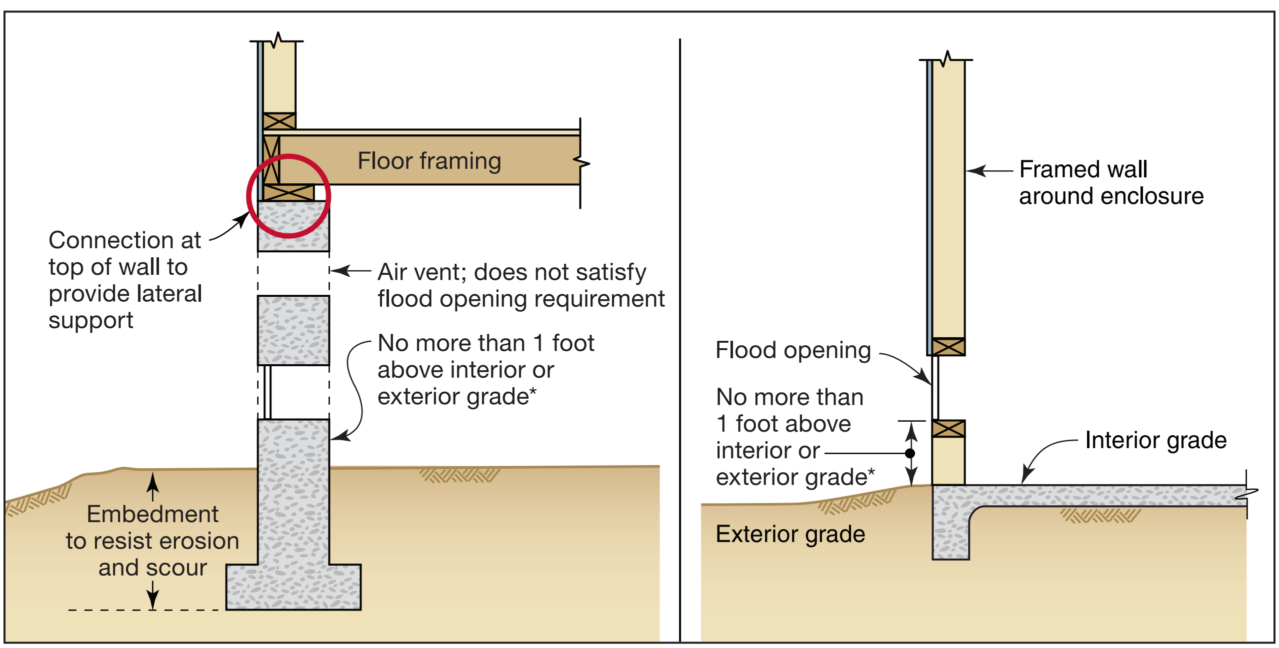


Figure 5E-13. Typical opening for solid foundation wall

These openings allow floodwater to reach equal levels on both sides of the walls and thereby lessen the potential for damage from hydrostatic pressure. While not a requirement for existing buildings built prior to a community's joining the NFIP, NFIP regulations require these openings for all new construction and substantial improvements of existing buildings in SFHAs.

The minimum criteria for design of these openings are:

- a minimum of two openings must be provided on different sides of each enclosed area, having a total net area of not less than 1 square inch for every square foot of enclosed area subject to flooding; this is not required if openings are engineered and certified;
- the bottom of all openings shall be no higher than 1 foot above grade; and
- openings may be equipped with screens, louvers, or other coverings or devices, provided those components permit the automatic entry and exit of floodwater and do not reduce the net open area to less than the required open area.

CROSS REFERENCE

For additional information on the regulations and design guidelines concerning foundation openings, please refer to FEMA 's NFIP Technical Bulletin 1-08, Openings in Foundation Walls for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program (FEMA, 2008).

It is important to make sure that none of the flood openings will be obstructed during a flood event. In wet floodproofed buildings, openings are sometimes obstructed by drywall or other wall coverings (Figure 5E-14), which can result in significant damage if the opening does not operate as intended. Figure 5E-15 shows an NFIP-compliant house with attached garage with flood openings to prevent the build-up of hydrostatic loads on the foundation walls.

Figure 5E-14. A house where flood openings have been covered by insulation and drywall

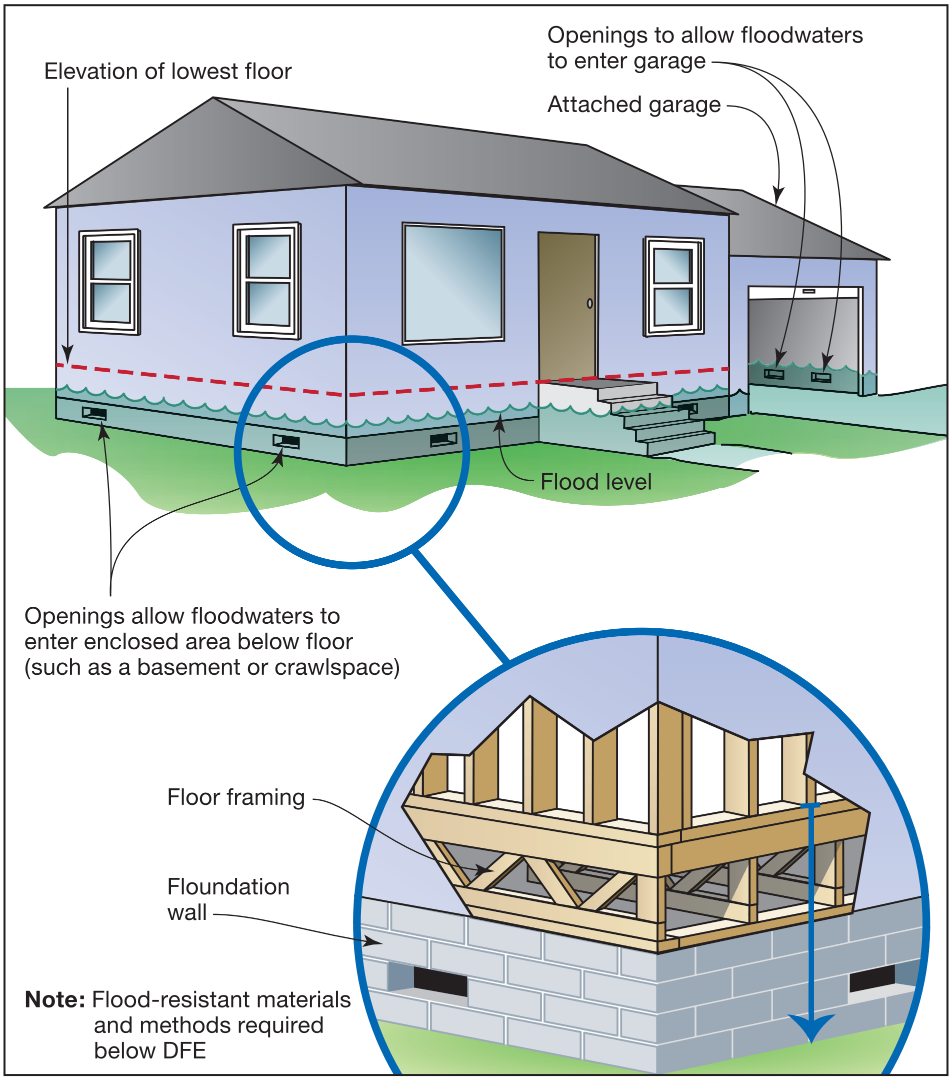


Figure 5E-15. NFIP-compliant house built on solid foundation walls with attached garage

5E.1.3 Houses on Piers, Columns, or Piles

The process of elevating a house on existing piles, piers, or columns is slightly more complex in that temporary relocation of the house may be part of the elevation process. With the use of this type of foundation, the house may need to be lifted off the existing foundation and temporarily relocated on site. The existing foundation is then removed and/or reconstructed, and the house is reset on the new foundation. In some instances, raising the home above the working area (instead or relocating off to the side) may provide sufficient room to install new pier and column foundations and to extend existing piers or columns upward.

