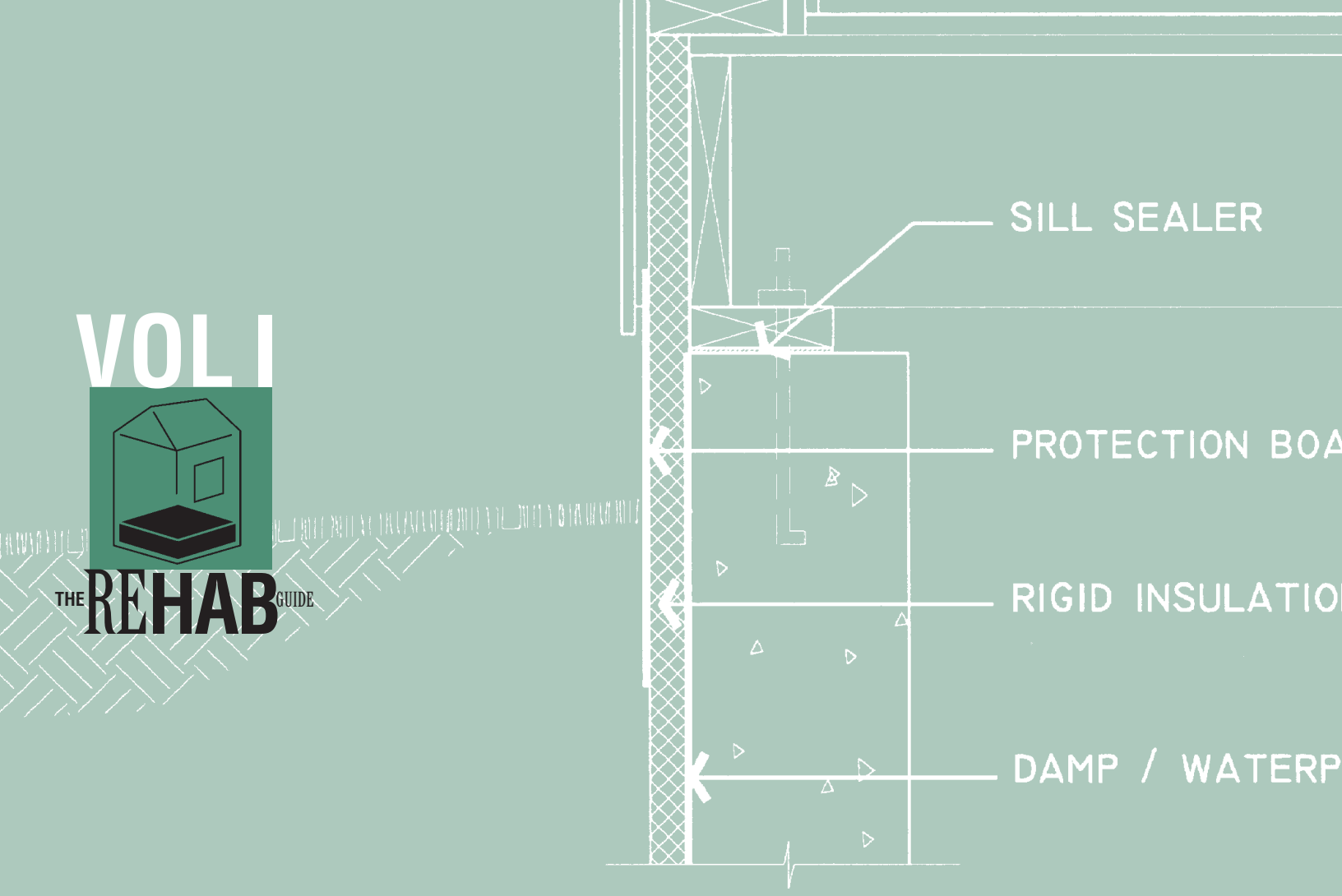
