2 Building Exterior

After the site inspection has been completed, systematically inspect the building's exterior for its condition and weathertightness. Begin either at the foundation and work up or begin at the roof and work down. Examine the quality and condition of all exterior materials and look for patterns of damage or deterioration that should be further investigated during the interior inspection. Determine the building's architectural style and note what should be done to maintain or restore its integrity and character. See Chapter 4 for assessing structural components of the building.

In regions of medium to high seismic activity, buildings with irregular shapes (in either plan or elevation) may be especially vulnerable to earthquakes. Examine the building for such irregularities, and if present, consider consulting a structural engineer.

In hurricane regions, examine screen and jalousie enclosures, carports, awnings, canopies, porch roofs, and roof overhangs to determine their condition and the stability of their fastenings. Then examine the following four critical areas of the exterior to determine their condition and strength: roofs, windows, doors, and garage doors.

In locations where wildfires can occur, some jurisdictions have restrictions on the use of flammable exterior materials. Check with the local building official or the fire marshal, or both, for detailed information.

Additional information on the evaluation and treatment of historic building exteriors is presented in the *Secretary of the Interior's Standards for Rehabilitation*, available full text online at http://www2.cr.nps.gov/tps.

When universal design is a part of a rehabilitation, consult HUD publication *Residential Remodeling and Universal Design* for detailed information about entrances, doors, and decks.

2.1 Foundation Walls and Piers

Foundation walls and piers in small residential buildings are usually made of masonry and should be inspected for cracking, deterioration, moisture penetration, and structural adequacy. See Sections 4.3 and 4.4. Wood posts and columns and concrete foundations and piers should be inspected in accordance with Sections 4.7 and 4.9.

2.2 Exterior Wall Cladding

Exterior walls above the foundation may be covered with a variety of materials, including wood siding or its aluminum and vinyl substitutes, wood or asbestos cement shingles, plywood with and without a medium density (plastic) overlay, stucco, brick or stone masonry, and an exterior insulation and finish system. These materials are designed to serve as a weathertight, decorative skin and, in warm climates should be light in color to reduce heat absorption. Inspect exterior claddings as follows:

- **Exterior wood elements.** Inspect all painted surfaces for peeling, blistering, and checking. Paint-related problems may be due to vapor pressure beneath the paint, improper paint application, or excessive paint buildup. Corrective measures for these problems will vary from the installation of moisture vents to complete paint removal. Mildew stains on painted surfaces do not hurt the wood and may be cleaned with a mildew remover.

  All wood elements should be checked for fungal and insect infestation at exposed horizontal surfaces and exterior corner joints, as specified for wood structural components in Section 4.7.

  Check the distance between the bottom of wood elements and grade. In locations that have little or no snow, the distance should be no less than six inches. In locations with significant, lasting snow, the bottom of wood elements should be no less than six inches above the average snow depth.

- **Aluminum and vinyl siding.** Aluminum and vinyl siding may cover up decayed or insect-infested wood but otherwise are generally low maintenance materials. Check for loose, bent, cracked, or

A second layer of shingles has filled the former gap between roof and zsiding, causing the siding to deteriorate. Shingles are cupped and beginning to fail as well.

The stucco is beginning to erode on this structure due to a poor roof drainage detail. A longer scupper would solve this problem.

broken pieces. Inspect all caulked joints, particularly around window and door trim. Many communities require aluminum siding to be electrically grounded; check for such grounding.

- **Asbestos cement shingles.** Like aluminum and vinyl siding, asbestos cement shingles may cover decayed or insect-infested wood. Check for loose, cracked, or broken pieces and inspect around all window and door trim for signs of deterioration.
- **Stucco.** Check stucco for cracks, crumbling sections, and areas of water infiltration. Old and weathered cracks may be caused by the material's initial shrinkage or by earlier building settlement. New, sharp cracks may indicate movement behind the walls that should be investigated. Refer to Section 4.5 for problems with masonry walls. It is difficult to match the color of stucco repairs to the original stucco, so plan to repaint surrounding stucco work where sections are mended.

- **Brick or stone veneers.** Inspect veneers for cracking, mortar deterioration, and spalling. Refer to Sections 4.3 and 4.5 for the inspection of above-ground masonry walls.
- **Exterior insulation and finish systems (EIFS).** EIFS, also known as synthetic stucco, has been in widespread residential use since the early 1990s. It generally consists of the following product layers (moving outward): insulation board, mesh and base coat layer, finish coat, and sealant and flashing.

  EIFS was originally designed as a nondraining water and moisture barrier system. A drainage-type EIFS that allows water and moisture to penetrate the surface and then drain away has been developed more recently. Most existing EIFS in residential applications is installed over wood framing and is of the nondraining type. Water leakage and consequent rotting of the wood framing have become serious problems in many installations, especially at wall openings such as windows and doors, where inadequate flashing details can allow water seepage into the wall interior.

  Manufacturers of EIFS differ in their installation methods. Inspecting existing EIFS is difficult because it is a proprietary product and there are no standard construction details. Use a trained specialist to check for concealed water damage and rot.

Exterior walls of older buildings usually contain no thermal insulation. Examine behind the cladding when possible to determine the presence of insulation, if any, and assess the potential for insulating the exterior walls.

Where mildew and mold are evident on exterior cladding or where interior walls are damp, there is the possibility that condensation is occurring in the walls. Moisture problems generally occur in cold weather when outside temperatures and vapor pressures are low and there are a number of water vapor sources within the building. The presence of moisture may be a result of an improperly installed or failed vapor barrier, or no vapor barrier at all. If condensation is suspected, an analysis of the wall section(s) in question should be made. This analysis will provide the information necessary to make the needed repairs.

2.3 Windows and Doors

Windows and doors are the most complex elements of the building's exterior and should be inspected from the outside as follows:

- **Exterior doors** should be examined for their condition, overall operation and fit, and for the functionality of their hardware. Door types include hinged, single and double doors of wood, steel, aluminum, and plastic with and without glazing. Check wood and plastic doors that are not protected from the weather. These doors should be rated for exterior use.

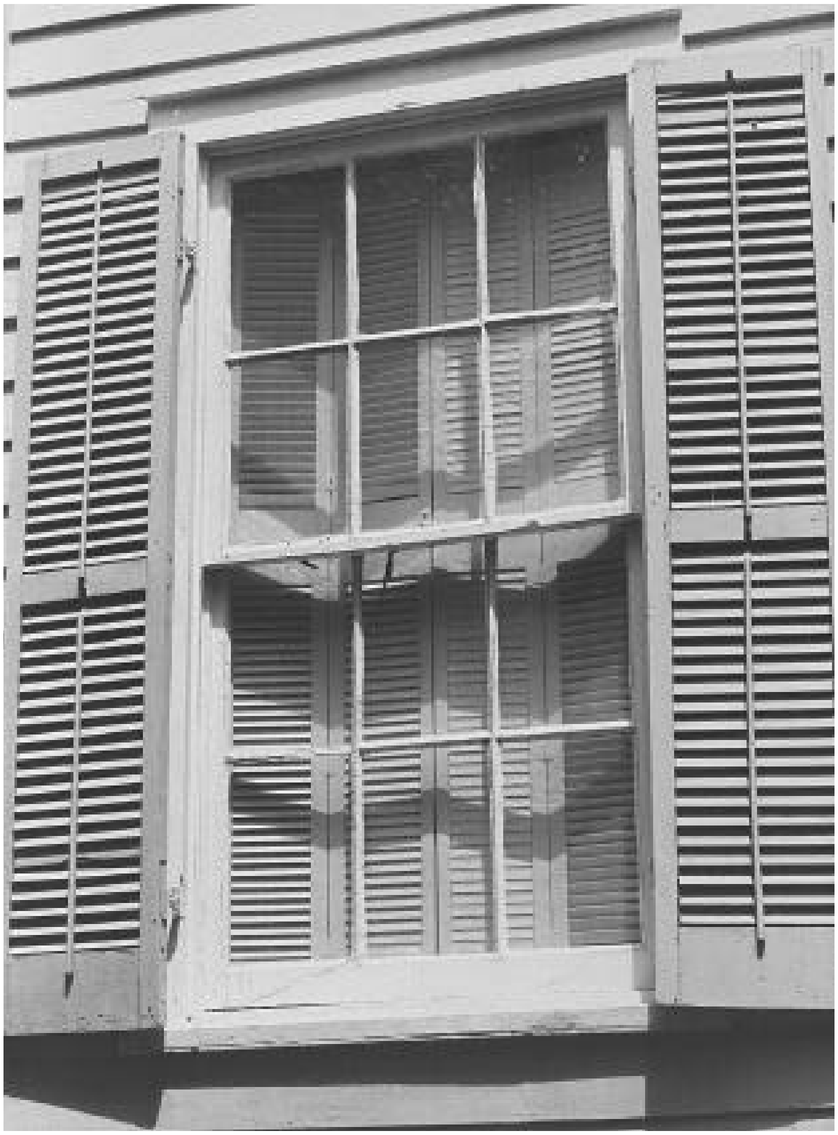
  In warm climates, jalousie doors may also be in use. Check these doors to make sure the louvers close tightly and in unison for weathertightness.

  Some buildings use glass framed doors of fixed and operable panels that have wood, vinyl-covered wood, and aluminum frames. Check the track of these sliding doors for dents, breaks, and straightness. Check the glides of operable panels for wear and check the sealing of fixed panels for weathertightness. Note the degree of physical security offered by doors and their locksets and pay special attention to pairs of hinged and sliding doors.

  Doors also should be inspected for the exterior condition of their frames and sills. Check doors that are not protected from the weather for the presence of essential flashing at the head.

  Glazing on exterior doors should be examined as described in the following section on windows. The interior condition and hardware of exterior doors will be examined during the interior inspection.

  In hurricane regions, check exterior doors, and especially double doors, for the presence of dead-bolt locks with a throw length of no less than one inch.
- **Windows** should be inspected for the exterior condition of their frames, sills and sashes, and for overall operation and



The glazing putty in this window is deteriorated in some locations. Repairs will be time consuming.

fit. The interior condition and hardware of windows will be examined during the interior inspection. There are eight types of windows and six types of frame material in general use in residential buildings. Frame materials are plastic, aluminum, steel, wood, plastic-clad wood, and metal-clad (steel or aluminum) wood. Window types are double hung, single hung, casement, horizontal sliding, projected out or awning, projected in, and fixed. In addition to these, there are jalousies: glass louvers on an aluminum or steel frame.

The glazing compound or putty around glass panels in older sashes should be examined especially carefully since this is often the most vulnerable part of the window and its repair is time consuming. Examine glazing tapes or strips around glass panels in steel or aluminum sashes for signs of deterioration such as hardened sealant or poor fit. Check metal sashes for weep holes that have been blocked by paint, sealant, or dirt. Weep holes are usually easy to clean. Check windows that are not protected from the weather for the presence of essential flashing at the head.

For windows close to the ground or easily accessible from flat roofs, note the degree of physical security provided by the windows and their locks.

In hurricane regions, check all windows and glass doors that are not protected by shutters to determine if they have been tested for impact resistance to windborne debris. If they have not been so tested, determine if plywood panels can be installed for their protection at the time of a hurricane warning.

- **Weather stripping.** Window and door weather stripping is generally of three types: metal, foam plastic, or plastic stripping. Check each type for fit. Check metal for dents, bends, and straightness. Check foam plastic for resiliency and plastic stripping for brittleness and cracks. Make sure the weather stripping is securely held in place.

- **Shutters.** Window shutters are generally of two types: decorative and functional. Decorative shutters are fixed to the exterior wall on either side of a window. Check the shutter's condition and its mounting to the wall. Functional shutters are operable and can be used to close off a window. Assess the adequacy of these shutters for their purpose: privacy, light control, security, or protection against bad weather. Check their operation and observe their condition and fit.

  Shutters close to the ground can be examined from the ground. Shutters out of reach from the ground should be examined during the interior inspection when windows are examined.

  In hurricane regions, check shutters to see if the shutter manufacturer has certified them for hurricane use. If they provide protection to windows and glass doors, determine if they have been tested for impact resistance to windborne debris.
- **Awnings.** Windows and glazed exterior doors sometimes have awnings over them, usually for sun control, but sometimes for decoration or protection from the weather. Awnings are usually made of metal, plastic, or fabric on a metal or plastic frame. Some are fixed in place, while others are operable and can be folded up against the exterior wall. Check the condition of awnings. Assess the adequacy of the attachment to the exterior wall. Fold up and unfold operable awnings and note the ease of operation. If an awning is used for sun control, assess its effectiveness and its effect on energy conservation.
- **Storm windows and doors** should be examined for operation, weathertightness, overall condition, and fit. Check the condition of screen and glass inserts; if they are in storage, locate, count, and inspect them. Check also to determine if the weep holes have been blocked by paint, sealant, dirt, or other substances. Opening weep holes is usually easy to do.
- **Garage doors** should be examined for operation, weathertightness, overall condition, and fit. Doors without motors should be manually opened and closed. Doors with motors should be operated using each of the operators on the system (key lock switch or combination lock key pad where control must be accessible on the exterior, remote electrical switch, radio signal switch, or photoelectric control switch). Check the operation for smoothness, quietness, time of operation, and safety. Check for the presence and proper operation of the door safety reversing device. Observe exposed parts of the installation for loose connections, rust, and bent or damaged pieces.

  Garage doors are made of wood, hardboard on a wood frame, steel, glass fiber on a steel frame, glass fiber, and aluminum. All come with glazed panes in a wide variety of styles. Check wood and hardboard for rot and water damage, check hardboard for cracking and splitting, check steel for rust, check glass fiber for ultraviolet light deterioration, and check aluminum for dents.

  In hurricane regions, examine garage doors, especially single doors on two-car garages, to determine if the assembly (door and track) has been tested for hurricane wind loads or has been reinforced.
- **Safety Glazing.** Glazed entrance doors including storm doors, sliding glass patio doors, and glazing immediately adjacent to these doors, but excluding jalousie doors, should be fully tempered, wire, or laminated glass or an approved plastic material. In addition, glazing adjacent to any surface normally used for walking must be safety glazing. Safety glazing is a building code requirement that applies to both new and replacement glazing.

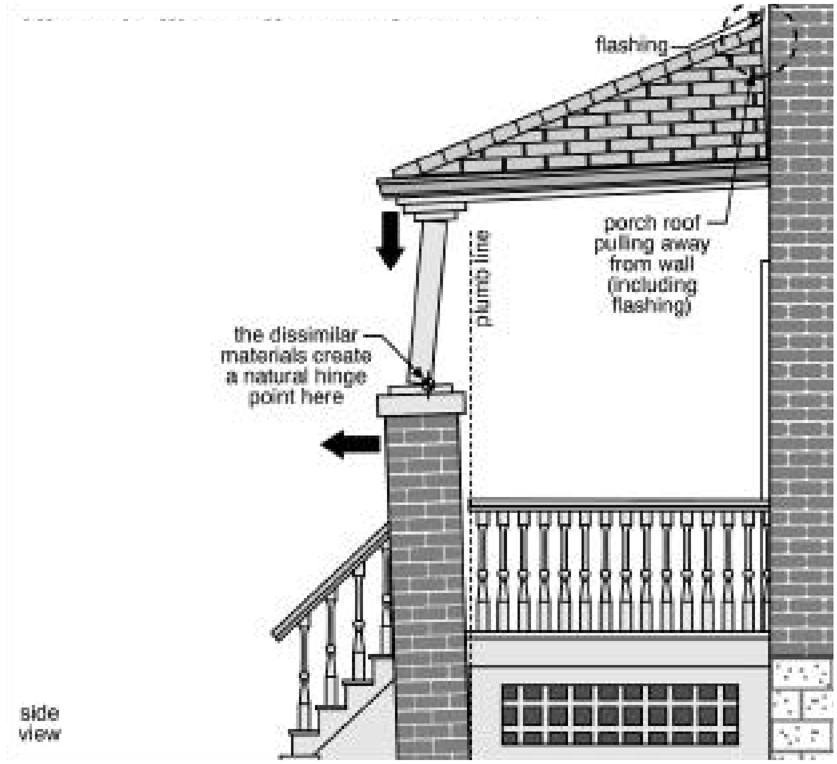
2.4 Decks, Porches, and Balconies

Decks, porches, and balconies are exposed to the elements to a greater extent than most other parts of a building and are therefore more susceptible to deterioration. Inspect for the following:

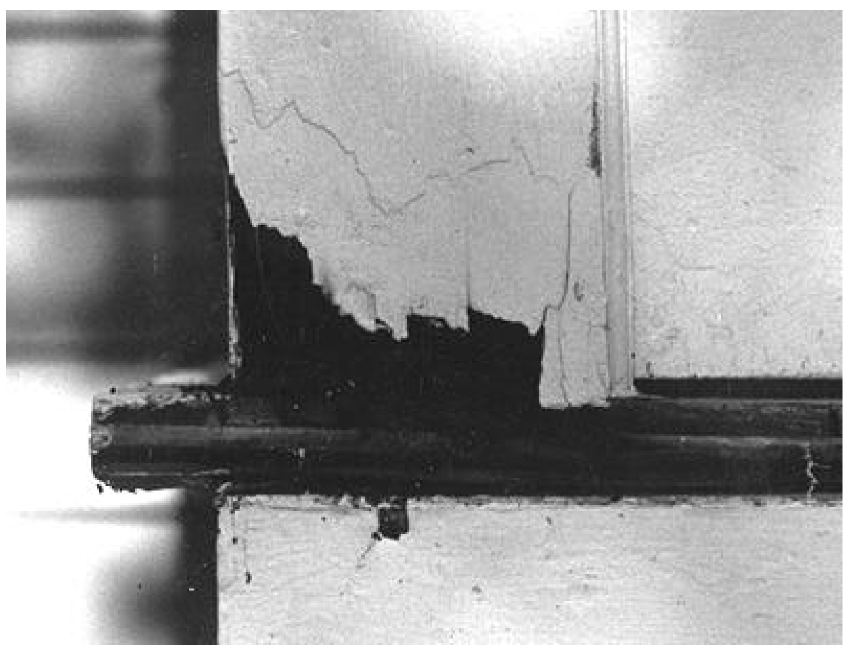
- **Condition.** Examine all porch, deck, and balcony supports for signs of loose or deteriorated components. See Section 4.7 for the inspection of wood structural components. Masonry or concrete piers should be plumb and stable; check them in accordance with Section 4.4. Make sure that structural connections to the building are secure and protected against corrosion or decay.

Examine porch floors for signs of deflection and deterioration. Where the porch floor or deck is close to the level of the interior floor, look for signs of water infiltration at the door sill and check for a positive pitch of the porch floor or deck away from the exterior wall.

- **Exterior railings and stairs.** Inspect the condition of all exterior stairs and railings. Every stair with more than three steps should have a handrail located 34 to 38 inches (865 to 965 mm) above the edges of the stair tread. Shake all railings vigorously to check their stability, and inspect their fastenings. Most codes for new construction require that porches, balconies, and decks located more than 30 inches (760 mm) above the ground have guards not less than 36 inches (915 mm) high and intermediate rails that will not allow the passage of a sphere 4 inches (100 mm) in diameter. Check wooden steps for proper support and strength and for rot and insect infestation. Inspect steel stairs for rust, strength, and attachment. Deteriorated stairs should be repaired or replaced.



The joint between the two parts of this support creates a hinge that can affect the roof structure.