5E.1.4 Slab-on-Grade Houses

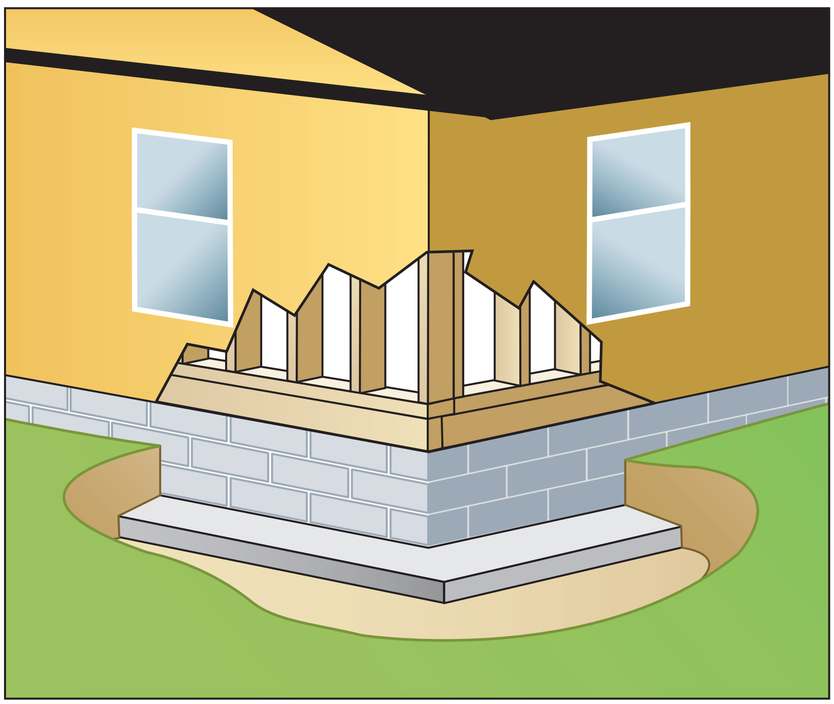
Although slab-on-grade houses may be the most difficult to raise, a number of elevation options exist with regard to raising the structure with or without the slab and using a first floor composed of wood or concrete. If the slab is to be raised with the house, a trench is normally dug under the house to provide a space for inserting lifting beams. However, intrusive techniques that place beams through the structural walls have proved to be successful in elevating some slab-on-grade homes, as well. If the existing slab is to remain in place, the house must be detached from the slab, the structure must be raised separately from the slab, and a new floor system must be built along with an elevated foundation.

5E.1.4.1 Elevating a Slab-on-Grade Wood-Frame House

The following procedures apply to elevating a wood-frame house with a slab-on-grade foundation:

- Elevating without the slab, using a new first floor constructed of wood trusses (see Figures 5E-16 through 5E-20); and
- Elevating with the slab intact (see Figures 5E-21 through 5E-23). The basic order of steps required for raising a slab on grade house with slab intact is illustrated in Figures 5E-21 through 5E-23; implementation demands highly specialized skill and equipment that are beyond the scope of this manual.

Figure 5E-16. Existing wood-frame house with slab and stem-wall foundation



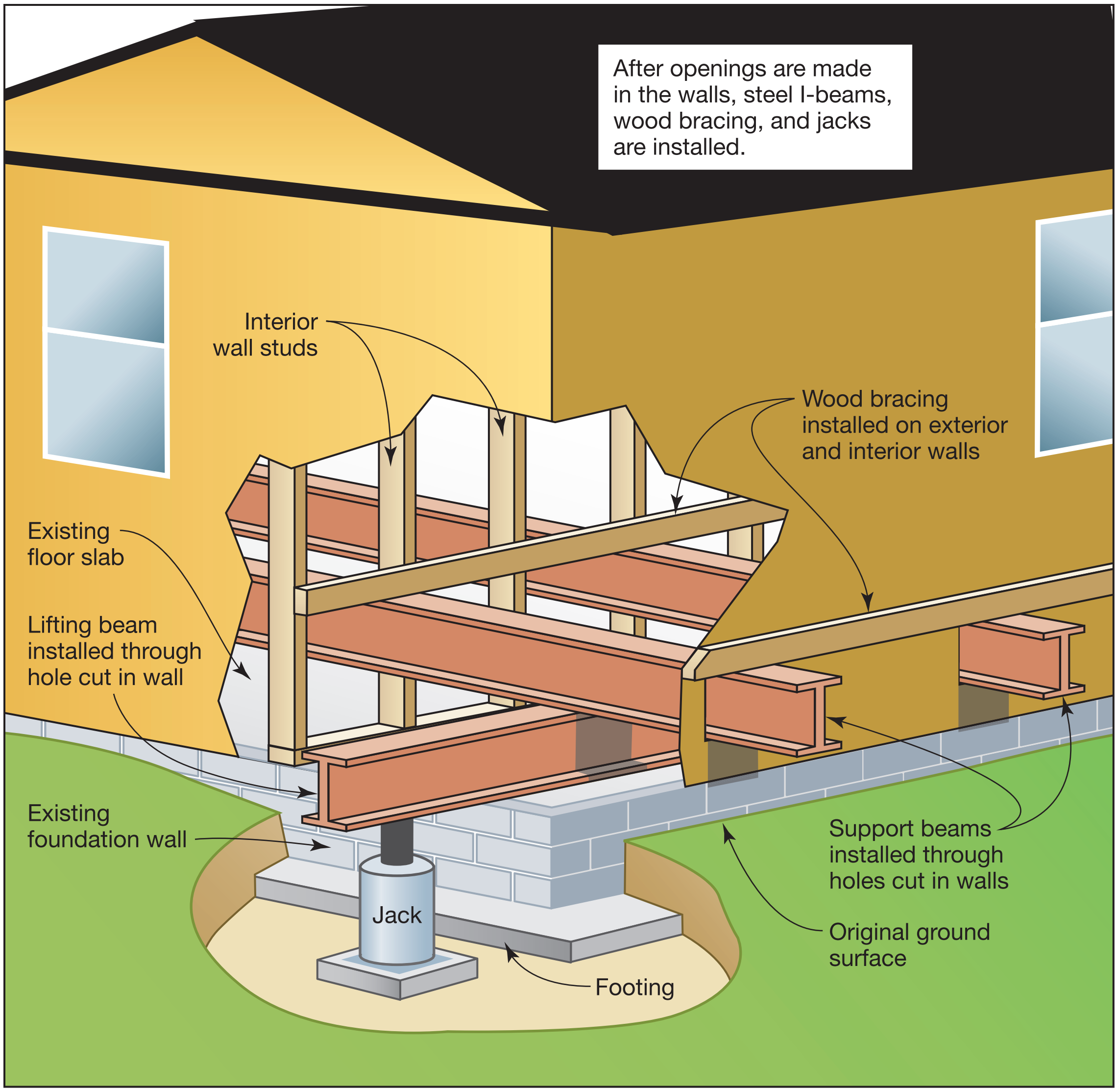


Figure 5E-17. Step 1 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Install steel I-beam network and prepare to lift walls

