INSPECTING FOUNDATION WALLS AND PIERS

This publication is designed to help the home inspector evaluate foundation walls and piers. Additionally, it provides insight into newer innovations pertaining to products and their usage. This book is offered as a learning tool to augment InterNACHI's Continuing Education online course in preparation for successful completion of the online course and final exam. This manual also provides a useful on-the-job reference guide for inspectors.

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DEFINITION of TERMS

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.

The **foundation bed** may be composed of solid rock, sand, gravel, or unconsolidated sand or clay. Rock, sand and gravel are the most reliable foundation materials. Unconsolidated sand and clay are common in many areas of the United States, but are not as desirable for foundations because they are subject to sliding and settling.

The **footing** distributes the weight of the building over a sufficient area of ground to ensure that the foundation walls will stand properly. Footings are usually concrete; however, in the past, wood and stone have been used. Some older houses were constructed without footings. Although it is usually difficult to determine the condition of a footing without excavating the foundation, a footing in a state of disrepair, or the lack of a footing, will usually be indicated either by settlement in the foundation walls or by large cracks. These cracks are called "Z" cracks.

The **foundation walls** support the weight of the structure and transfer this weight to the footings. The foundation walls may be made of stone, brick, concrete, or concrete blocks. The exterior should be moisture-proofed with either a coating of Portland cement mortar or a membrane of waterproof material. The membrane may consist of plastic sheeting, or a sandwich of standard roofing felt joined and covered with tar or asphalt. Waterproofing the foundation and walls will prevent water from penetrating the wall material and leaving the basement or cellar walls damp.

MASONRY

All exposed masonry should be inspected for cracking, spalling, bowing (vertical bulging), sweeping (horizontal bulging), 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, crawlspace or attic. Also note whether the walls are solid masonry or masonry-cavity, 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.

A common masonry wall crack probably caused by thermal or moisture expansion. Active cracks can be sealed with a flexible sealant; inactive cracks may be pointed.

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 more effectively exploit the compressive strength of masonry. This was done 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.

Testing

Two methods of testing are sometimes useful for assessing masonry. Probe holes are 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 then 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. In a hammer test, the masonry is tapped lightly with a hammer, and the resonance of the sound produced is evaluated.

Two additional tests may also be useful: ASTM E518, the Standard Test Methods for Flexural Bond Strength of Masonry; and ASTM E519, the Standard Test Method for Diagonal Tension (Shear) in Masonry Assemblages. These test should be performed by a qualified masonry contractor.

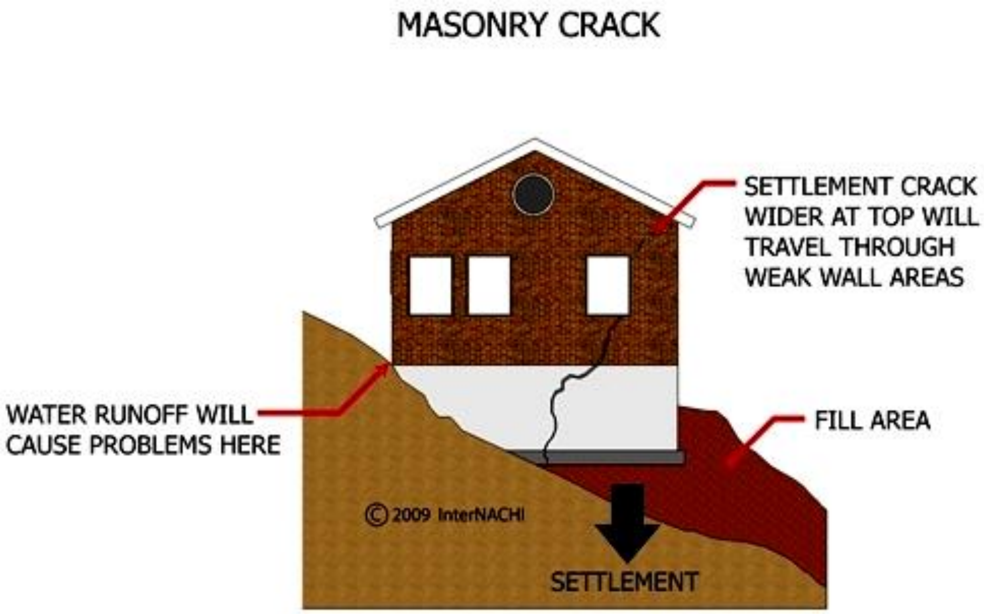
The brick shown above is greatly spalled as a result of excessive moisture penetration and subsequent freezing. Although individual bricks can be replaced and the mortar pointed, the damage cannot be repaired. If re-pointed, the new mortar should be of the same composition as the existing.

MASONRY CRACKS

Although masonry can deform elastically over long periods of time to accommodate small amounts of movement, large movements normally cause cracking. This is known as masonry cracking.

Cracks may appear along the mortar joints or through the masonry units. Cracking can result from a variety of problems:

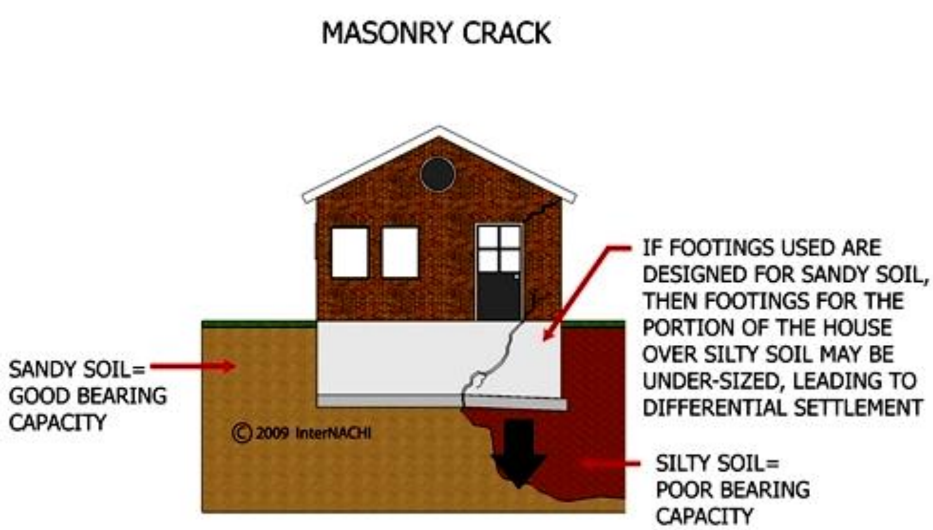
- differential settlement of foundations;
- drying shrinkage (particularly in concrete block);
- expansion and contraction due to ambient thermal and moisture variations;
- improper support over openings, the effects of freeze-thaw cycles;
- the corrosion of iron and steel wall reinforcement;
- differential movement between building materials;
- expansion of salts; and
- the bulging or leaning of walls.



Differential Settlement Caused by Variable Soil Types

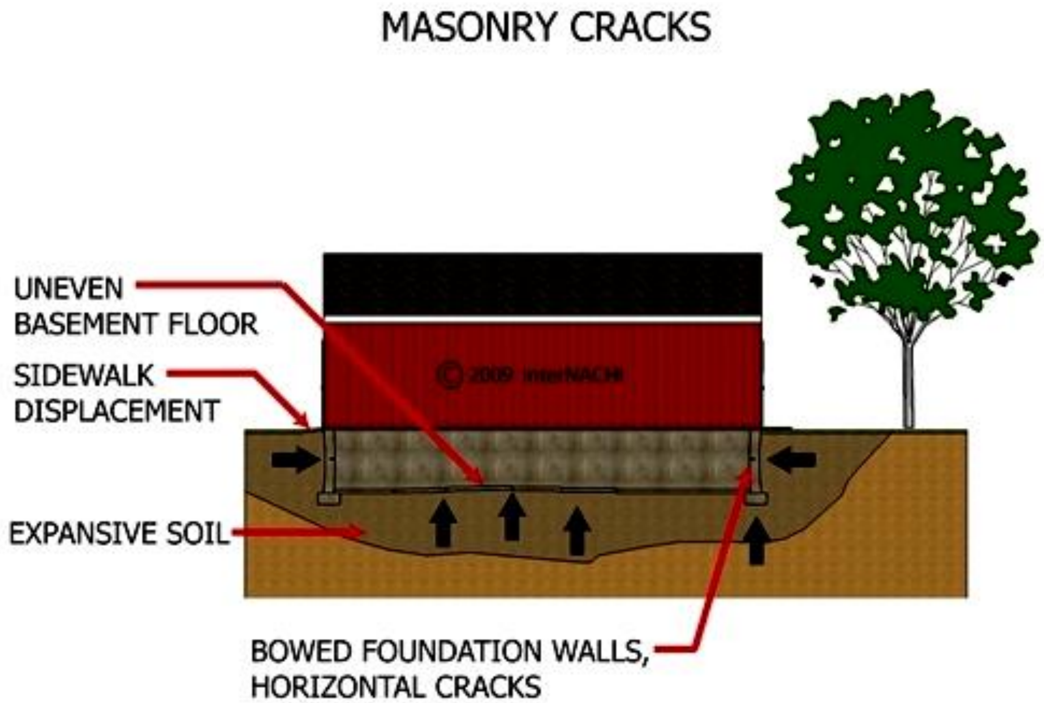
Cracks should always be evaluated to determine their cause and whether corrective action is required. Look for signs of movement. A clean crack indicates recent movement; a dirty or previously filled crack may be inactive. A pocket lens may be useful for such an examination.

Correlate the width of larger cracks to the age of the building. A 1/2-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.



Testing

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. All tests should be performed by a licensed contractor.



Evidence of Frost Heaving

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. Re-mortaring cyclical cracks will hold them open and cause more cracking.

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

The photo at right shows an extreme case of structural failure in a masonry wall due to foundation settlement. The wall and foundation must be completely rebuilt.

BRICKS and MORTAR

The two important qualities of mortar are its ability to bond to masonry and its internal strength. A sign of mortar deterioration 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 the tops of walls. In such cases, the water should be redirected and the joints should be re-pointed. 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 with 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.

Testing

To determine the composition of existing mortar (the percentage of lime and other materials), a sample can be removed and chemically analyzed by a testing laboratory. This should be done by a qualified structural engineer.

The deterioration of masonry units in the form of spalling, dusting, or flaking of brick 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 caused by 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, with the exception of replacement of 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 the moisture and/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 into the brick wall just above the ground line, or by injecting a damp-proofing material into the same area. Recommend a masonry specialist for this type of repair.

ABOVE-GROUND MASONRY WALLS

Inspect above-ground stone, brick, and 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 creates stress 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 the next 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 and 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.

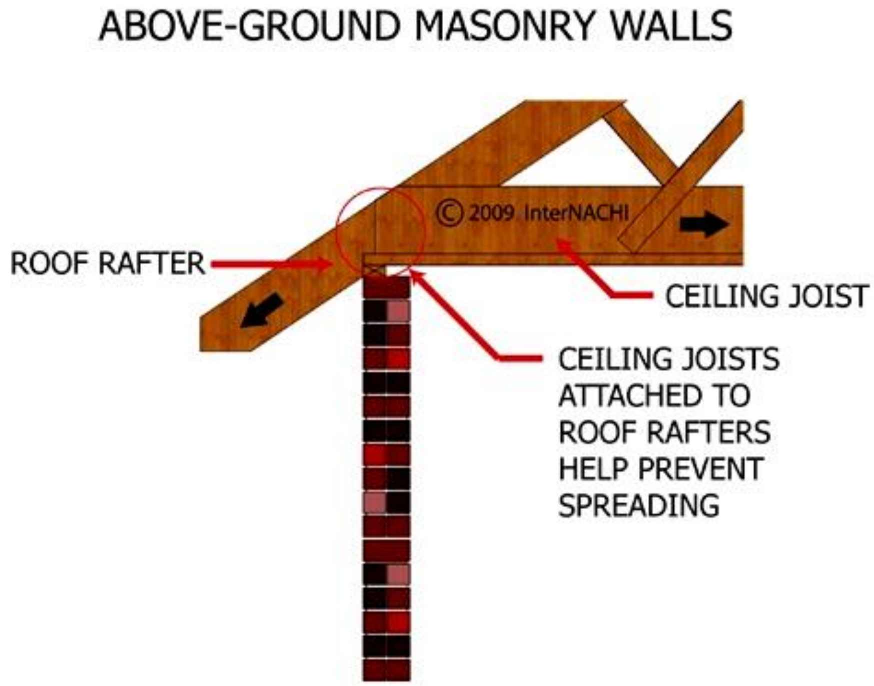
Such distress includes:

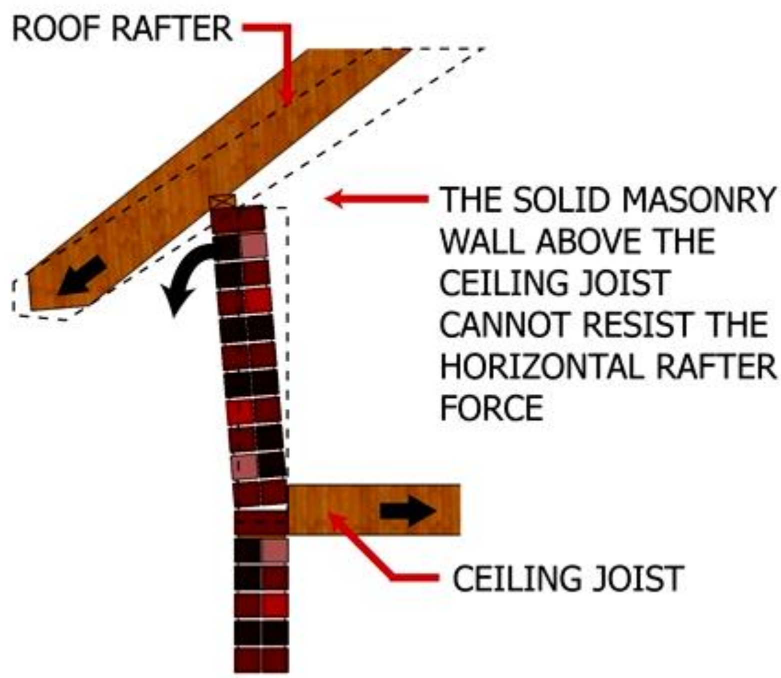
- cracking around sills, cornices, eaves, chimneys, parapets, and other elements subject to water penetration, usually due to the migration of water into the masonry. The water expands upon freezing, breaking the bond between the mortar and the masonry, and eventually displacing the masonry itself. The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

- cracking around iron and steel lintels caused by the expansive force of corrosion that builds up on the surface of the metal. This corrosion 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 open. If the joint has been sealed, the sealant or mortar should be removed. These conditions can usually 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.

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

Walls that extend above ceiling joists:





FIRE DAMAGE

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, recommend a qualified structural engineer for further appraisal. Hollow masonry units can be examined by a structural engineer for internal cracking. Such units may need replacement if seriously damaged. Masonry walls plastered on the side in direct contact with flame may have been sufficiently protected and will have suffered few, if any, ill effects.