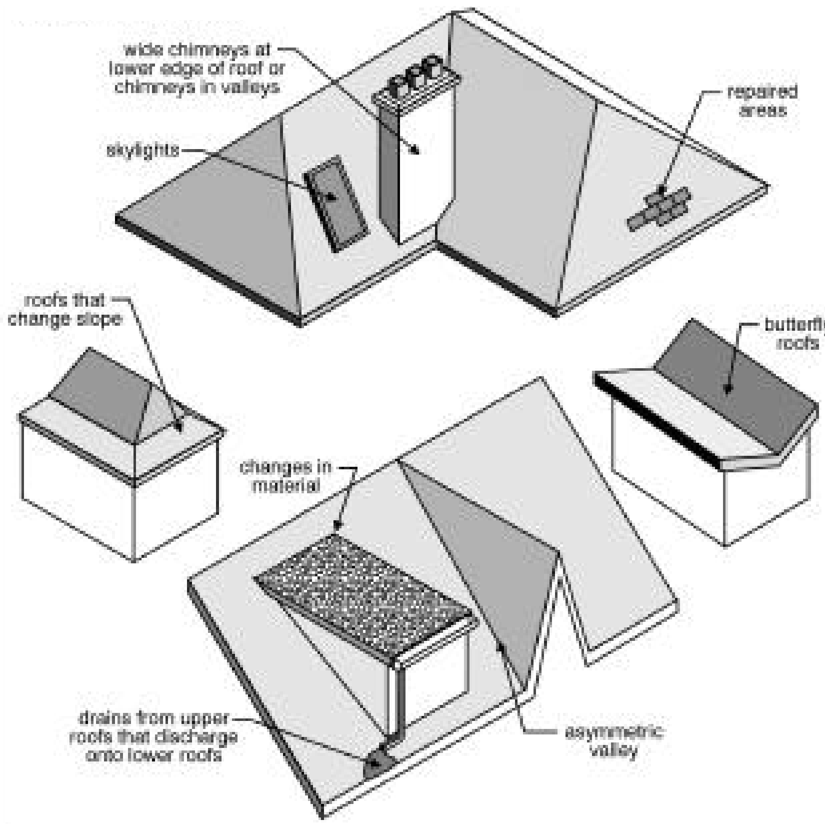


A rotted corner post on a screened porch. In this case, the rotted section of the post and a small section of the floor beneath it were removed and replaced with sound wood.

Stair treads should be as level as possible without holding water. Stair riser heights and tread depths should be, respectively, uniform.

2.5 Pitched Roof Coverings

Pitched or steep sloped roofs are best inspected when direct access is gained to all their surfaces. Use binoculars to inspect roofs that are inaccessible or that cannot be walked on. Look for deteriorated or loose flashing, signs of damage to the roof covering, and valleys and gutters clogged with debris. Carefully examine exterior walls and trim for deterioration beneath the eaves of pitched roofs that have no overhang or gutters. There are four categories of pitched roof covering materials and their condition should be checked as follows:



Vulnerable roof areas

- **Asphalt shingles.** Asphalt or "composition" shingles have a service life of about 20 years for the first layer and about 15 years for a second layer added over the first layer, depending on their weight, quality, and exposure. When they begin to lose their granular covering and start to curl they should be replaced. No more than two layers of asphalt shingles should normally be in place at any one time. If a second layer of asphalt shingles has been applied, check to see if all the flashing materials (galvanized steel, aluminum, rubber) in the first layer were removed and replaced with new flashing at the second layer.

  Check the roof slope. A slope of 4 in 12 or steeper is referred to as normal. A slope of between 3 in 12 and 4 in 12 is referred to as low. No asphalt shingle roof should be less steep than 3 in 12. If the roof has a normal slope, check the underlayment if possible. It should be at least a single layer of 15-pound (6.8 kg) asphalt saturated felt. Low-slope roofs should have at least two such felt layers. If ice dam flashing at overhanging eaves is needed (see Section 2.8) or present, make sure it extends three feet beyond the plane of the interior face of the exterior wall below for a low-slope roof and two feet for a normal-slope roof.
- **Wood shingles or shakes.** This type of covering has a normal life expectancy of 25 to 30 years in climates that are not excessively hot and humid, but durability varies according to wood species, thickness, the slope of the roof, whether shingles are made of heartwood, and whether they have been periodically treated with preservative. Shakes are hand-

This slate roof should be carefully investigated since it has a makeshift repair. Other problems include the chimney, which is too low, and the vent pipe, which is too narrow.

split on at least one face and either tapered or straight. Shingles are sawn and tapered. Check the roof slope. The minimum slope for wood shingles is 3 in 12 and the minimum slope for shakes is 4 in 12. As wood shingles and shakes age, they dry, crack, and curl. In damp locations they rot. Replace them when more than one-third show signs of deterioration. These materials are easily broken. They should not be walked on during the inspection. If the roof is historic or relatively complex, consult a wood roofing specialist.

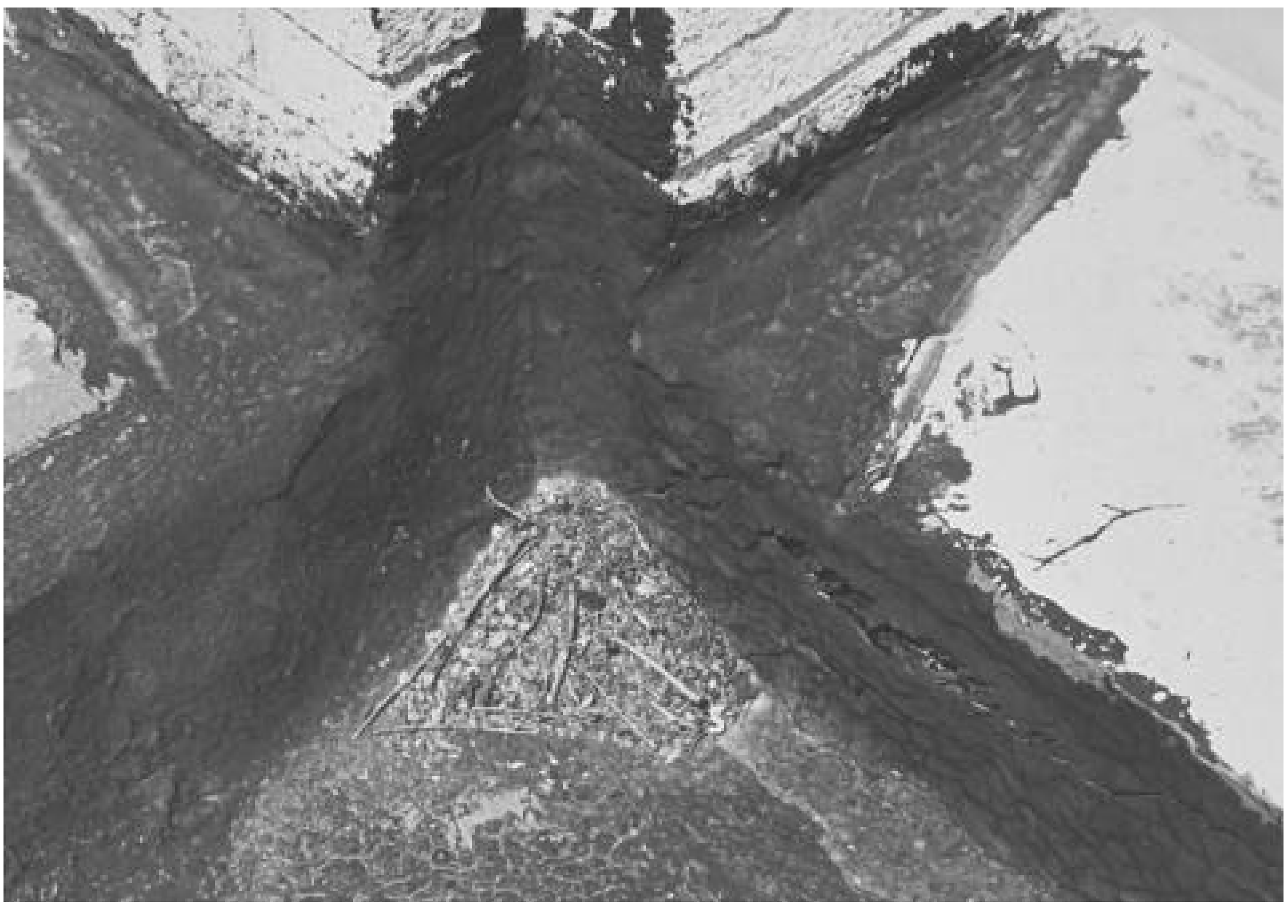
- **Metal roofing.** Metal can last 50 years or more if properly painted or otherwise maintained. Metal roofs may be made of galvanized iron or steel, aluminum, copper, or lead; each material has its own unique wearing characteristics. Inspect metal roofs for signs of rusting or pitting, corrosion due to galvanic action, and loose, open, or leaking seams and joints. The slope of metal roofing can be from one-half inch per foot (1:24) to very steep. The types of metal, seams, and slope determine the construction details. There are three basic seam types—batten, standing, and flat—as well as flat and formed metal panels. Snow guards are needed on steeper slopes and in locations with heavy, long-lasting snow, bracket and pipe snow guards also may be necessary. Low-slope metal roofs that are coated with tarlike material are probably patched or have pin holes and cannot be counted on to be leak-free. If the roof is historic or relatively complex, consult a metal roof specialist.

- **Slate, clay tile, and asbestos cement shingles.** These roof coverings are extremely durable and, if of high quality and properly maintained, may last the life of the structure. Check the roof slope. The minimum slope for roofs of these materials is 4 in 12. Slate shingles should be secured by copper nails except in the very driest of climates; look at the underside of the roof sheathing in the attic or check the nails on broken shingles. Nail heads should be covered with sealant. Nails for tile roofs should be non-corroding. All of these roof coverings are brittle materials and easily broken, and should not be walked on during the inspection. Use binoculars to look for missing, broken, or slipping pieces. Slate is particularly susceptible to breakage by ice or ice dams in the winter, and should therefore be especially well drained. Snow guards are needed on steeper slopes, and in locations with heavy, long-lasting snow, snow guards also may be necessary. Moss will sometimes grow on asbestos cement shingles; it should be removed with a cleaner to prevent capillary water leaks. Slate, clay tile, and asbestos shingles should be repaired or replaced by a qualified roofer.

Examine the underside of the roof later during the interior inspection.

2.6 Low-Slope Roof Coverings

A roof that is nearly level or slightly pitched is called a low-slope roof. No roof should be



The built-up roof and flashings in this photograph are in poor condition. Patching may work temporarily, but the roof and flashings should be replaced.

dead level flat; it must have at least a slight slope to drain. Problems in low-slope roofs are common and more difficult to diagnose than pitched roof problems because the path of water leakage through flat roofs is often quite hard to trace. Look for signs of ponded water due to either improper drainage or sagging of the roof deck. If the cause is a sagging deck, it should be structurally corrected before it worsens. Low-slope roofs are expensive to repair, so extra care should be taken in their examination.

Inspect the flashing and joints around all roof penetrations, including drains, soil stacks, chimneys, skylights, hatchways, antenna mountings, and other roof-mounted elements. Note if metal flashings need painting or reanchoring and if asphaltic or rubber flashings are brittle or cracked. Check parapet wall caps and flashing for signs of damage due to wall movement.

Examine all portions of the roof covering. Look for signs of previous repairs that may indicate trouble spots. There are four categories of low-slope roof covering materials and they should be inspected as follows:

- **Built-up roofing.** Built-up roofs are composed of several layers of roofing felt lapped and cemented together with bituminous material and protected by a thin layer of gravel or crushed stone. Built-up roofs vary greatly in life span, but those used in residential buildings usually last about 20 years, depending on their quality, exposure, number of plies, and the adequacy of their drainage. Because built-up roofs are composed of several layers, they can contain moisture in the form of water or water vapor between layers. Moisture not only accelerates deterioration, it can also leak into a building. Look for cracking, blistering, alligatoring, and wrinkling, all of which may indicate the need for roof replacement or repair. Consult an experienced roofer for a further evaluation if you are in doubt.

  Test: An infrared or nuclear scanner can be used to detect areas of moisture in built-up roofs. Once located, these areas can be more thoroughly checked with a moisture meter or a nuclear meter. Such tests must be performed by a trained roofing inspector and are normally used to determine areas that need replacement on very large roofs.

- **Single-ply membrane roofing.** A single-ply membrane roof consists of plastic, modified bitumen, and synthetic rubber sheeting that is laid over the roof deck, usually in a single ply and often with a top coating to protect it from ultraviolet light degradation. Single-ply roofs are installed in three basic ways: fully adhered, mechanically attached, and loose laid with ballast. If properly installed and properly maintained, a single-ply roof should last 20 years. Roof penetrations and seams are the most vulnerable parts of single-ply membrane roofing and should be carefully checked. The material is also susceptible to ultraviolet light deterioration. A protective coating can be used to protect it, but the coating should be reapplied periodically. Check carefully for surface degradation on an unprotected roof and fading of the coating on a protected roof. Check also for signs of water ponding and poor drainage.
- **Roll roofing.** Roll roofing consists of an asphalt-saturated, granule-covered roofing felt that is laid over the roof deck. It can only provide single- or two-ply coverage. Inspect roll roofing for cracking, blistering, surface erosion, and torn sections. Seams are the most vulnerable part of roll roofing, and should be carefully checked for separation and lifting. Also check for signs of water ponding and poor drainage.
- **Metal roofing.** See Section 2.5.

The underside of the low-slope roof should be examined during the interior inspection. If it is inaccessible, look for signs of water leakage on interior ceilings and walls.

2.7 Skylights

From the exterior, check all skylights for cracked or broken glazing material, adequate flashing, and rusted or decayed frames. Skylights will be checked again during the interior inspection. Leaking skylights are common. Replacement skylights must comply with the building code.

The gutters on this low-slope roof are deteriorating largely because of the accumulated detritus that they hold. They should be inspected and cleaned periodically.

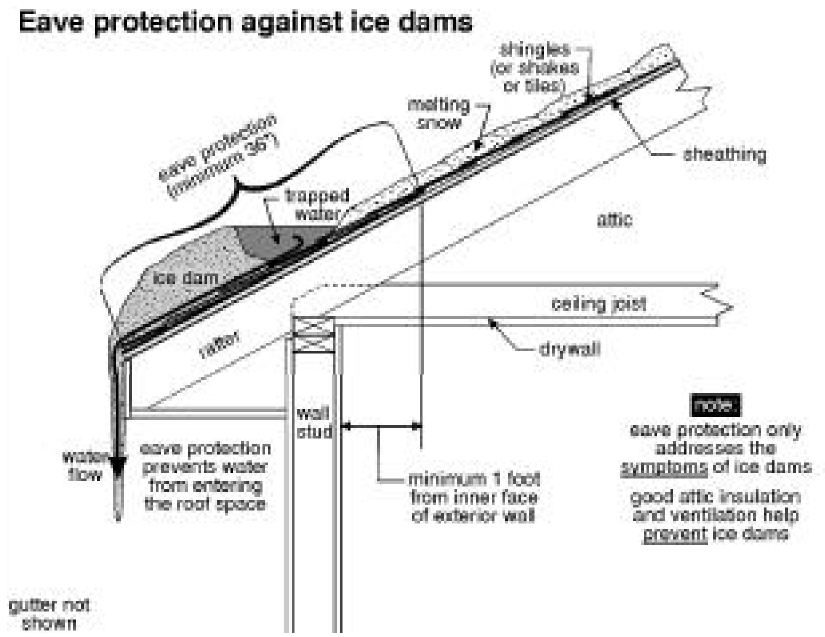
2.8 Gutters and Downspouts

Buildings with pitched roofs can have a variety of drainage systems. With a sufficient overhang, water can drain directly to the ground without being intercepted at the roof edge. See Section 1.1. Usually, pitched roofs end in gutters that are drained by downspouts.

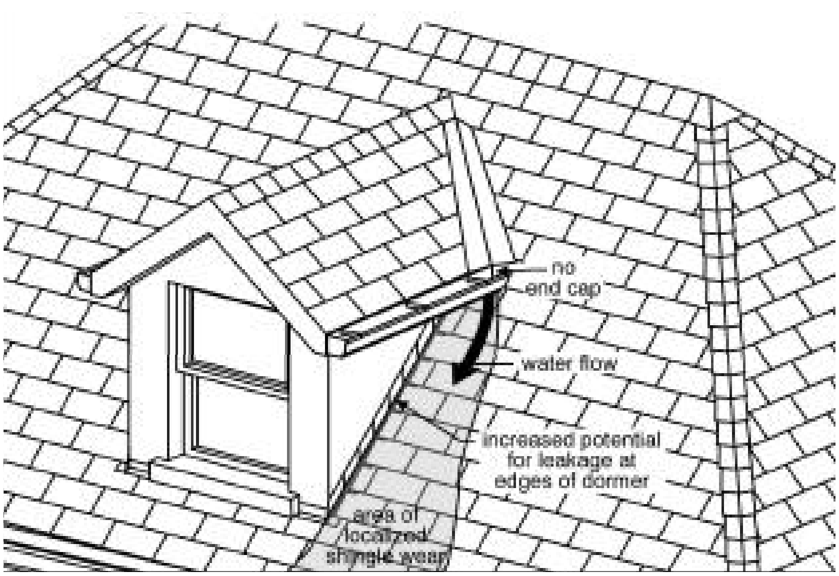
Low-slope roof drainage is accomplished in one of three ways: without gutters or downspouts, with gutters and downspouts, or by downspouts that go down through a building's interior. Drainage without gutters and downspouts can damage the exterior wall with overflow. If the roof has no gutters and downspouts or interior downspouts, carefully examine the exterior walls for signs of water damage.

Gutter and downspout materials are usually galvanized steel, aluminum, copper, or plastic.

- **Gutters** should have a minimum ratio of gutter depth to width of 3 to 4; the front edge should be one-half inch (13 mm) lower than the back edge; and four inches is considered the minimum width except on the roofs of canopies and small porches. Make certain all gutters are clean and slope uniformly, without low areas, to downspouts. If there is a screen or similar device to prevent anything but water from flowing into the gutter, check its condition, fit, and position, to be sure water really can enter the gutter. Check gutters without screens or similar devices to be sure that basket strainers are installed at each downspout. Check the physical and functional



Eave protection against ice dams



Dormer gutters improperly discharging onto the roof

condition of all gutters. Joints should be soldered or sealed with mastic. Also examine the placement of gutters: the steeper the roof pitch, the lower the gutter placement. On roofs with lower slopes make sure gutters are placed close to the roof's surface. Hangers should be placed no more than three feet apart. Where ice and snow are long lasting, hangers should be placed no more than 18 inches (460 mm) apart. Wherever a gutter is exposed, check the strength of its fastening to the roof fascia or building exterior. Rusted fasteners and missing hangers should be replaced.

- **Ice dams** can form on pitched roof overhangs in cold climates subject to prolonged periods of freezing weather, especially those climates with a daily average January temperature of 30 °F (-1 °C) or less. Heat loss through the roof and heat from the sun (even in freezing temperatures) can cause snow on a roof to melt. As water runs down the roof onto the overhang, it freezes and forms an ice dam just above the gutter. The ice dam traps water from melting snow and forces it back under the shingles and into the building's interior. Check the edge of the roof overhang for evidence of ice dams and observe the eaves and soffit for evidence of deterioration and water damage. Check gutters and the immediately adjacent roofing for the presence of electrical de-icing cables, which may be evidence of an ice dam problem. When the interior inspection is made, check the inside of exterior walls and adjacent ceilings for signs of water damage. If the house has an attic, check the underside of the roof deck at exterior walls for signs of water damage.

- **Downspouts** should be checked for size. Seven square inches is generally the minimum except for small roofs or canopies. Check downspout attachments; there should be attachments or straps at the top, at the bottom, and at each intermediate joint. Check straps for rust, deformation, and failed or loose fasteners. Check the capacity of the drainage system. At least one downspout is usually needed for each 40 feet (12 m) of gutter. For roofs with gutters, make sure that downspouts are clear and that they discharge so water will drain away from the foundation. See Section 1.1. For low-slope roofs without gutters, interior downspouts cannot be examined from the roof, but check that basket strainers are in place. During the interior inspection, examine areas through which interior downspouts pass for signs of water damage.