Figure 5E-18.
Step 2 of elevating an existing wood-frame house without the slab using a new first floor constructed of wood trusses: Lift house, extend masonry foundation wall, and install wood floor trusses; relocate utility and mechanical equipment above flood level

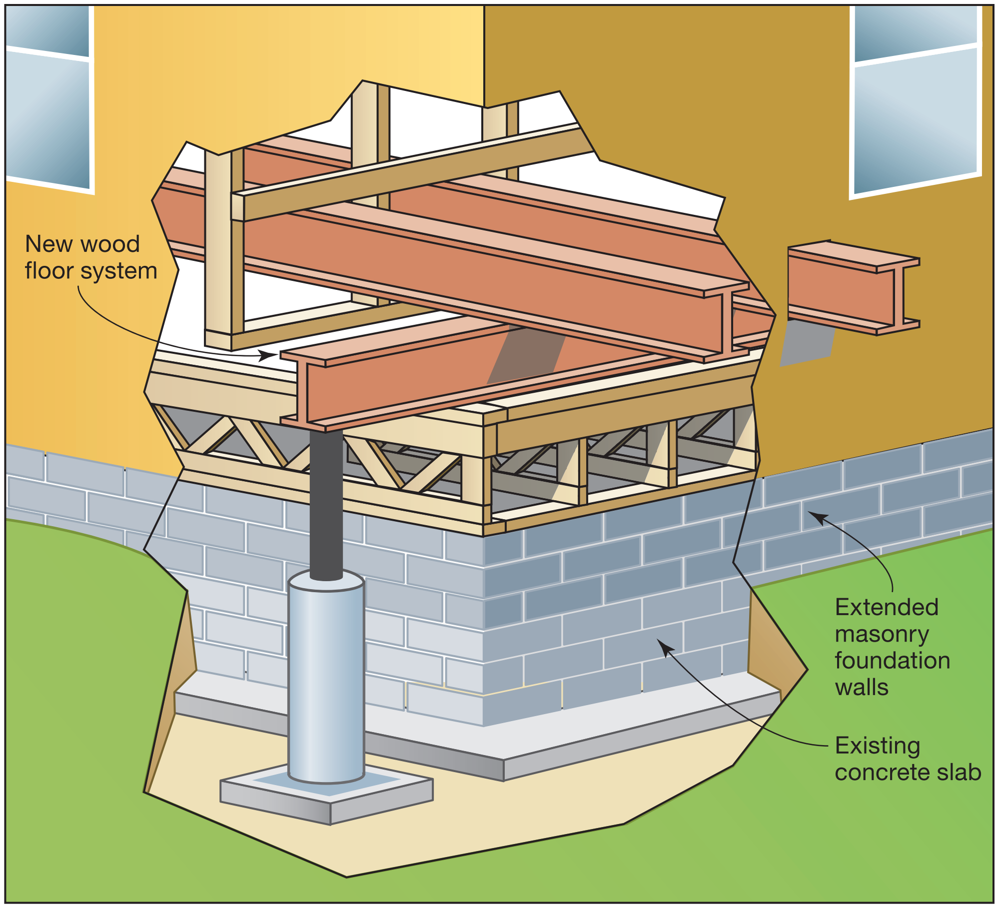
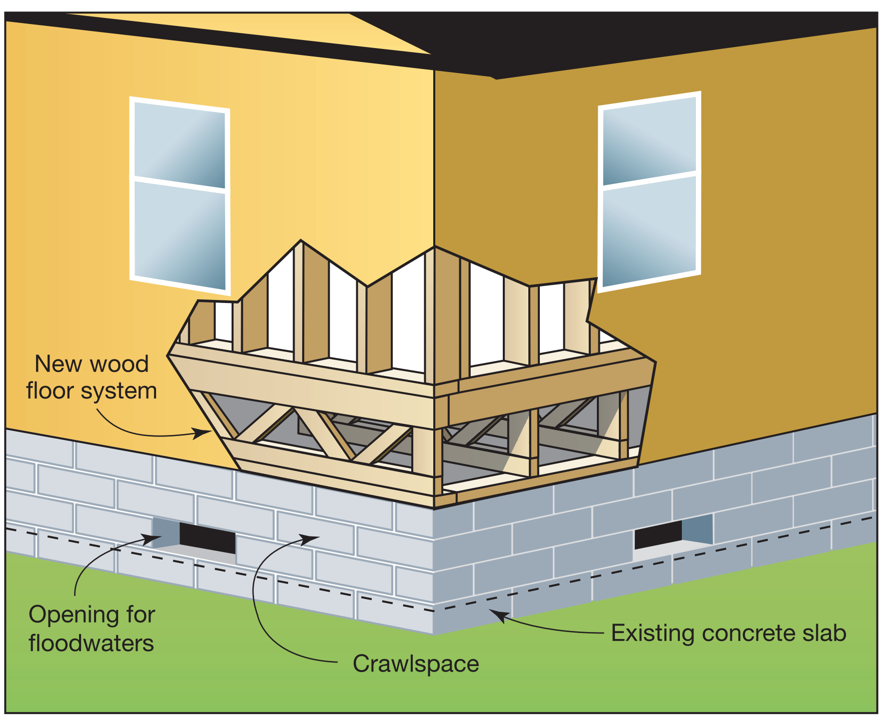


Figure 5E-19.
Step 3 of elevating an existing wood-frame house without the slab and with extended stem wall using a new first floor constructed of wood trusses: Set house on new foundation and remove I-beams