STRUCTURAL FAILURE

Wall Cracking or Displacement Associated with the Structural Failure of Building Elements

Problems related to the structure, aside from those caused by differential settlement or earthquakes, are usually found over openings and (less commonly) under roof eaves and in areas of structural overloading. Such problems include:

- cracking and displacement of masonry over openings, resulting from the deflection and failure of the lintels and arches that span the openings. In older masonry walls with wood lintels, cracking will occur as the wood sags and 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 and stone may crack and fail when there is wall movement and when their mortar joints deteriorate. When such lintel deflections and 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 counter-thrust 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 a failure in the horizontal roof ties, which 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. In this case, 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 another possible solution.

- cracking due to overloading (or interior movement) is fairly uncommon, but may be caused by a point load (often added during an alteration) which is 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. This cracking 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 may have taken place. Recommend a structural engineer experienced in such matters.

Bulging Walls

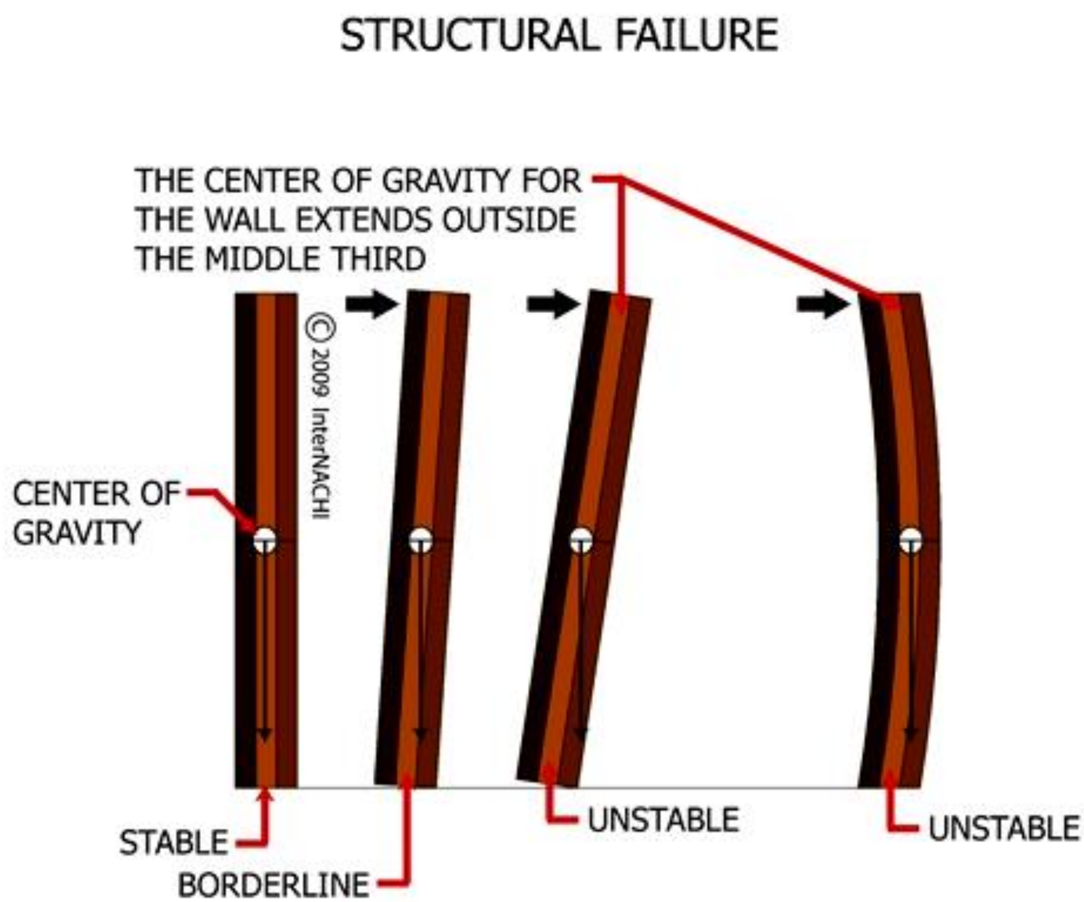
Masonry walls sometimes show signs of bulging as they age. A wall itself may bulge, or the bulge may only be in the outer withe. Bulging often takes place so slowly that the masonry doesn't crack and, therefore, it may go unnoticed over a long period of time. The bulging of the whole wall is usually due to thermal or moisture expansion of the wall's outer surface, or due 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 accumulate behind the bulge and prevent 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. This can cause the inner course to settle and the outer course to bulge outward.

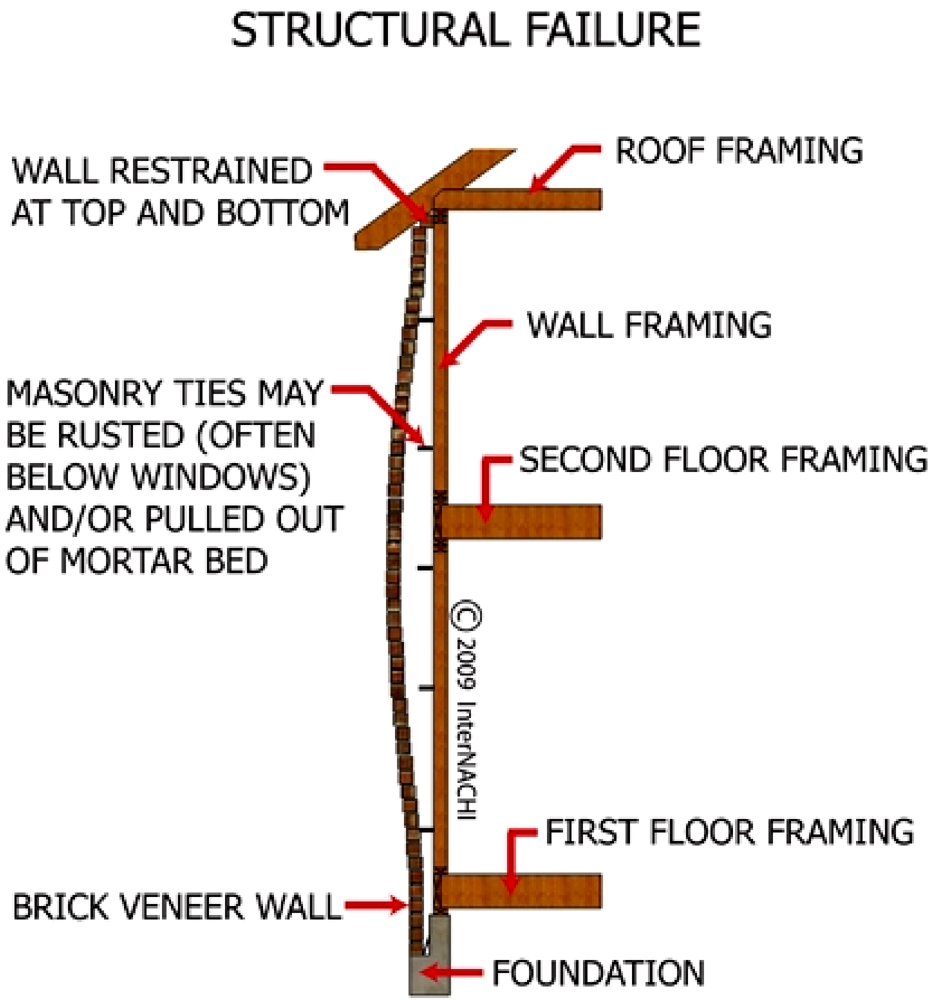
When wall bulges occur in solid masonry walls, the walls may be insufficiently tied to the structure, or their mortar may have lost its bond strength. Large bulges must be tied back to the structure; the star-shaped anchors on the exterior of masonry walls of many older buildings are examples of such 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.



The V3 Rule for Wall Stability

Leaning Walls

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



Above: a bowed brick veneer wall

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

Testing

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 third of its base (the V3 Rule). In such an event, recommend a structural engineer.

QUIZ 1

1. T/F: A 1/2-inch-wide crack in a 50-year old building may be a sign of rapid settlement.

- True
- False

2. A footing in disrepair can lead to _______ in the foundation walls.

- Z-cracks
- pock marks
- flaking

3. Foundation walls and piers in small residential buildings are usually made of _____________.

- preservative-treated wood
- steel
- masonry

4. T/F: Rock, sand and gravel are the most reliable foundation materials.

- True
- False

5. Vertical bulging in the masonry is known as _________.

- sweeping
- bowing
- spalling

6. Horizontal bulging in the masonry is known as ____________.

- sweeping
- bowing
- spalling

7. In a ________ test, the masonry is tapped lightly and the resonance of the sound produced is evaluated.

- hammer
- hacksaw
- hearing

(continued)

8. Excessive moisture penetrating and subsequent freezing can lead to _________.

- spleening
- forking
- spalling

9. T/F: Cyclical cracks should be re-mortared.

- True
- False

10. Masonry walls exposed to fire will resist damage in proportion to their _________.

- age
- height
- thickness

Answer Key to Quiz 1

1. T/F: A 1/2-inch-wide crack in a 50-year old building may be a sign of rapid settlement.
   Answer: False
2. A footing in disrepair can lead to Z-cracks in the foundation walls.
3. Foundation walls and piers in small residential buildings are usually made of masonry.
4. T/F: Rock, sand and gravel are the most reliable foundation materials.
   Answer: True
5. Vertical bulging in the masonry is known as bowing.
6. Horizontal bulging in the masonry is known as sweeping.
7. In a hammer test, the masonry is tapped lightly and the resonance of the sound produced is evaluated.
8. Excessive moisture penetrating and subsequent freezing can lead to spalling.
9. T/F: Cyclical cracks should be re-mortared.
   Answer: False
10. Masonry walls exposed to fire will resist damage in proportion to their thickness.

INNOVATIONS: CEMENT ADMIXTURES

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, including its workability, curing temperature range, set time, or color. Some admixtures have been in use for a very long time, such as calcium chloride, which is used to provide a cold-weather setting concrete. Others are more recent and represent an area of expanding possibilities for increased performance. Not all admixtures are economical to use on a particular project. Also, some characteristics of concrete, such as low absorption, can be achieved simply by consistently adhering to high-quality concreting practices.

The chemistry of concrete admixtures is a complex topic requiring in-depth knowledge and experience. A general understanding of the options available for concrete admixtures is necessary for acquiring the right product for the job, based on climatic conditions and job requirements.

Based on their functions, admixtures can be classified into the following five major categories:

- retarding admixtures;
- accelerating admixtures;
- super-plasticizers;
- water-reducing admixtures; and
- air-entraining admixtures.

Among other important admixtures that do not fit into these categories are admixtures whose functions include bonding, shrinkage reduction, damp-proofing, and coloring. The following information provides details on the five categories of concrete admixtures.

Retarding Admixtures

Retarding admixtures slow down the hydration of cement, which lengthens its set time. Retarders are used in hot-weather conditions in order to overcome the accelerating effects of higher temperatures, and on large masses of concrete to lengthen setting time.

Because most retarders also act as water reducers, they are frequently called water-reducing retarders. Per the chemical admixture classification by the ASTM, ASTM C 494 Type B is simply a retarding admixture, while Type D is both retarding and water-reducing, resulting in concrete with greater compressive strength because of the lower water-to-cement ratio.

Retarding admixtures consist of both organic and inorganic agents. Organic retardants include unrefined calcium, sodium, NH4, salts of lignosulfonic acids, hydrocarboxylic acids, and carbohydrates. Inorganic retardants include oxides of lead and zinc, phosphates, magnesium salts, fluorates and borates.

An example of a retardant's effects on concrete properties includes lignosulfate acids and hydroxylated carboxylic acids, which slow the initial setting time by at least an hour, and no more than three hours, when used at 65 to 100 degrees Fahrenheit. The concrete contractor, however, need not memorize these chemical-specific results. Given the specific job requirements and goals, the concrete supplier should offer appropriate admixtures and concrete mixes from which to choose.

Accelerating Admixtures

Accelerators shorten the set time of concrete, allowing a cold-weather pour, early removal of forms, early surface finishing and, in some cases, early load application.

Proper care must be taken while choosing the type and proportion of accelerators as, under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete.

Calcium chloride is a common accelerator used to accelerate the time of set and the rate of strength-gain. It should meet the requirements of ASTM D 98. Excessive amounts of calcium chloride in concrete mix may result in rapid stiffening, increase in drying shrinkage and corrosion of reinforcement. In colder climates, calcium chloride should not be used as an anti-freeze. Large amounts of calcium chloride are required to lower the freezing point of the concrete, which may ruin the concrete.

Super-Plasticizers

Super-plasticizers, also known as plasticizers, include water-reducing admixtures. Compared to what is commonly referred to as a "water reducer" or "mid-range water reducer," super-plasticizers are "high-range water reducers." High-range water reducers are admixtures that allow large water reduction or greater flowability without substantially slowing set time or increasing air entrainment (as defined by the manufacturers, concrete suppliers and industry standards).

Each type of super-plasticizer has defined ranges for the required quantities of concrete mix ingredients, along with the corresponding effects. They can maintain a specific consistency and workability at a greatly reduced amount of water. Amounts needed vary by the particular concrete mix and type of super-plasticizer used. They can also produce a high-strength concrete. As with most types of admixtures, super-plasticizers can affect other concrete properties, as well. The specific effects, however, should be provided by the manufacturer or concrete supplier.

Water-Reducing Admixtures

Water-reducing admixtures require less water to make a concrete of equal slump or increased slump at the same water content. They can have the side effect of changing initial set time. Water reducers are mostly used for hot-weather concrete placing, and to aid pumping.

A water-reducer plasticizer, however, is a hygroscopic powder, which can entrain air into the concrete mix via its effect on water's surface tension, thereby obtaining some of the benefits of air-entrainment.

Air-Entraining Admixtures

Air-entraining agents entrain small air bubbles in the concrete. The major benefit of this is enhanced durability in freeze-thaw cycles, which is especially important in cold climates. While some strength can be lost with increased air in concrete, it can generally be overcome by reducing the water-to-cement ratio via the improved workability made possible by the air-entraining agent, or through the use of other appropriate admixtures. As always, admixtures should only be combined in a concrete mix by a competent professional, because some of the admixtures can interact in undesirable ways.

Bonding admixtures, including the addition of compounds and materials such as polyvinyl chlorides and acetates, acrylics, and butadiene-styrene co-polymers, can be used to assist in bonding new or fresh concrete with old or set concrete.

Coloring agents have become more commonly used, especially for patios and walkways. Most are surface-applied, and often have the additional effect of surface hardening. Such surface-applied coloring admixtures generally should not be used on air-entrained concrete. Integrally colored concrete is also available.

Waterproofing and damp-proofing admixtures, including soaps, butyl stearate, mineral oil and asphalt emulsions, are used to decrease the amount of water penetration into the larger pores of concrete. "Antifreeze" admixtures are accelerators used in very high amounts (with a corresponding high price) which achieve a very fast set time. They do not, however, have properties to protect against freezing. In general, these are not used for residential work.

Cement substitutes also change concrete properties, but are not generally classified as admixtures.