  On buildings with multiple roofs, one roof sometimes drains to another roof. Where that happens, water should not be discharged directly onto roofing material. Check to be sure that water is always directed to a gutter and that higher gutters discharge to lower gutters through downspouts.

  Occasionally, wooden gutters and downspouts are used, usually in older or historic residences. They may be built into roof eaves and concealed by roof fascias. Wooden gutters are especially susceptible to rot and deterioration and should be carefully checked.

  Pitched roofs in older buildings may end at a parapet wall with a built-in gutter integrated with the roof flashing. Here, drainage is accomplished by a scupper (a metal-lined opening through the parapet wall that discharges into a leader head box that in turn discharges to a downspout). Check the leader head box to be sure it has a strainer. Check the scupper for deterioration and open seams and check all metal roof flashings, scuppers, leader head boxes, and downspouts to make certain they are made of similar metals.

2.9 Chimneys

Chimneys should project at least two feet above the highest part of a pitched roof and anything else that is within 10 feet (3 m). A chimney should project at least three feet from its penetration from the roof (required minimum heights may vary slightly). Check the local building code. If the chimney is not readily accessible, examine what you can with binoculars from the highest vantage point you can find.

Flues should not be smaller in size than the discharge of the appliance they serve. The minimum flue area for a chimney connected to a fireplace is normally 50 square inches (320 cm^2) for round linings, 64 square inches (410 cm^2) for rectangular linings, and 100 square inches (650 cm^2) for an unlined chimney. Be extremely cautious about unlined chimneys; check the local building code. Flues should extend a minimum of four inches above the top of a masonry chimney. The height between adjacent flues in a multiple flue chimney without a hood should vary approximately four inches to avoid downdrafts. The same is true of a chimney with a hood unless a withe of masonry completely separates every flue.

Masonry chimneys without hoods should have stone or reinforced concrete caps at the top. Cement washes with or without reinforcing mesh are also used, but they are the least durable. Some masonry chimneys have hoods over the flues. Hoods on masonry chimneys consist of stone or reinforced concrete caps supported on short masonry columns at the perimeter of chimney tops, or sheet metal caps supported on short sheet metal columns. The height of a hood above the top of the highest flue should be at least 25 percent greater than the narrowest dimension of the flue.

Check the condition of chimney tops and hoods. If a cement wash is not properly sloped or is extensively cracked, spalled, or displays rust stains, it should be replaced. Reinforced concrete caps and stone caps with minor shallow spalling and cracking should be repaired. Those with extensive spalling or cracking should be replaced. Sheet metal hood caps with minor rust or corrosion should be repaired, but if rust or corrosion is extensive, replacement is needed.

Metal spark screens are sometimes used on wood and coal-burning fireplace chimneys. Check the condition and fit of spark screens. Dirty or clogged screens adversely affect draft and should be cleaned.

Where a masonry chimney is located on the side of a pitched roof, a cricket is needed on the higher side to divert water around the chimney. Check the cricket to be sure that its seams are watertight, that it is properly flashed into the chimney and roofing, and that it extends the full width of the chimney.

In seismic zones, check the bracing of masonry chimneys from the top of the firebox to the cap, and particularly the portion projecting above the roof. Consider consulting a structural engineer to determine the need for additional bracing or strengthening.

If the chimney is prefabricated metal encased in an exterior chase of siding, check the chase top to be sure it is properly interlocked with the metal chimney's counterflashing so that the assembly is watertight. Also check the chase top for slope: water should drain off the enclosure. Check for the presence of a terminal metal rain cap and make certain the flue terminates not less than two inches and not more than eight inches above the enclosure top.

If the chimney is prefabricated metal and not encased, check the adjustable flashing at the roof to be sure it is tightly sealed to the chimney, preferably with counterflashing, and check for the presence of a stack cap.

2.10 Parapets and Gables

In seismic zones, check the bracing of masonry parapets and gables. Consider consulting a structural engineer to determine the need for additional bracing or strengthening.

2.11 Lightning Protection

Lightning is a problem in some locations. Check the local building code. Lighting protection may be required to prevent powerline surge damage to electrical service, telephone service, or radio and television leads; to protect tall trees close to buildings; or to protect an entire building.

A lightning protection system is an interconnected aggregation of lightning rods, bonding connections, arresters, splicers, and other devices that are installed on a building or tree to safely conduct lightning to the ground. Lightning protection components and systems are identified by Underwriters Laboratories in three classes. Class I includes ordinary buildings (including residences) under 75 feet (22 m) in height. A Class I lightning protection system consists of lightning rods located on the roof and on projections, such as chimneys; main conductors that tie the lightning rods together and connect them with a grounding system; bonds to metal roof structures and equipment; arresters to prevent powerline surge damage; and ground terminals, usually rods or plates driven or buried in the earth. Lightning protection systems should be examined by a certified technician.

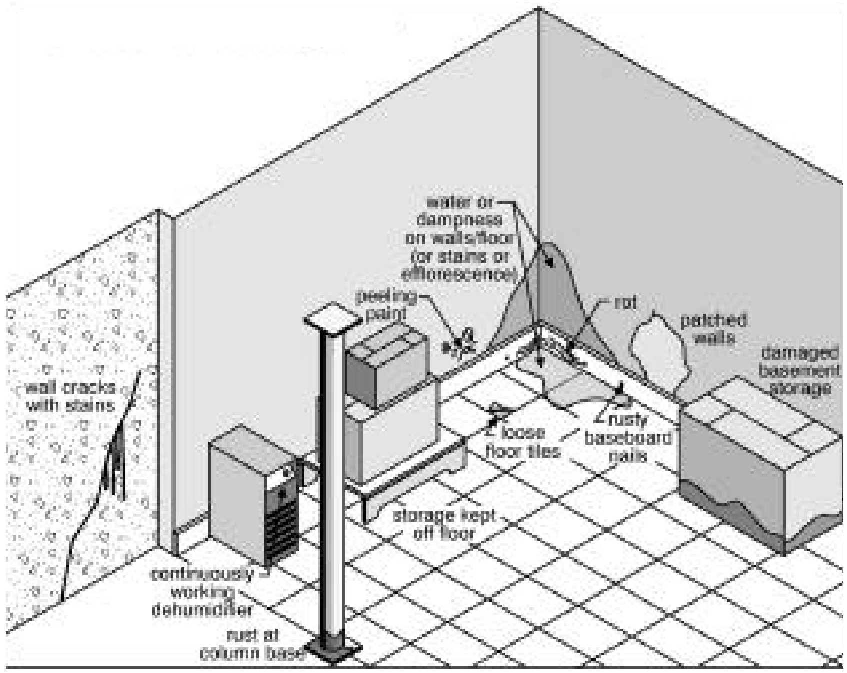
Using Appendix D, consult the following sources for technical information about lightning protection systems:

- Lightning Protection Institute, *Installation Code*, LPIB175.
- National Fire Protection Association, NFPA 780, *Standard for the Installation of Lightning Protection Systems.*
- Underwriters Laboratories, Inc., UL 96, *Lightning Protection Components* and UL 96A, *Installation Requirements for Lightning Protection Systems.*

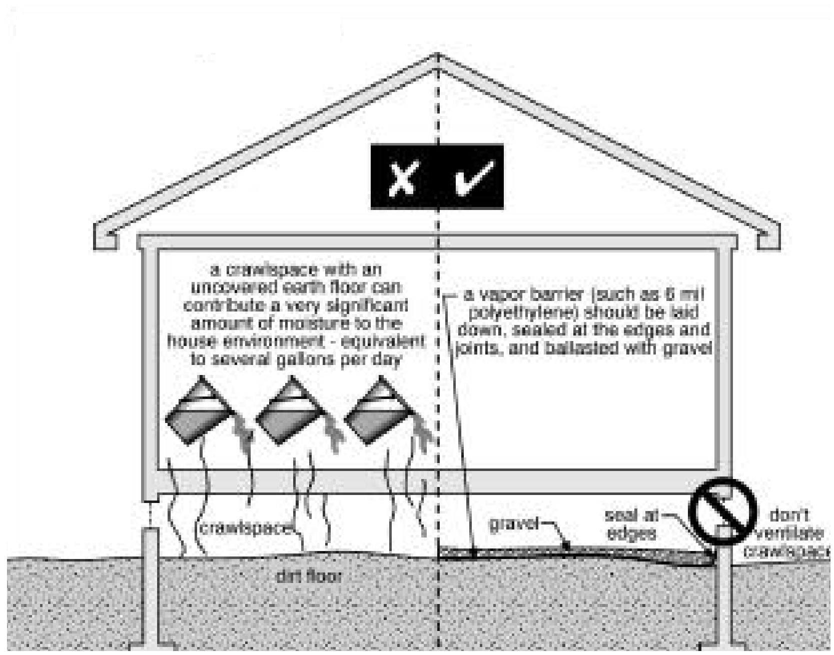
3
Building Interior

Following the inspection of the site and the building's exterior, move indoors and systematically inspect all interior spaces, including basement or crawl space, finished rooms, halls and stairways, storage spaces, and attic. Begin either at the lowest level and work up or at the attic and work down. Examine the overall quality and condition of the building's construction and finish materials. If the interior has unique woodwork or other stylistic features, consider how these may be incorporated to best advantage in the building's reuse. Look for patterns of water damage or material deterioration that indicate underlying problems in the structural, electrical, plumbing, or HVAC systems. These systems will be inspected separately after the interior inspection has been completed.

When universal design is a part of a rehabilitation project, consult HUD publication *Residential Remodeling and Universal Design* for detailed information about doors, kitchens, bathrooms, laundry areas, closets, stairs, windows, and floor surfaces.



Clues to water problems in basements



An uncovered earth floor in a crawl space can significantly increase moisture within the building.

3.1
Basement or Crawl Space

The basement or crawl space is often the most revealing area in the building and usually provides a general picture of how the building works. In most cases, the structure is exposed

Termite infestation is most common in basements and crawl spaces, particularly near foundation walls. Probe all suspect areas thoroughly.

overhead, as are the HVAC distribution system, plumbing supply and DWV lines, and the electrical branch circuit wiring.

- **Moisture.** One of the most common problems in small residential structures is a wet basement. Examine walls and floors for signs of water penetration such as dampness, water stains, peeling paint, efflorescence, and rust on exposed metal parts. In finished basements, look for rotted or warped wood paneling and doors, loose floor tiles, and mildew stains.

  Determine the source of any moisture that may be present. It may come through the walls or cracks in the floor, or from backed-up floor drains, leaky plumbing lines, or a clogged air conditioner condensate line. If moisture appears to be coming through the walls, re-examine the roof drainage system and grading around the exterior of the building (the problem could be as simple as a clogged gutter). Recheck the sump pump, if there is one, to be sure the discharge is not draining back into the basement. Look for unprotected or poorly drained window wells, leaking exterior faucets, and signs of leakage in the water supply line near the building. See Section 6.2 for water distribution system problems. If foundation walls are cracked, examine them in accordance with Section 4.4.

  Check the elevation of an earthen floor in a crawl space If the water table on the site is high or the drainage outside the building is poor, the crawl space floor should not be below the elevation of the exterior grade.

  If the basement or crawl space is merely damp or humid, the cause simply may be lack of adequate ventilation, particularly if the crawl space has an earthen floor.

  Check the ventilation. By measurement and calculation, compare the free area of vents with the plan area of the crawl space. The free vent area to crawl space area ratio should be 1 to 150 in a crawl space with an earthen floor and 1 to 1,500 in a crawl space with a vapor barrier of one perm or less over the earthen floor. If the calculated ratio is less, consider adding ventilation, particularly in hot and humid climates, and especially if moisture is present.

  Check the location of the vents through the foundation or exterior wall. There should be one vent near every corner of the crawl space to promote complete air movement. Check vents for screens. They should have corrosion resistant mesh in good condition with maximum 1/8-inch (3.2 mm) openings. If the ventilation appears to be inadequate and additional vents cannot be cut in the foundation or exterior wall economically, consider adding a vapor barrier and mechanical ventilation.

- **Fungal and insect infestation.** Look for signs of fungal growth on wood, particularly in unventilated crawl spaces.

Inspect all foundation walls, piers, columns, joists, beams, and sill plates for signs of termites and other wood inhabiting insects in accordance with Section 4.7. Also see Appendix B, Wood Inhabiting Organisms.

- **Thermal insulation.** Examine the amount and type of insulating material, if any, above unheated basements and crawl spaces. Determine the amount of insulation required for the space and whether additional insulation can or should be added. Check for adequate vapor barriers.
- **Structural, electrical, plumbing, and HVAC systems.** Understand enough about the layout of each system to make an informed inspection of the remainder of the building's interior. A more complete assessment of these systems will be performed later.

❑ ***Note the type of structural system*** (wood frame, masonry bearing wall, etc.). Locate main support columns and posts, major beams, and bearing walls.

❑ ***Find the main electrical panel box,*** if it is in the basement, and note how the branch circuits are generally distributed. Note also the type of wiring that is used.

❑ ***Trace the path of the main water supply*** line and check the composition of all piping materials.

❑ ***Observe the general location of the heating/cooling unit,*** if it is in the basement, and the general layout of the HVAC distribution system.

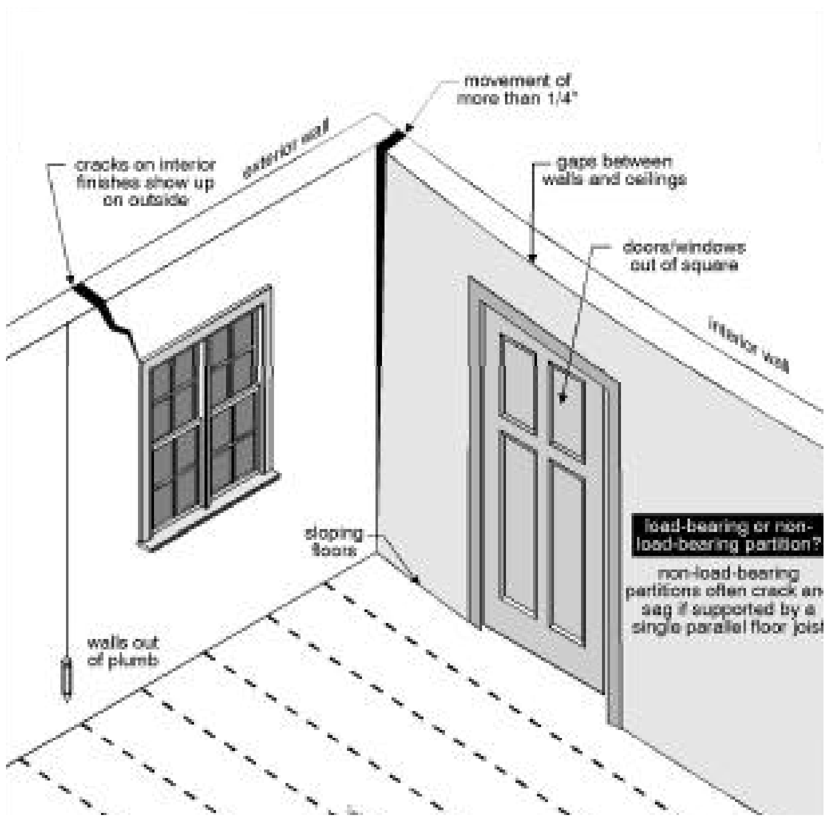
❑ ***Locate the access to the crawl space,*** check that it is large enough for a person to enter, observe the interior of the crawl space, and if mechanical equipment is located inside, check that access is large enough for any required maintenance.

3.2 Interior Spaces, General

This section deals with inspection procedures that are common to all interior spaces, including finished attics and basements. Examine the following elements and conditions of interior spaces:

- **Walls and ceilings.** Check the general condition of all surfaces, ignoring cosmetic imperfections. Look for cracks and peeling paint or wallpaper. Note signs of exterior water penetration or interior leakage. Whenever possible, probe behind wallpaper, paneling, ceiling tiles, and other coverings for problems that may have been concealed but not corrected.

  Look for sags and bulges in old plaster work. Gently tap and push on the plaster; if an area sounds hollow or feels flexible, it is a good indication that the plaster has separated from its backing. If such areas



Interior clues to structural problems

are found, it may be best to replaster or overlay the wall or ceiling with wallboard.

Wall and ceiling cracks are usually caused by building settlement, deflection, warping of wood structural elements, or small seasonal movements of building components due to temperature and humidity variations. Seasonal movements will make some cracks regularly open and close; these may be filled with a flexible, paintable sealant, but otherwise cannot be effectively repaired. Cracks due to settlement, deflection, or warping can be repaired if movement has stopped, as is often the case.

Large wall and ceiling cracks may indicate structural problems. See Sections 4.3 through 4.5 for cracks associated with masonry wall problems and Section 4.7 for cracks associated with structural wood framing problems.

Inspect drywall-covered walls and ceilings by checking for nail popping, joint cracks, and other signs of deterioration or failure, such as rust stains at fasteners and corner beads.

Examine paneled walls by pushing or tapping on the paneling to determine if it is securely attached. Look for delamination of veneers. If the paneling is obviously not original, try to look behind it to see what problems may be covered up.

Lift suspended ceiling panels and observe above them. Check the condition of the original ceiling, if any. Tiled ceilings should be examined similarly. On top floors, inspect for ceiling penetrations that may form thermal bypasses to the unconditioned spaces above.

Check the heating source in every room. This particular heater, when tested, was operable and safe.

- **Exterior walls.** In buildings built after 1960, try to determine if the exterior walls are insulated and contain a vapor barrier. Vapor barriers should be placed on the interior side of the insulation in cold climates and on the exterior side of the insulation in warm, moist climates.
- **Floors.** Examine the floor's finish or covering. Inspect hardwood floors to determine if they will need cleaning or sanding. If sanding is required, be sure to check (by removing a floor register or piece of baseboard trim) how much the floor thickness has been reduced by previous sandings. Too much sanding will expose floor nails and, if present, tongue-and-groove joints.

  Inspect resilient floors and carpeting for their overall condition and quality. If they are to be replaced, check that their floor underlayment is sound.

  If the floor feels springy, sagging, or unstable, inspect it in accordance with Section 4.7.

- **Interior doors.** Inspect the condition of doors and door frames including the interior of entrance doors and storm doors. Check hardware for finish, wear, and proper functioning. Binding doors or out-of-square frames may indicate building settlement. See Section 4.4.
- **Windows.** Inspect window sash and frames for damage and deterioration. Operate each window, including storm windows and screens, to determine smoothness, fit, and apparent weathertightness. Pay particular attention to casement windows. When open they are easily damaged by wind and hinge damage may keep them from closing properly. Also carefully check casement operating hardware to be sure it operates smoothly and easily. Note the type and condition of glass in each window and assess its effect on energy use. If possible, determine if the window has a thermal break frame. Check for the presence and adequacy of security hardware. Examine the functioning of sash cords and weights in older double hung windows. Open windows above the ground floor (or others not fully inspected from the outside) and check their exterior surfaces, frames, sills, awnings, and shutters, if any.

Test: Air infiltration through windows and doors can be checked by the test method described in ASTM E783, *Standard Test Method for Field Measurement of Air Leakage Through Installed Windows and Doors.* The test should be performed by an experienced technician.

Test: Water penetration through windows and doors can be checked by the test method described in ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Curtain Walls, and Doors by Uniform or Cyclic Static Air Pressure Difference.* The test should be performed by an experienced technician.

Consider window-related code requirements for natural light, ventilation, and egress capability. Most codes require the following:

❏ ***Natural light.*** Habitable rooms should be provided with natural light by means of exterior glazed openings. The area required is a percentage of the floor area, usually eight percent.

❏ ***Ventilation.*** Habitable rooms should be provided with operable windows. Their required opening size is a percentage of the floor area, usually four percent. A mechanical ventilation system can be provided in lieu of this requirement.