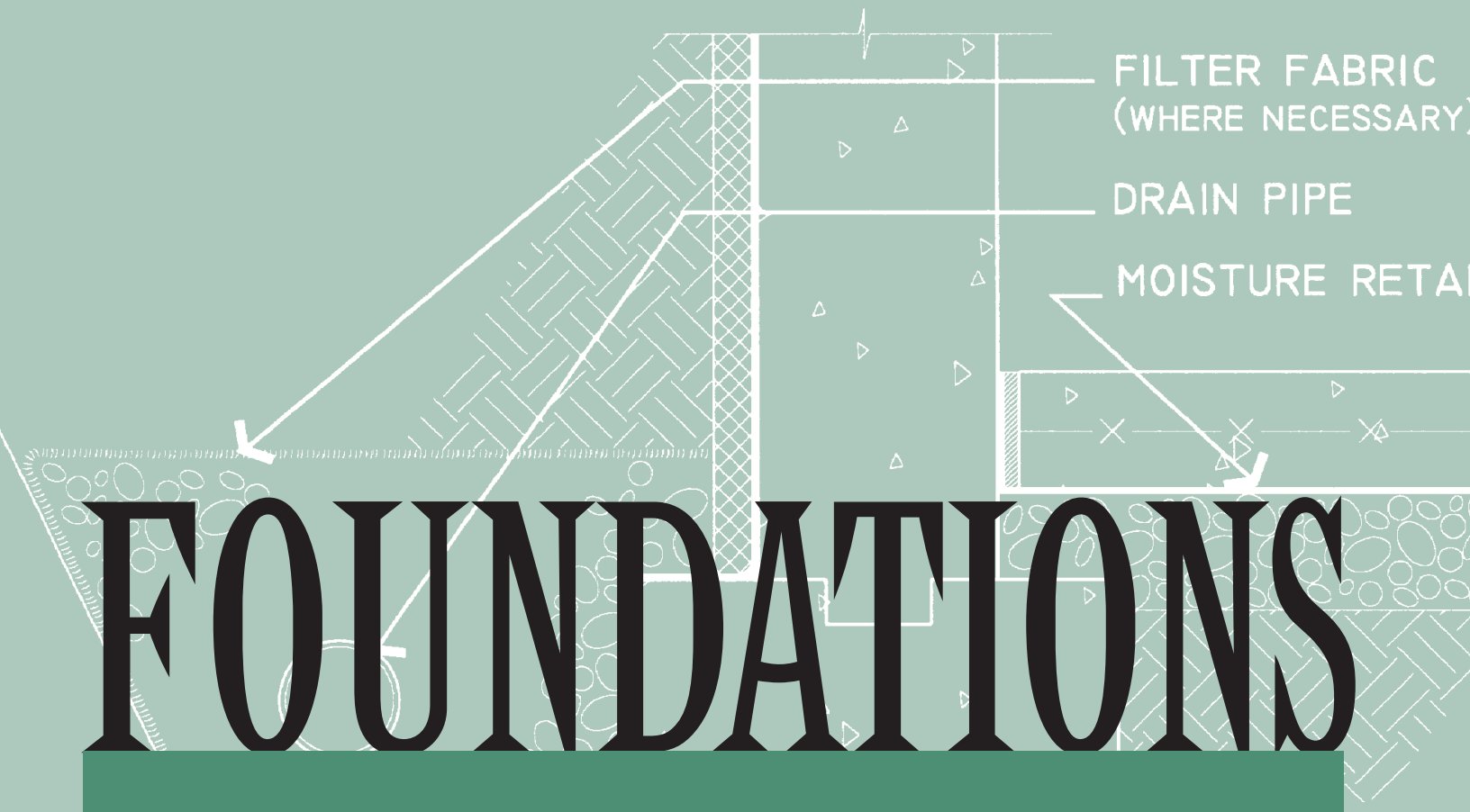
VOL I