Most organic chemical-type admixtures are affected by cement type and brand, water-to-cement ratio, aggregate grading, and temperature. Damp-proofing and waterproofing admixtures still have uncertain value and hazards. These are just two cases that point to the learning curve required of anyone working with admixtures.

In some cases, if directions are not followed exactly, including the addition of supplemental materials to balance the negative or undesirable side effects of an admixture, the resulting concrete mix may be compromised. For example, retarding admixtures generally have a possibility of rapid concrete stiffening, resulting in difficulty in placement and finishing. Therefore, an in-depth knowledge of the potentially complex interrelated effects is required to use a number of admixtures successfully.

This is even more critical when several parties are involved in the manufacture of the concrete, such as the producer, the placing contractor, and the builder. The finished concrete is a combined result of a number of individual decisions.

Choosing an appropriate admixture for a specific job should be the responsibility of an experienced expert. Alternatives to the use of admixtures should always be considered.

The environmental impact of certain admixtures is questionable. Some super-plasticizers may impact the environment through pollution of ground and surface waters. More research remains to be conducted in this area.

Finally, admixtures cannot compensate for bad practice and low-quality materials.

INNOVATIONS: CEMENT SUBSTITUTES

Producing cement uses a great deal of energy, so finding a waste product that can substitute for cement makes good environmental sense. According to the Environmental Building News (EBN), as much greenhouse gas is created producing the Portland cement used in the U.S. as is created operating 22 million compact cars. In addition, the U.S. imports about 20% of the 100 million metric tons of cement it uses annually, adding to its cost and using more energy. Burning coal to make electric power creates a great deal of waste fly ash. A smaller amount of slag is created when producing iron in blast furnaces. Coal fly ash, blast-furnace slag and other mineral admixtures can substitute for cement in concrete mixes for buildings which will save energy and recycle a waste product, thereby improving the quality of the concrete and reducing costs. Cement substitutes should be distinguished from concrete additives, such as plasticizers and air-entrainment agents, and from aggregate substitutes, such as ground glass or ground scrap rubber.

Types of Cement Substitutes

Fly ash is one of the byproducts of burning coal to create electric power. Two-thirds of the 55 million tons of fly ash produced in the U.S. in 1999 was sent to waste piles, with only 9 million tons used to make concrete. The carbon content of fly ash is a major concern. Class C fly ash, most of which is produced in the West from lignite coal, contains little carbon. However, Class F fly ash, produced primarily from anthracite and bituminous coal, contains significant amounts of carbon. Class C and Class F materials also differ from source to source with regard to strength, rate of strength-gain, color and weatherability. Ensuring a consistent supply is a concern among concrete suppliers.

Slag is a byproduct of the production of both iron and steel, and ground iron slag from blast furnaces can be used for making concrete. About 12.4 million tons of blast-furnace slag was used in the U.S. in 1999, of which 2 million tons were used in concrete. In addition, another 1.1 million tons were imported for use by the construction industry. Because the demand for the product is rising while the supply is falling, new grinding plants are coming online to process imported slag. The added energy used to ship and grind the slag makes it somewhat less energy-saving than fly ash, but far better than Portland cement.

Silica fume was once a cheap waste product, but high demand has made it a high-cost admixture used primarily for bridges and other structures where top weathering performance and high strength are needed. Concrete made from silica fume is expensive, however, not only because of the material cost, but because the powdery fineness of the fume makes it hard to handle. It is often turned into slurry before use.

As long as quality is controlled, rice hull ash is another material that can be used to replace cement. So far, its use remains in the laboratory stage, although a consistent-quality ash needed for concrete is available.

Slow Strength-Gain

Generally, cement substitutes work in two ways. First, they hydrate and cure like Portland cement. Second, they are "pozzolans," providing silica that reacts with hydrated lime, an unwanted byproduct of concrete curing. Blast-furnace slag is most like Portland cement and least like a pozzolan. Class F fly ash is most like a pozzolan, and Class C fly ash is somewhere in the middle. While stronger and more durable in the end, it takes more time than Portland cement for pozzolans to gain strength. For most construction purposes, high early strength is very desirable because it allows quicker finishing of slabs and earlier removal of forms. Reducing the amount of water can compensate for slow strength-gain. Researchers have made concrete in the lab from high percentages of cement substitute by drastically reducing the water content and adding super-plasticizers to maintain the required slump, but such mixes are not yet common and may be costly.

Mixes with 15% to 25% fly ash and somewhat higher percentages of slag can be used in home building with only a modest slowing of strength-gain. Higher percentages can be used in footings, where high early strength is typically not important. Precasters and concrete masonry unit (CMU) producers can maintain precise control of the mix, and use more admixtures. However, they require high early strength for fast reuse of forms, so precast concrete seldom has high percentages of cement substitutes.

Air-Entrainment and Carbon Content

Some fly ash, and most of the Class F fly ash used in the East, contains high levels of carbon, which are unburned coal particles resulting from the lower-temperature burning (low-NOx) that improves air quality. Carbon particles absorb the soapy air-entraining chemicals used to improve cold-weather performance, and, in this way, make the air content unpredictable. This problem has led some Northern suppliers to substitute slag admixture for fly ash, since slag contains no carbon. The fly ash industry is addressing this problem by processing high-carbon fly ash to remove most of the carbon.

Concrete with mineral admixtures may require more air-entraining chemicals to ensure freeze-thaw protection because the small particles of these minerals can fill voids in the concrete that would otherwise be air bubbles.

Strength

Strength is improved by the substitution of some mineral admixtures for Portland cement. Class C fly ash and slag improve strength more than Class F fly ash. In applications where high strength is critical, such as in high-rise buildings, silica fume is the cement substitute of choice, resulting in compressive strengths of 15,000 psi and higher.

Color

Class C fly ash results in a buff-colored concrete; Class F is a darker gray. Slag concrete is lighter in color, with high reflectivity. During curing, slag concrete may show a blue-green mottling, called "greening." However, the color is usually gone from the surface in a week. Its disappearance depends on oxidation, so slag cement is not recommended for swimming pools.

Weatherability

There are three weatherability conditions that cement substitutes help alleviate:

- permeability and chloride-induced corrosion: De-icing salts can migrate through pores in the concrete, break down the passive protective layer around the re-steel, and cause corrosion that leads to spalling. The pozzolanic action of cement substitutes removes the calcium hydroxide that makes the concrete permeable and, therefore, is highly desirable in roadways. A high percentage of fly ash is not recommended for slabs and paving exposed to the weather because of dusting and scaling of the surface.

- alkali-silica reaction (ASR): High-silica aggregates and high-alkali cement (which is becoming more common) can create ASR, which causes internal expansion and crazing of concrete. Cement substitutes, especially slag, remove the alkalinity through pozzolanic action. Class C fly ash varies in this ability, while Class F fly ash is very effective.

- sulfate attack: Concrete made with 60% or more slag is very effective in mitigating attack by sulfates found in some arid soils, seawater and wastewater. The pozzolanic action of fly ash also contributes to sulfate resistance.

Although the federal government and the heavy-construction industry have used cement substitutes for decades, residential contractors are less familiar with their use. As the fly ash industry develops processes to remove carbon, variations in the composition of fly ash will become less important, and its popularity will rise. The U.S. blast-furnace slag supply is declining and the demand growing, so future growth in its use depends on imports. Silica fume remains costly and difficult to handle, and rice hull ash and other potential substitutes are not yet being marketed.

PRECAST CONCRETE FOUNDATION and WALL PANELS

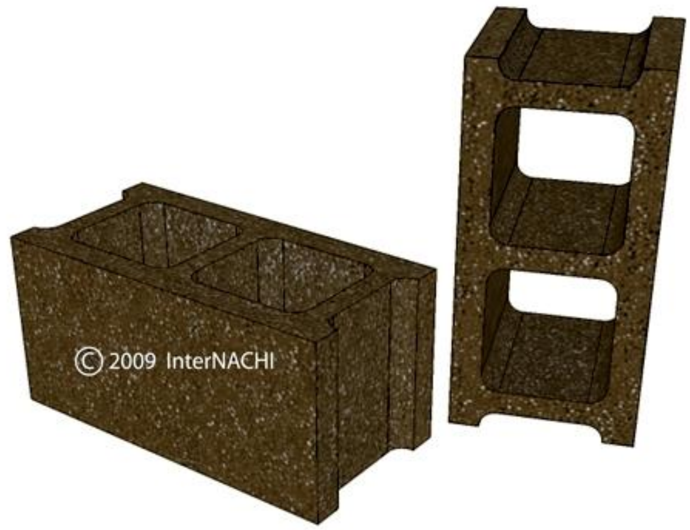
Precast concrete foundation and wall panels can take many forms. Some consist of steel-reinforced concrete ribs that run vertically and horizontally in the panels. Others are solid precast concrete panels. Panels are precast and cured in a controlled factory environment so that weather delays can be avoided. A typical panelized foundation can be erected in four to five hours, without the need to place concrete on-site for the foundation. The result is a foundation that can be installed in any climate zone in one-sixth the time needed for a formed concrete wall.

Some manufacturers cast the concrete against foam insulation that provides the form during manufacture, and adds R-value in the wall. Panels range in size from 2 to 12 feet in width by 8 to 12 feet in height, and are typically installed with a crane on top of 4 to 6 inches of compacted stone. The stone facilitates sub-slab drainage, and adequately carries and transfers the load from the foundation wall. Panel connections consist of bolts and sealant. The foundation can be back-filled as soon as it is braced, per the manufacturer's specifications.

The controlled temperature of the processing plant allows the manufacturer to work with concrete admixtures that focus on ultimate strength rather than cure time and temperature. Manufacturers are able to produce mixes that harden to 5,000 psi, which is stronger than concrete block and concrete walls formed and cast in the field. Better control of the concrete mixture and curing environment allows the use of low water-to-cement ratios that result in a dense material that prevents water penetration.

INSULATING CONCRETE FORMS (IFCs)

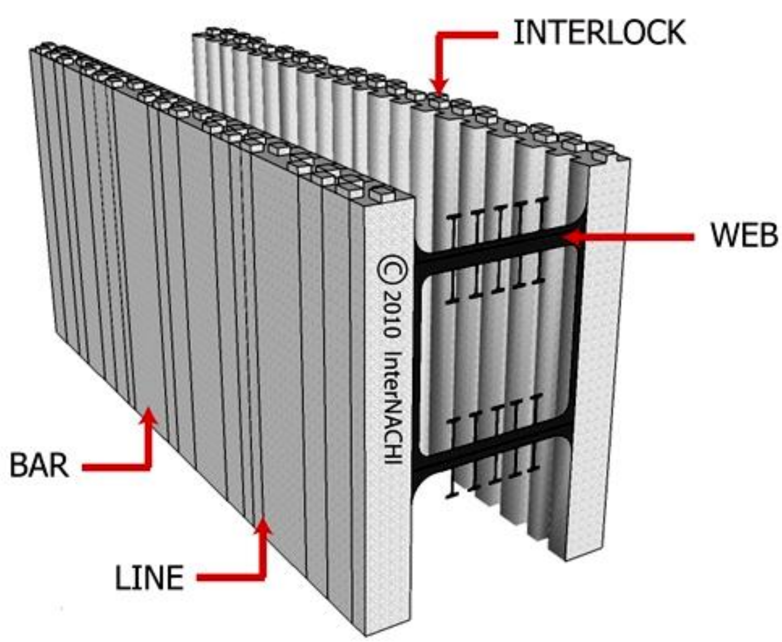
Concrete forms have taken on a new shape and purpose. Insulating concrete forms (ICFs) are rigid, plastic foam forms that hold concrete in place during curing, and they remain in place afterward to serve as thermal insulation for concrete walls. The foam sections are lightweight and result in energy-efficient, durable construction.



ICFs consist of insulating foam, expanded polystyrene (EPS), and extruded polystyrene (XPS). The three basic form types are hollow foam blocks, foam planks held together with plastic ties, and 4 x 8 panels with integral foam or plastic ties. ICFs can be used to form various structural configurations, such as a standard wall, post and beam, or grid. They provide backing for interior and exterior finishes.

Insulation values of ICF walls vary depending on the material and its thickness. Typical insulation values range from R-17 to R-26, compared to R-13 to R-19 for most wood-frame walls. The strength of ICF structures versus lumber depends on configuration, thickness, and reinforcement. However, ICF walls are designed as reinforced concrete, having high wind and seismic resistance.

There are many ICF wall types. Products are differentiated based on the type of form and the shape of the concrete sections. Products are further differentiated by how forms attach to each other, how finishes are attached to the wall, insulating values, foam types, and other features.



FORMWORK for VENTILATED CONCRETE SLABS

The formwork pictured at the right is Cupolex®, an innovative modular building unit used to create ventilated under-floor cavities. Both slab-on-grade and structural slabs can be created using this formwork. This technology is designed to enhance energy-efficient buildings, and can assist in eradicating problems associated with contaminated soils. The under-floor cavity can reduce dampness, mold and mildew, while providing ventilation in all directions beneath the slab. This cavity can also convey any potential volatile organic compounds (VOCs) and permeating gases from contaminated soils, including radon, to the outside of the building.

Cupolex® is made of polypropylene and manufactured from non-toxic, recycled materials into plastic modular elements, and pre-formed in various sizes. They connect to compose a self-bearing structure, suitable for placement of concrete to create a slab of variable thickness. Cupolex® is a permanent formwork and cannot be used twice. The distinctive domed shape of the modular elements is used to form concrete slabs that provide an internal orthogonal space, allowing for optimum air circulation.

The individual elements are designed to be connected to one another to form a self-bearing structure, resting on a pre-built base. Cupolex® is, therefore, ready after installation for any required steel reinforcement, and for placement of concrete. Continuous space is available beneath the array of Cupolex® elements that can be used for installing ductwork, cables, piping, and heating and ventilation systems. The material is durable, withstands extreme temperatures and aging, and will not break or tear.

Until code approvals in the U.S. market are achieved, slabs designed with the Cupolex® system usually will require the stamp or seal of a licensed professional engineer.

INNOVATIONS: CONCRETE FOOTING and PIER FORMS

There are new alternatives to conventional forming methods for concrete footings and piers that are quicker and less expensive than usual. For point footings, there are two approaches:

- rigid plastic footing forms; or
- fabric "bag" footing forms.

Continuous strip footings use a specialized fabric form held in place by a temporary structural system.

Typically, a standard construction tube provides the form for a concrete pier. However, a special fabric alternative can also provide a suitable pier form, when properly installed and braced.

Plastic rigid footing forms differ mostly in their shape, though there are variable sizes available, as well. Some are similar to the conventional block shape, while others are bell-shaped with a round base. They have a circular opening on top to accept the concrete, as well as to connect to the construction tubes above.

Rigid footing forms have ribs to provide extra strength, and some have small holes to release air during the pour.

Fabric "bag" footing forms are exactly what their name implies. They are flexible fabric sacks with a circular hole on top into which concrete is poured. The shape of the fabric form approximates a standard rectangular footing, but all edges are rounded, with bowed sides, and the form may be installed on and conform to uneven ground.

For footings that require rebar reinforcing, there is a form sack which has a zipper to open the top of the "bag" enough to get the reinforcing rods inside the fabric form before placing the concrete.