❏ ***Egress.*** Every sleeping room and habitable basement room should have at least one operable window or exterior door for emergency egress or rescue. Egress windows should have a minimum net clear opening of 5.7 square feet (0.53 m2), with a clear height of at least 24 inches (610 mm), a clear width of at least 20 inches (510 mm), and a sill height not more than 44 inches (1120 mm) above the floor. Emergency egress or rescue windows and doors should not have bars or grilles unless they are releasable from inside without a key, tool, or special knowledge.

- **Closets.** Inspect all closets for condition and usability. It is best that they have a clear depth of at least 24 inches (610 mm). Check all shelving and hanging rods for adequate bracing. Check for proper type and location of closet light fixtures; lights positioned close to shelves present both a hazardous condition and an impediment to the use of shelves.
- **Trim and finishes.** Examine baseboards, sills, moldings, cornices, and other trim for missing or damaged sections or pieces. Replacement trim may no longer be readily obtainable, so determine if trim can be salvaged from more obscure locations in the building.
- **Convenience outlets and lighting.** Look for signs of inadequate or unsafe electrical service as described here and in Chapter 5. Generally speaking, each wall should have at least one convenience outlet and each room should have one switch-operated outlet or overhead light. Examine the condition of outlets and switches and feel them for overheating. Make sure they are mounted on outlet boxes and that light fixtures are securely attached to walls or ceilings.

  Operate switches and look for dimmed or flickering lights that indicate electrical problems somewhere in the circuit.

The electrical system will be re-examined more thoroughly later in the inspection. Also check the light switches for sparks (arcing) when switches are turned on and off. Switches that are worn should be replaced.

- **HVAC source.** As described here and in Chapter 7, locate the heating, cooling, or ventilating source for every room. If there is a warm air supply register but no return, make sure doors are undercut one inch (25 mm) for air flow.

  With the HVAC system activated, check the heat source in each room and make sure it is functioning. The HVAC system will be more completely examined later in the inspection.

- **Skylights.** Examine the undersides of all skylights for signs of leakage and water damage. Inspect skylight components for damage, deterioration, and weathertightness. Operate openable skylights to determine their smoothness of operation, fit, and apparent weathertightness.

3.3 Bathrooms

Examine bathrooms in accordance with the procedures for other interior rooms, and additionally inspect:

- **Electrical service.** Wherever possible, switches and outlets should not be within arm's reach of the tub or shower. Consider installing ground fault interrupters (GFIs) in the outlets. See Chapter 5.

  Check the condition and operation of all switches, outlets, and light fixtures.

  If there is an exhaust fan, check its operation. It should be properly ducted to an attic vent or the building's exterior.

- **Plumbing.** Examine all exposed plumbing parts for leaking or signs of trouble or deterioration. Inspect the lavatory for secure attachment and support. Check the operation of all fixtures and decide which fixtures and trim should be replaced.

  Check the condition of all plumbing fixtures by examining for chipping, scratches, mold, stains, and other defects.

  Check the condition and operation of the lavatory, toilet, tub, and shower.

  A common problem in bathrooms is leakage around tubs and showers. If possible, inspect the ceiling below each bathroom for signs of water damage or recent patching and painting.

  Whirlpool baths should be operated for at least 20 minutes. Check how well a constant water temperature is maintained. Examine jets for evidence of mold and mildew and determine if the piping should be flushed out.

  Determine the flushing capacity of the toilet. If it is not a water-saving fixture, consider replacing it with a water-saving toilet with a 1.6 gallon (6 L) flushing capacity. Operate the toilet. Assess its bowl cleaning ability, especially if it is a water-saving fixture.

  Pressure assisted toilets use water pressure to compress air in a tank that makes the 1.5 to 1.6 gallon (5.7 to 6 L) flush very effective in cleaning the fixture bowl and preventing buildup in the soil pipe. Operate the toilet. Listen for excessive noise from vibration due to loose pieces of equipment, check for leaks, and look for rust on the tank and piping.

  Check for a faulty shower pan by covering the shower drain tightly and filling the shower base with about an inch of water. Let stand for at least an hour, if possible. Look for signs of water leakage on the ceiling below. The presence of excessive sealant around the shower base or drain may indicate attempts to remedy a shower pan leak by preventing water from reaching the pan. This is only a temporary solution and the pan should be properly repaired.

  If there is a medicine cabinet, check its condition and check its door fit and operation.

- **Tub and shower enclosures.** Check the condition, fit, and operation of tub and shower enclosures. Note whether any glazing is safety glazing, as required by the building code for new installation and replacement.

- **Ceramic tile.** Look for damaged or missing tiles, or tiles that have been scratched, pitted, or dulled by improper cleaning. Check the condition

This kitchen cabinetry is plain but adequate.

of all grouted and caulked joints. If a portion of the tile is defective or missing, all tile may have to be replaced since finding additional tiles of matching size, color, and texture may be impossible.

- **Ventilation.** The bathroom should be ventilated by either a window, an exhaust fan, or a recirculation fan. Poor ventilation will be indicated by mildew on the ceiling and walls.

3.4 Kitchens

Examine kitchens in accordance with the inspection procedures for other interior rooms, and additionally inspect:

- **Counters and cabinetry.** Check countertops for cracks or food traps and examine kitchen cabinets carefully for signs of vermin infestation. Look for missing, broken, or damaged hardware and cabinet parts. Check doors and drawers for fit and smooth operation, and wall cabinets for secure attachment. Compare the cost of replacement to the cost of reconditioning.
- **Electrical service.** Determine the adequacy and safety of electrical service to the kitchen, as described here and in Chapter 5. As a guide, new residential buildings are usually required to have a ground fault interrupter (GFI) of at least one 20 amp/120 volt circuit in all outlets over a countertop used for portable kitchen appliances. Separate circuits are also required for each major appliance as follows:

Refrigerator	20 amp/120 volt
Dishwasher	20 amp/120 volt
Garbage disposal	20 amp/120 volt
Range	40 to 50 amp/ 240 volt

Operate all electrical appliances simultaneously, including exhaust fans, to determine that they are connected and can run steadily without overloading their circuits.

- **Plumbing.** Visually inspect the condition of the sink for chipping, scratches, stains, and other defects. Decide whether it should be replaced. Check faucets for corrosion and proper operation. Make sure an air gap exists between the faucet and the flood rim to prevent possible back-siphoning. See Chapter 6.

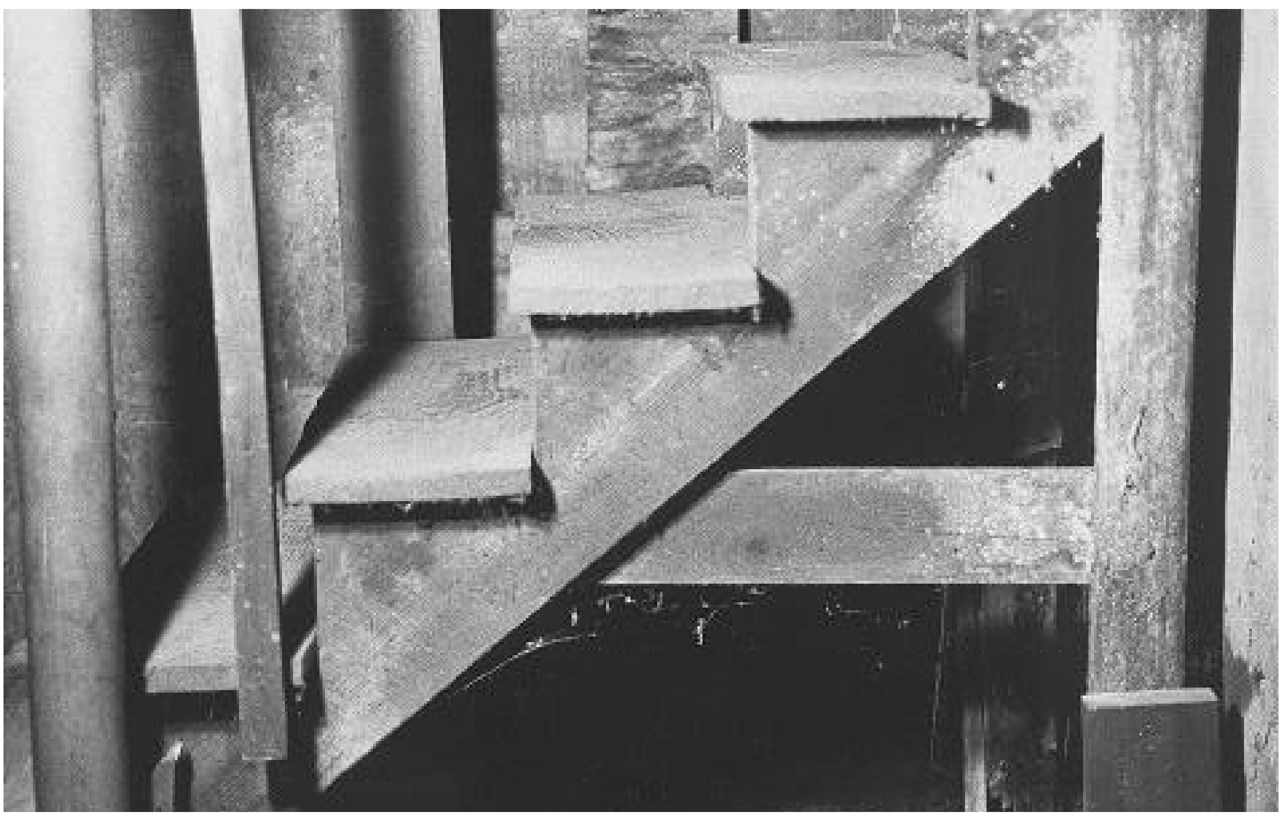
  Turn the faucets on and off several times and look for drips and leaks in both the supply and drainage lines. Fill the sink and check that it drains promptly. Operate the disposal and dishwasher listening and watching for smooth operation. Look for leaks in plumbing connections. Check for the existence of an air vent for the dishwasher unless there is no disposal or unless the dishwasher pumps to the top outlet of the disposal. Check the spray hose. Decide whether either appliance should be replaced.

- **Ventilation.** See that exhaust fans and range hoods are ducted to the outside and not to a cupboard, attic, crawl space, or wall. A recirculation range hood fan is acceptable. Check the filter medium. Ducts, hoods, and filters should be free of grease buildup.

  Operate exhaust fans and vented range hoods to determine whether they are functional and whether they should be kept or replaced.

3.5 Storage Spaces

Inspect all closets and other storage spaces for cleanliness, functionality, proper lighting, and means of adequate ventilation.



The rotted supports beneath this stair were repaired by scabbing on small blocks of wood, which is insufficient. The supports should be replaced and the source of moisture investigated.

3.6 Stairs and Hallways

Inspect stairs and hallways as follows:

- **Light.** Stairs and hallways should be well lighted and have three-way light controls. Public stair and hallway lights in multifamily buildings should be operated from centralized house controls.

  Check the operation of all stair and hallway lights.
- **Smoke detectors.** Stairs and hallways are the appropriate location for smoke detectors. Detectors should be located on or near the ceiling, near the heads of stairs, and away from the corners.

  Check the operation of all smoke detectors by activating them with a smoke source or by pushing their test buttons.
- **Stair handrails and guardrails.** Handrails are normally required to be 34 to 38 inches (865 to 965 mm) above the stair nosing on at least one side of all stairs with three or more risers. Guardrails are required on open sides of stairways and should have intermediate rails that will not allow the passage of an object 4 inches (100 mm) in diameter. Shake all railings vigorously to check their stability and inspect their fastenings.
- **Stair treads and risers.** Check that all treads are level and secure. Riser heights and tread depths should be, respectively, as uniform as possible. As a guide, stairs in new residential buildings must have a maximum riser of 7-3/4 inches (197 mm) and a minimum tread of 10 inches (254 mm). Inspect the condition and fastening of all stair coverings.
- **Stair width and clearance.** Stairs should normally have a minimum headroom of 6’-8" (2030 mm) and width of 3’-0" (915 mm). For multifamily buildings, check the local housing code for minimum dimensions of public hallways and stairs.
- **Structural integrity of stairs.** Check that all stairs are structurally sound. Examine basement stairs where they meet the floor and where they are attached to the floor joists above. See Section 4.7.

3.7 Laundries and Utility Rooms

Laundry areas and utility rooms in small residential buildings are usually located in the basement or off the kitchen. Inspect them as follows:

- **Laundries.** Look for leaks or kinks in plumbing connections to the washer and examine electrical or natural gas connections to the dryer. Inspect dryer venting and make sure it exhausts to the outside and is not clogged or otherwise restricted. Gas dryer vents that pass through walls or combustible materials must be metal.

  Examine the laundry tub, if one exists, and decide whether it should be replaced. Check its plumbing and its capacity to handle discharged water from the washer.

  In multifamily laundry areas, examine floors and walls for water damage. The laundry should have a floor drain. Determine whether the laundry is of proper size and in the proper location for the planned rehabilitation.

  Operate washers and dryers and observe their functioning. Listen for noise that indicates excessive wear. Determine whether they should be replaced.
- **Furnace rooms.** Rooms containing fuel-burning equipment should not be located off a sleeping room in a single family residence, and must be in a publicly accessible area in a multifamily building. Check local code requirements for applicable fire safety and combustion air criteria.

3.8 Fireplaces and Flues

Inspect fireplaces and flues as follows:

- **Fireplaces**. Inspect the firebox for deterioration or damage. If there is a damper, check its operation. Make sure the hearth is of adequate size to protect adjacent combustible building materials, if any. A depth from the face of the fireplace of 20 inches (510 mm) and a width that extends one foot (305 mm) beyond the fireplace opening on either side is a minimum for older fireplaces. Also check local codes.

Burn some newspaper to check the draw. Discoloration around the mantel may indicate a smoky fireplace with poor draw.

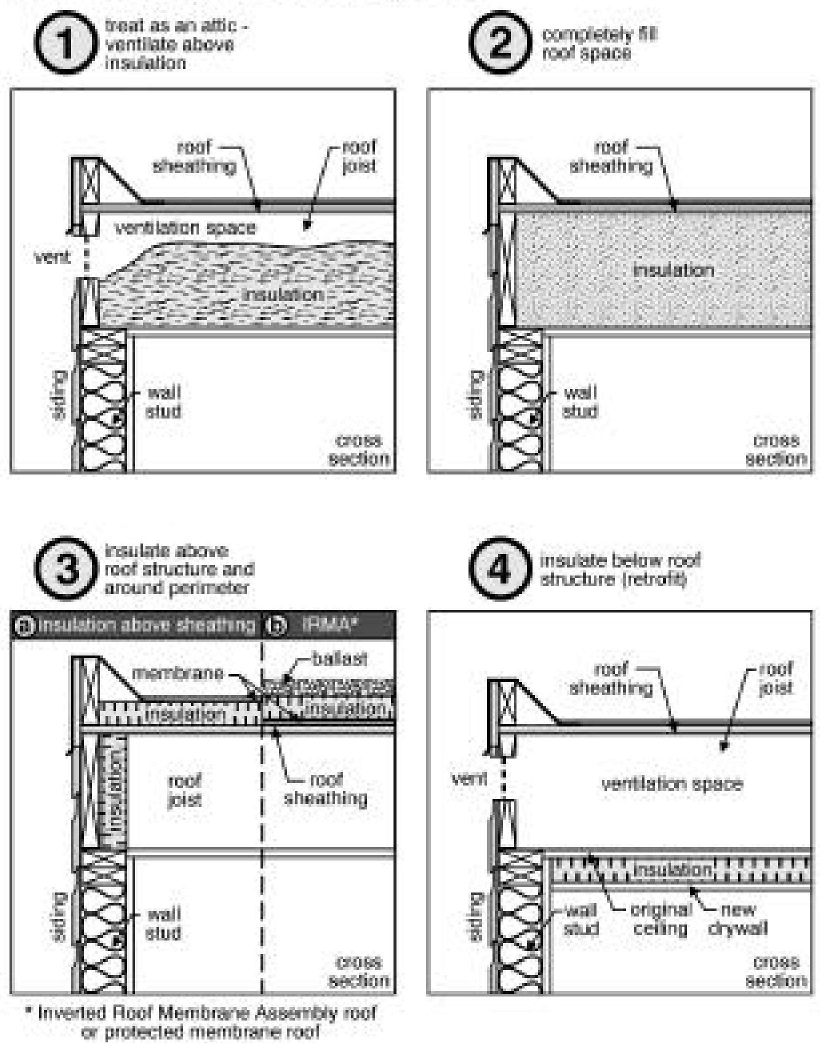
- **Flues.** Check the flue lining in masonry chimneys. It should be tight along its entire length. Linings should be intact, unobstructed, and appropriate for the fuel type. It is difficult to properly examine flue linings visually, and a mirror may be helpful. An obstructed flue can usually be opened by a chimney sweep, but consult a chimney expert if the integrity of the flue is in doubt. Analyze unlined chimneys for the possible installation of metal liners. If there is an attic, use it to examine chimney construction more closely. See Section 7.2 for clearances around smoke pipes.
- **Smoke pipe connections.** Check that the smoke pipes from furnaces, water heaters, stoves, and related devices are tightly connected to the chimney and that they do not enter a fireplace flue. See additional requirements in Section 7.2.
- **Ash dump and pit.** If the fireplace has an ash dump at the bottom of the firebox, check the operation, fit, and condition of the door and check the shaft to the ash pit to be certain it is unobstructed and not overflowing with ashes. If the chimney has an ash pit, check the operation, fit, and condition of the pit access door. The fit should be tight enough to prevent dust and ash from escaping.

The structural condition of chimneys should be inspected in accordance with Section 4.6.