THE REHAB GUIDE





FOUNDATIONS

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FOUNDATIONS

VOLUME I OF THE REHAB GUIDE

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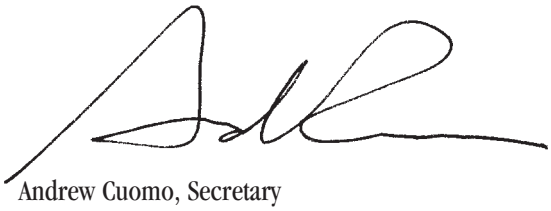
FOREWORD

Housing rehabilitation is an essential component of any strategy to meet our Nation's need for affordable housing. Although the individualized nature of the rehabilitation industry sometimes inhibits the rapid adoption of leading edge technologies, progress does not rest solely upon new ideas and ways of doing things. A breakthrough material, a labor-saving tool, or a cost-cutting technique is valuable only if it is widely adopted. Such acceptance is gained through the construction industry's knowledge of these new developments.

To that end, the Department of Housing and Urban Development has commissioned a set of guidebooks that will present state-of-the-art techniques, materials, and technologies for housing rehabilitation. This volume, "Foundations" is the first of nine guidebooks known collectively as *The Rehab Guide* that will appear over the next few years.

I am pleased to present this important publication in the hope that it will become a valuable resource and will lead to affordable, high quality rehabilitation, and better housing for all Americans.



Andrew Cuomo, Secretary
US Department of Housing and Urban Development

1 THE REHAB GUIDE: FOUNDATIONS

1.1 INTRODUCTION

This publication, *The Rehab Guide: Foundations* is one in a series of guidebooks produced by the U.S. Department of Housing and Urban Development to keep the design and construction industry abreast of innovations and state-of-the-art practices in home rehabilitation. As is too often the case, innovative techniques, materials, technologies, and products are slow to make their way into accepted practice. *The Rehab Guide* series is intended to accelerate this process by informing builders, architects, engineers, and other housing rehabilitation professionals about such innovations and state-of-the-art practices.

The Rehab Guide was also prompted by the lack of a comprehensive publication to make the design and construction industry aware of innovative and cost-saving developments in housing rehabilitation. Professional trade magazines, conferences, and trade shows offer some distribution of this information, but they are rarely focussed exclusively on housing rehabilitation, as this series is, nor are they comprehensive. It is evident that such innovations will not advance unless the industry is made aware of them and they are tested.

FOCUS OF *THE REHAB GUIDE*

The focus of this series is on housing rehabilitation, which is different than home improvement. Rehabilitate means "to restore to good condition," not necessarily to improve to a state that is significantly different than the original. This is a fine line, but it distinguishes this series from "home improvement" books written for the amateur. *The Rehab Guide* focuses on building technology, materials, components, and techniques rather than "projects" such as adding a new room, converting a garage into a den, or finishing an attic. Nor is *The Rehab Guide* intended to be a "diagnostic" tool; a number of such books is already available to the industry.

The content for this guidebook, *Foundations*, has been gathered from professionals in the housing rehabilitation field; manufacturers and suppliers of innovative technologies, materials, components, tools, and equipment; trade shows, conferences, reports, and publications considering such issues; trade organizations; and building research centers. Assistance from the Remodelor's™ Council of the National Association of Home Builders, the National Association of the Remodeling Industry, and the National Multi-Housing Council was also solicited.

HOW THE GUIDE IS ORGANIZED

Nine volumes will eventually make up *The Rehab Guide* in its entirety, and they are listed on the back cover of this volume. Each one is devoted to distinct elements of the house, and within each volume is a range of issues that are common to that element of home rehabilitation work. The present volume, *Foundations*, for example, covers topics from the design and engineering of rehab foundation systems to shoring and repair, waterproofing, crack repair, drainage, and insulation. Each volume addresses a wide range of techniques, materials, and tools, and recommendations based on regional differences around the country. Throughout *The Rehab Guide*, special attention is given to issues related to energy efficiency, accessible design, and sustainability.