Additionally, there is a foundation pier product developed specifically for manufactured housing that uses footing form bags as a key part of its design.

Fabric strip footing forms can be used for level and step footings, as well as for deep footings, and they can be installed over uneven ground and rock (if it is structurally acceptable to do so). A simple, temporary form must be built, to which the fabric attaches in order to hold its shape while the concrete cures. This is made with a board on each side that defines the top edge of the form to which the fabric attaches, held at the required height and width by a special "yoke" support system. Long boards that hold the fabric in place must be stabilized laterally. This is achieved by regularly spaced metal stakes pounded into the ground along either side of the form. Once the concrete sets, the rigid formwork may be removed and reused, while the fabric form remains in place.

There is a proprietary foundation pier product called The Buttress®, which combines the fabric bag with a steel pier, and which has been developed specifically for the HUD-code housing market.

For large pier pads, a system similar to the fabric forms for strip footings can be used. This system essentially consists of a sufficient area of fabric laid out over the ground, with its side walls held in place by a temporary form system of top-edge boards and metal stakes, similar to the form described for the strip footing system.

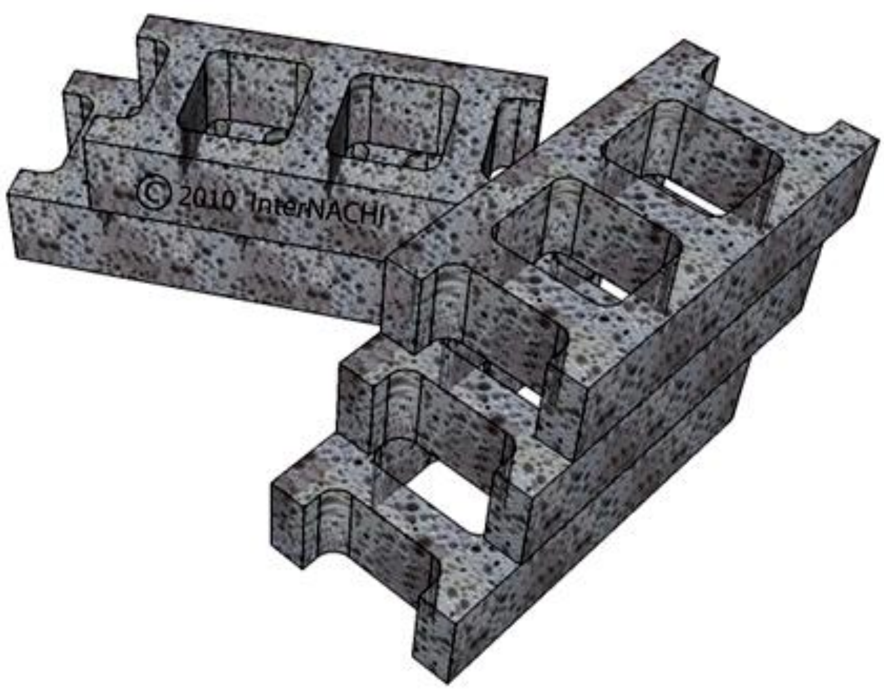
Fabric pier form material comes in 120-foot lengths, with diameters of 8 inches and larger. They are the shape of a tube with an attachment tab running down their length. Because they are made of a flexible fabric, the forms are flat before filled with concrete. The fabric is easily cut to length.

PUMICE-CRETE®

Pumice-Crete® is a low-density and resource-efficient concrete consisting of pumice aggregate, Portland cement, and water. It is an economical alternative to conventional building materials because it combines strength and insulation in one product. Besides the variety of design applications for which it can be used, Pumice-Crete® is a durable, fireproof, and noise-mitigating material that holds up in a variety of climates.

Pumice is a lightweight, sponge-like volcanic rock formed by the expansion of gases during rapid cooling of molten lava. This glass froth is found in shallow deposits in New Mexico, Arizona, California, Oregon, Washington and Idaho.

Due to the material's inert nature, it does not react with any ingredients of concrete or steel. With an average cured weight of less than 50 pounds per cubic foot, Pumice-Crete® produces a cured strength of 400 psi (compared to 2,000 psi in concrete), with an insulating value of R-1.5 per inch (compared to R-0.1 in concrete). Although more than 350 residences have been built in Colorado and New Mexico using Pumice-Crete®, no official fire rating has been performed.



INNOVATIONS: CONCRETE AGGREGATE SUBSTITUTES

Conventional concrete aggregate consists of sand (fine aggregate) and various sizes and shapes of gravel and stones. However, there is a growing interest in substituting alternative aggregate materials largely as a potential use for recycled materials.

There is significant research on many different materials for aggregate substitutes, such as granulated coal ash, blast-furnace slag, and various solid wastes, including fiberglass waste materials, granulated plastics, paper and wood products and waste, sintered sludge pellets, and similar materials. However, the only two materials that have been significantly applied are glass cullet and crushed recycled concrete itself.

Even though aggregate typically accounts for 70% to 80% of the concrete volume, it is commonly thought of as inert filler having little effect on the finished concrete's properties. However, research has shown that aggregate plays a substantial role in determining workability, strength, dimensional stability, and durability of the concrete.

Also, aggregates can have a significant effect on the cost of the concrete mixture. Certain aggregate parameters are known to be important for engineered-use concrete, including hardness, strength and durability. The aggregate must be "clean," without absorbed chemicals, clay coatings, or other fine materials in concentrations that could alter the hydration and bond of the cement paste.

It is important to note the differences between aggregate and cement because some materials use both as a cementitious material and as aggregate (such as certain blast-furnace slags).

Aggregate composed of recycled concrete generally has a lower specific gravity and a higher absorption rate than conventional gravel aggregate. New concrete made with recycled concrete aggregate typically has good workability, durability and resistance to saturated freeze-thaw action. The compressive strength varies with the compressive strength of the original concrete and the water-to-cement ratio of the new concrete. It has been found that concrete made with recycled concrete aggregate has at least two-thirds the compressive strength and modulus of elasticity of natural aggregate concrete.

Field testing has shown that crushed and screened waste glass may be used as a sand substitute in concrete. Nearly all waste glass can be used in concrete applications, including glass that is unsuitable for uses such as glass bottle recycling. Some of the specific glass waste materials that have found use as fine aggregate are "non-recyclable" clear window glass, and fluorescent bulbs with very small amounts of contaminants. Possible applications for such waste-glass concrete are bike paths, footpaths, gutters, and similar non-structural work.

The current lack of widespread, reliable data on aggregate substitutes can hinder its use. To design consistent, durable recycled-aggregate concrete, more testing is required to account for variations in the aggregate's properties. Also, recycled aggregate generally has a higher absorption rate and a lower specific gravity than conventional aggregate.

Research has revealed that the seven-day and 28-day compressive strengths of recycled-aggregate concrete are generally lower than values for conventional concrete. Moreover, recycled aggregates may be contaminated with residual quantities of sulfate from contact with sulfate-rich soil and chloride ions from marine exposure.

Glass aggregate in concrete can be problematic due to the alkali-silica reaction between the cement paste and the glass aggregate which, over time, can lead to weakened concrete and decreased long-term durability. Research has been done on types of glass and other additives to stop or decrease the alkali-silica reaction and, thereby, maintain finished concrete strength. However, further research is still needed before glass cullet can be used in structural concrete applications.

INNOVATIONS: FIBROUS CONCRETE REINFORCEMENT

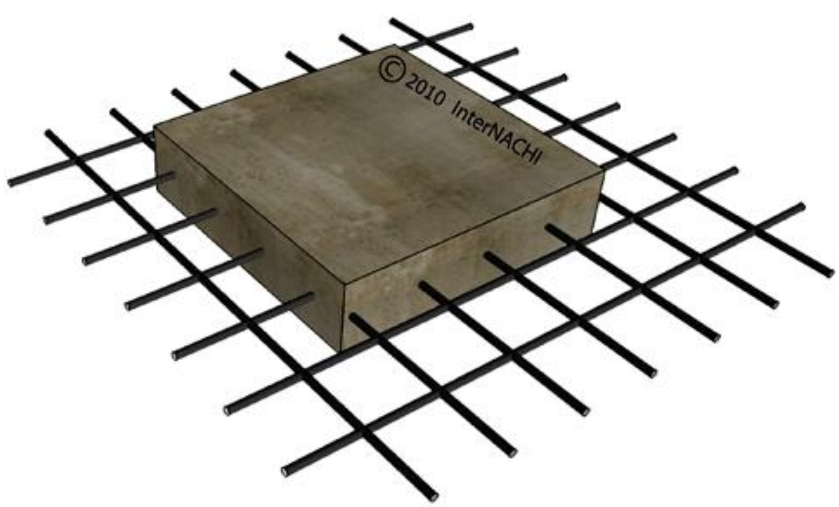
Reinforcing concrete to keep it from cracking is nothing new. Even the earliest civilizations used natural fibers to inhibit cracking in masonry structures. Today, synthetic-fiber reinforcement is available to reinforce non-structural concrete applications with superior results. Currently, the most widely used form of reinforcement is welded-wire fabric (WWF), a mesh of steel wires that is placed in concrete. However, synthetic-fiber reinforcement avoids the increased labor costs and difficulty in placement that are associated with WWF.

Synthetic-fiber reinforcement prevents cracks in concrete, unlike WWF, which controls crack width. Cracks actually need to occur before the WWF goes to work. Small-diameter synthetic fibers, such as nylon, glass, steel and polypropylene, are now being added to concrete to reduce shrinkage-cracking by more than 80%, according to independent lab tests. Reducing cracks improves concrete impermeability, increases its toughness and long-term weatherability, and can reduce callbacks in concrete slab floors, decks, driveways and walkways. According to fiber manufacturers, the placement, curing and finish characteristics of the concrete are not affected by the addition of fibrous reinforcement.

When added at higher content by volume, larger-diameter synthetic fibers, such as steel and polyolefin (added at 0.5% to 1.5%, respectively), also enhance hardened flexural strength, but at an increased cost.

Fibrous reinforcement is used primarily to reduce cracking in non-structural concrete applications. However, steel fibers rust and can cause surface discoloration.

WELDED WIRE FABRIC



INNOVATIONS: AUTOCLAVED AERATED CONCRETE (AAC)

Builders in the U.S. can use an innovative concrete material that Scandinavians have used for decades. Autoclaved aerated concrete (AAC) is a precast structural product made with natural raw materials. In 1914, the Swedes invented a mixture of cement, lime, water and sand that expands by adding aluminum powder. The material was further developed to what we know today as autoclaved aerated concrete, which is also called autoclaved cellular concrete. It is an economical, sustainable, solid block that provides thermal and acoustic insulation, as well as fire and termite resistance. AAC is available in a variety of forms, ranging from wall and roof panels to blocks and lintels. Although it has been a popular building material in Europe for over 50 years, AAC has only been introduced to the U.S. in the past two decades.

To manufacture AAC, Portland cement is mixed with lime, silica sand or recycled fly ash (a byproduct from coal-burning power plants), water, and aluminum powder or paste, and then poured into a mold. The reaction between aluminum and concrete causes microscopic hydrogen bubbles to form, expanding the concrete to about five times its original volume. After the hydrogen evaporates, the now highly aerated concrete is cut to size and formed by steam-curing in a pressurized chamber -- an autoclave. The result is a non-organic, non-toxic, airtight material that can be used for wall, floor and roof panels, blocks and lintels, and which, according to the manufacturers, generates no pollutants or hazardous waste during the manufacturing process.

AAC units are available in numerous shapes and sizes. Panels are 24 inches wide, between 8 to 12 inches thick, and up to 20 feet long. Blocks come in lengths of 24 inches, 32 inches and 48 inches, between 4 to 16 inches thick, and 8 inches high.

AAC features include structural capacity, thermal, fire and acoustical resistance properties. With an R-value of approximately 1.25 per inch, depending on density, AAC significantly out-performs conventional concrete block and poured concrete. Consistency in quality and color may be difficult to obtain in AAC made with fly ash. Unfinished exterior walls should be covered with an exterior cladding, or parged with mortar, when exposed to physical damage, dirt and water because atmospheric debris can collect in the open cells. If installed in high-humidity environments, interior finishes with low-vapor permeability and exterior finishes with a high-permeability are recommended.

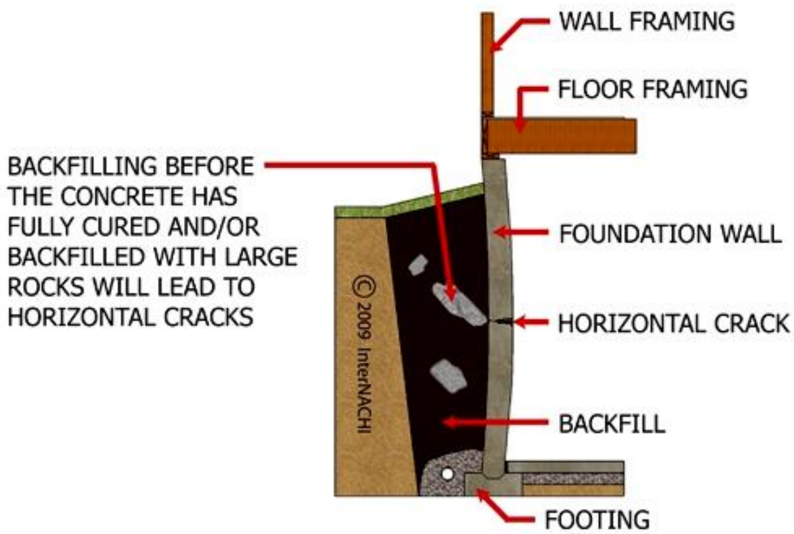
Because of the thermal mass of AAC and its ability to store and release energy over time, AAC may be beneficial in climates where outdoor temperature fluctuates over a 24-hour period from above to below the indoor temperature conditioned air-set point.

CRACKING in CONCRETE

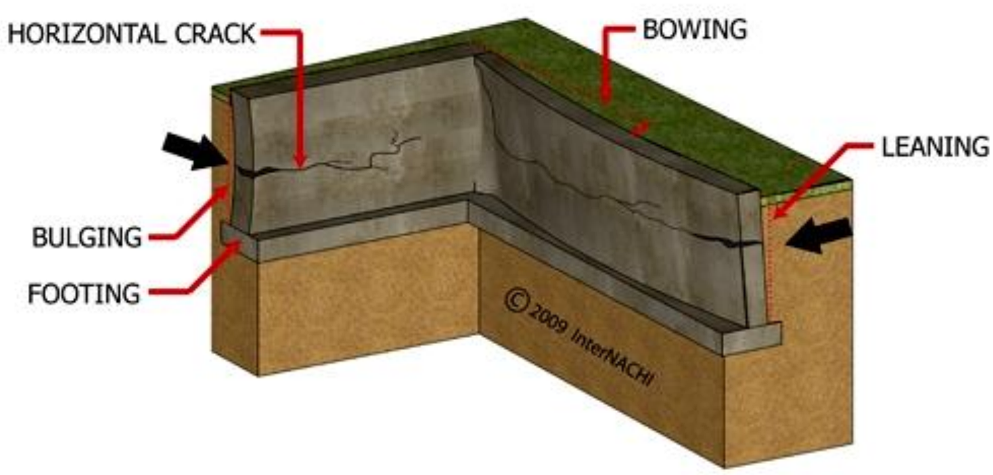
Cracking Associated with Drying Shrinkage in Concrete Block Foundation Walls

The shrinkage of concrete block walls during the drying process will often result in patterns of cracking similar to that caused by differential settlement: tapering cracks that widen as they move, resulting in a diagonal upward pattern. 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 third of the wall, and the footer beneath them remains intact. Shrinkage cracking is rarely serious and, in an older building, may have been previously repaired. If the wall is unsound, its structural integrity can sometimes be restored by pressure-injecting concrete epoxy grout into the cracks, or by adding pilasters.