3.9 Attics and Roof Truss and Joist Spaces

Attics are defined here as unconditioned spaces between the roof and the ceiling or walls of the building's inhabited rooms. In small residential buildings with pitched roofs, attics are usually partially or fully accessible. In buildings with low-slope roofs, they may be inaccessible or virtually nonexistent. Inspect all accessible attic spaces as follows:

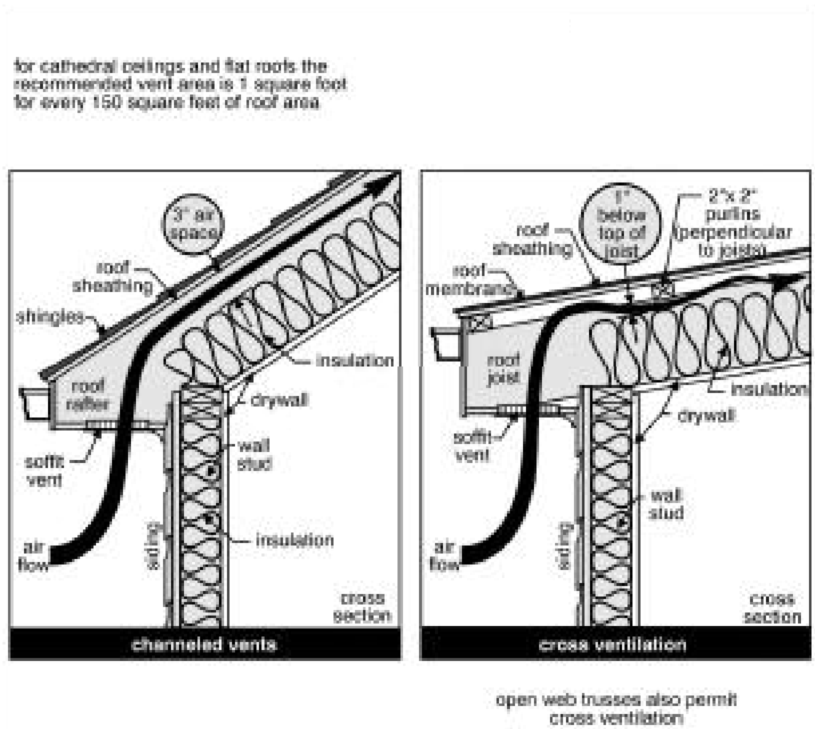
- **Roof leaks.** Look for signs of water leakage from the roof above and try to locate the source of leakage by tracing its path. This may be difficult to do beneath built-up roofs or beneath loosely laid and mechanically fastened single-ply roofs, since water may travel horizontally between layers of roofing materials. Determine the extent of any damage and the probable cost of repairs.
- **Attic ventilation.** Signs of inadequate ventilation are rusting nails (in roof sheathing, soffits, and drywall ceilings), wet or rotted roof sheathing, and excessive heat buildup in attics. Where attics exist but are inaccessible, check if access could be provided through ceilings or gable ends. Check for adequate attic ventilation by calculating the ratio of the free area of all vents to the floor area. Free area of vents is their clear, open area. If a vent has an insect screen, its free area is reduced by half. The vent free area to floor area ratio should be 1 to 150. If the calculated ratio is less, consider adding ventilation, especially in hot and humid climates. When an attic also contains an occupied space, check that the ventilation from the unconditioned, unoccupied areas at the eaves is continuous to the gable or ridge vents. Also check that the free area of eave vents is approximately equal to the free area of ridge or gable vents. If ventilation appears to be inadequate and additional vents cannot be added economically, consider adding mechanical ventilation.
- **Roof truss and joist space ventilation.** Most buildings with low-slope roofs and some buildings with pitched roofs do not have attics. Instead, these buildings have ceilings at the bottom of joists, rafters, or trusses. The truss space and the space between each joist or rafter and above the ceiling needs ventilation. Look for vents below the eaves and check to see that the ratio of free vent area to roof area is 1 to 150. If the calculated ratio is less, consider adding ventilation. Open one or more of the vents if possible. Probe the ventilating cavity to determine the amount of insulation and free air space and try to assess the general condition of the surrounding building components. It is difficult to inspect for ventilation in these



Methods of insulating and ventilating low-slope roof structures

buildings without removing a part of the ceiling to measure the free depth and width of ventilation space and to determine whether the truss, joist, or rafter spaces contain insulation. If there is no evidence of water damage from condensation, an intrusive investigation is usually not warranted. At ridge, cornice, eave, or soffit vents, check for the presence of insect screens. If insect screens are present, check their condition.

- **Vents.** Check the condition of ridge, gable, cornice, eave, and soffit vents. Look for rusted or broken screens and rusted frames. Make sure openings are clear of dirt and debris. At larger ventilation openings on a building's exterior and where louvered grilles are used, such as at gables, check for the presence of one-half-inch-square (13 x 13 mm) 14 or 16 gauge aluminum mesh bird screen. If there is none or it is in poor condition, consider having new bird screen installed.
- **Thermal insulation.** Examine the amount and type of existing insulating material. Check to see that insulation faced with a vapor barrier has been installed face-side down with the vapor barrier closest to the conditioned space, and that vapor barriers are properly located between the ceiling and the first layer of insulation. Determine the proper amount of insulation to the attic and whether additional insulation is needed. If attic insulation is placed against the roof sheathing, check for a ventilated air space between the insulation and the sheathing. If there is no air space, check for the presence of moisture and deterioration of sheathing and rafters. Ensure that insulation is held away from recessed lighting fixtures, and inspect spaces around vents, stacks, ducts, and wiring for thermal bypasses. Inspect attic doors or access hatches, heating or cooling ducts that pass through the attic, and whole-house attic fans for thermal bypasses. Check the local jurisdiction for thermal resistance (R) requirements.



Methods of ventilating pitched roof structures over habitable spaces

A split ceiling joist or trust chord can be easily repaired by propping it back in place and attaching new structural pieces to each side.

- **Exhaust ducts and plumbing stacks.** Check that all plumbing stacks continue through the roof and do not terminate in the attic and that they are not broken or damaged. Also check that exhaust ducts are not broken or damaged and do not terminate in the attic but either continue through the roof, gable, or wall or vent directly to a ridge vent.
- **Structural conditions.** Inspect the roof structure in accordance with Section 4.7.

3.10 Whole Building Thermal Efficiency Tests

Several whole building tests can be performed to help evaluate the thermal efficiency of the building envelope.

Test: A building pressurization test can be used to determine air infiltration and exfiltration. The test is particularly useful for “tightening up” an older building. See ASTM E779, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization.* A tracer gas test may also be used; see ASTM E741, *Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution*. Such tests are usually performed by an energy specialist or an HVAC technician.

Test: A hand-held infrared scanner can be used to detect building “hot spots” due to interior air leakage or excessive heat loss through uninsulated building components. This test should be performed in cold weather when the building is heated; the greater the differential between inside and outside temperatures, the more accurate the results. Infrared scanners are commercially available; their use varies by manufacturer. Thermography can be used for the same purpose, but it requires much more expensive equipment and a trained operator. Thermographic tests should be performed by an energy specialist, mechanical engineer, or others with the proper training and equipment.

3.11 Sound Transmission Control Between Dwelling Units

Check the floors and walls between dwelling units for adequacy of sound transmission control using the current building code for guidance. Floors that separate dwelling units, and floors that separate a dwelling unit from a public or service area should have an Impact Insulation Class (IIC) of not less than 45. IIC is determined in accordance with ASTM E492, *Standard Method of Laboratory Measurement of Impact Sound Transmission Through Floor-Ceiling Assemblies Using the Tapping Machine*. Walls and floors that separate dwelling units in two-family residences, and walls that separate townhouses, should have a Sound Transmission Class (STC) of not less than 45. STC is determined in accordance with ASTM E90, *Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements*.

Technical data that identifies STC and IIC attenuation for different types of construction is provided by product manufacturers and trade associations, such as the Gypsum Association or the National Concrete Masonry Association. See the Gypsum Association's publication GA-530, *Design Data—Gypsum Products*, and the National Concrete Masonry Association's *Tek Note 13-1, Sound Transmission Class Ratings for Concrete Masonry Walls.*

3.12 Asbestos

Asbestos is a naturally occurring fibrous mineral used in many construction products. It is considered to be a carcinogen. Asbestos has been used in sealant, putty, and spackling compounds; in vinyl floor tiles, backing for vinyl sheet flooring, and flooring adhesives; in ceiling tiles; in textured paint; in exterior wall and ceiling insulation; in roofing shingles; in cement board for many uses including siding; in door gaskets for furnaces and wood-burning stoves; in concrete piping; in paper, mill board, and cement board sheets used to protect walls and floors around wood-burning stoves; in fabric connectors between pieces of metal ductwork; in hot water and steam piping insulation, blanket covering, and tape; and as insulation on boilers, oil-fired furnaces, and coal-fired furnaces. Use of asbestos has been phased out since 1978, but many older houses contain asbestos-bearing products.

Products containing asbestos are not always a health hazard. The potential health risk occurs when these products become worn or deteriorate in a way that releases asbestos fibers into the air. Of particular concern are those asbestos-containing products that are soft, that were sprayed or troweled on, or that have become crumbly. The Environmental Protection Agency believes that so long as the asbestos-bearing product is intact, is not likely to be disturbed, and is in an area where repairs or rehabilitation will not occur, it is best to leave the product in place. If it is deteriorated, it may be enclosed, coated or sealed up (encapsulated) in place, depending upon the degree of deterioration. Otherwise, it should be removed.

A certified environmental professional should perform the inspection and make the decision whether to enclose, coat, encapsulate, or remove deteriorated asbestos-containing products. Testing by a qualified laboratory as directed by the environmental professional may be needed in order to make an informed decision. Encapsulation, removal, and disposal of asbestos products must be done by a qualified asbestos-abatement contractor.

For more information consult the *Guidance Manual: Asbestos Operations and Maintenance Work Practices*, available from the National Institute of Building Sciences.

3.13 Lead

Lead has been determined to be a significant health hazard if ingested, especially by children. Lead damages the brain and nervous system, adversely affects behavior and learning, slows growth, and causes problems related to hearing, pregnancy, high blood pressure, nervous system, memory, and concentration.

- **Lead-based paint.** Most homes built before 1940 used paint that was heavily leaded. Between 1940 and 1960, no more than half the homes built are thought to have used heavily leaded paint. In the period from 1960 to 1980, many fewer homes used lead-based paint. In 1978, the U.S. Consumer Product Safety Commission (CPSC) set the legal limit of lead in most types of paint to a trace amount. As a result, homes built after 1978 should be nearly free of lead-based paint. In 1996, Congress passed the final phase of the Residential Lead-Based Paint Hazard Reduction Act, Title X, which mandates that real estate agents, sellers, and landlords disclose the known presence of lead-based paint in homes built prior to 1978.

  Lead-based paint that is in good condition and out of the reach of children is usually not a hazard. Peeling, chipping, chalking, or cracking lead-based paint is a hazard and needs immediate attention. Lead-based paint may be a hazard when found on surfaces that children can chew or that get a lot of wear and tear, such as windows and window sills, doors and door frames, stairs, railing, banisters, porches, and fences. Lead from paint chips that are visible and lead dust that is not always visible can both be serious hazards. Lead dust can form when lead-based paint is dry scraped, dry sanded, or heated. Dust also forms when painted surfaces bump or rub together, such as when windows open and close. Lead chips and dust can get on surfaces and objects that people touch. Settled lead dust can re-enter the air when people vacuum, sweep, or walk through it.

  If the building is thought to contain lead-based paint, consider having a qualified professional check it for lead hazards. This is done by means of a paint inspection that will identify the lead content of every painted surface in the building and a risk assessment that will determine whether there are any sources of serious lead exposure (such as peeling paint and lead dust). The risk assessment will also identify actions to take to address these hazards. The federal government is writing standards for inspectors and risk assessors. Some states may already have standards in place. Call local authorities for help with locating qualified local professionals. While home test kits for lead are available, the federal government is still testing their reliability. These tests should not be the only method used before doing rehabilitation or to ensure safety.

  For more information on lead-based paint consult the HUD Office of Lead Hazard Control Web site at http://www.hud.gov:80/lea.

- **Lead in drinking water** is a direct result of lead that is part of the plumbing system itself. Lead solder was used in pipe fittings in houses constructed prior to 1988. Lead has been used in plumbing fixtures such as faucets, and in some older homes the service water pipe from the main in the street to the house is made of lead.

  The transfer of lead into water is determined primarily by exposure (the length of time that water is in contact with lead). Two other factors that affect the transfer are water temperature (hot water dissolves lead quicker than cold water) and water acidity (“soft” water is slightly corrosive and reacts with lead).

  The current federal standard for lead in water is a limit of 15 parts per billion. The only way to find out whether there is lead in the house’s water is to have the water tested by an approved laboratory. Two samples should be tested: water that has been sitting in the pipes for at least four hours, and water that has been allowed to flow not less than one minute before the sample is taken. Tests are inexpensive ($15 to $25).

If there is evidence of lead in the system, consider having water tested for lead. If the house has a water filter, check to see if it is certified to remove lead.

For more information on lead in drinking water call the Environmental Protection Agency's Safe Drinking Water Hotline: 1-800-462-4791 or visit the Web site of the EPA Office of Water at http://www.epa.gov/safewater.

For more information on lead hazards in general, call the National Lead Information Center clearinghouse: 1-800-424-LEAD. For the hearing impaired, call TTY 1-800-526-5456.

3.14 Radon

Radon is a colorless, odorless, and tasteless gas that is present in varying amounts in the ground and in water. Radon is produced by the natural radioactive decay of uranium deposits in the earth. Prolonged exposure to radon in high concentrations can cause cancer. The EPA has set guidelines for radon levels in residential buildings.

- **Airborne radon.** The EPA recommends that mitigation measures be undertaken in residential buildings when radon concentrations are 4 picocuries per liter (4 pCi/L) of air and above.

  The radon concentration in a house varies with time and is affected by the uranium-radium content in the soil, the geological formation beneath the house, the construction of the house, rain, snow, barometric pressure, wind, and pressure variations caused by the periodic operation of exhaust fans, heating systems, fireplaces, attic fans, and range fans. Radon concentrations are variable and may be high in one house and low in an adjacent house. To determine if a house has a radon problem, it must be tested.

  Test: A long-term test is the most accurate method of determining the average annual radon concentration. However, because time is usually limited, there is a three- to seven-day test that uses a charcoal canister. It is available from most home do-it-yourself stores or through radon testing service companies.

- **Waterborne radon.** A house's domestic water supply from its well can contain radon. There are locations with well water containing 40,000 or more pCi/L. The health problems from drinking water with radon are insignificant compared to breathing airborne radon, but radon can be released into the air when water is run into a plumbing fixture or during a shower. It takes a high concentration of radon in water to produce a significant concentration in the large volume of air in a house. While there is no maximum established at this time for radon in water, consider removing radon at the water service entrance when the level exceeds 10,000 pCi/L.

  Test: Private well water testing is normally not a part of radon testing. Therefore, if the house has a private well, consult the local health department to determine whether water testing in the house's area is recommended. How this is to be done should be determined by a listed radon mitigation contractor.

If a building is found to have a radon problem, consult a certified radon mitigation contractor who has met the requirements for listing under the EPA's Radon Contractor Proficiency Program about mitigation procedures.

For more information on radon mitigation see Ventilation for Soil Gases, chapter 7 in *The Rehab Guide*, Volume 1, *Foundations*, available from HUD or full text online at http://www.pathnet.org.

3.15 Tornado Safe Room

If a building is located in a tornado-risk area, and if it has a tornado shelter or safe room, it should be investigated by a structural engineer for structural adequacy.

4
Structural System

Small residential buildings do not have for the most part inherent structural problems. Even many 19th-century buildings, that often show signs of settlement, may have only minor structural faults that can be readily remedied. Major structural problems, when they do occur, are usually quite obvious. It is the less obvious problems that require careful inspection and informed diagnosis. Such problems are often detected through a pattern of symptoms rather than any one symptom. This chapter describes signs of structural distress, deterioration, and damage by material type: masonry (the most difficult to assess), wood, iron and steel, and concrete. If applicable, also refer to Appendix A, The Effects of Fire on Structural Systems, and Appendix B, Wood Inhabiting Organisms.

Figure 4.1
Assessing Structural Capacity

Unless there is obvious overloading, significant deterioration of important structural components, or additional loading is anticipated, there is usually little need to verify the building's structural design or to recompute its structural capacity. A thorough visual inspection of its structural components is all that is normally necessary. On some occasions, however, ceilings or other building elements may have to be opened for a selective inspection of critical structural members. A sufficient number of members must be examined to afford a reasonable assurance that they are representative of the total structure.

Test: A laboratory test may be helpful in determining the strength of a masonry wall section or some other structural component. A representative sample of the material or component in question must be removed from the structure for the test, which should be performed under the guidance of a qualified structural engineer and conducted by a certified testing laboratory. Refer to the ASTM tests listed in Sections 4.3, 4.8, and 4.9.

If doubt remains about the building's structural capacity after visual inspection, laboratory tests may be the next step. Also, if the building's structural loading is to be dramatically increased during its rehabilitation by such things as a water bed, stone kitchen countertop, tile flooring, or heavy stove and oven, a quantitative analysis should be made of all the structural members involved. Simple calculations may be made in accordance with *Ambrose's Simplified Engineering for Architects and Builders* or, when wood-supported spans are involved, the use of the span tables in CABO *One- and Two-Family Dwelling Code*, the *International Residential Code for One- and Two-Family Dwellings*, or the local building code may be sufficient. More complex calculations should be performed by a qualified structural engineer in accordance with ASCE 11, *Guideline for Structural Condition Assessment of Existing Buildings.*

4.1
Seismic Resistance

If the building is in seismic zones 2B, 3, and 4 (California, Idaho, Nevada, Oregon, Washington, and portions of Alaska, Arizona, Arkansas, Hawaii, Missouri, Montana, New Mexico, Utah, and Wyoming), have a structural engineer check the following conditions for structural vulnerability. Note that wood frame buildings with brick or stone veneer are still considered wood frame.

- **Wood frame buildings that are not physically anchored** to their foundations. Such buildings may be vulnerable to shifting or sliding.
- **Wood frame buildings** and wood-framed portions (porches, for example) or other buildings when they are **supported above ground** on either short

wood studs (cripple walls) or on piers of stone, masonry, or concrete. Such buildings may be vulnerable to tilting or falling over.

- **Unreinforced and inadequately reinforced masonry buildings.** Such buildings may be vulnerable to total or partial collapse due to inadequate reinforcement or to inadequate anchorage of roofs and walls to the floors. Use as a reference Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings, Appendix Chapter 1 of the *Uniform Code for Building Conservation*.
- **Buildings of any type that have irregular shapes.** Such buildings may be vulnerable to partial collapse.
- **Wood frame and masonry buildings with more than one story above grade where the story at grade is a large unobstructed open space,** such as a garage. Such buildings may be vulnerable to collapse of the story at grade.
- **Wood frame and masonry buildings with more than one story above grade that are constructed on sloping hillsides,** and buildings of any type of construction and height that are constructed on steep slopes of 20 ºF (-7 ºC) or more. Such buildings may be vulnerable to sliding.

If the building is in seismic zone 2A (Connecticut, Massachusetts, Rhode Island, South Carolina, and portions of Georgia, Illinois, Indiana, Kansas, Kentucky, Maine, New Hampshire, New Jersey, New York, North Carolina, Oklahoma, Pennsylvania, Tennessee, Vermont, and Virginia) and has more than two stories above grade, consider having a structural engineer check for the last two conditions (large unobstructed open space at grade and sloped sites).

Buildings not of wood frame or masonry construction, such as stone, adobe, log, and post and beam structures, as well as buildings with more than one type of construction in any seismic zone, should be investigated by a structural engineer to determine their seismic vulnerability.

Masonry bearing wall buildings in seismic zones 2B, 3, and 4 should be investigated by a structural engineer for the presence of reinforcing steel. Use as a reference Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings, Appendix Chapter 1 of the *Uniform Code for Building Conservation*.

Have a structural engineer check the anchorage of wood framed structures to their foundations and investigate all such structures supported on cripple walls or piers in seismic zones 2, 3, and 4.

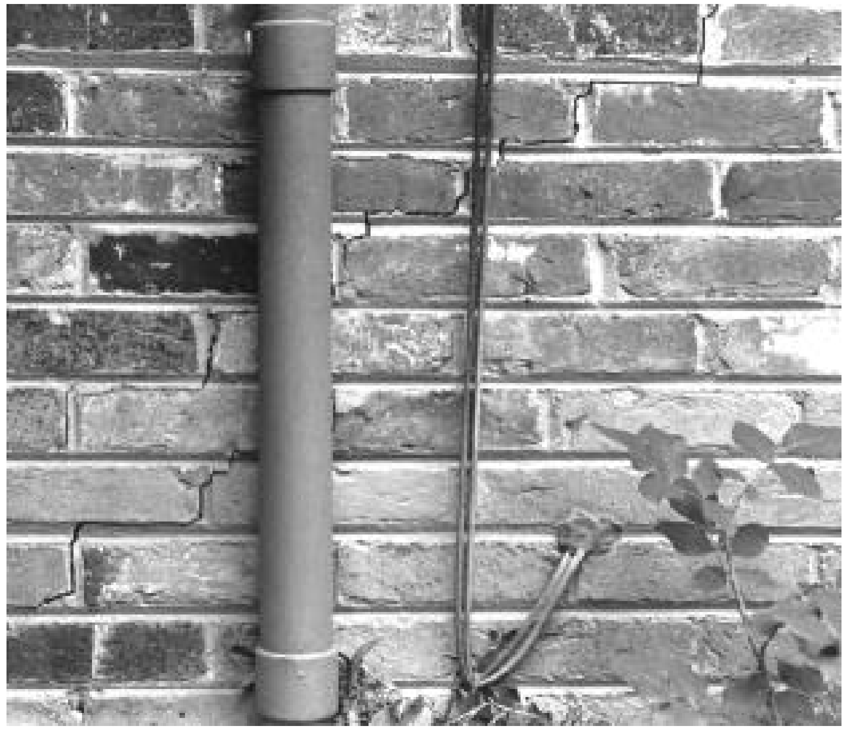
In all seismic zones, a structural engineer should investigate buildings with more than one story above grade where the story at grade is a large unobstructed open space or the building is on a sloping hillside and in seismic zones 2B, 3, and 4, buildings with an irregular shape.