EASILY ACCESSIBLE FORMAT

The Rehab Guide is written and presented in a format intended for easy use. The spiral bound volumes open flat so that they can be easily photocopied, and they can be assembled and stored in a single three-ring binder. Within each volume, drawings, photos, and other graphic materials supplement written descriptions of a broad range of items: state-of-the-art and innovative building technology, products, materials, components, construction and management techniques, tools, equipment, software—virtually any and all items that make housing rehabilitation more efficient in terms of cost and time. While the content focuses on present technologies and techniques that are currently part of the house-building industry, *The Rehab Guide* also includes information on materials, products, and procedures from other construction sectors (such as commercial, industrial, institutional) that are relevant to housing rehabilitation.

The information is organized in different sections according to rehab subjects, and under headings that make this book easy to understand. "Essential Knowledge" gives the reader a basic overview of the important issues related to the section heading. Next, "Techniques, Materials, Tools" presents state-of-the-art and innovative approaches to accomplishing the work. Each entry is explained in detail, including its advantages and disadvantages. This makes it easy for readers to compare approaches and choose the one that is most applicable to their particular project. By design, the "Techniques, Materials, Tools" section is an overview, not a detailed description of implementation. "Further Reading" lists the valuable resources relevant to the subject which readers can go to for more detailed information. Finally, "Product Information" provides names and addresses of manufacturers of products, materials, systems, and components mentioned in the text so that more information can be attained. By virtue of their being listed here, such products are not necessarily being recommended; their existence and availability is being brought to the reader's attention. New products should be carefully evaluated in the field as to their efficacy. The product lists are not comprehensive, and we encourage readers to bring new materials and products to our attention to be included in later editions of *The Rehab Guide.*

A NOTE ON SOURCES

Particularly useful sources of technical information on masonry construction, including the repair of basements, are publications by the American Concrete Institute, the Portland Cement Association, and the National Concrete Masonry Association. The International Concrete Repair Institute, while largely focused on institutional and commercial projects (including multi-family housing), publishes a valuable directory of product manufacturers, contractors, and consultants titled *Who's Who in Concrete Repair*.

Other valuable and detailed sources of information from the general construction industry include technical trade magazines such as *Construction Specifier* and the *Concrete Repair Bulletin*. Publications relating more directly to residential construction include the *Journal of Light Construction*, *Old House Journal*, *This Old House*, *Fine Homebuilding*, and *Energy Design Update*. Valuable sources of publications on foundation and slab construction include the NAHB's Home Builder Press and Bookstore and the Canada Mortgage and Housing Corporation, which has an extensive catalog of excellent books and articles on a wide range of subjects on housing construction and rehab. The most complete and comprehensive books on foundations are the *Building Foundation Design Handbook* and the *Builder's Foundation Handbook*. Both were prepared for the US Department of Energy. While the former publication, prepared by the Underground Space Center at the University of Minnesota, is now out of print, the latter, prepared by the Oak Ridge National Laboratory, is available from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; 703–487–4650.

2 FOUNDATION DESIGN & ENGINEERING

2.1 EXISTING FOUNDATION OVERVIEW

The great majority of residential foundations are either concrete or concrete block. Concrete dominates in most areas, especially in the South, Southwest, and West. Concrete block is more common in the industrialized states of the Northeast and the Northcentral United States.

Foundations of older houses built more than 60 years ago, particularly those in rural areas, are often made of stone. Within the last 15 years prefabricated foundations of pressure-treated wood or concrete have become more popular. Recent foundation developments have included various combinations of expanded polystyrene (EPS) or extruded polystyrene (XPS) and rigid sheathing materials as well as systems that combine concrete and polystyrene forms, commonly referred to as insulating concrete form systems. Such systems are not commonly used in rehab work and thus are not included in *The Rehab Guide*. Detailed information on the different types of insulating forms is available from the Insulating Concrete Forms Association.