How back-filling can affect foundation walls:



How horizontal cracks relate to foundation wall movement:



Sweeping or Horizontal Cracking of the Foundation Walls

The sweeping or horizontal cracking of brick and concrete block foundation walls may be caused by improper back-filling, vibration (from the movement of heavy equipment and vehicles close to the wall), and by the swelling or freezing and heaving of water-saturated soil adjacent to the wall. Like the shrinkage associated with drying, sweeping or horizontal cracking may have occurred during the original construction and was 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 soil is suspected as the cause of the cracking, examine the exterior for sources of water, such as broken leaders or poor surface drainage. Frost heaving may be the culprit if the damage is above local frost depth, or if it occurred during an especially cold period.

SETTLEMENT

All stone, brick, concrete and concrete block foundations should be inspected for problems associated with differential settlement. Although serious settlement problems are relatively uncommon, uneven or differential settlement can be a major structural problem in small residential buildings. 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 and 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, and 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 include:

- soil consolidation under the footings;
- soil shrinkage due to the loss of moisture to nearby trees and large plants;
- soil swelling due to inadequate and/or blocked surface or house drainage;
- soil heaving due to frost and 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, and 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; and
- soil compaction and movement due to vibration from heavy equipment, vehicular traffic, blasting, and/or from ground tremors (earthquakes).

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; instead, the wall will elastically deform.

More rapid settlement, however, produces cracks that taper, starting large at one end and then diminishing to a hairline crack at the other end, 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 path along mortar joints, although individual masonry units may be split.

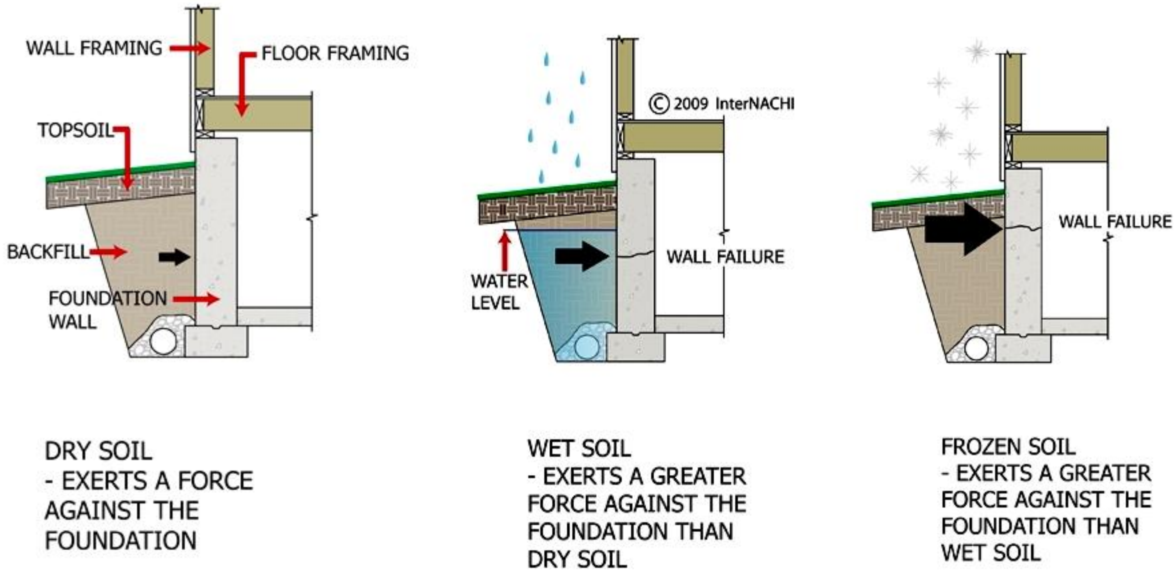
Settlement cracks (as opposed to the similar-appearing shrinkage cracks that are especially prevalent in concrete block) may extend through contiguous building elements, such as floor slabs, masonry walls above the foundation, and interior plaster work. Tapering cracks, or cracks that are nearly vertical 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.

This pier (at right) has been over-stressed by movement of the porch and column. The entire assembly should be rebuilt.

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

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. It is possible that the problem can only be rectified by under-pinning. Older buildings with severe settlement problems may be very costly to repair. In such cases, recommend the advice of a structural or soil engineer.

The effects of soil pressure on foundation walls:



Problems Associated With Masonry Piers

Masonry piers are often used to support internal loads on small residential buildings, and 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. Sometimes, they tend to deteriorate. Common problems include:

- 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. 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 cause the pier to rise or tilt and trigger 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 over-stressing. Above-ground piers exposed to the weather are subject to freeze-thaw cycles and subsequent physical damage. Piers in many older residential structures are often of made of poorly constructed masonry that deteriorates over the years. A sign of over-stressed piers is vertical cracking and bulging.

- loss of bearing of beams, joists, or floors due to the above conditions, or due to movement of the structure itself.

Piers should be examined for signs of settlement and their adequacy in accepting bearing loads. Inspectors should note their condition and ensure that they are plumb. Check their width-to-height ratio, which should not exceed 1:10. Piers 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.

BRICK VENEER WALLS

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 particular 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's held; and
- vertical cracking at corners, and/or horizontal cracking near the ground, which is caused by thermal movement of the wall. This cracking is similar to that in solid masonry and 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 cyclical and should be filled with a flexible sealant. In cases of severe cracking, expansion joints may have to be installed.

A deteriorated parapet wall that badly needs re-pointing. Fortunately, the wall has not yet exhibited serious movement, but it will, if left in disrepair.

QUIZ 2

1. Retarding admixtures slow down the hydration of cement, which lengthens its ______.

- amount
- lifespan
- set time

2. Accelerating admixtures ________ the set time of concrete.

- shorten
- eliminate
- lengthen

3. Super-plasticizers are ____________.

- "free-range water inhibitors"
- "low-range water reducers"
- "high-range water reducers"

4. Water-reducing admixtures are mostly used for ____________.

- hot-weather concrete placing
- high-altitude concrete placing
- cold-weather concrete placing

5. Air-entraining admixtures entrain __________ in the concrete.

- small water droplets
- small air bubbles
- dry concrete dust

6. T/F: Admixtures can usually compensate for poor workmanship and low-quality materials.

- True
- False

7. _________ cracks are often mistaken for settlement cracks.

- Shrinkage
- Frost-heave
- Seismic

(continued)

8. Sweeping cracks in the foundation are ______________.

- primarily cosmetic in nature
- common and non-serious
- potentially serious

9. Rapid settlement produces ________ cracks.

- serious
- tapering
- widening

10. T/F: Frozen soil exerts a greater force against the foundation than wet soil.

- True
- False

11. T/F: Inspectors should note the condition of masonry piers and ensure that they are plumb.

- True
- False

12. Some causes of foundation settlement include: _____________.

- soil erosion
- soil compaction
- soil swelling
- soil shrinkage
- all of these

Answer Key is on the next page.

Answer Key to Quiz 2

1. Retarding admixtures slow down the hydration of cement, which lengthens its set time.

2. Accelerating admixtures shorten the set time of concrete.

3. Super-plasticizers are "high-range water reducers."

4. Water-reducing admixtures are mostly used for hot-weather concrete placing.

5. Air-entraining admixtures entrain small air bubbles in the concrete.

6. T/F: Admixtures can usually compensate for poor workmanship and low-quality materials.
   Answer: False

7. Shrinkage cracks are often mistaken for settlement cracks.

8. Sweeping cracks in the foundation are potentially serious.

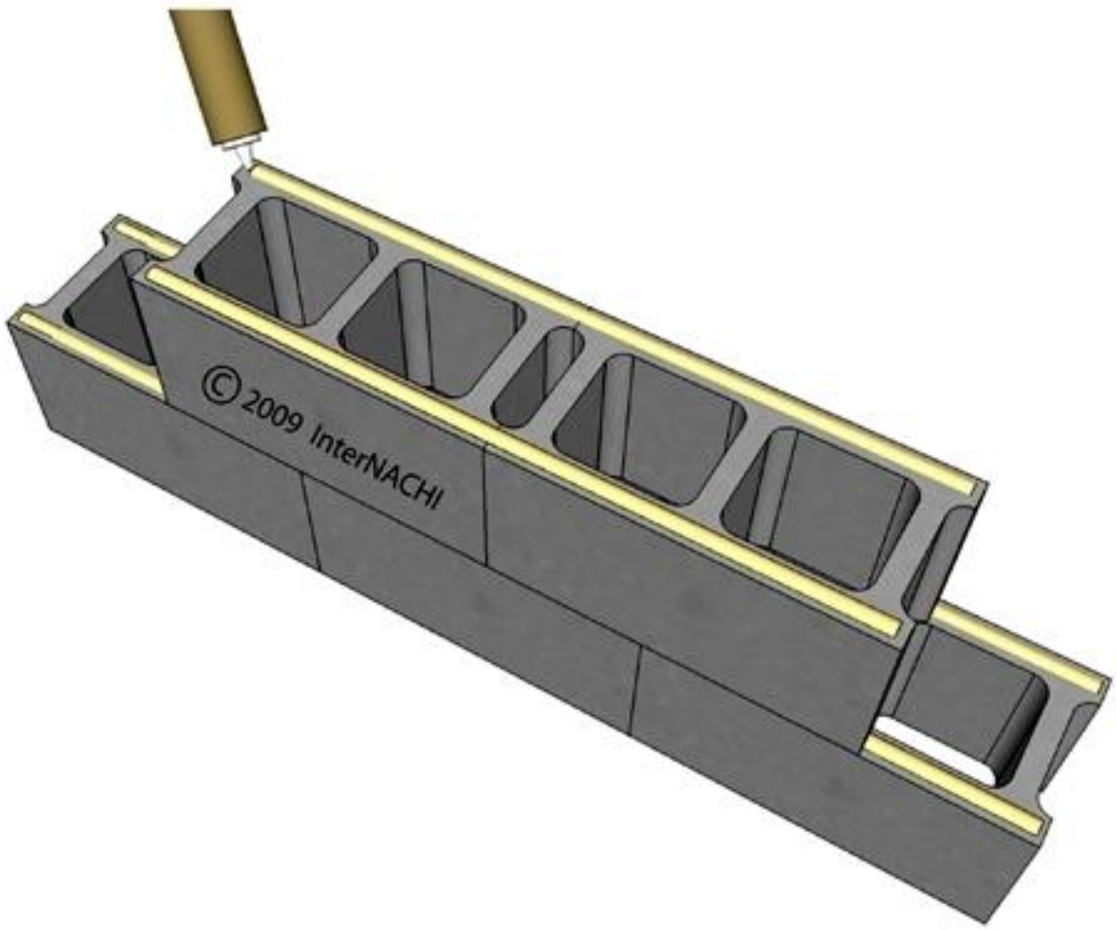
9. Rapid settlement produces tapering cracks.

10. T/F: Frozen soil exerts a greater force against the foundation than wet soil.
    Answer: True

11. T/F: Inspectors should note the condition of masonry piers and ensure that they are plumb.
    Answer: True

12. Some causes of foundation settlement include: all of these.

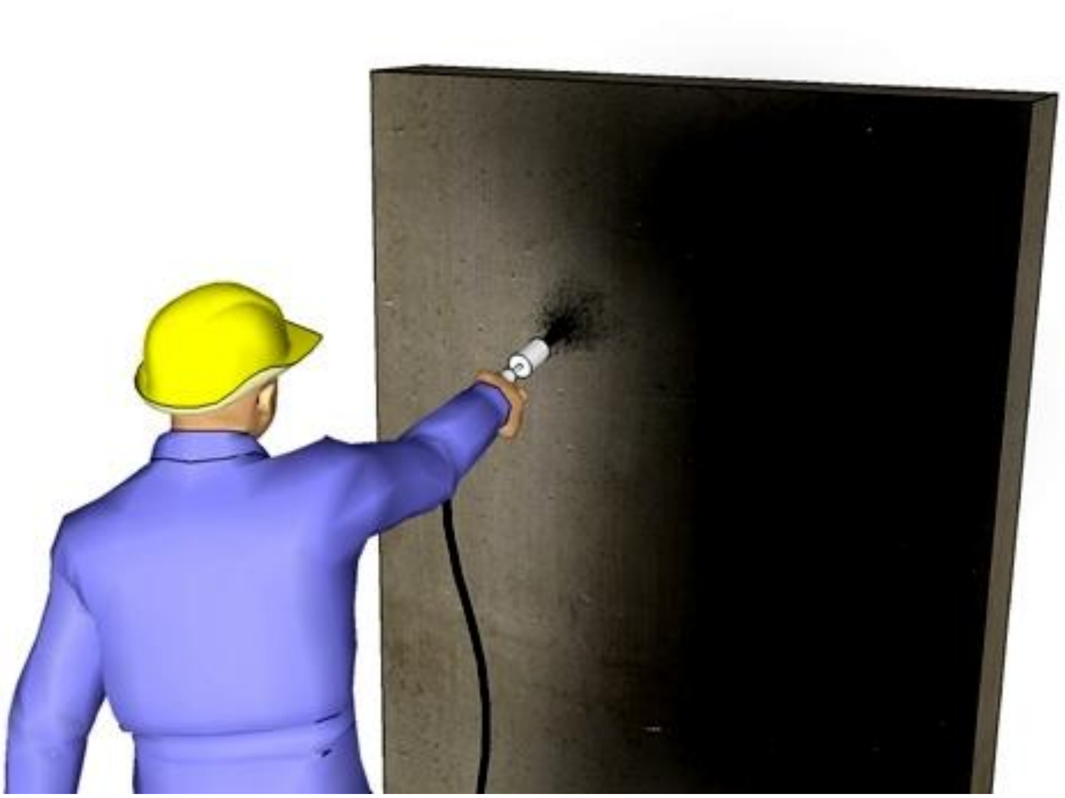
MASONRY and CONCRETE ADHESIVES



Mortar has traditionally provided the bonding agent for masonry units. The principle types, M, N, S and O, use a combination of cements, lime, sand and water to hold building blocks together and provide a seal from the elements. However, as new adhesives are developed, manufacturers have experimented with their use to improve bond strength and reduce labor costs.

Masonry adhesives are pre-mixed and available in several packaging formats, from caulk tubes and squeeze bottles to pressurized bulk containers. Several beads of the mix can be applied at the same time when an application wand is used.