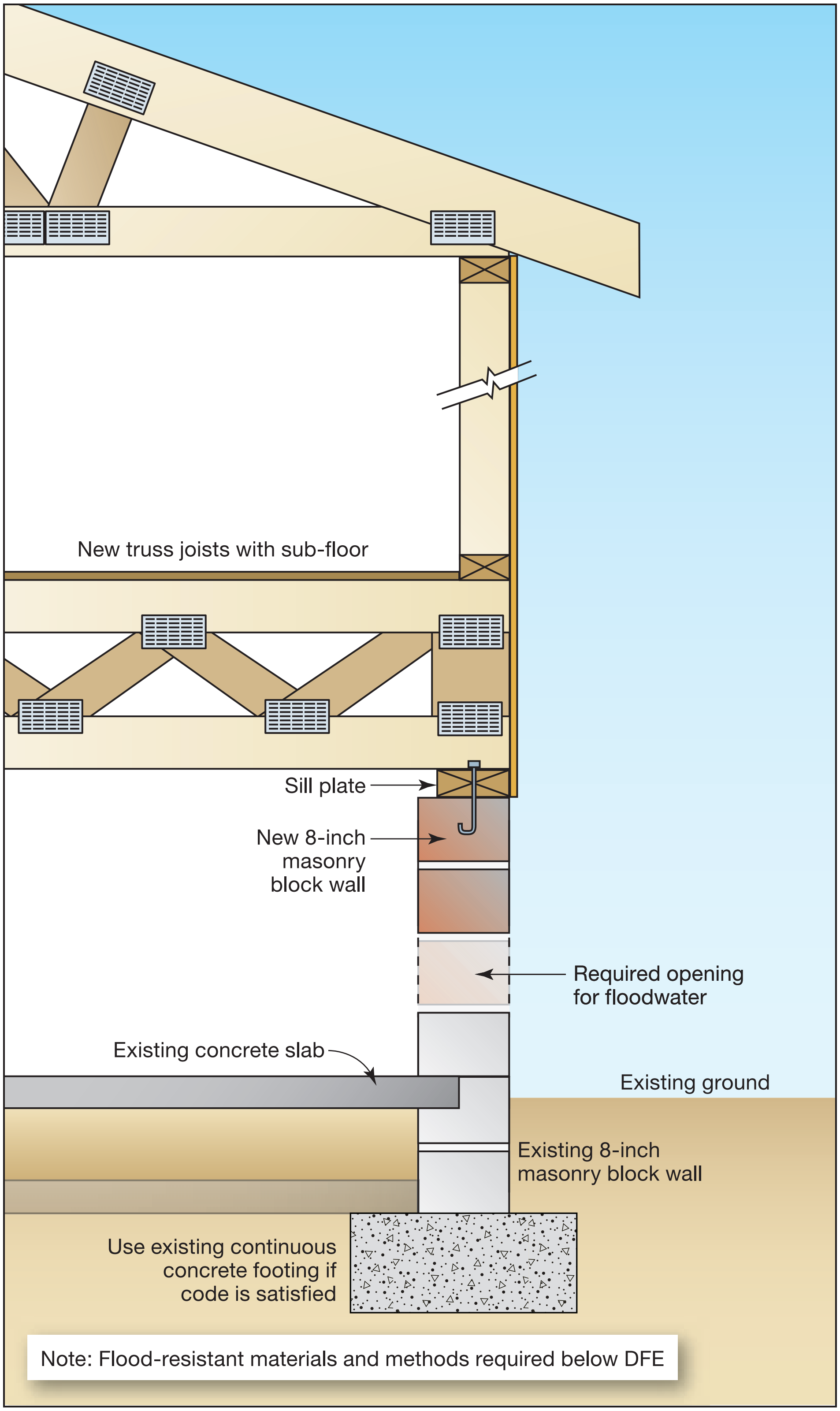


Figure 5E-20.
Cross-section of elevated wood-frame house (slab not raised) with extended stem-wall foundation and newly installed wood truss floor

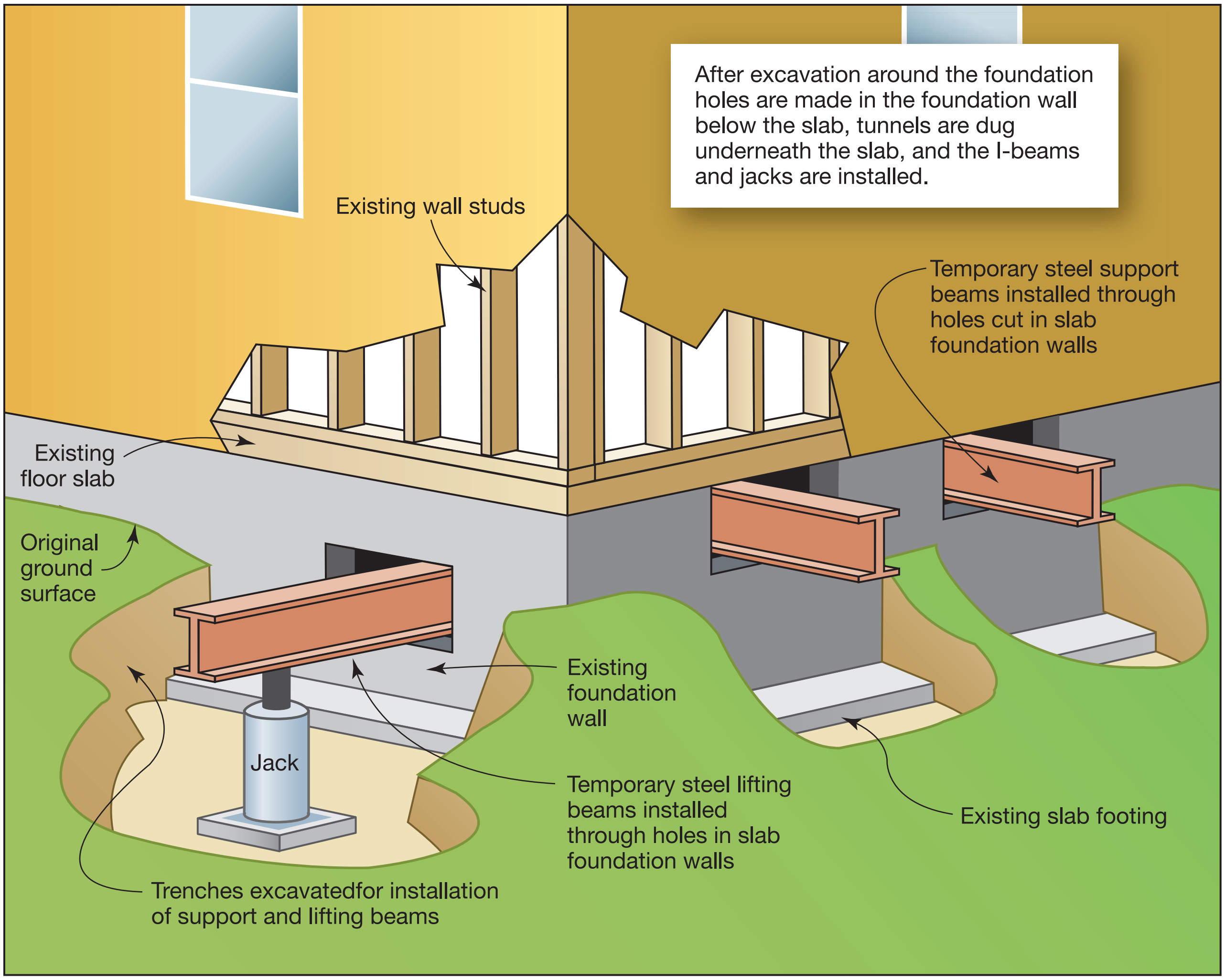


Figure 5E-21. Step 1 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Excavate under existing slab and install network of steel I-beams. Step 2 (not shown): Raise the wood-frame house with the slab intact, extend foundation stem walls, and install new piers.