Building codes typically require that new construction, where it replaces existing construction, be installed in accordance with current codes. Because a variety of codes—regional, state, and municipal—are in force throughout the U.S., and these codes are now in the process of being revised and consolidated into a single code, it is incumbent upon the rehab architect and contractor to carefully research and understand the pertinent code issues as they relate to foundation design and construction.

Building codes typically referencing American Concrete Institute (ACI) standards set minimum requirements for the size, strength, composition, reinforcement, and installation of concrete and concrete block foundation walls and footings. Local building inspectors responding to construction problems they have encountered, as well as prevailing practice in their areas, will sometimes require thicker or more heavily reinforced walls than those required by code minimums. However, if engineering calculations prove otherwise, thinner walls or less reinforcement may be allowed. Production builders in many areas of the country have historically preferred to build thicker concrete and concrete block foundation walls with as little reinforcement as possible. This means that the footings and foundation walls of many existing houses are often unreinforced, contributing, in some instances, to settlement and cracking problems. When replacing concrete walls it is important to analyze the soil conditions carefully and to comply with local code requirements, adding reinforcement to compensate for poor drainage soil or subsurface water conditions.

The design of concrete foundation walls is well covered by building codes and the ACI standards referenced in the codes, as well as in publications by the Portland Cement Association and the National Association of Home Builders. The design of concrete block foundation walls is likewise covered by building codes, the ACI standards referenced in the codes, as well as publications by the National Concrete Masonry Association (NCMA).

FURTHER READING

CONCRETE

Residential Concrete, National Association of Home Builders Research Center, 1994.
Building Movement and Joints, EB086, PCA, 1982.

Design and Control of Concrete Mixtures, EB001, PCA, 1994 (rev.).

"Foundation Replacement," Greg Casorso, *Journal of Light Construction*, Sept. 1, 1994.

Guide to Residential Cast-in-Place Concrete Construction, ACI 332R-84, American Concrete Institute, 1984.

Concrete Construction Handbook, McGraw-Hill, 1993.

CONCRETE BLOCK

NCMA Guide for Home Owners and Home Builders on Residential Concrete Masonry Basement Walls, National Concrete Masonry Association, 1994.

Concrete Masonry Handbook for Architects, Engineers, and Builders, Portland Concrete Association, 1991.

Recommended Practice for Laying Concrete Block, Portland Cement Association, 1993.

Homeowners Guide to Building with Concrete, Brick and Stone, SP038, PCA, 1988.

Design of Concrete Masonry Foundation Walls, TEK 15-1A, National Concrete Masonry Association, 1994.

Strength Design of Reinforced Concrete Masonry Foundation Walls, TEK 15-2A, National Concrete Masonry Association, 1994.

2.2 BASEMENT FLOORS

ESSENTIAL KNOWLEDGE

Most houses with basements built in this century have concrete basement floor slabs, typically 4 inches thick. A number of these floors may be in poor repair due to deterioration, heaving from expansive soils, or settlement due to poor initial soil compaction or water-related soil displacement. In the event of severe cracking, spalling, or other distress, it may be advisable to replace sections of, or the entire, floor slab. If the floor slab is in poor condition but retains substantial structural integrity, a new unbonded floor can be poured over the existing one. If the existing floor is structurally sound, but uneven or moderately deteriorated, it is possible to pour a thin, self-bonding topping that can provide a smooth finish that is suitable as a finished surface or an underlayment for floor coverings such as tile or carpet.