INNOVATIONS: CONCRETE WATERPROOFING SYSTEMS



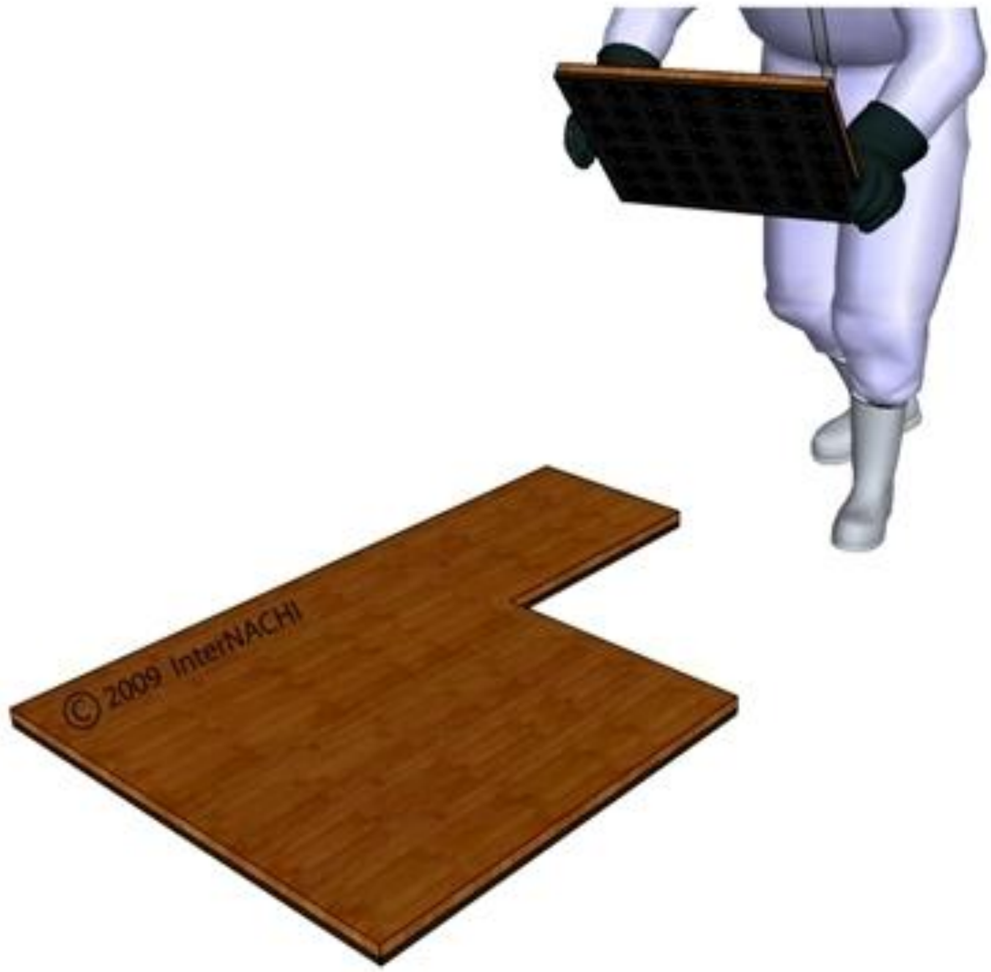
Anyone who has experienced damage from water seepage knows that it is a costly and time-consuming process to repair. One way to help reduce water seepage is by using crystalline concrete waterproofing. This method uses a catalytic reaction to seal the pores, capillaries and shrinkage cracks that occur naturally in concrete. Crystalline waterproofing penetrates into the concrete.

Long available for industrial applications, crystalline waterproofing is now ready for use in residential applications. It consists of a dry powder compound of Portland cement, very fine treated silica sand, and proprietary chemicals. Combining the product with water and applying it to the surface of concrete results in a catalytic reaction that forms non-soluble crystalline fibers within the pores and capillary tracts of concrete. This seals the concrete against moisture penetration.

Crystalline waterproofing replaces traditional solvent-based waterproofing on foundation walls. However, exterior parging, bituminous waterproofing, or a drainable layer may be required by the building code.

Water penetration through basement and crawlspace foundation walls is usually caused by condensation and/or from an exterior water source due to inadequate grading, rainwater collection, and/or poor footing drains. The source of condensation or exterior water intrusion must be corrected prior to the application of crystalline concrete waterproofing.

WATER-RESISTANT POLYETHYLENE SUB-FLOOR SYSTEMS



Polyethylene flooring systems that are specially designed for use over concrete floors can alleviate moisture problems associated with placing wood sub-flooring in direct contact with concrete slabs. The systems are made of a molded polyethylene base. The base prevents the migration of moisture, while its undulating, raised pattern creates an airspace between sub-floor and concrete. One type of pattern resembles plastic cleats, while another is zig-zag.

FOUNDATION DRAINAGE PANELS

The foundation is a vulnerable place for water intrusion. Improper drainage around the foundation is a major cause of leaking foundations. When a drainage system is used in residential construction, it is usually a combination of a layer of gravel for drainage with a foundation drain, usually either drain tile or perforated PVC pipe. Months later, as drainage occurs, small soil particles can fill the drainage path, resulting in reduced drainage of ground water. Water pressure then builds up and eventually causes leakage through the foundation wall.

Engineered, prefabricated foundation drainage panels are designed to facilitate the movement of ground water, which reduces the stress of the water pressure on the foundation's waterproofing. The drainage panels provide an unobstructed path from the surface grade to the footing, allowing the footing drain to collect and move water away from around the foundation. Some of these systems also provide thermal resistance and can reduce interior condensation.

Foundation drainage panel systems combine with waterproofing membranes to provide protection from ground water in areas where there is a high water table and/or hydrostatic pressure. The standard gravel drainage course and foundation drains with damp-proofing on the foundation are applicable in areas with occasional or no groundwater.

The typical foundation drainage system consists of a waterproofing membrane at the foundation with a pre-formed path, such as a grid system or a solid porous board, and a filter to keep the drain path clear of small particle buildup. The filter is usually a course of specially-graded aggregates, ranging from crushed stone and gravel to coarse, angular sand. Geotechnical fabrics, commonly called "filter fabrics," are now frequently used to allow the flow of water while preventing small particles from passing through. These fabrics use less space, are more reliable, and are relatively easy to install.

The drainage path can be designed using several different methods:

- a solid drainage board with a porous structure, allowing moisture and water to drain vertically down to the foundation drain. These board-type systems provide protection of the waterproof membrane and thermal insulation;
- an air space created by a dimpled plastic grid, or "geogrid." Condensation can also be collected in this air space;
- a traditional gravel course, with filter fabric to the outside, and a protection board over the foundation waterproofing. Washed pea-gravel and screened crushed stone work well for this drainage course; and
- panels with an air space to quickly move the water to the drains, reducing hydrostatic pressure against the foundation.

Most of these systems also provide protection to the damp-proof or waterproof membrane.

Dimpled polyethylene sheets can be used in two ways:

- with the dimples toward the foundation wall. This provides an air space for condensation, using the backside as an impervious barrier. When properly sealed, the system resists ground water percolating through to the face of the foundation, thereby protecting it from the moisture.
- some products have a filter fabric adhered to the dimple-side of the panel. In this case, the flat side of the panel is placed toward the foundation. The drainage path is created by the dimples, and protected by the filter fabric.

Another method for providing a path with the filter fabric is the use of a "geogrid." A geogrid is a twisted-wire plastic mesh, often shaped into a diamond-lath pattern, faced with filter fabric. These are normally rather thin, flat membranes offering effective drainage characteristics in a minimal space.

Enkadrain™ employs a fused, entangled polymer filament geomatrix, or plastic wire mesh, faced with filter fabric to provide the drainage layer.

The American Wick Drain Corporation makes a sheet-drain system connected to a strip drain at the bottom of the foundation wall. The strip drain can be connected to piping to lead the water away from the foundation.

Form-a-Drain®, made by the Certainteed Corporation, is a rectangular drainage conduit that also acts as a footing form, saving several installation steps.

Foam plastic insulated panels may be used outside foundation walls to move water to drain tile or pipe at the bottom of the wall. As mentioned previously, these panels also provide thermal insulation. Panels may or may not be faced with a geotextile membrane. Geotech™, for example, is an un-faced board of expanded polystyrene. It allows water to move between the bead structure of the material, and the polystyrene offers insulating value.

Other foam foundation panels are made from extruded polystyrene, grooved on the soil-side and covered with filter fabric. The filter fabric allows the water to enter the grooves which, in turn, transfers it to the drain tile. The polystyrene insulation has a low permeability rating, and provides insulative value.

Some drainage panels are composed of rock (mineral), wool, and fiberglass material oriented to provide vertical drainage to the foundation drain. No filter fabric is necessary with these materials.

FOUNDATION FLOOD VENTS

To be eligible for flood insurance through FEMA's National Flood Insurance Program (NFIP), foundations must be constructed with certain flood damage-mitigation features. In coastal areas and riverine zones where high-velocity floodwaters can occur, homes must be elevated on open-pile foundations, and enclosures below the living space must be located at an elevation higher than the 100-year base flood elevation and must be designed to break away in a storm surge.

Homes built in floodplains where floodwater velocity levels are lower than coastlines and riverine zones (less than 5 feet per second), and on perimeter-type foundations, should be designed so that the exterior walls of the foundation automatically equalize hydrostatic flood forces by allowing for the free flow of floodwater. This minimizes structural flood damage by reducing the horizontal hydrostatic force that unbalanced water levels impose on foundation walls.

Foundation designs meeting NFIP requirements must include prescribed openings or an engineer's certification that the following minimum criteria have been met:

- A minimum of two openings (on different foundation wall elevations) having a total net area of not less than 1 square inch for every square foot of enclosed area subject to flooding shall be provided.
- The bottom of all openings shall be no higher than 1 foot above grade.
- Openings may be equipped with screens, louvers, valves, or other coverings or devices, provided that they permit the automatic entry and exit of floodwaters.

Any openings that allow for the free flow of floodwater into or out of a foundation will meet NFIP requirements, subject to minimum size and location criteria. Even voids in the continuity of a block foundation (or "blocks turned sideways," as one Maryland Department of the Environment technical note refers to it) will suffice.

Depending on their method of operation, conventional crawlspace ventilation grills may also serve to equalize water around the foundation during a flood. However, some air vents that are thermostatically controlled may not disengage in cold weather to allow water entry. If crawlspace vents will also be used as floodwater vents, the number and location of vents to be used should be specified, based on the floodwater vent criteria.

Several manufacturers have developed unitized, shuttered products that meet the minimum flood venting requirements of NFIP. Smart Vent, Inc. markets several types of vents, including the Smart VENT®, which automatically opens and closes as floodwaters rise and fall. It also features temperature-controlled louvers which open in warm weather to provide 50 inches of net-free ventilation area, and then close in cold weather.

Each Smart VENT®, sized 8x16 inches, is certified to protect 200 square feet of foundation area. Another model, Flood VENT™, is used when flood protection, not ventilation, is needed. This model has a non-vented insulated door that minimizes heat loss, air leakage, and pest intrusion when the door is closed, but swings open during a flood. Another manufacturer, Floodex, has obtained pre-certification of its floodwater vent.

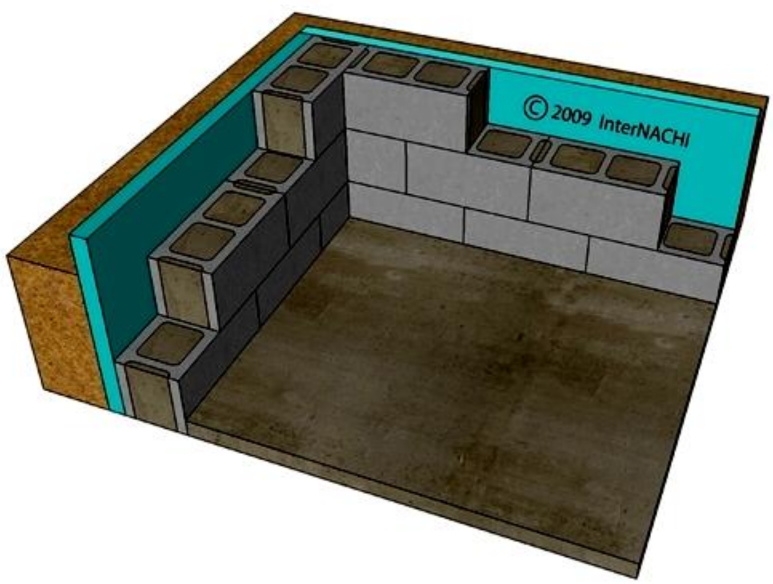
STEEL FOUNDATION SYSTEMS

The Fast Track Foundation System® is a series of structural corrugated steel wall panels positioned along an existing in-place structure, then cast into place, creating a foundation wall. The foundation panels can be used for new construction, foundation retrofits, and modular and manufactured homes.

The foundation system can also be used in low-cost tornado shelter applications. Fast Track Systems® received recognition in the 2002 Innovative Housing Technology Competition, which is co-sponsored by Popular Science magazine and the NAHB Research Center.

The panel material is commercially available corrugated steel, 18-gauge, galvanized G-90 "B-deck" (1.5-inch thick). The bottom panel edges are cast into a concrete footing, providing anchorage and bearing. With vertical flutes, panels serve as a bearing foundation wall. Panels are joined together with a caulked joint along the contiguous-edge, and then they are treated with a protective coating.

FROST-PROTECTED SHALLOW FOUNDATIONS (FPSFs)



Frost-protected shallow foundations (FPSF) provide protection against frost damage without the need for excavating below the frost line. An FPSF has insulation placed strategically around the outside walls to direct heat loss from the building toward the foundation, and also to use the earth's natural geothermal energy. Traditionally, foundations are protected from frost-heaving damage by placing the footing below the frost line.

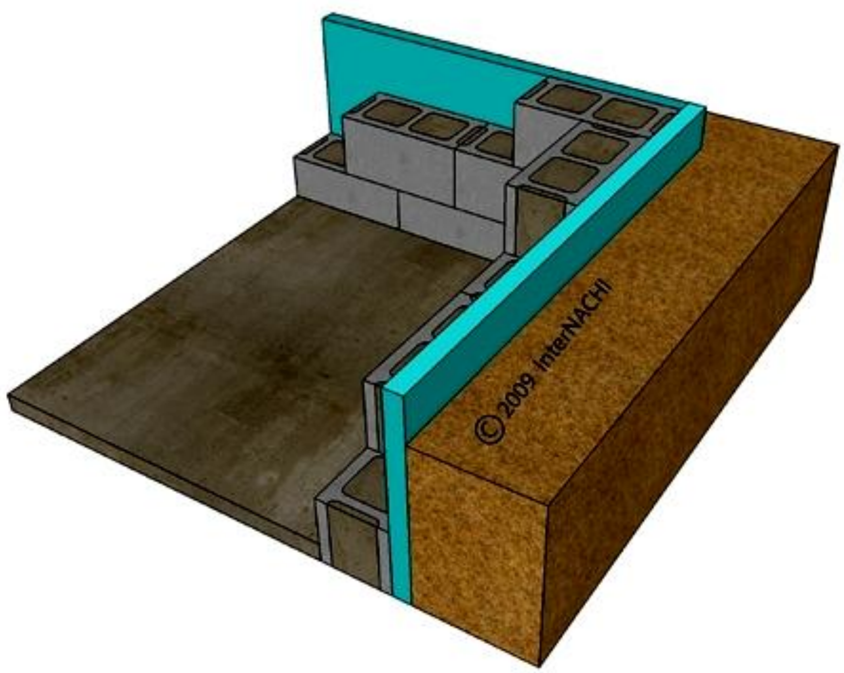
Because FPSFs are protected from freezing by thermal insulation, the bottoms of footings can be just 12 to 16 inches below grade. This reduces excavation costs, making FPSFs an economical alternative for protecting foundations against frost damage.