4.2 Wind Resistance

The coasts of the Gulf of Mexico, the south- and mid-Atlantic coast, the coastal areas of Puerto Rico, the U.S. Virgin Islands and Hawaii as well as the U.S. territories of American Samoa and Guam are vulnerable to hurricanes in the late summer and early fall. Hurricanes are large, slow moving, damaging storms characterized by gusting winds from different directions, rain, flooding, high waves, and storm surges. Winter storms along the mid- and north-Atlantic coast can be more damaging than hurricanes because of their greater frequency, longer duration, and high erosion impacts on the coastline. Even in states not normally considered susceptible to extreme wind storms, there are areas that experience dangerously high winds. These areas are typically near mountain ranges and include the Pacific Northwest coast. Other extreme wind areas include the plains states, which are especially subject to tornadoes.

In addition to the direct effects of high winds and winter on buildings, hurricanes and other severe storms generate airborne debris that can damage buildings. Debris, such as small stones, tree branches, roof shingles and tiles, building parts and other objects, is picked up by the wind and moved with enough force to damage and even penetrate windows, doors, walls, and roofs. When a building's exterior envelope is breached by debris, the building can become pressurized, subjecting its walls and roof to much higher damaging wind pressures. In general, the stronger the wind, the larger and heavier the debris it can carry and the greater the risk of severe damage.

If the building is in a hurricane or high-wind region, have a structural engineer check its structural system for continuity of load path, including resistance to uplift forces. If there is an accessible attic, check for improper attachment of the roof sheathing to the roof framing members by looking for unengaged or partially engaged nails. Check for the presence of hurricane hold-down clips for joists, rafters, and trusses at the exterior wall. Examine the gable end walls and the roof trusses for lateral bracing. Check to see whether the exterior wall and other load-bearing walls are securely attached to the foundation.



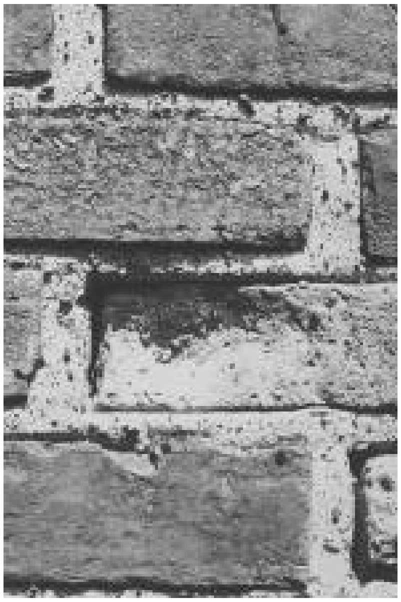
A common masonry wall crack probably caused by thermal or moisture expansion. If possible, monitor such cracks over a period of time to see if they're active. Active cracks should be sealed with a flexible sealant; inactive cracks may be pointed.

4.3 Masonry, General

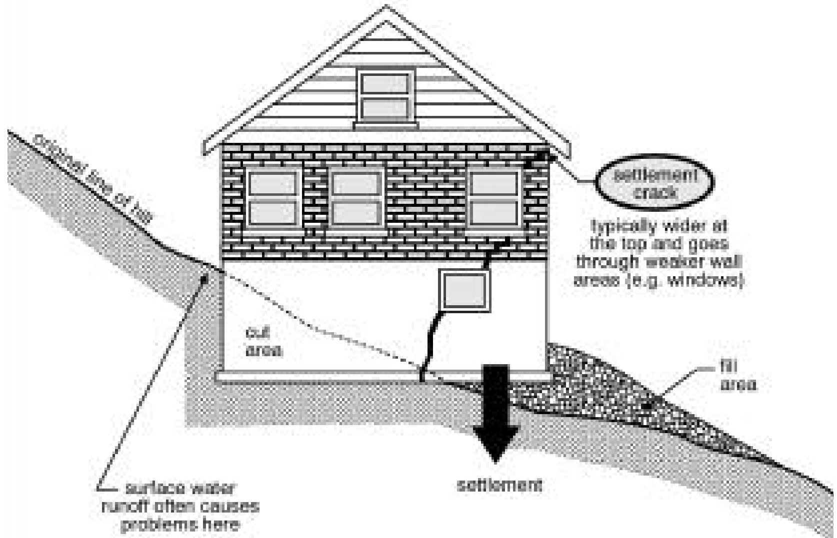
All exposed masonry should be inspected for cracking, spalling, bowing (bulges vertically), sweeping (bulges horizontally), leaning, and mortar deterioration. Before beginning a detailed masonry inspection, determine which walls are load-bearing and which are not. Usually this can be done by examining the beams and joists in the building's basement or crawl space or attic. Note also whether the walls are solid masonry or masonry cavity, or whether they are non-structural brick or stone veneer. The overall quality of the building's construction, and often that of its neighborhood, will be a good indicator of the condition of its masonry.

There may be a substantial difference in the masonry walls in buildings built during the last 40 to 50 years compared to those constructed earlier. Walls became thinner as designers began to exploit more effectively the compressive strength of masonry by using higher strength masonry materials and mortars. This change came at the expense of flexibility as such walls are often more brittle than their massive ancestors and, therefore, more subject to stress-induced damage.

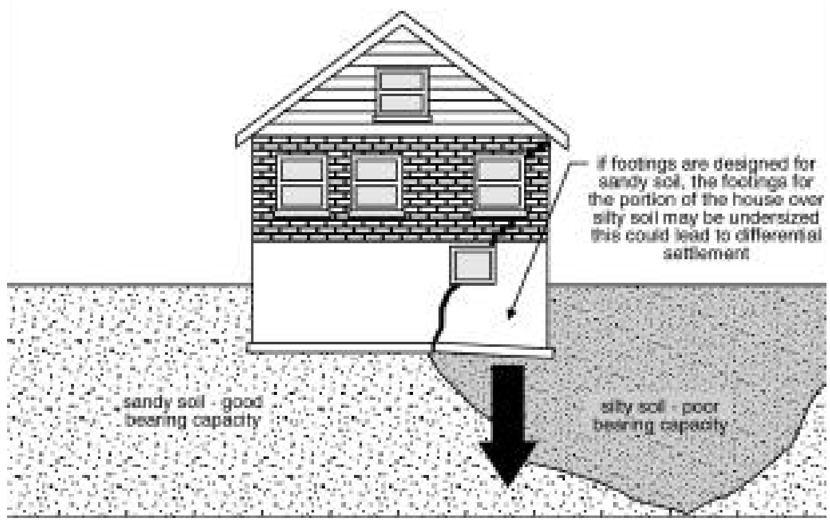
Tests: Two methods of testing are sometimes useful for assessing masonry. Probe holes can be drilled through the joints or masonry units with a masonry bit and probed with a stiff wire (or, if available, a fiber optic device) to determine a wall's thickness and the adequacy of its mortar. The probe holes are patched after the investigation has been completed. A hammer test can be used to determine the structural soundness of masonry units and their bond to the mortar. The masonry is tapped lightly with a hammer and the resonance of the sound produced is evaluated. Two tests may also be useful: ASTM E518, *Standard Test Methods for Flexural Bond Strength of Masonry*, and ASTM E519, *Standard Test Method for Diagonal Tension (Shear) in Masonry Assemblages*. See a qualified masonry consultant for the proper use of these tests on existing masonry.



The brick shown here is highly spalled from the effects of excessive moisture penetration and subsequent freezing. The damage cannot be repaired, although individual bricks can be replaced and the mortar pointed. The new mortar should be of the same composition as the old.



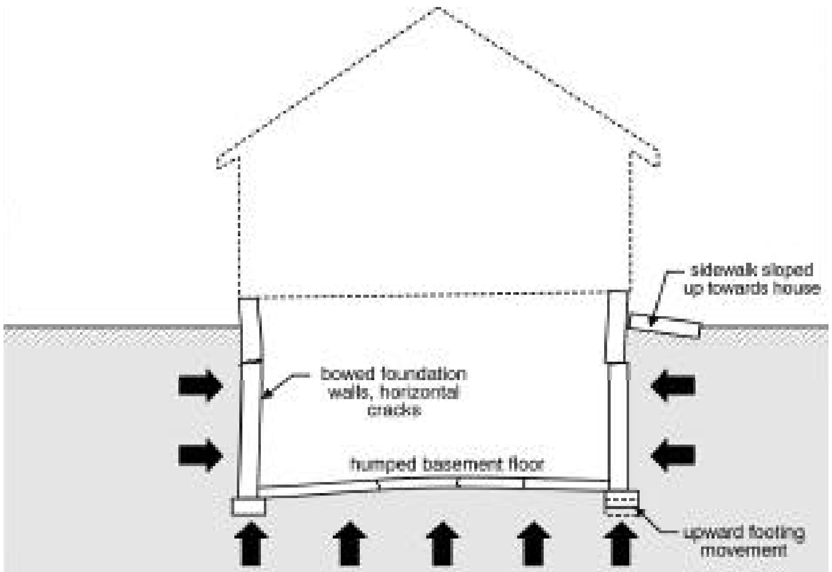
Building settlement due to cut and fill excavation



Differential settlement caused by variable soil types

- **Masonry cracking.** Although masonry can deform elastically over long periods of time to accommodate small amounts of movement, large movements normally cause cracking. Cracks may appear along the mortar joints or through the masonry units. Cracking can result from a variety of problems: differential settlement of foundations, drying shrinkage (particularly in concrete block), expansion and contraction due to ambient thermal and moisture variations, improper support over openings, the effects of freeze-thaw cycles, the corrosion of iron and steel wall reinforcement, differential movement between building materials, expansion of salts, and the bulging or leaning of walls. These problems are more fully discussed in Sections 4.4 and 4.5.

  Cracks should always be evaluated to determine their cause and whether corrective action is required. Look for



Evidence of frost heaving

An extreme case of structural failure in a masonry wall due to foundation settlement. The wall and foundation must be completely rebuilt.

signs of movement. A clean crack indicates recent movement; a dirty or previously filled crack may be inactive (a pocket lens may be useful for such an examination). Correlate the width of larger cracks to the age of the building. A one-half-inch crack in a new building may be a sign of rapid settlement, but in a building 50 years old, it may indicate a very slow movement of only 1/100 of an inch (0.25 mm) per year. In each case the cause and treatment may differ.

Test: Crack movement can be measured with a commercially available joint movement indicator. This device is temporarily fastened over the crack and a scribe records movement over a period of time. Cyclical movements may take six months or more to measure, but diurnal movements can be recorded over a few days. Hand measurements can also be made of crack movements, but these will be less precise and require repeated field visits.

Cracks associated with thermal expansion and contraction may open and close with the season. These are cyclical cracks, which may gradually expand as accumulating mortar debris jams them farther apart after each cycle. Such cracks should be cleaned and protected by flexible sealants; remortaring cyclical cracks will hold them open and cause more cracking.

When there are masonry problems, it is advisable to procure the services of a structural engineer. If problems appear to be due to differential settlement, a soils engineer also may be required.

- **Mortar deterioration.** The two important qualities of mortar are its ability to bond to masonry and its internal strength. A sign of poorly made mortar may be random cracking at the bond joint. Until about the end of the 19th century, the standard mortar for masonry was a mixture of sand and pure lime or lime-possolan-sand. These low strength mortars gave masonry the ability to absorb considerable strain. Accordingly, the tendency to crack was reduced and when cracks did appear in the mortar joints, they were to a great extent capable of chemical reconstitution or "self healing." Thus, the age of the building may be a good clue in evaluating its mortar problems. Older mortar (or mortar of any age that uses hydrated lime) will be softer and may require pointing, but otherwise may be responsible for a sound wall.

  Most often, mortar deterioration is found in areas of excessive moisture, such as near leaking downspouts, below windows, and at tops of walls. In such cases the remedy is to redirect the water flow and point the joints. Pointing should be performed with mortar of a composition similar to or compatible with the original mortar. The use of high strength mortar to point mortar of a lower strength can do serious damage to the masonry since the pointing can't "flex" with or act in a similar way to the rest of the joint. It is useful to remember that mortar acts as a drainage system to equalize hydrostatic pressure within the masonry. Nothing should be done to reduce its porosity and thereby block water flow to the exterior surface.

  Test: To determine the composition (percentage of lime and other materials) of existing mortar, remove a sample and have it chemically analyzed by a testing laboratory. This should be done under the supervision of a qualified structural engineer.

- **Deterioration of brick masonry units.** The spalling, dusting, or flaking of brick masonry units may be due to either mechanical or chemical damage. Mechanical damage is caused by moisture entering the brick and freezing, resulting in spalling of the brick's outer layers. Spalling may continue or may stop of its own accord after the outer layers that trapped the interior moisture have broken off. Chemical damage is due to the leaching of chemicals from the ground into the brick, resulting in internal deterioration. External signs of such deterioration are a dusting or flaking of the brick.

  Very little can be done to correct existing mechanical and chemical damage except to replace the brick. Mechanical deterioration can be slowed or stopped by directing water away from the masonry surface and by pointing mortar joints to slow water entry into the wall. Surface sealants (damp proofing coatings) are rarely effective and may hasten deterioration by trapping moisture or soluble salts that inevitably penetrate the wall and in turn cause further spalling. Chemical deterioration can be slowed or stopped by adding a damp proof course (or injecting a damp proofing material) into the brick wall just above the ground line. Consult a masonry specialist for this type of repair.

4.4 Masonry Foundations and Piers

Inspect stone, brick, concrete, or concrete block foundations for signs of the following problems (this may require some digging around the foundation):

- **Problems associated with differential settlement.** Uneven (differential) settlement can be a major structural problem in small residential buildings, although serious settlement problems are relatively uncommon. Many signs of masonry distress are incorrectly diagnosed as settlement-related when in fact they are due to moisture and thermal movements.

  Indications of differential settlement are vertical distortion or cracking of masonry walls, warped interior and exterior openings, sloped floors, and sticking doors and windows. Settlement most often occurs early in the life of a building or when there is a dramatic change in underground conditions. Often such settlement is associated with improper foundation design, particularly inadequate footers and foundation walls. Other causes of settlement are:

❑ ***soil consolidation*** under the footings

❑ ***soil shrinkage*** due to the loss of moisture to nearby trees or large plants

❑ ***soil swelling*** due to inadequate or blocked surface or house drainage

❑ ***soil heaving*** due to frost or excessive root growth

❑ ***gradual downward drift of clay*** soils on slopes

❑ ***changes in water table*** level

❑ ***soil erosion*** around footers from poor surface drainage, faulty drains, leaking water mains or other underground water movements (occasionally, underground water may scour away earth along only one side of a footer, causing its rotation and the subsequent buckling or displacement of the foundation wall above)

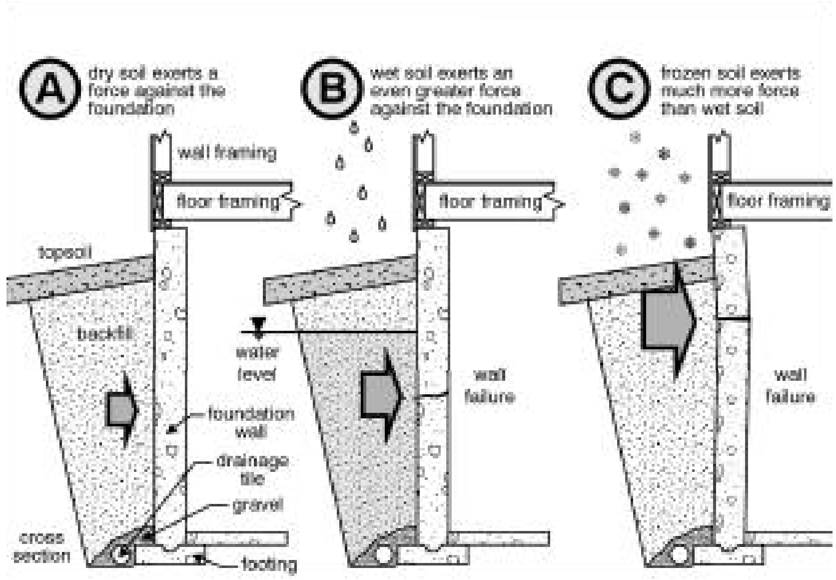
❑ ***soil compaction*** or movement due to vibration from heavy equipment, vehicular traffic, or blasting, or from ground tremors (earthquakes).

This pier has been overstressed by movement of the porch and column. The entire assembly should be rebuilt.

Gradual differential settlement over a long period of time may produce no masonry cracking at all, particularly in walls with older and softer bricks and high lime mortars; the wall will elastically deform instead. More rapid settlements, however, produce cracks that taper, being largest at one end and diminishing to a hairline at the other, depending on the direction and location of settlement below the wall. Cracking is most likely to occur at corners and adjacent to openings, and usually follows a rough diagonal along mortar joints (although individual masonry units may be split). Settlement cracks (as opposed to the similar-appearing shrinkage cracks that are especially prevalent in concrete block) may extend through contiguous building elements such as floor slabs, masonry walls above the foundation, and interior plaster work. Tapering cracks, or cracks that are nearly vertical and whose edges do not line up, may occur at the joints of projecting bay windows, porches, and additions. These cracks indicate differential settlement due to inadequate foundations or piers under the projecting element.

Often settlement slows a short time after construction and a point of equilibrium is reached in which movement no longer occurs. Minor settlement cracking is structurally harmful only if long-term moisture leakage through the cracks adversely affects building elements. Large differential settlements, particularly between foundation walls and interior columns or piers, are more serious because they will cause movements in contiguous structural elements such as beams, joists, floors, and roofs that must be evaluated for loss of bearing and, occasionally, fracture.

Should strengthening of the foundation be required, it can be accomplished by the addition of new structural elements, such as pilasters, or by pressure-injecting concrete epoxy grout into the foundation wall. If movement continues and cracking is extensive, it is possible that the problem can only be rectified by underpinning. Older buildings with severe settlement problems may be very costly to repair. Seek the advice of a structural or soils engineer in such cases.



The effect of soil pressure on foundation walls

- **Problems associated with masonry piers.** Masonry piers are often used to support internal loads on small residential buildings or to support projecting building elements such as bay windows, porches, and additions. In some cases they support the entire structure. Piers often settle differentially and over a long period of time (particularly when they are exposed to the weather) they tend to deteriorate. Common problems are:

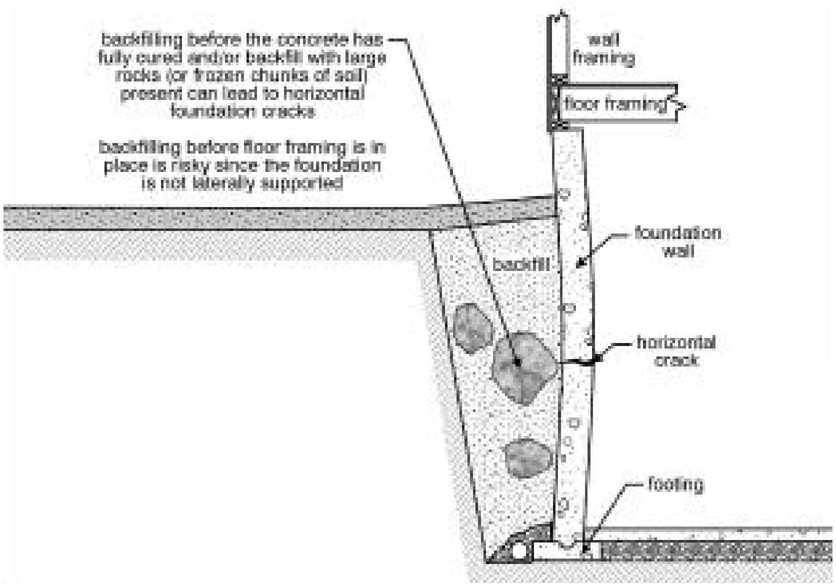
❑ ***Settlement or rotation of the pier footing,*** which causes a lowering or tilting of the pier and subsequent loss of bearing capacity. Wood frame structures adjust to this condition by flexing and redistributing their loads or by sagging (see Section 4.7). Masonry walls located over settled piers will crack.