TECHNIQUES, MATERIALS, TOOLS

1. PROVIDE A NEW FLOOR SLAB OR REPLACE A PORTION OF THE EXISTING SLAB.

If the existing basement floor is earth, it must be excavated to a point no deeper than the bottom of the wall footing. The subgrade should be prepared to provide uniform support. Slabs supported by expansive soils should be designed to withstand or accommodate swelling and shrinkage of the subgrade. A minimum of 4 inches of gravel, crushed stone, or course sand should be placed under the slab. Where possible, this granular base should cover the top of the footing by several inches so that the slab can settle somewhat without being restrained by the footing—which could lead to cracking. Moisture retarders, usually polyethylene

sheeting, are typically required by code or local conditions in areas with poor draining soils and high water tables, to help prevent moisture migration through the slab. (The term "moisture retarder" is used instead of "vapor barrier" for on-grade or under-slab conditions because this layer inhibits the migration of ground water as well as vapor. True "barriers" are rarely achieved in conventional construction, thus the term "retarder" is used). The ACI, however, recommends eliminating the moisture retarder where local ground conditions and codes permit because the polyethylene sheet retards the curing of the bottom surface of the concrete and can aggravate slab edge curling, drying, and plastic shrinkage cracking problems. More guidance can be found in the reference documents in FURTHER READING.
ADVANTAGES: Provides useable, finished basement space.
DISADVANTAGES: Excavation and pouring of new slab is potentially costly and difficult to undertake without sufficient access.

2. POUR A NEW FULLY BONDED FLOOR SLAB OVER THE EXISTING SLAB.

If the surface of the existing slab is clean, sound, and of good quality but needs to be leveled to serve as a base for a finished floor, a 1- to 2-inch (or thicker) overlay topping can be poured on the existing slab. Conventional, low-slump concrete can be used with a high sand content and small aggregate (maximum size 3/8 inch) with or without the use of latex admixtures. In addition, fast-drying, specially formulated proprietary portland cement-based thin topping/underlayments are available. These products are often referred to as self-leveling and are primarily used to provide a level floor surface and to repair floors that have deteriorated or spalled. Toppings provide a finished floor surface; underlayments require a floor covering material such as tile or carpet. Gypsum self-leveling toppings work satisfactorily in the absence of moisture, and are not normally specified for basement slabs where there may be moisture problems.
ADVANTAGES: A relatively inexpensive repair that can contribute significantly to the appearance and use of a basement. Self-leveling mixtures are typically rapid-setting and designed to reduce shrinkage and cracking.
DISADVANTAGES: Self-leveling mixtures cannot be used where there is a possibility of a significant water problem. In general, cracks in the base slab can be expected to be transmitted through the new slab. Will raise the floor height and reduce headroom.

3. PROVIDE A NEW UNBONDED FLOOR SLAB OVER THE EXISTING SLAB.

When the existing floor slab is not in suitable condition for the application of a bonded overlay, a new unbonded 4-inch slab can be applied. The existing slab should be swept clean and badly worn areas or holes should be filled with a cement-sand mortar to provide a reasonably flat base. A layer of polyethylene sheeting serves as a bond-breaker as well as a moisture retarder. Nonstructural welded wire reinforcement is typically recommended to help distribute shrinkage stresses and to minimize the size of cracks (reinforcement should be placed at the slab center and have sufficient topping to prevent spalling). Polyethylene or nylon fiber reinforcement can also be added to the concrete to help control (but not eliminate) cracks. In areas with extremely expansive soils or exceptionally high water table additional slab reinforcement may be advisable.
ADVANTAGES: A permanent fix that can add value to the house without the need to remove the existing slab. Will act independently of the existing slab and may prevent cracks from reappearing on the new surface.
DISADVANTAGES: More expensive than a topping. Will raise the floor height. May require significant time to cure, due to use of nonabsorbtive polyethylene sheeting under the slab.

FURTHER READING

Concrete Slab Surface Defects: Causes, Prevention, Repair, 1S177, Portland Cement Association, 1987.

Residential Concrete, National Association of Home Builders Research Center, 1994.

Guide for Concrete Floor and Slab Construction, 302.IR, American Concrete Institute, 1996.