Insulated footings have been in use since as early as the 1930s by Frank Lloyd Wright in the Chicago area. There are now more than 1 million homes in Norway, Sweden and Finland with insulated shallow footings, recognized by their building codes as standard practice. It is estimated that there are more than 5,000 buildings in the United States that have successfully used frost-protected shallow foundations.

FPSFs are similar to conventional foundations except in insulation placement and footing depth. The bottoms of FPSF footings are placed about 12 to 16 inches below grade. FPSFs have vertical insulation placed at the outside edge of the foundation, extending from above grade to the bottom of the footing.

When required in colder climates, "wing" insulation extends outward horizontally from the footing. The colder the climate, the further the wing insulation is extended. Wing insulation is unnecessary in moderate climates.

The insulation used in FPSFs is commonly rigid expanded or extruded polystyrene foam suitable for below-grade application, and it must be in compliance with ASTM C 578 Standards. An FPSF can be used for both heated and unheated portions of a building.



WOOD FOUNDATIONS

Preservative-treated lumber is pressure-infused with chemicals to resist infestation and decay, and the process is so effective that manufacturers are now recommending treated plywood and lumber as an alternate material for crawlspace, basement and stem-wall foundations.

Using a wood foundation system eliminates the need to cast and cure concrete footings (although a slab floor may be included), and allows construction in any weather by the same crew that completes other wood framing. Wood foundations also resist cracking, and are easy to insulate and finish for additional interior living areas. More than 300,000 U.S. homes have been constructed with wood foundation systems.

Wood foundation systems were first developed in the 1960s, after the development of preservative-treated lumber and plywood allowed wood materials to be used in applications for which it previously would have been subject to decay. Manufacturers that produce preservative-treated lumber and related applications have developed procedures and guidelines for constructing wood foundations, while other companies specialize in custom-designed and panelized systems.

Because wood foundations are significantly lighter than concrete and block walls, they may be placed on gravel beds, eliminating the need to cast and cure a concrete footing.

A concrete slab may form the floor within the foundation, but most manufacturers promote the use of a treated wood floor system. This eliminates concrete work from the schedule altogether, allowing construction to proceed in any weather, with work completed by the same crew that does the rest of the wood framing.

Typically, walls are framed with 2x8 treated studs on 16-inch centers, or as specified by the designers. The exterior foundation surfaces are clad with 1/2-inch or 5/8-inch treated plywood, with polyethylene film applied before back-filling.

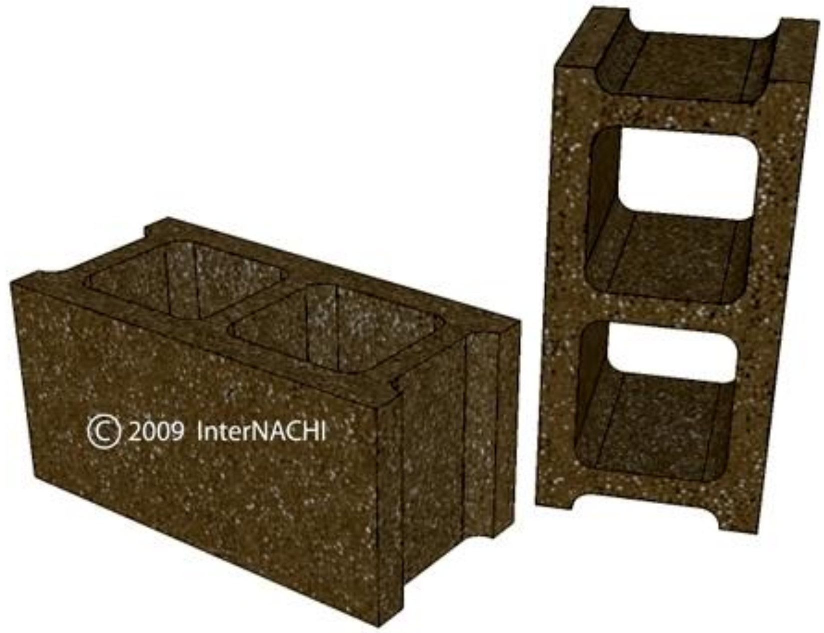
For basements finished as living space, the cavities of the wood foundation framing are easily insulated with conventional batts or blown cellulose. Plumbing, wiring and drywall are installed as for any framed wall. Finishing concrete and block walls might require chase construction, special cutting equipment, furring strips, and/or masonry adhesive.

Manufacturers state that wood foundations are also more thermally efficient and elastic and, therefore, less subject to cracking and moisture penetration.

Permanent wood foundations must be preservative-treated in accordance with the American Wood-Preservers' Association (AWPA) Standard C22, titled "Lumber and Plywood for Permanent Wood Foundations: Preservative Treatment by Pressure Processes."

ICF WALLS: WOOD FIBER COMPOSITE FORMS

Concrete walls can be constructed of cement-bonded recycled wood-chip insulated concrete forms (ICFs) that hold concrete in place during curing, and remain in place to provide thermal and noise insulation. The blocks are lightweight, and are available with mineral-fiber insulation to provide an energy-efficient, fire- and termite-resistant, durable structural wall system.



The system is inherently moisture-regulating, capable of absorbing high levels of moisture in the air without damage. The wall form, however, does not support or promote fungal or mold growth. The material is capable of being installed both above and below grade, and is available in various widths and insulation thicknesses.

Cement/wood fiber blocks are similar to the newer ICF systems comprised of foam insulation with metal or plastic joiner ties. Cement/wood fiber blocks are intended to be dry-stacked, and are designed with horizontal and vertical cells that are filled with concrete to form the structural portion of the wall. Vertical and horizontal interlocking channels simplify alignment.

The wood fiber used in the manufacture of the block may be partially or fully comprised of post-industrial softwood, which is then mineralized with cement. The basic material's heat-resistance is approximately 1.75 per inch thickness. The product's R-value ranges from about R-8 for an 8-inch block with no additional insulation, to R-20 for a 12-inch block with a 3-inch mineral wool insert. No bridging occurs since the solid portions of the material at the ribs have an insulative value of about R-14.

The hygroscopic properties of the material allow it to readily take up excess moisture in the air and store it without it being absorbed, and without damage to the material. This attribute helps to balance changes in the relative humidity of the indoor environment. On the exterior, the material can act as a drainage plane if subjected to liquid water—a distinct possibility in a basement. An air barrier may be required for some finishes.

The thermal-mass benefits of the concrete are enhanced with cement/wood fiber blocks, since at least two-thirds of the insulation is on the exterior of the mass. This proximity of the mass to the indoor environment serves to stabilize the indoor air temperature, and to take advantage of direct solar gains in heating periods.

VAPOR BARRIERS

Crawlspace Vapor Barriers

Throughout the United States, even in desert areas, there is moisture in the ground from groundwater being absorbed. Even in an apparently dry crawlspace, a large amount of water is entering the home. In a dry crawlspace, the moisture is drying out as fast as it is entering, which causes high moisture levels in the crawlspace and elsewhere in the house. A solid vapor barrier is recommended in all crawlspaces, and should be required if moisture problems exist. This vapor barrier, if properly installed, also reduces the infiltration of radon gas. Of course, if the moisture is coming from above ground, a vapor barrier will collect and hold the moisture. Therefore, any above-ground source of moisture must be found and eliminated. The source may be as obvious as sweating pipes, or may be more difficult to spot, such as condensation on surfaces. The solution can be as simple as applying insulation to exposed sections of the piping, or complex enough to require power exhaust fans and the addition of insulation and vapor barriers.

The more common causes of moisture problems in a new home are moisture trapped within the structure during construction, and a continuing source of excess moisture from the basement, crawlspace or slab. To resolve this potential problem, 6-mil plastic sheets should be laid as vapor barriers over the entire crawlspace floor. The sheets should overlap each other by at least 6 inches, and should be taped in place. The plastic should extend up the perimeter walls by about 6 inches. The plastic sheets should be attached to the interior walls of the crawlspace with mastic or batten strips. All of the perimeter walls should be insulated, and insulation should be between the joists at the top of the walls. Vents, which may need to be opened in the late spring and closed in the fall, should not be blocked. If not properly managed, moisture originating in the crawlspace can cause problems with wood flooring, and create many biological threats to health and property. A properly placed vapor barrier can prevent or reduce problem moisture from entering the home.

Concrete paints, waterproofing sealers and cement coatings are a temporary fix. They crack and peel, and cannot stop gases, such as water vapor and radon.

Damp basement air spreads mold and radon through the house. Efflorescence (white powder stains) and musty odors are telltale signs of moisture problems. Basement remodeling traps invisible water vapor, causing mold and mildew.

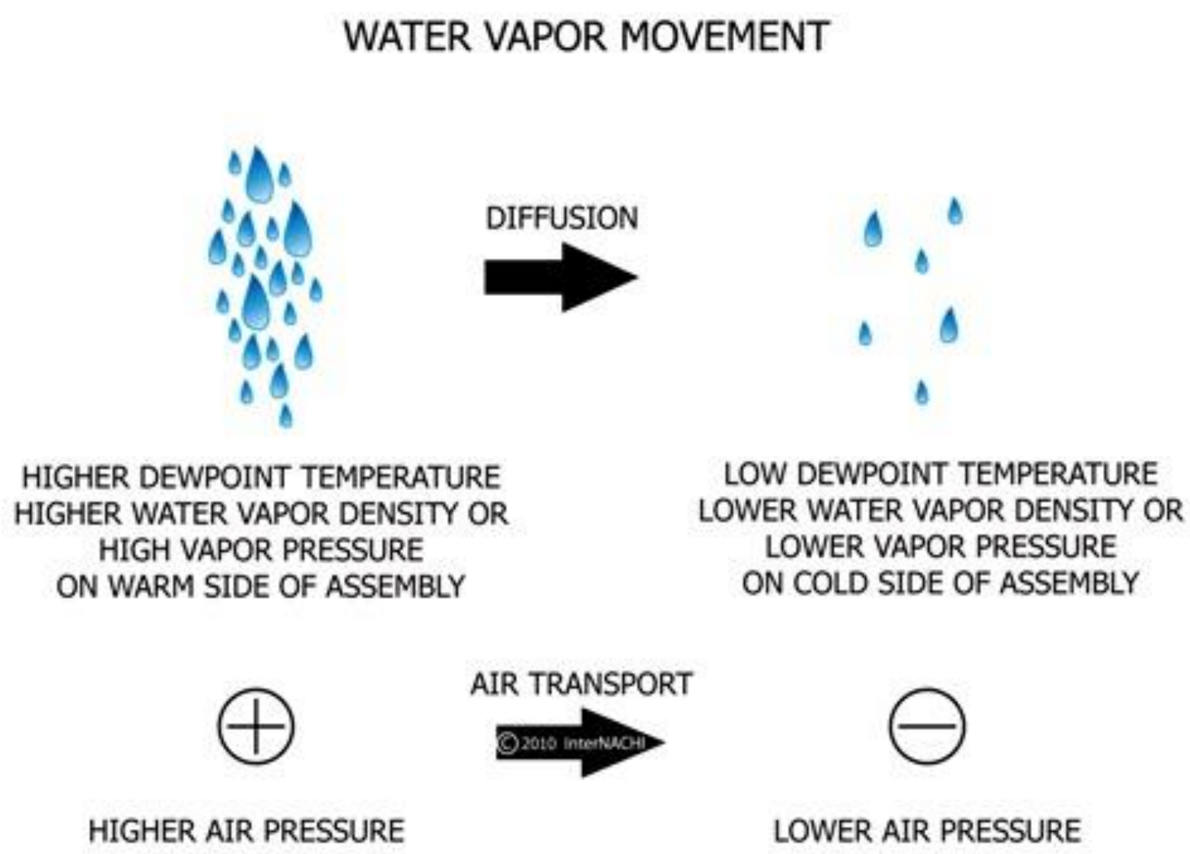
Most basements start leaking within 10 to 15 years. The basement walls and floors should be sealed and preserved before they deteriorate. The basement floor should be concrete which has been poured on at least 6 inches of gravel. The gravel distributes groundwater movement under the concrete floor, reducing the possibility of the water penetrating the floor. A waterproof membrane, such as plastic sheeting, should be laid before the concrete is poured for additional protection against flooding and infiltration of radon and other gases.

The basement floor should be gradually but uniformly sloped in all directions toward a drain or a series of drains. These drains will permit the basement to drain if it becomes flooded.

Water and moisture marks on the floor and walls are signs of ineffective waterproofing or moisture-proofing. Cellar doors, hatchways and basement windows should be weather-tight and rodent-proof. A hatchway can be inspected by standing at the lower portion with the doors closed; if daylight can be seen, the door needs to be sealed or repaired.

Vapor Barriers for Concrete Slab Homes

Strip-flooring and related products should be protected from moisture migration by a slab. Proper on-grade or above-grade construction requires that a vapor barrier be placed beneath the slab. Moisture tests should be done to determine the suitability of the slab before installing wood products. A vapor barrier equivalent to 4- or 6-mil polyethylene should be installed on top of the slab to further protect the wood products and the residents of the home.



PLASTIC DUCTWORK SYSTEMS

Plastic ductwork systems are well-suited for underground applications because they are resistant to rust and other forms of corrosion. These systems are manufactured with either high-density polyethylene (HDPE) or polyvinyl chloride (PVC). When installed properly, they are watertight and airtight, and can withstand temperatures up to 150° F.

Plastic ductwork is available in diameters of 4 to 24 inches, with a variety of fittings, including Ts, Ys, elbows, 45-degree elbows, register boxes, saddle boots, saddle connections, reducers, couplings, end caps, and starting collars. Plastic plenum boxes are also available for underground installation.

While it is preferable to install ductwork in conditioned spaces to maximize energy-efficiency, it is not always possible. In some areas of the United States, placing ducts underground may be the next best strategy, particularly if the slab edge is insulated. In hot climates, for example, it is more energy-efficient for the cooling ducts to be under the slab than exposed in a hot attic. In areas where ground moisture and water intrusion may be an issue, however, extra care must be taken when installing the underground ductwork to protect it from excess water.