❑ ***Frost heaving of the footing or pier,*** a condition caused by the lack of an adequate footing or one of insufficient depth. This will result in raising or tilting the pier, and in structural movement above it similar to that caused by settlement or rotation of the footing. Such a condition is most common under porches.

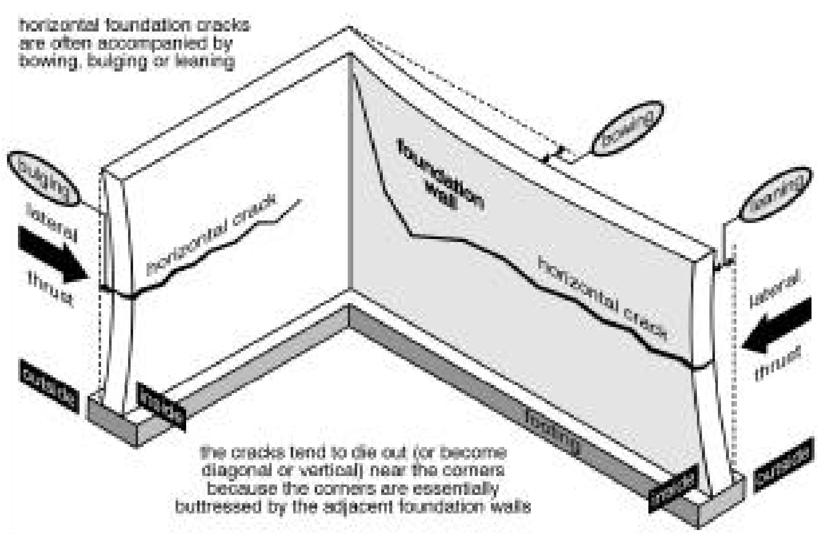
❑ ***Physical deterioration of the pier*** due to exposure, poor construction, or overstressing. Above-ground piers exposed to the weather are subject to freeze-thaw cycles and subsequent physical damage. Piers for many older residential structures are often of poorly constructed masonry that deteriorates over the years. A sign of overstressing of piers is vertical cracking or bulging.

❑ ***Loss of bearing of beams, joists, or floors*** due to the above conditions or due to movements of the structure itself.

Piers should be examined for plumbness, signs of



How backfilling can affect foundation walls



How horizontal cracks relate to foundation wall movement

settlement, condition, and their adequacy in accepting bearing loads. Check their width to height ratio, which should not exceed 1:10. Those that are deficient should be repaired or replaced. When appearance is not a factor (as is often the case), piers can be supplemented by the addition of adjacent supports.

- **Cracking associated with drying shrinkage in concrete block foundation walls.** The shrinkage of concrete block walls as they dry in place often results in patterns of cracking similar to that caused by differential settlement: tapering cracks that widen as they move diagonally upward. These cracks usually form during the building's first year, and in existing buildings will appear as "old" cracks and exhibit no further movement. Although such cracks are often mistaken for settlement cracks, shrinkage cracks usually occur in the middle one-third of the wall and the footer beneath them remains intact. Shrinkage cracking is rarely serious, and in an older building may have been repaired previously. If the wall is unsound, its structural integrity sometimes can be restored by pressure-injecting concrete epoxy grout into the cracks or by adding pilasters.
- **Sweeping or horizontal cracking of the foundation walls.** The sweeping or horizontal cracking of brick or concrete block foundation walls may be caused by improper backfilling, vibration from the movement of heavy equipment or vehicles close to the wall, or by the swelling or freezing and heaving of water saturated soils adjacent to the wall. Like drying shrinkage, sweeping or horizontal cracking may have occurred during the original construction and been compensated for at that time. Such distress, however, is potentially serious as it indicates that the vertical supporting member (the foundation wall) that is carrying a portion of the structure above is "bent" or

"broken." It may be possible to push the wall back into place by careful jacking, and then reinforcing it with the addition of interior buttresses or by pressure-injecting concrete epoxy grout into the wall. If outside ground conditions allow, the wall can be relieved of some lateral pressure by lowering the ground level around the building. When expansive soils are suspected as the cause of the cracking, examine the exterior for sources of water such as broken leaders or poor surface drainage. Suspect frost heaving if the damage is above local frost depth or if it occurred during an especially cold period.

4.5 Above-Ground Masonry Walls

Inspect above-ground stone, brick, or concrete block walls for signs of the following problems:

- **Brick wall cracking associated with thermal and moisture movement.** Above-ground brick walls expand in warm weather (particularly if facing south or west) and contract in cool weather. This builds up stresses in the walls that may cause a variety of cracking patterns, depending on the configuration of the wall and the number and location of openings. Such cracks are normally cyclical and will open and close with the season. They will grow wider in cold weather and narrower in hot weather. Look for cracking at the corners of long walls, walls with abrupt changes in cross section (such as at a row of windows), walls with abrupt turns or jogs, and in transitions from one- to two-story walls. These are the weak points that have the least capacity for stress. Common moisture and thermal movement cracking includes:

  ❑ ***Horizontal or diagonal cracks near the ground at piers in long walls*** due to horizontal shearing stresses between the upper wall and the wall where it enters the ground. The upper wall can thermally expand but its movement at ground level is moderated by earth temperatures. Such cracks extend across the piers from one opening to another along the line of least resistance. This condition is normally found only in walls of substantial length.

  ❑ ***Vertical cracks near the end walls*** due to thermal movement. A contracting wall does not have the tensile strength to pull its end walls with it as it moves inward, causing it or the end walls to crack vertically where they meet.

  ❑ ***Vertical cracks in short offsets and setbacks*** caused by the thermal expansion of the longer walls that are adjacent to them. The shorter walls are "bent" by this thermal movement and crack vertically.

  ❑ ***Vertical cracks near the top and ends of the facade*** due to the thermal movement of the wall. This may indicate poorly bonded masonry. Cracks will tend to follow openings upward.

  ❑ ***Cracks around stone sills or lintels*** caused by the expansion of the masonry against both ends of a tight-fitting stone piece that cannot be compressed.

  Cracks associated with thermal and moisture movement often present only cosmetic problems. After their cause has been determined, they should be repaired with a flexible sealant, since filling such cyclic cracks with mortar will simply cause the masonry to crack in another location. Cracks should be examined by a structural engineer and may require the installation of expansion joints.

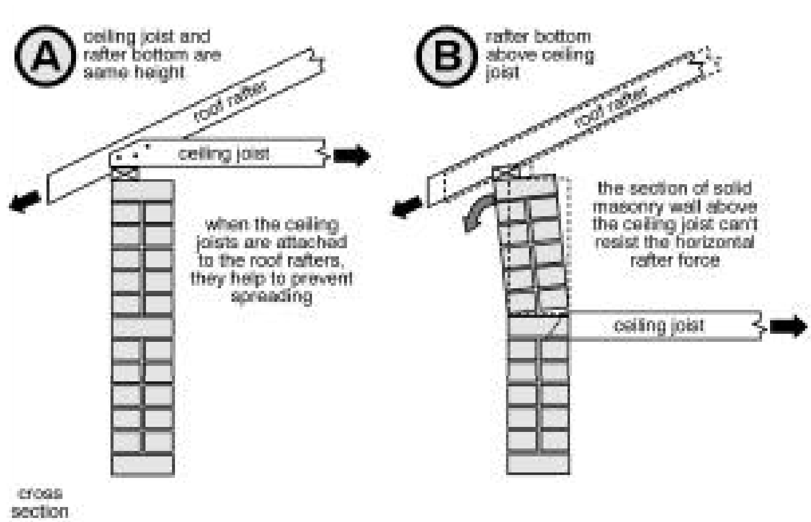
- **Brick wall cracking associated with freeze-thaw cycles and corrosion**. Brick walls often exhibit distress due to the expansion of freezing water or the rusting of embedded metals. Such distress includes:

  ❑ ***Cracking around sills, cornices, eaves, chimneys, parapets, and other elements subject to water penetration,*** which is usually due to the migration of water into the masonry. The water expands upon freezing, breaking the bond between the mortar and the masonry and eventually displacing the masonry itself. The path of the water through the wall is indicated by the pattern of deterioration.

  ❑ ***Cracking around iron or steel lintels,*** which is caused by the expansive force of

Despite the loss of masonry, this arch is intact and can be repaired with matching bricks.

corrosion that builds up on the surface of the metal. This exerts great pressure on the surrounding masonry and displaces it, since corroded iron can expand to many times its original thickness. Structural iron and steel concealed within the masonry, if exposed to moisture, can also corrode, and cause cracking and displacement of its masonry cover. Rust stains usually indicate that corrosion is the cause of the problem. Check to make sure the joint between the masonry and the steel lintel that supports the masonry over an opening is clear and



Walls that extend above ceiling joists

open. If the joint has been sealed, the sealant or mortar should be removed.

These conditions usually can be corrected by repairing or replacing corroded metal components and by repairing and pointing the masonry. Where cracking is severe, portions of the wall may have to be reconstructed. Cracks should be examined by a structural engineer.

- **Wall cracking or displacement associated with the structural failure of building elements.** Structure-related problems, aside from those caused by differential settlement or earthquakes, are usually found over openings and (less commonly) under roof eaves or in areas of structural overloading. Such problems include:

❑ ***Cracking or displacement of masonry over openings,*** resulting from the deflection or failure of the lintels or arches that span the openings. In older masonry walls with wood lintels, cracking will occur as the wood sags or decays. Iron and steel lintels also cause cracking as they deflect over time. Concrete and stone lintels occasionally bow and sometimes crack.

Masonry arches of brick or stone may crack or fail when there is wall movement or when their mortar joints deteriorate.

When such lintel deflections or arch failures occur, the masonry above may be supporting itself and will exhibit step cracks beginning at the edges of the opening and joining in an inverted "V" above the opening's midpoint. Correcting such problems usually means replacing failed components and rebuilding the area above the opening.

Occasionally masonry arches fail because the walls that surround them cannot provide an adequate counterthrust to the arch action. This sometimes happens on windows that are too close to the corners of a wall or bay. In such cases, the masonry arch pushes the unbraced wall outward, causing it to crack above the opening near or just above the spring of the arch. When this occurs, the end walls must be strengthened.

❑ ***Cracking or outward displacement under the eaves of a pitched roof*** due to failure in the horizontal roof ties that results in the roof spreading outward. The lateral thrust of the roof on the masonry wall may cause it to crack horizontally just below the eaves or to move outward with the roof. The roof will probably be leaking as well. When this occurs, examine the roof structure carefully to ascertain whether there is a tying failure. If so, additional horizontal ties or tension members will have to be added and, if possible, the roof pulled back into place. The damaged masonry can then be repaired. The weight also can be transferred to interior walls. Jacking of the ridge and rafters is possible too.

❑ ***Cracking due to overloading (or interior movement),*** which is fairly uncommon, but may be caused by a point load (often added during an alteration) bearing on a wall of insufficient thickness. If the member has been concealed, such a problem will be difficult to investigate. The addition of interior wall supports or bracing, however, may correct the source of the problem by relieving the load.

❑ ***Cracking due to ground tremors from nearby construction, heavy vehicular traffic, or earthquakes,*** which is roughly vertical in direction and occurs more toward the center of the building. Buildings exhibiting such cracking should be treated on a case-by-case basis, since serious structural damage has possibly taken place. Consult a structural engineer experienced in such matters.

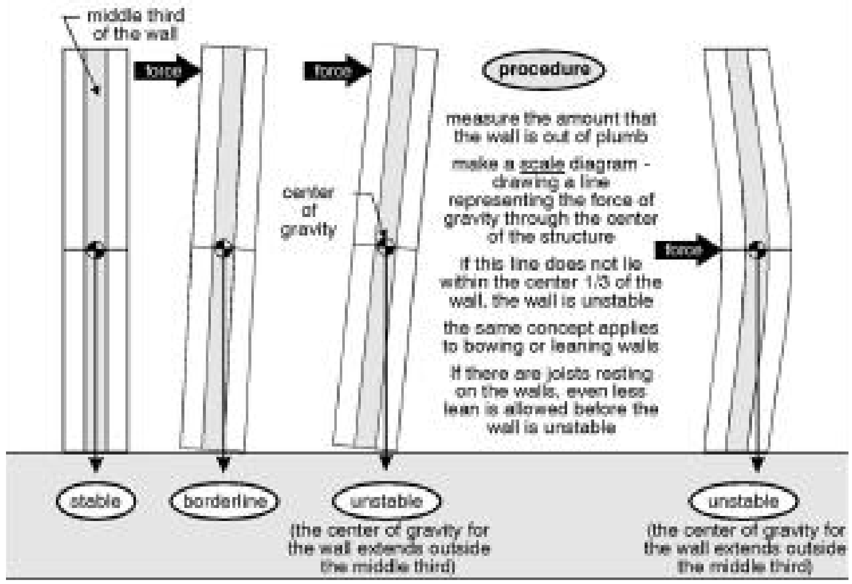
- **Bulging of walls.** Masonry walls sometimes show signs of bulging as they age. A wall itself may bulge, or the bulge may only be in the outer withe. Bulging often takes place so slowly that the masonry doesn't crack, and therefore it may go unnoticed over a long period of time. The bulging of the whole wall is usually due to thermal or moisture expansion of the wall's outer surface, or to contraction of the inner withe. This expansion is not completely reversible because once the wall and its associated structural components are "pushed" out of place, they can rarely be completely "pulled" back to their original positions.

The effects of the cyclical expansion of the wall are cumulative, and after many years the wall will show a detectable bulge. Inside the building, separation cracks will occur on the inside face of the wall at floors, walls, and ceilings.

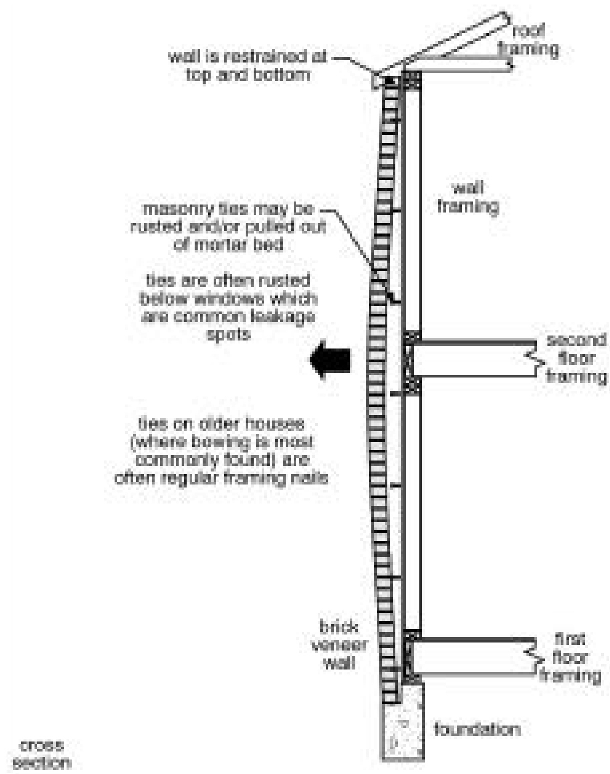
Bulging of only the outer masonry withe is usually due to the same gradual process of thermal or moisture expansion: masonry debris accumulates behind the bulge and prevents the course from returning to its original position. In very old buildings, small wall bulges may result from the decay and collapse of an internal wood lintel or wood-bonding course, which can cause the inner course to settle and the outer course to bulge outward.

When wall bulges occur in solid masonry walls, the walls may be insufficiently tied to the structure or their mortar may have lost its bond strength. Large bulges must be tied back to the structure; the star-shaped anchors on the exterior of masonry walls of many older buildings are examples of such ties (check with local building ordinances on their use). Small bulges in the outer masonry course often can be pinned to the inner course or dismantled and rebuilt.

- **Leaning of walls**. Masonry walls that lean (invariably outward) represent a serious, but uncommon, condition that is usually caused by poor design and construction practices, particularly inadequate



The V3 rule for wall stability



A bowed brick veneer wall

A deteriorated parapet wall that badly needs repointing. Fortunately, the wall has not yet exhibited serious movement, but it will if left unrepaired.

structural tying or poor foundation work. When tilting or leaning occurs, it is often associated with parapets and other upper wall areas, especially those with heavy masonry cornices cantilevered from the wall. Leaning can produce separation cracking on the end walls and cracking on the interior wall face along floors, walls, and ceilings. Leaning walls can sometimes be tied back to the structure and thereby restrained. In such cases, the bearing and connections of interior beams, joists, floors, and roof should be examined.

When large areas or whole walls lean, rebuilding the wall, and possibly the foundation, may be the only answer.

Test: A wall is usually considered unsafe if it leans to such an extent that a plumb line passing through its center of gravity does not fall inside the middle one-third of its base (called the V3 rule). In such an event, consult a structural engineer.

- **Problems associated with brick veneer walls.** Brick veneer walls are subject to the forces of differential settlement, moisture- and thermal-related cracking, and the effects of freezing and corrosion. Common problems peculiar to brick veneer walls are:

❑ ***Cracks caused by wood frame shrinkage,*** which are most likely to be found around fixed openings where the independent movement of the veneer wall is restrained. These cracks are also formed early in the life of the building and can be repaired by pointing.

❑ ***Bulging,*** which is caused by inadequate or deteriorated ties between the brick and the wall to which it is held.

❑ ***Vertical cracking at corners or horizontal cracking near the ground caused by thermal movement of the wall,*** which is similar to that in solid masonry or masonry cavity walls, but possibly more pronounced in well-insulated buildings because of the reduction in the moderating effect from interior temperatures. Thermal cracks are cyclic and should be filled with a flexible sealant. Where there is severe cracking, expansion joints may have to be installed.

- **Problems associated with parapet walls.** Parapet walls often exhibit signs of distress and deterioration due to their full exposure to the weather, the splashing of water from the roof, differential movement, the lack of restraint by vertical loads or horizontal bracing, and the lack of adequate expansion joints. Typical parapet problems include:

  ❑ ***Horizontal cracking at the roof line*** due to differential thermal movement between the roof line and the wall below, which is exposed to moderating interior temperatures. The parapet may eventually lose all bond except that due to friction and its own weight and may be pushed out by ice formation on the roof.

  ❑ ***Bowing*** due to thermal and moisture expansion when the parapet is restrained from lengthwise expansion by end walls or adjacent buildings. The wall will usually bow outward since that is the direction of least resistance.

  ❑ ***Overhanging the end walls*** when the parapet is not restrained on its ends. The problem is often the most severe when one end is restrained and the other is not.

  ❑ ***Random vertical cracking near the center of the wall*** due to thermal contraction.

  ❑ ***Deterioration of parapet masonry*** due to excessive water penetration through inadequate coping or flashing, if any, which when followed by freeze-thaw cycles causes masonry spalling and mortar deterioration.

  Carefully examine all parapet walls. Check their coping and flashing for watertightness and overall integrity. In some cases, structurally unsound parapets can be stabilized and their moisture and thermal movements brought under control by the addition of expansion joints. In other cases, the wall may require extensive repair or rebuilding. All repairs should include adequate expansion joints.