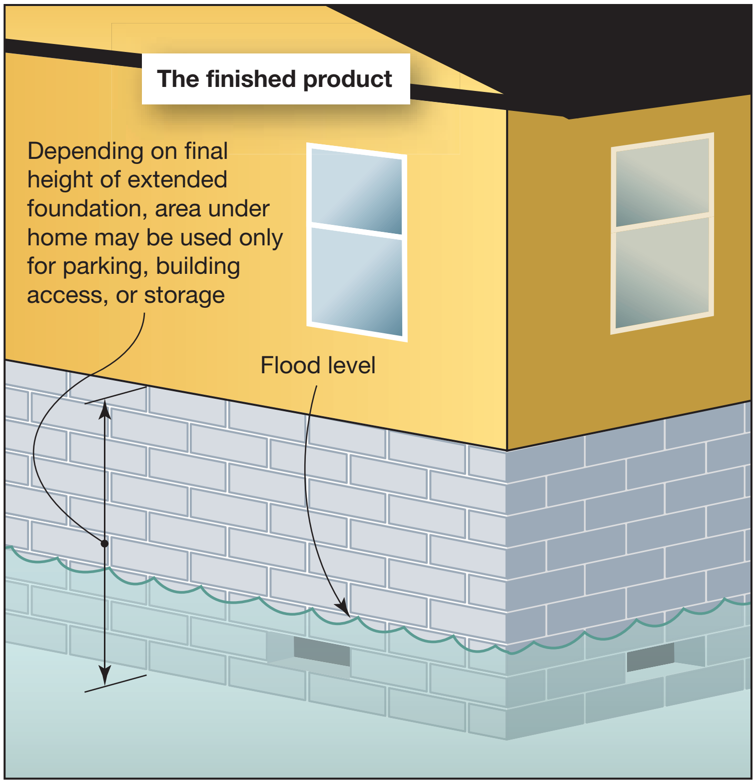


Figure 5E-22.
Step 3 of elevating an existing wood-frame house with stem wall foundation and the slab intact: Set the house on the new foundation and remove the I-beams

5E.1.4.2 Elevating a Slab-on-Grade Masonry House

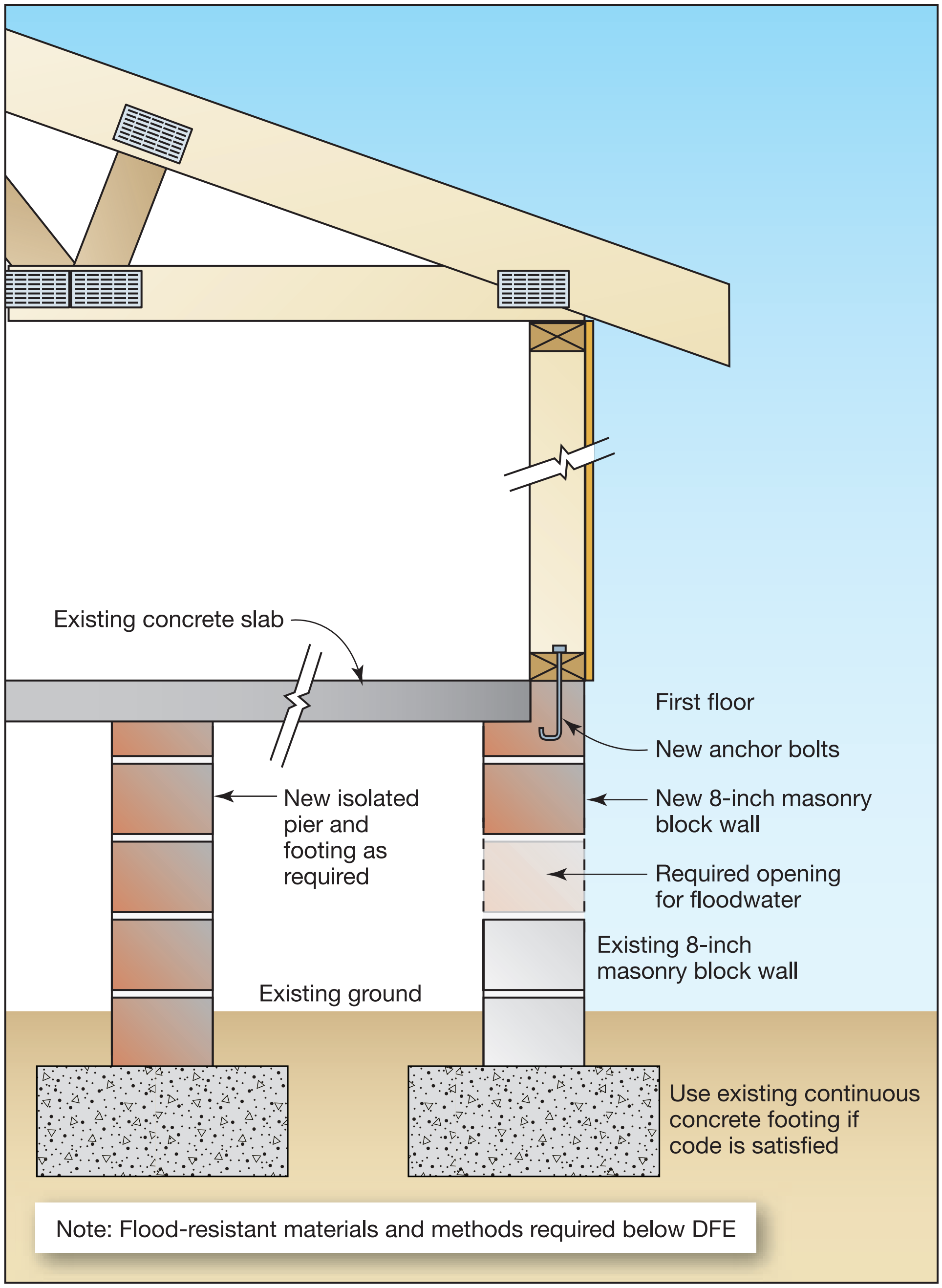
The following alternatives apply to elevating a masonry house with a slab-on-grade foundation:

- elevate a slab-on-grade masonry structure with the slab intact;
- elevate a slab-on-grade masonry structure without the slab, and using a first floor constructed of wood framing;
- install an elevated concrete slab within an existing masonry structure;
- install an elevated wood-frame floor system within an existing masonry structure;
- create a new masonry livable area on top of an existing one-story masonry structure; and
- create a new wood-frame livable area on top of an existing one-story masonry structure.

5E.1.5 Heavy Building Materials/Complex Design

The elevation process becomes even more complex with added weight, height, or complex design of the house. Brick or stucco veneers may require removal prior to elevation. Combination foundations (i.e., slab-on-grade and basement) should be evaluated jointly, as well as separately, and the worst case scenario utilized for design purposes. Building additions may need to be elevated independently from the main structure. Due to the extreme variability of structural conditions, a structural engineer should evaluate the suitability of lifting this type of home.

Figure 5E-23.
Cross-section of elevated wood-frame house with stem wall foundation and the slab intact



The entire elevation design process is illustrated with a detailed example of the design for a crawlspace house (Figure 5E-24).