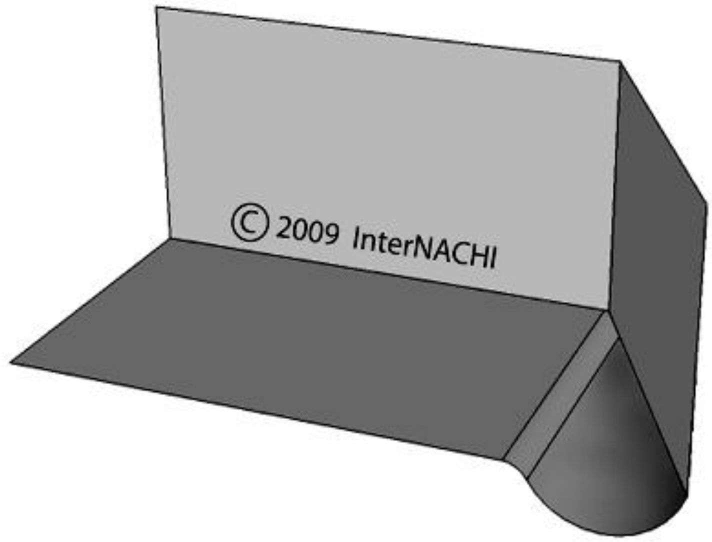
HDPE

These underground air ducts and fitting systems were first introduced into the market in 2003 for use with forced-air heating and cooling systems. The ducts consist of a high-density polyethylene (HDPE) liner covered with a layer of air-entrained polyethylene. The HDPE pipes have a K-value equal to PVC wrapped with R5. The ducts and fittings are typically blue in color.

PVC

Conventional PVC plastic pipe can also be used in below-ground duct applications. The pipe and fittings are typically white, black or gray in color. Sunlight contains ultraviolet rays which degrade PVC, so care must be taken during construction to protect the PVC from exposure to the elements. The ductwork is made from the same material as PVC plastic pipe used in below-ground plumbing systems, which have been installed successfully in the United States since the 1950s.

FLASHING PRODUCTS: MANUFACTURED ROOF and PAN



Water intrusion in building walls is the primary cause of premature building failure, and the root cause of costly and time-consuming litigation nationwide. Continual wetting and drying of wall cavities not only destroys wood fibers, but can also provide a breeding ground for mold and mildew. These will foul the appearance and air quality surrounding the moist area.

Intrusion can occur in all types of buildings and in most climates, and typically will infiltrate at planar and material junctions in buildings, such as roof-wall junctions, door and window openings, and where architectural features meet cladding and veneer.

Flashing, a redundant barrier at the locations most likely to admit moisture, has long been the traditional approach to sealing architectural features and material junctions. Today, there are numerous new flashing products available that are able to handle the increasing complexity of modern designs, while still offering off-the-shelf convenience.

Roof Flashing

Many roofs have multiple intersections, such as valleys, crickets and abutments to adjacent walls, which are prone to water leakage. Pre-formed components, such as drip edges, step flashings, kick-out diverters, and specialty pipe and chimney caps, provide solutions that eliminate the guesswork for specialty trades -- such as roofers and siding installers -- and generally streamline construction.

Pan Flashing

Window and door sills present another opportunity for water leakage from wind-driven precipitation. Industry experts have long recommended that these areas be flashed with water dams at the back and up the sides of the sills with a forward slope for positive drainage.

There are many manufactured sill pan systems available on the market today. Often made of molded and sometimes recycled plastics, these products include drainage channels to direct water away from the window frame. These are available in standard opening widths and can be cut and customized on site. Some systems include trim strips so that any part of the system visible after installation can be covered for aesthetics.

QUIZ 3

1. **Polyethylene flooring systems that are specially designed for use over concrete floors can alleviate __________ problems.**

- vibration
- moisture
- noise

2. **________________ is a major cause of leaking foundations.**

- The use of preservative-treated wood
- Sandy soil
- Improper drainage around the foundation

3. **Frost-protected shallow foundations are protected from freezing by _________.**

- thermal insulation
- a special chemical bonding process
- installing them below the frost line

4. **To be eligible for flood insurance through FEMA's National Flood Insurance Program (NFIP), _____________________.**

- the applicant family must qualify as low-income
- the home must be located in a 100-year floodplain
- the home's foundation must be constructed with certain flood damage-mitigation features

5. **Traditionally, foundations are protected from frost-heaving damage by placing the footing _______ the frost line.**

- at
- above
- below

(continued)

6. A wood foundation using preservative-treated lumber resists ________.

- decay
- cracking
- termites
- all of these

7. There is moisture in the ground from groundwater being absorbed, _____ in desert areas.

- even
- only
- especially
- except

8. _____________ are telltale signs of moisture problems in a basement.

- Termites and infiltration of tree roots
- Dust and spiders
- Efflorescence and musty odors

9. A vapor barrier can reduce the infiltration of ____________.

- moisture
- all of these
- radon
- mold

10. When installed properly, plastic ductwork systems are watertight and airtight, and can withstand temperatures up to ______.

- 85° F
- 32° F
- 150° F

Answer Key is on the next page.

Answer Key to Quiz 3

1. Polyethylene flooring systems that are specially designed for use over concrete floors can alleviate moisture problems.

2. Improper drainage around the foundation is a major cause of leaking foundations.

3. Frost-protected shallow foundations are protected from freezing by thermal insulation.

4. To be eligible for flood insurance through FEMA's National Flood Insurance Program (NFIP), the home's foundation must be constructed with certain flood damage-mitigation features.

5. Traditionally, foundations are protected from frost-heaving damage by placing the footing below the frost line.

6. A wood foundation using preservative-treated lumber resists all of these.

7. There is moisture in the ground from groundwater being absorbed, even in desert areas.

8. Efflorescence and musty odors are telltale signs of moisture problems in a basement.

9. A vapor barrier can reduce the infiltration of all of these.

10. When installed properly, plastic ductwork systems are watertight and airtight, and can withstand temperatures up to 150° F.

MODULAR BLOCK RETAINING WALL SYSTEMS

Modular block or segmental retaining walls employ interlocking concrete units that tie back into the earth to efficiently resist loads. These pre-engineered modular systems are an attractive, economical and durable alternative to stone and poured concrete retaining walls. The inherent design flexibility can accommodate a wide variety of site constraints, project sizes, and aesthetic preferences.

Individual (and usually identical) precast concrete units interlock, offset-stack, or are placed structurally independent of each other and anchored into the backfill. These independent tier systems are advantageous for seismic areas.

The components of a complete system can include foundation soil, leveling pad, precast concrete units of high-strength concrete, shear pins (if units don't interlock), multiple-depth walls, and additional soil reinforcement, such as geotextile, welded-wire fabric, and dead-man anchors (if the wall is over a certain height), retained soil, and drainage fill.

Some systems have relatively shallow units, while others have units with a tail for deep embedment for taller and more vertical walls (walls are never perfectly vertical). The soil reinforcement consists of horizontal layers that extend into the backfill.

Being gravity structures, these systems rely on their own weight and coherent mass to resist overturn and sliding forces. The segmental feature affords the wall a permeability to relieve hydrostatic pressure, so less material is required for resistance. Because they are considered flexible structures, the footings usually need not reach the frost line. Some systems allow for landscaping of the wall between tiers (depending on site conditions), while others are designed as structural frames to be covered with landscaping.

These systems have been installed all over the U.S.; distributor locations vary per manufacturer.

MANUFACTURED HOUSING GROUND-ANCHOR SYSTEMS

Manufactured homes are not usually installed with permanent foundations, but instead sit on short piers that resist mostly gravity loads.

Ground anchors are plates or augers imbedded in the soil that limit lateral building movement down through tension members tied back to the home's chassis. In this way, forces from high winds, earthquakes and floods are resisted through the coherent mass of the earth acting with the anchors. Properly applied, these systems are a cost-effective way to limit structural failure compared to conventional manufactured housing foundations, saving lives and property.

In a complete ground-anchor foundation system, the house is supported by several steel I-beams, which are supported by an array of short piers. Tensile members, usually diagonal, connect the main beams with each anchor assembly. An anchor consists of a rod between the anchor head and anchor base, which is buried 3 to 9 feet into terra firma, and allows the combined mass of the retained soil to resist uplift and lateral forces. Types of ground anchors include "manta ray" plate anchors, "rock anchors" for rock embedment, single- and double-helix anchors that are augered into place, and rods or chains that anchor into a poured structural fill. Tension members may be steel rods, straps or link chains. Most systems offer stabilizer plates to limit the anchor heads' horizontal displacement.

The most common ground anchors are auger, or helix-type, systems. They are applicable to several types of piers, and feature anchors with a single- or double-helix base, and an optional lateral stabilizer near the anchor head. The helix is a 4- or 6-inch circular plate in the shape of a short spiral. Steel straps hold the home's chassis to the anchor heads.

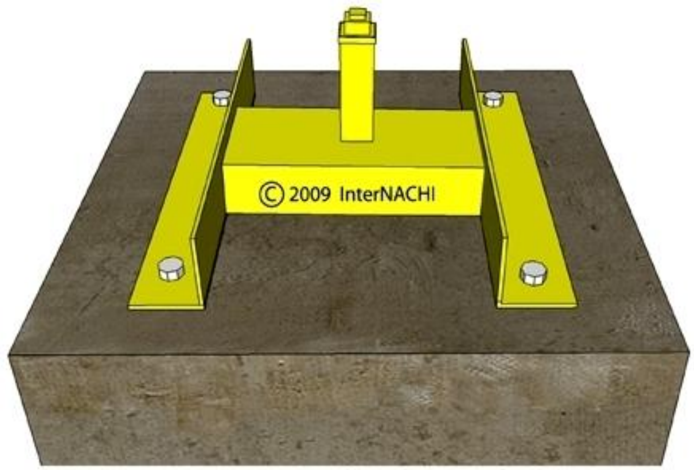
Variations include steel rod anchors, which may be encased in a poured structural fill collar, or "rock anchors," which may be installed in solid rock.

Earth-Lok® is a "manta ray"-type anchor system designed for earthquakes. It features a large anchor plate (up to 6x6 inches) that can be driven up to 18 feet into the ground. The plate is then rotated with a gad, or second steel rod, and pulled back to lock. A galvanized threaded rod holds the plate to the home's chassis, which is clamped to a series of steel pyramidal supports. Only certified crews can install the system.

Another system, Ground-Loc®, makes use of link chains or all-thread rods tying the home's chassis into an anchoring material poured into excavated cavities in the earth. Working with piers made by other companies, the manufacturer provides pier-to-chassis clamps and all-thread rods to tie the carrying beams together.

One model converts the foundation to a permanent foundation, thus qualifying the home as real property, enabling a low-interest mortgage.

MANUFACTURED HOUSING DISASTER-RESISTANT PIER



A good foundation gives homeowners peace of mind. For manufactured homes, one option is a disaster-resistant pier system -- stout members rigidly connecting the home's chassis to a slab, grade beam, or array of pads. Some systems incorporate lateral or diagonal bracing for greater resistance. Although often referred to as earthquake-resistant bracing (ERB) systems, many also resist high winds, frost heaves, and floods.

Not only are these systems cost-effective in reducing structural movement (compared to conventional manufactured housing foundations), they can save lives and property.

In a complete disaster-resistant pier system, several rolled steel beams (the chassis) are supported by an array of stout adjustable steel piers which are connected to both the chassis and the concrete slab, or base pad, with high-strength bolts. Individual pier adjustment usually consists of threaded rods, or a vertical series of holes for a cross-bolt.

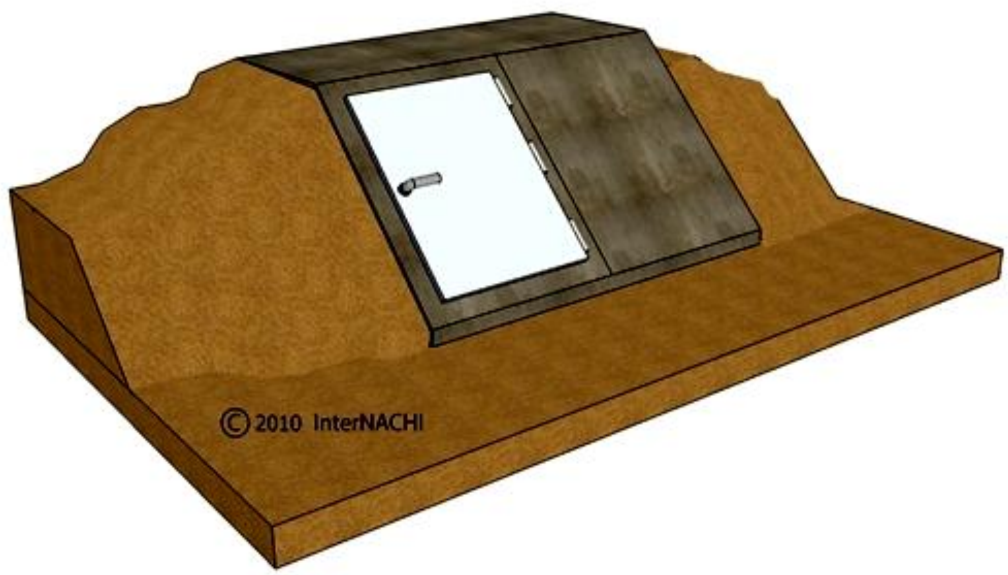
Several manufacturers offer a secondary support system, or seismic isolator, to prevent the home from dropping too low, should the piers fail. This can be installed separately as an economical retrofit. Optional brackets connecting the pier heads to the floor joists help prevent piers from tilting from a vertical position.

Piers overturning from wind or earthquake loads is one of the most common types of failure, and there is a variety of remedies. Many systems use pyramidal piers secured to pads at the base and to locking devices at chassis beams. The pier is made of steel angles that meet at a collar holding an adjusting bolt. One system embeds the pier base in a concrete "foot" poured into a geotextile form bag. Another system substitutes recycled plastic pier pads for permanent, pressure-treated wood or concrete pads.

Other systems install piers on precast grade beams and broad pads. The pier base is secured to a wide horizontal steel plate or frame to distribute the pier's base load over a broader area. The pier has a square cross-section. Some systems feature rigid steel angle struts and cross-bracing to stabilize adjacent piers, triangulating the loads.

Pier system retailers tend to specialize in retrofitting, while wholesalers try to deal exclusively with new construction. Distributor locations vary by manufacturer. Many pier units are shipped at least partially assembled, so shipping costs may be high. Lead time varies from two days to about two weeks.

PREFABRICATED STORM SHELTERS



Storm shelters can help reduce the risk of injury and death caused by tornadoes and hurricanes. Prefabricated shelters, designed to withstand the high wind and flying debris of Category 5 hurricanes and F5 tornadoes, are available for in-home and exterior installation.

Ready-to-install exterior concrete, metal and fiberglass storm shelters are available for low-profile in-ground installation on flat and sloped terrains. In-home shelters are anchored to the home's foundation, and come in a variety of materials and configurations. Most in-home units can double as functional living space.

Storm shelters vary in size, with a typical size about 6x 8 feet. FEMA, the Federal Emergency Management Agency, recommends 6 square feet of area per person, and a means of ventilating the space is required. Handicap-accessible models are available.

Manufacturers offer various sizes, access methods, and elements which can include carpeting, seating, and an emergency jack to remove exit door obstructions, among other features.