Slabs On Grade, CCS-1, American Concrete Institute, 1994.

Resurfacing Concrete Floors, IS144, Portland Cement Association, 1996.

PRODUCT INFORMATION

There are numerous companies that manufacture self-leveling toppings and other concrete repair products. Some of those with national distribution include:

Abatron, Inc., 5501 95th Avenue, Kenosha, WI 53144, 800–445–1754.
Ardex, Inc., 1155 Stoops Ferry Road, Coraopolis, PA 15108, 412–264–4240.
Dayton Superior Corp., 721 Richard Street, Miamisburg, OH 45342, 800–745–3700.
Harris Specialty Chemicals (Thoro Systems Products), 10245 Centurian Parkway, Jacksonville, FL 32256–0564, 800–327–1570.
Larsen Products Corp., 8264–1 Preston Court, Jessup, MD 20794–9680, 800–633–6668.
Laticrete International, Inc., One Laticrete Park North, Bethany, CT 06524–3423, 800–243–4788.
Master Builders, Inc., 23700 Chagrin Boulevard, Cleveland, OH 44122, 800–628–9990.
Maxxon Corp. (formerly Gyp-Crete Corp.) 920 Hamel Road, Hamel, MN 55340, 800–356–7887.
WR Bonsal Co., P.O. Box 241148, Charlotte, NC 28224, 800–334–0784.
WR Meadows, Inc., P.O. Box 543, Elgin, IL 60121, 800–342–5976.
Quick Crete Co., 2987 Clairmont Road, Suite 500, Atlanta, GA 30329, 800–282–5828.
Sika Corp., P.O. Box 297, Lyndhurst, NJ 07071, 800–933–7452.
Sonneborn Building Products, Inc., 889 Valley Park Dr., Shakopee, MN 55379, 800–828–0253.
Sto Concrete Restoration Division, P.O. Box 44609, Atlanta, GA 30336–5609; 800–542–3057.
Tamms Industries Co., 7405 Production Drive, Mentor, OH 44060, 800–218–2667.

2.3 CRAWL SPACE FLOORS

ESSENTIAL KNOWLEDGE

Many crawl spaces in older houses do not have permanent, hard-surface floors. Typically the ground has been left exposed, frequently resulting in excessive moisture, odors, vermin, and insects. It is difficult and costly to place conventional concrete in the confined areas of existing crawl spaces, and because the grade of the crawlspace may slope, conventional concrete mixtures will not provide uniform coverage. New concrete mixtures using lightweight aggregates have been introduced specifically for this use.

TECHNIQUES, MATERIALS, TOOLS

POUR A CRAWL SPACE FLOOR SLAB OF LIGHTWEIGHT CONCRETE.

A specialty concrete product using Zonolite or Vermiculite aggregate has been developed by FTF Crawlspace Specialists that can be pumped from lightweight mobile mixing equipment and quickly installed. The fast drying mixture with a consistency of heavy shaving cream will adhere to almost any surface, including walls. Trowel finished to an average depth of 3 inches over a polyethylene moisture retarder, this material is cured for light traffic in 7 days.

ADVANTAGES: Can conform to sloping and irregular surfaces; less expensive and disruptive than conventionally pumped concrete; can be pumped through narrow openings and hard to reach areas; dries fast; reduces moisture and soil gas problems.

DISADVANTAGES: Lightweight concrete cannot sustain heavy traffic or heavy objects.

PRODUCT INFORMATION

FTF Crawlspace Specialists, Five Mountain Drive, New Milford, CT, 06776, 860–350–1092.