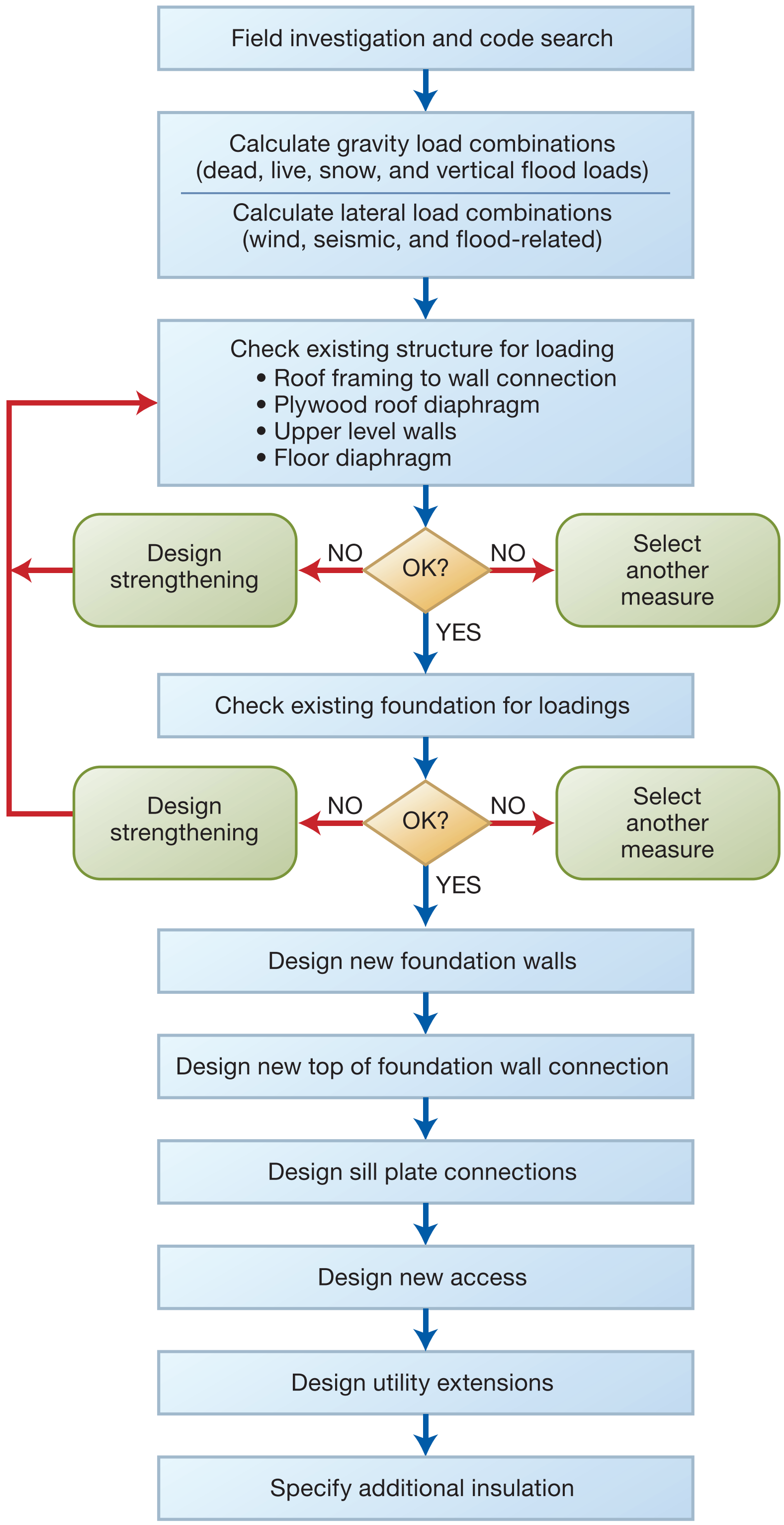


Figure 5E-24. Design process for an elevated house on foundation walls

5E.2 Field Investigation Concerns

To determine whether elevation is an appropriate retrofit technique for a particular building, a field investigation should be performed. In addition to a site visit and inspection, a data review and code search should be conducted.

5E.2.1 Property Inspection and Existing Data Review

During the field investigation, the designer should inspect the property and review existing data to confirm the applicability of the selected alternative and to confirm specific design guidance such as the height of elevation and type of foundation to be utilized. The designer should utilize the guidance presented in Chapter 5. Much of the data has been previously discussed in Chapters 3 and 4. At a minimum, the designer should collect information on the checklist in Figure 5E-25.

5E.2.2 Code Search

During the field investigation, the designer should also conduct a search of local floodplain ordinances, local and State building codes, restrictions to deeds, restrictions in subdivisions, and zoning regulations. In addition, a visit with the local building official should be planned to determine any special requirements for the locality. During the code search, the following should be determined:

- elevation and foundation requirements per the floodplain ordinance and flood hazard map;
- requirements of the building code that governs the elevation project;
- design wind speed;
- design seismic zone;
- ground snow loads;
- frost depths;
- restrictions on height (overall building, portions of building relative to materials in use, allowable height/thickness ratios); and
- restrictions on foundations.

Elevation Field Investigation Worksheet

Owner Name:_________________________ Prepared By:_________________________

Address: ____ Date: _______________

Property Location: ____

Does site topography data cover required area? ☐ Yes ☐ No

Additional data required:

Any construction access issues?

Site and building utilities identified? ☐ Yes ☐ No

Potential utility conflicts identified? ☐ Yes ☐ No

Describe conflicts: ____

Review homeowner preferences: ____

Can aesthetics reconcile with site and building constraints? ☐ Yes ☐ No

How?

Confirm type and condition of existing framing:

☐ member sizes ☐ spans ☐ connections ☐ supports

Confirm type and condition of foundation:

☐ type ☐ depth ☐ size

Confirm types and condition of existing construction materials:

☐ roof ☐ floor ☐ walls ☐ foundation

Confirm soil information:

☐ type ☐ depth of rock ☐ bearing capacity ☐ susceptibility to erosion and scour

Confirm characteristics of flood-related hazards:

☐ base flood elevation (BFE) ☐ velocity ☐ design flood elevation (DFE) ☐ frequency

☐ duration ☐ potential for debris flow

Confirm characteristics of non-flood-related hazards:

☐ wind ☐ seismic ☐ snow ☐ other

Review accessibility considerations:

☐ access/egress ☐ special resources for elderly, disabled, children

Architectural constraints noted: ______________________________________

Is clearance available to install lifting beams and jacking equipment? ☐ Yes ☐ No

Check local codes/covenants for height or appearance restrictions:

☐ deed/subdivision rules ☐ local building codes

Restrictions: ____

Figure 5E-25. Elevation Field Investigation Worksheet

5E.3 Design

The design process for an elevated structure shown in Figure 5E-24 consists of the following steps:

Step 1: Calculate the vertical loads.

The computation of vertical loads, which includes building dead and live loads (gravity loads) and buoyancy forces, was presented in Chapter 4.

CROSS REFERENCE

To illustrate the design process, a worked example is shown in Appendix C for Steps 1-7. Information on Step 9 is presented in Chapter 5F. The designer should refer to local codes for guidance on Steps 8 and 10. The example demonstrates numerous considerations necessary for an elevation project, but is not technically exhaustive.

Snow Loads: There are no "typical" equations for houses, since the calculation of snow loads depends on the building code in use, the geographic area in which the house is located, and the size and shape of the house and roof. The governing building code will clearly spell out the correct procedure to follow. Most procedures are simple and straightforward. Some houses will be more complex due to their shape or the quantity of snow that must be allowed for. However, the general procedures are as follows:

- consult snow maps in the building code and/or local requirements with the local building official to determine the ground snow load;
- determine the importance factors;
- analyze the surrounding terrain, trends in snow patterns, and slope of roof to determine the exposure factors;
- determine the snow load;
- determine the considerations for drifting snow by examining any adjacent house or structure, a mountain above the house, or higher roofs; and
- determine the considerations for sliding snow by examining the steep slope on the roof or higher roofs.