- **Fire damage to brick masonry walls**. Masonry walls exposed to fire will resist damage in proportion to their thickness. Examine the texture and color of the masonry units and probe their mortar. If they are intact and their basic color is unchanged, they can be considered serviceable. If they undergo a color change, consult a qualified structural engineer for further appraisal. Hollow masonry units should be examined for internal cracking, where possible, by cutting into the wall. Such units may need replacement if seriously damaged. Masonry walls plastered on the fire side may have been sufficiently protected and will have suffered few, if any, ill effects. See also Appendix A, Effects of Fire on Structural Systems.

4.6 Chimneys

Chimneys, like parapets, have greater exposure to the weather than most building elements, and have no lateral support from the point where they emerge from the roof. Common problems are:

- **Differential settlement of the chimney** caused by an inadequate foundation. If the chimney is part of an exterior wall, it will tend to lean away from the wall and crack where it is joined to other masonry. In some cases, the chimney can be tied to the building. Consult a structural engineer.

- **Deterioration of masonry near the top** due to a deteriorated cap that allows water into the masonry below and exposes it to freeze-thaw cycles. This cap is often made of a tapered layer of mortar, called a cement wash, that cracks and breaks after several years. Check the cap. If it is mortar and the chimney has a hood, repair the mortar. If it is mortar and the chimney does not have a hood, replace the mortar with a stone or concrete cap. If the cap is stone or concrete, repair it or replace it. Also see Section 2.9.

- **Leaning of the chimney where it projects above the roof** due to deteriorated mortar joints caused either by wind-induced swaying of the chimney or by

A deteriorated chimney cap. Mortar, rather than concrete, is often improperly used (as it was here) to cap the chimney. The masonry below will eventually deteriorate unless the cap is replaced.

sulfate attack from flue gases and particulates within the chimney when the chimney is not protected by a tight flue liner. Deteriorated mortar joints should be pointed, and unstable chimneys or those with a noticeable lean should be dismantled and rebuilt. Chimney-mounted antennas should be removed if they appear to be causing structural distress.

4.7 Wood Structural Components

Wood structural components in small residential buildings are often directly observable only in attics, crawl spaces, or basements. Elsewhere they are concealed by floor, wall, and ceiling materials. Common signs of wood structural problems are sloping or springy floors, wall and ceiling cracks, wall bulges, and sticking doors and windows, although many such problems may be attributable to differential settlement of the foundation or problems with exterior masonry bearing walls (see Sections 4.4 and 4.5).

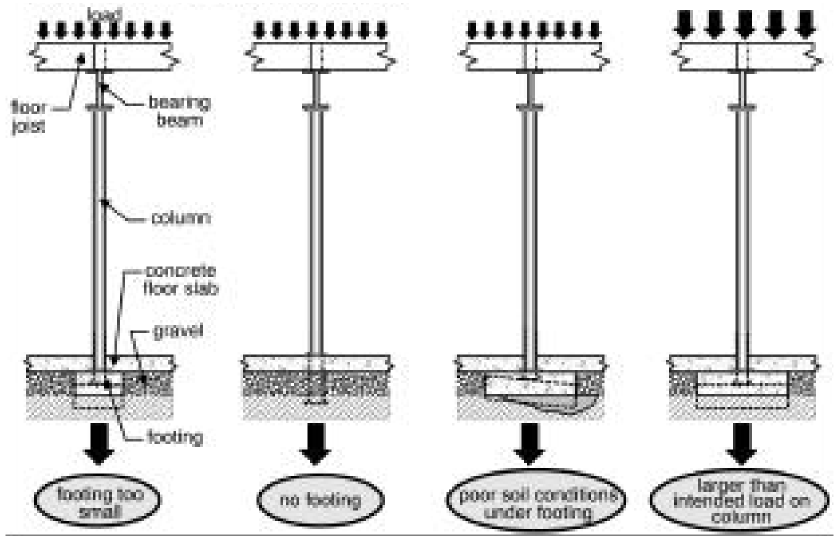
When failures in wood structural components occur, they usually involve individual wood members and rarely result in the failure of the entire structure. Instead, an elastic adjustment takes place that redistributes stresses to other components in the building. The four types of problems commonly associated with such components in small residential buildings are 1) deflection and warping, 2) fungal and insect attack, 3) fire, and 4) connection failure and improper alteration. Inspect for these problems as follows:

- **Deflection, warping, and associated problems.** Some deflection of wood structural components or assemblies is common in older buildings and normally can be tolerated, unless it causes loss of bearing or otherwise weakens connections or it opens watertight joints in roofs or other critical locations. Deflection can be arrested by the addition of supplemental supports or strengthening members. Once permanently deflected, however, a wood structural component cannot be straightened.

  Warping of individual wood components almost always takes place early in the life of a building. It will usually cause only superficial damage, although connections may be loosened and occasionally there may be a loss of bearing.

  Look for the following problems associated with wood structural components:

  ❑ ***Loss of bearing in beams and joists over foundation walls, piers, or columns*** due to movements caused by long-term deflection of the wood beams or joists, differential movements of the foundation elements, localized crushing, or wood decay. Check the bearing and connections of all exposed structural elements that are in contact with the foundation and look for



Some reasons for column settling

The sagging floor is caused by settlement of a basement support. It may be possible to jack the floor and its adjacent wall into a level position, but this should be done slowly and carefully.

symptoms of bearing failure where these elements are concealed, such as bowing or sloping in the floor above, and cracking or tilting of foundation walls, piers, and columns.

❑ ***Sagging, sloping, or springing of floors*** due to foundation settlement, excessive spans, cut or drilled structural elements, overloading, or removal of supporting walls or columns on the floor above or below. Each case must be diagnosed separately. In older buildings, columns or walls that helped support or stabilize the floor above may have been removed during a previous alteration; conversely, partitions, bathrooms, kitchens, or similar remodelings may have been placed on a floor not designed to support such additional loads. Depending on the circumstances, sagging, sloping, or springing floors may be anything from an annoyance to an indication of a potentially serious structural problem. Check below the floor for adequate supports and bearing and for sound connections between structural elements. Look for signs of supporting walls that have been removed, missing joist hangars, and for inappropriate cuts or holes in joists for plumbing, electric, or HVAC lines or ducts. Also look for signs of insect or fungal attack.

Test: Roll a marble or similar heavy round object over suspect floor areas to determine the direction and degree of slope, if any. A carpenter's level also can be used. For large or complex areas, a transit or laser level is more appropriate.

❑ ***Floor sagging near stairway openings*** due to gradual deflection of the unsupported floor framing. This is a common problem in older houses and usually does not present a structural problem. Correction, if desired, will be difficult since the whole structural assembly surrounding the stair has deformed. Look for signs that a supporting wall below the opening has been removed. Where this has occurred, structural modification or the addition of a supporting column may be required.

❑ ***Floor sagging beneath door jambs*** resulting from improper support below the jamb. This can be a structural concern. If needed, additional bracing can be added between the joists where the sag occurs, but with some difficulty if above a finished ceiling.

❑ ***Cracking in interior walls around openings,*** which may be caused by inadequate, deflected, or warped framing around the openings; differential settlement; or on the interior of masonry load-bearing walls, by problems in the exterior masonry wall. Cracking due to framing problems is usually not serious, although it may be a cosmetic concern that can be corrected only by breaking into the wall. See Sections 4.4 and 4.5 for cracking caused by differential settlement or masonry wall problems.

❑ ***Sagging in sloped roofs*** resulting from too many layers of roofing material, failure of fire retardant plywood roof sheathing, inadequate bracing, or undersized rafters. Sometimes three or more layers of shingles are applied to a roof, greatly increasing its dead load. Or, when an attic story has been made into a habitable space or otherwise altered, collar beams or knee walls may have been removed. A number of factors, such as increases in snow and wind loads, poor structural design, and construction errors result in undersized rafters. Check for all these conditions.

❑ ***Failure of Fire Retardant Plywood (FRP)*** used at party walls between dwelling units in some townhouses, row houses, and multiple dwellings is not uncommon. Premature failure of the material is due to excessive heat in the attic space. On the exterior, sagging of the roof adjacent to a party wall often is evident. On the interior, check for darkening of the plywood surface, similar to charring, as an indication of failure that requires replacement of the FRP with a product of comparable fire resistance and structural strength.

❑ ***Spreading of the roof downward and outward*** due to inadequate tying. This is an uncommon but potentially serious structural problem. Look for missing collar beams, inadequate tying of rafters and ceiling joists at the eaves, or inadequate tying of ceiling joists that act as tension members from one side of the roof to the other. Altered trusses can also cause this problem. Check trusses for cut, failed, or removed members, and for fasteners that have failed, been completely removed, or partially disconnected. Spreading can be halted by adequate bracing or tying, but there may be damage to masonry walls below the eaves (see Section 4.5). It is possible that the roof can be jacked back to its proper position. Consult a structural engineer.

❑ ***Deflection of flat roofs*** due to too great a span, overloading, or improper support of joists beneath the roof. This is a common problem and is usually of no great concern unless it results in leaking and subsequent damage to the structure, or unless it causes water to pond on the roof, thereby creating unacceptable dead loads. In both cases, the roof will have to be strengthened or releveled.

- **Fungal and insect attack.** The moisture content of properly protected wood structural components in buildings usually does not exceed 10 to 15 percent, which is well below the 25 to 30 percent required to promote decay by the fungi that cause rot or to promote attack by many of the insects that feed on or inhabit wood. **Dry wood will never decay.**

  Inspect all structural and non-structural wood components for signs of fungus and insect infestation, including wood stains, fungi, termite shelter tubes, entry or exit holes, signs of tunneling, soft or discolored wood, small piles of sawdust or "frass," and related signs of infestation.

A common location of fungal and insect infestation is where wood door frames touch concrete or earth at grade.

Test: Probe all suspect wood with a sharp instrument and check its moisture content with a moisture meter. Wood with a meter reading of more than 20 to 25 percent should be thoroughly examined for rot or infestation. Sound wood will separate in long fibrous splinters, but decayed wood will lift up in short irregular pieces. See Appendix B, Wood Inhabiting Organisms, for more detailed information.

Exterior building areas or components that should be checked are:

❑ ***Places where wood is in contact with the ground,*** such as wood pilings, porch and deck supports, porch lattices, wood steps, adjacent fences, and nearby wood piles.

❑ ***Foundation walls*** that might harbor shelter tubes, including tubes in the cracks on wall surfaces.

❑ ***Frames and sills*** around basement or lower level window and door frames, and the base of frames around garage doors.

❑ ***Wood framing*** adjacent to slab-on-grade porches or patios.

❑ ***Wood near or in contact with roofs,*** drains, window wells, or other areas exposed to periodic wetting from rain or lawn sprinklers, etc.

Interior areas or components to be checked for rot or infestation are:

❑ ***Spaces around or within interior foundation walls*** and floors, crawl spaces, piers, columns, or pipes that might harbor shelter tubes, including cavities or cracks.

❑ ***The sill plate*** that covers the foundation wall, and joists, beams, and other wood components in contact with it.

❑ ***Wood frame basement partitions.***

❑ ***Baseboard trim*** in slab-on-grade buildings.

❑ ***Subflooring*** and joists below kitchen, bathroom, and laundry areas.

❑ ***Roof sheathing*** and framing in the attic around chimneys, vents, and other openings.

Damage to wood from fungal or insect attack usually can be repaired at a reasonable cost by replacing or adding supplemental support to affected components after the source of the problem has been corrected. Damage is rarely severe enough to seriously affect the structural stability of a building, although individual members may be badly deteriorated. Consult an exterminator when evidence of insect attack is found.

- **Fire-damaged wood.** When exposed to fire, wood first "browns," then "blackens," then ignites and begins to char at a steady rate. The charred portion of the wood loses its structural strength, but the clear wood beneath does not, unless it undergoes prolonged heating.

  The remaining strength of wood exposed to fire can be determined by removing the char and estimating the size and strength of the new cross section. Damaged structural members may be reinforced by bolting additional structural members in a configuration that restores their original design strength. Consult a structural engineer before repairing major structural beams or girders. See also Appendix A, Effects of Fire on Structural Systems.

- **Connection failure and improper alteration.** Open-web wood trusses are commonly used in small residential buildings as roof and floor structures. Those trusses with wood chords and wood webs usually use metal plate connectors. Where there is evidence of moisture, examine connectors for corrosion and for loss of embedment due to distortion of truss members. Also check glue laminated timber beams for delamination where there is evidence of moisture. Where possible, examine truss, rafter, and joist hangers for corrosion and proper nailing.

  Buildings are often altered incrementally by the addition of pipes and ducts when unfinished spaces, such as basements and attics, are made habitable or when kitchens and bathrooms are remodeled. Observe joists, rafters, and beams for holes cut through them, especially for any size cutouts at or near their top or bottom. Observe wood trusses for cuts through chords and webs of open web trusses and webs and flanges of plywood trusses.

4.8 Iron and Steel Structural Components

Metal structural components used in small residential buildings are usually limited to beams and pipe columns in basements, angles over small masonry openings, and beams over long spans elsewhere in the structure. These components are almost always made of steel, although in buildings erected before 1890 to 1900 they may be of cast or wrought iron. While cast iron is weaker in tension than steel, when found in small buildings it is rarely of insufficient strength unless it is deteriorated or damaged.

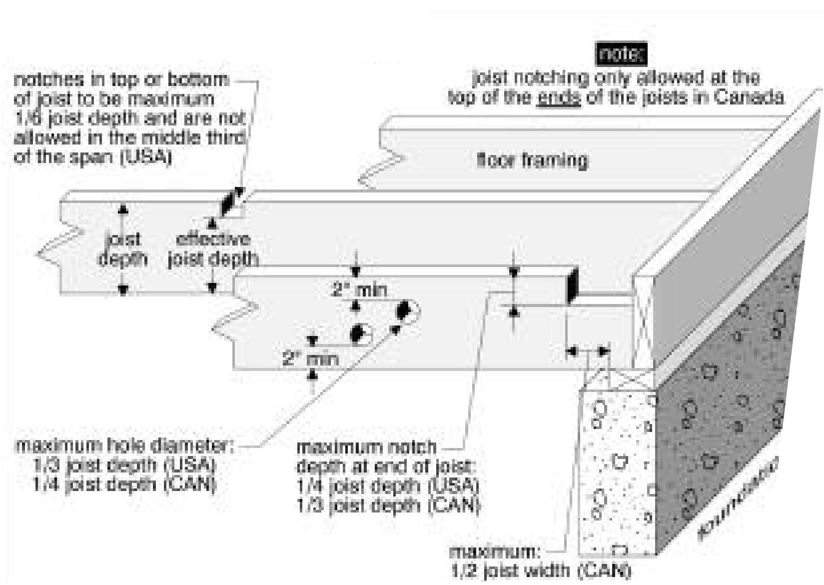
Problems with iron and steel structural components usually

This fire-damaged wood should be carefully probed to determine the extent of charring. In this case, the wood was replaced.

center on corrosion. Inspect them as follows:

- **Lintels and other embedded metal components in exterior masonry walls** can corrode and in time become severely weakened themselves. Rain and snow often contain carbonic, sulfuric, nitric, or hydrochloric acid that lowers the pH of rain water, thereby accelerating corrosion. Check all embedded iron and steel to determine its condition.

  Make sure lintels have adequate bearing. Corrosion can also displace surrounding masonry; see Section 4.5.
- **Columns** should be checked for adequate connections at



Joist notching and drilling criteria

Failure of a concrete lintel and sill due to differential settlement of the building. Permanent repairs will be quite expensive. Note the makeshift shoring of the lintel.

their base and top, and for corrosion at their base if they rest at ground level. Eccentric (off-center) loading or noticeable tilting of columns should be remedied.

- **Beams** should be checked for bearing, adequate connections to the structure, and deflection. Bearing can be significantly reduced on pilasters, piers, or columns in differentially settled buildings; inspect such conditions carefully (see Section 4.4). Beams in small residential buildings rarely deflect. If deflection is found, however, the cause should be determined and supplemental supports or plates should be added to correct the problem.
- **Fire damage to iron and steel structural components** should be carefully inspected. Iron and steel rapidly lose their load-bearing capacity when exposed to fire and will undergo considerable expansion and distortion. In general, a structural iron or steel member that remains in place with negligible or minor distortions to its web, flanges, or end connections should be considered serviceable. Sagging or bent members, or those with a loss in bearing capacity should be replaced or reinforced with supplemental plates.

Test: When the quality or composition of an iron or steel structural component is in doubt, a small sample of the metal (called a "coupon") may be removed from a structurally unimportant location and sent to a testing laboratory for evaluation. The sample should be tested in accordance with

ASTM E8, *Standard Test Methods for Tension Testing of Metallic Materials*, and ASTM E9, *Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature*. Such work should be performed under the auspices of a structural engineer.

4.9 Concrete Structural Components

Concrete is commonly used for grade and below-grade level floors and for footings. It also may be used for foundations, beams, floors above grade, porches or patios built on grade, exterior stairs and stoops, sills, and occasionally as a precast or poured-in-place lintel or beam over masonry openings. Concrete structural components are reinforced. Welded steel wire mesh is used in floors at and below grade, patios built on grade, walks and drives, and short-span, light-load lintels. All other concrete structural components usually are reinforced with steel bars.

Inspect for the following:

- **Cracking at corners or openings in concrete foundations below masonry exterior walls** due to drying shrinkage of concrete walls that are prevented from contracting by the mass of the masonry above. This cracking will occur early in the life of the building. Minor cracks can be filled with mortar and major cracks with concrete epoxy grout.
- **Cracking of interior slabs on grade** is usually due to shrinkage or minor settlement below the slab. If cracking is near and parallel to foundation walls, it may have been caused by the movement of the walls or footers (see Section 4.4). Cracking can also result from soil swelling beneath the slab, a condition that may be caused by water from clogged or broken basement or footer drains. Rarely is such cracking structurally harmful to the building.
- **Cracking of exterior concrete elements,** such as porches, patios, and stairs, is usually due to heaving from frost or nearby tree roots, freeze-thaw cycles, settlement, or a combination of these conditions. It is compounded by the use of deicing salts. Such cracking rarely presents a structural problem to the building, but is often a practical problem that can best be remedied by replacing the concrete and providing the new work with more stable support. Cracks in existing concrete elements that are not seriously deteriorated may be cyclical and can be filled with a flexible sealant.
- **Fire damage to concrete structural components** should be thoroughly evaluated. Concrete heated in a building fire will lose some compressive strength, although when its temperature does not exceed 550 ºF (290 ºC) most of its strength eventually will be recovered. If the concrete surface is intact, it can usually be assumed to be in adequate condition. Superficial cracking can be ignored. Major cracks that could influence structural behavior are generally obvious and should be treated on a case-by-case basis. Cracks can be sealed by injecting concrete epoxy grout. Paints are available to restore the appearance of finely cracked or crazed concrete surfaces. See also Appendix A, Effects of Fire on Structural Systems.

  Tests: Two specialized tests may sometimes be useful for estimating the quality, uniformity, and compressive strength of in-situ concrete. The first is the Windsor Probe, a device that fires a hardened steel probe into concrete. See ASTM C803, *Standard Test Method for Penetration Resistance of Hardened Concrete*. The second test is the Schmidt Hammer, which measures the rebound of a hardened steel hammer dropped on concrete. See ASTM C805, *Standard Test Method for Rebound Number of Hardened Concrete*.

For additional information about inspecting and repairing concrete, consult the following publications from the American Concrete Institute: ACI 201.1R, *Guide for Making a Condition Survey of Concrete in Service;* ACI 364.1R, *Guide for Evaluation of Concrete Structures Prior to Rehabilitation;* and ACI 546.1R, *Concrete Repair Guide.*