NOTE

If the governing building code does not provide applicable guidance on loading associated with flooding, wind, seismic, or snow, refer to ASCE 7.

Step 2: Calculate the lateral loads.

The calculation of building lateral loads includes wind, seismic, and flood-related loads. One objective of the wind and seismic analysis is to determine which loading condition controls the design of specific structural components.

Wind Analysis: There are no "typical" equations for houses, since the calculation of wind loads depends upon the building code in use and the size and shape of the house. The governing building code will clearly spell out the correct procedure to follow. Most procedures are simple and straightforward. Some houses will be more complex due to their shape. However, the general procedure, as discussed in Chapter 4, is presented below.

- determine the wind speed and pressure by consulting wind maps within the building code, and checking local requirements with the local building official;
- determine the importance factors and the exposure category;
- determine the wind gust and exposure factors and analyze the building height and shape, whether the wind is parallel or perpendicular to the roof ridge, and whether it is windward or leeward of roofs/walls;
- determine the wind load; and
- distribute the load to resisting elements based upon the stiffness of shear walls, bracing, and frames.

NOTE

ASCE 7 and the IRC provide basic wind speed maps showing wind velocities and frequencies. If the local code enforced is the IRC, the designer should refer to the IRC wind speed map (Figure 4-19). If no local code is in force, the designer should refer to ASCE 7, Minimum Design Loads for Buildings and Other Structures.

Seismic Analysis: There are no "typical" equations for houses since the calculation of seismic loads depends upon the building code in use and the size and shape of the house. The governing building code will clearly spell out the correct procedures to follow. Some houses will be more complex due to their shape. However, the general procedures, as discussed in Chapter 4, are presented below.

- calculate the dead loads by floor, including permanent dead loads (roof, floor, walls, and building materials) and permanent fixtures (cabinets, mechanical/electrical fixtures, stairs, new locations for utilities, etc.);
- determine if the snow load must be included in the dead load analysis; most building codes require the snow load to be included for heavy snow regions and will list these requirements;
- determine the seismic zone and importance factors;
- determine the fundamental period of vibration (height of structure materials used in building);
- determine the total seismic lateral force by analyzing site considerations, building weights, and the type of resisting system;
- distribute the loads vertically per the building code, keeping in mind the additional force at the top of the building; and
- distribute the loads horizontally according to the building code and the stiffness of resisting elements. The code-prescribed minimum torsion of the building (center of mass versus center of rigidity), shear walls, bracing, and frames must be considered.

Flood-Related Forces: The computation of flood-related forces was presented in Chapter 4 and includes the following:

- determine the DFE;
- determine the types of flood forces (hydrostatic or hydrodynamic);
- determine the susceptibility to impacts from debris (ice, rocks, trees, etc.);

- determine the susceptibility to scour;
- determine the applicability of and susceptibility to alluvial fans;
- determine the design forces; and
- distribute the forces to resisting elements based upon stiffness.

Step 3: Check ability of existing structure to withstand additional loading.

Chapter 4 presented general information on determining the ability of the existing structure to withstand the additional loadings imposed by retrofitting methods. The process detailed below is similar for each of the building types most people will encounter. First, the expected loadings are tabulated and compared against allowable amounts determined from soil conditions, local code standards, or building material standards. The following list of existing building components and connections should be checked.

Roofs: The plywood roof diaphragm, trusses, connections, and uplift on roof sheathing should be capable of resisting the increased wind and seismic loads. The Engineered Wood Association (http://www.apawood.org) has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA,2011) and APA Form T325, *Roof Sheathing Fastening Schedules for Wind Uplift* (APA, 2006).

These reference materials or the local building codes will give the designer the necessary plywood thicknesses and connection specifications to resist the expected loadings and/or will provide loading ratings for specific material types and sizes.

If the roof diaphragm and sheathing are not sufficient to resist the increased loading, the design can strengthen these components by:

- increasing the thickness of the materials; and/or
- strengthening the connections with additional plates and additional fasteners.

Roof Framing-to-Wall Connections: The roof framing connections to walls should be checked to ensure that they will resist the increased wind loads. Of critical importance are the gable ends, where many wind failures occur. The Engineered Wood Association has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA, 2011) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary truss size, configuration, and connection specifications to resist the expected loadings, and/or will provide loading ratings for specific truss and connection types and sizes.

If the roof trusses and wall connections are not sufficient to resist the increased loading, the design can strengthen these components by:

CROSS REFERENCE

For additional information on the performance of various building system products, refer to product evaluation reports prepared by the model code groups or the National Evaluation Service (NES).

- increasing the amount of bracing between the trusses; and/or
- strengthening the connections with additional plates and additional fasteners.

Upper Level Walls: The upper level walls are subject to increased wind pressure and increased shear due to increased roof loads. Both the short and long walls should be checked against the shear, torsion, tension, and deflection, utilizing the governing loading condition (wind or seismic).

The Engineered Wood Association has published several references that are useful in this calculation, including APA SR-1013, *Design for Combined Shear and Uplift from Wind* (APA, 2011) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary wall size and configuration and connection specifications to resist the expected loadings and/or will provide loading ratings for specific wall types, sizes, and connection schemes.

If the upper level walls are determined to be unable to withstand the increased loadings, the designer is faced with the difficult task of strengthening what amounts to the entire house. In some situations, this may be cost- prohibitive, and the homeowner should look for another retrofitting method, such as relocation. Measures the designer could utilize to strengthen the upper level walls include:

- adding steel strapping (cross bracing) to interior or exterior wall faces;
- adding a new wall adjacent to the exterior or interior of the existing wall;
- bolstering the interior walls in a similar fashion; and/or
- increasing the number and sizes of connections.

Floor Diaphragm: The floor diaphragm and connections are subject to increased loading due to wind, seismic forces, and flood. The existing floor diaphragm and connections should be checked to ensure that they can withstand the increased forces that might result from the elevation.

The Engineered Wood Association has published several references that are useful in this calculation, including APA Form Y250. *Shear Transfer at Engineered Wood Floors* (APA, 1999) and APA Form L350, *Diaphragms and Shear Walls* (APA, 2007).

These reference materials or the local building codes will give the designer the necessary floor size and configuration and connection specifications to resist the expected loadings, and/or will provide loading ratings for specific floor types, sizes, and connection schemes.

If the floor diaphragm or connections are determined to be unable to withstand the increased loadings, the designer could strengthen these components by:

- adding a new plywood layer on the bottom of the existing floor diaphragm;
- increasing the number and size of bracing within the floor diaphragm; and
- increasing the number and size of connections.

Step 4: Analyze the existing foundation.

The existing foundation should be checked to determine its ability to withstand the increased gravity loads from the elevation, the increased lateral loads due to soil pressures from potential backfilling, and the increased overturning pressures due to seismic and wind loadings. The designer should tabulate all of the gravity loads (dead and live loads) plus the weight of the new foundation walls to determine a bearing pressure, which is then compared with the allowable bearing pressure of the soil at the site. Not including expected buoyancy forces in this computation will yield a conservative answer.

If the existing footing is insufficient to withstand the additional loadings created by the elevated structure, the design of foundation supplementation should be undertaken. The foundation supplementation may be as straightforward as increasing the size of the footing and/or more substantial reinforcement. The designer may refer to the ACI manual for footing design, recent texts for walls and footing design, and applicable codes and standards.

Step 5: Design the new foundation walls.

The design of a new foundation, whether solid or open, is usually governed by the local building codes. These codes will have minimum requirements for foundation wall sizes and reinforcing schemes, including seismic zone considerations. The designer should consult the appropriate code document tables for minimum requirements for vertical wall or open foundation reinforcement.

CROSS REFERENCE

For wet floodproofing applications, where openings in foundation walls are necessary, refer to Chapter 5W, Wet Floodproofing.

For new slab applications where the lower level is allowed to flood and the slab is not subject to buoyancy pressures, the designer can use the Portland Cement Association document *Concrete Floors on Ground* (2008) as a source of information to select appropriate thicknesses and reinforcing schemes based upon expected loadings. The slab loadings will vary based upon the overall foundation design and the use of the lower floor.

Step 6: Design top of foundation wall connections.

Top of wall connections are critical to avoid pullout of the sole plate, floor diaphragm, and/or sill plate from the masonry foundation. A preliminary size and spacing of anchor bolts is assumed, and uplift, shear, and tension forces are computed and compared against the allowable loads for the selected bolts. Where necessary, adjustments are made to the size and spacing of the anchor bolts to keep the calculated forces below the allowable forces. Connections should be designed for all appropriate load combinations as discussed in Chapter 5.

Step 7: Design the sill plate connections.

The existing sill plate connections will be subject to increased lateral loads and increased uplift forces due to increased wind and buoyancy loading conditions. The sill plate is designed to span between the anchor bolts and resist bending and horizontal shear forces. The designer should refer to the appropriate wood design manual that provides recommended compression, bending, shear, and elasticity values for various sill plate materials. Using these values, the designer checks the connection against the expected forces to ensure that the actual forces are less than the allowable stresses. If the sill plate connection is insufficient to withstand expected loadings, the size of the sill plate can be increased (or doubled), and/or the spacing of the anchor bolts can be reduced.

Step 8: Design new access.

The selection and design of new access to an elevated structure is done in accordance with local regulations governing these features. Special homeowner requirements, such as for aesthetics, handicapped accessibility, and/or special requirements for children and the elderly, can be incorporated using references previously discussed in Chapter 3.

Incorporating the new access often applies to multiple egress locations and may present a unique challenge to the designer as greater area is required on the existing site to accommodate the increase in elevation from adjacent grade to egress. A particular obstacle may arise with attached garages where the living space is elevated and the garage slab remains at original grade as allowed for areas designated for building access, parking, and storage only. Besides the area and height constraints required for the additional stairs to the elevated egress, the designer must also resolve drainage and aesthetic issues created by the newly discontinuous roof system.

Connection of the new access to the house should be designed in accordance with the local codes. The foundation for the access measure will either be freestanding and subject to its own lateral stability requirements or it will be an integral part of the new elevated structure. In either case, analysis of the structure to ensure adequate foundation strength and lateral stability should be completed in accordance with local codes.

It should be noted that any access below the BFE should incorporate the use of flood-resistant materials. The designer should refer to FEMA's NFIP Technical Bulletin 2-08, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program* (FEMA, 2008).

Step 9: Design the utilities extensions.

The field investigation will reveal the specific utility systems that will require relocation, extension, or modification. Whenever possible, utility systems should be relocated above the DFE. Local utility companies should be contacted about their specific requirements governing the extension of their utility service. In many instances, the local utility company will construct the extension for the homeowner. Critical issues in this extension process include:

- handling of utilities encased in the existing slab or walls;
- coordination of disconnection and reconnection;
- any local codes that require upgrades to the utility systems as part of new construction or substantial repair or improvement;
- introduction of flexible connections on gas, water, sewer, and oil lines to minimize potential for seismic damage;
- potential for relocation or elevation of electrical system components from existing crawlspace and/or basement areas; and
- design of separate GFI-type electrical circuits and use of flood-resistant materials in areas below the BFE.

CROSS REFERENCE

Guidance on the selection of an elevation or relocation contractor is provided in Chapter 5R, Relocation.

Step 10: Specify the increased insulation requirements.

Elevated floors and extended utility system components may increase the potential for heat loss through increased exposure and airflow and necessitate additional insulation. The designer should evaluate the energy efficiency of each aspect of the project, compare existing insulation (R-values) against the local building code, and specify additional insulation (greater R-value) where required.

5E.4 Construction Considerations

Following are some important points for consideration both prior to and during implementation of a structure elevation project.

Prior to elevating any house:

- obtain all permits and approvals required;
- ensure that all utility hookups are disconnected (plumbing, phone, electrical, cable, and mechanical);
- estimate the lifting load of the house; and
- identify the best location for the principal lift beams, lateral support beams, and framing lumber, and evaluate their adequacy (generally performed by a structural engineer or the elevation contractor).

5E.4.1 Slab-on-Grade House, Not Raising Slab with House

Procedures for elevating a slab-on-grade house without raising the slab:

- holes are cut for lift beams in the exterior and interior walls;
- main lifting beams are inserted;
- holes are cut for the lateral beams;
- lateral beams are inserted;
- bracing is installed to transfer the loads across the support walls and lift remaining walls;
- jacks are moved into place and structure is prepared for lifting;
- straps and anchors used to attach house to slab-on-grade are released;
- the house is elevated and cribbing installed;
- slab around edges is removed to allow for new foundation;
- the new foundation is constructed;
- new support headers and floor system are installed;
- any required wind and seismic retrofit is completed;

- house is attached to new foundation;
- all temporary framing is removed, holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

5E.4.2 Slab-on-Grade House, Raising Slab

Procedures for elevating a slab-on-grade house and raising the slab:

- trenches are excavated for placement of all support beams beneath slab;
- lifting and lateral beams are installed;
- jacks are moved into place and the structure is prepared for lifting;
- the house is elevated and cribbing installed;
- the new foundation is constructed;
- any required wind and seismic retrofit is completed;
- house is attached to new foundation;
- support beams are removed;
- access holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

5E.4.3 House Over Crawlspace/Basement

Procedures for elevating a house over a crawlspace or basement:

- masonry is removed as necessary to allow for placement of support beams;
- main lifting beams are installed;
- lateral beams are installed;
- jacks are moved into place and the structure is prepared for lifting;
- all connections to foundation are removed;

- house is elevated and cribbing installed;
- existing foundation walls are raised or demolished, depending on whether the existing foundation walls can handle the new loads;
- new footings and foundation walls are constructed if the existing foundation walls/footings cannot withstand the additional loading;
- basement is backfilled where appropriate;
- house is attached to new foundation;
- support beams are removed;
- access holes are patched;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.

5E.4.4 House on Piers, Columns, or Piles

If the house is to remain in the same location, the house will most likely need to be temporarily relocated to allow for the footing and foundation installation. If the house is being relocated within the same site, the footings should be constructed prior to moving the house. Procedures for elevating a house on piers, columns, or piles:

- main support beams are installed;
- lateral beams are installed;
- jacks are moved into place and the structure prepared for lifting;
- house is elevated and cribbing is installed;
- if the house is being relocated, see section 5R;
- existing foundation is demolished and removed and new pier and column foundation is installed or existing foundation elements are extended upward and reinforced as needed
- house is attached to new foundation;
- support beams are removed;
- all utilities are reconnected;
- new stairways and access are constructed; and
- all utilities below the DFE are floodproofed.