3 PERMANENT WOOD & PREFABRICATED FOUNDATIONS

3.1 PERMANENT WOOD FOUNDATION SYSTEMS

ESSENTIAL KNOWLEDGE

Permanent wood foundations have been used in over 200,000 homes over the past quarter-century, and offer an alternative to concrete or masonry systems. In rehab work, permanent wood foundations might be suitable if a large section of an existing foundation wall is damaged beyond repair and must be replaced. They should also be used when replacing damaged portions of an existing permanent wood foundation. The basic elements of permanent wood foundations include a 2x footing plate resting on crushed stone, on top of which a 2 by 4, 2 by 6, or 2 by 8 (depending on number of stories, stud spacing, and backfill height) stud wall is constructed and sheathed with plywood. All wood must be pressure-treated with either Ammoniacal Copper Arsenate (ACA), Ammoniacal Copper Zinc Arsenate (ACZA) or Chromated Copper Arsenate (CCA). All fasteners should be galvanized or stainless, and the exterior of the plywood sheathing covered with 6-mil polyethylene sheeting for drainage.

TECHNIQUES, MATERIALS, TOOLS

REPLACE PORTION OF EXISTING FOUNDATION WITH PERMANENT WOOD FOUNDATION SYSTEM.

Once the source of damage has been corrected, the damaged part of the existing foundation wall should be removed so that the new foundation wall can mate with the existing wall. The ground must be excavated to the level of the existing footings. The new foundation wall can be supported on treated wood footing plates and crushed stone footings (Fig. 1), or can rest on the existing footings, if feasible. According to guidelines developed by the Southern Pine Council, the new permanent wood foundation sections are connected to the existing foundation using lead expansion shields with 1/2 inch-diameter galvanized lag screws for concrete or masonry foundations. If mating to an existing permanent wood foundation, additional studs may be needed in the older section to fasten the new portion with lag screws.

ADVANTAGES: Work can be conducted in cold weather that limits concrete or masonry construction, giving more flexibility to the construction schedule. Permanent wood foundations can be installed without heavy equipment and in areas of the existing building that have limited access. Approved by all model code agencies.

DISADVANTAGES: May require significant excavation, depending on extent of foundation wall to be replaced.

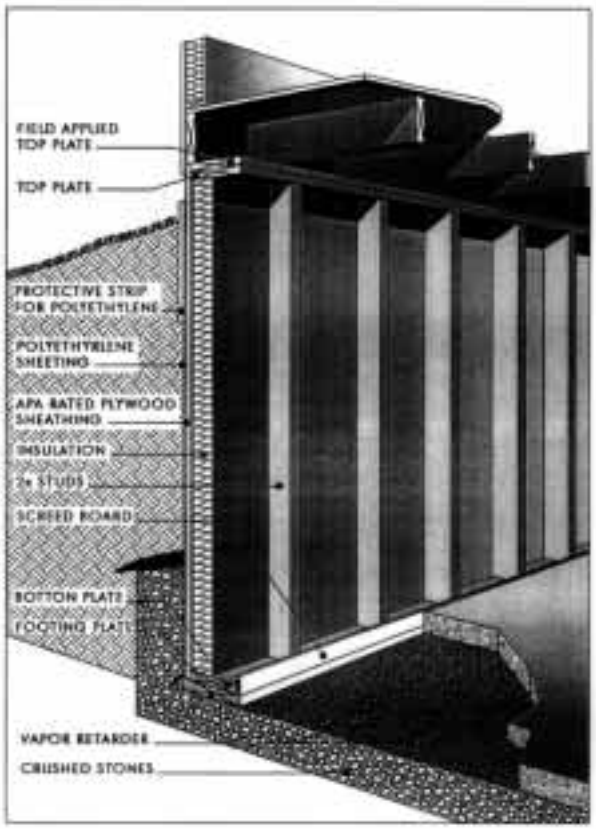


FIGURE 1. PERMANENT WOOD FOUNDATION

FURTHER READING

Building Foundation Design Handbook, Ken Labs et al., prepared for the U.S. Dept. Of Energy by the Underground Space Center, University of Minnesota, 1988.

Permanent Wood Foundation Design & Construction Guide, Southern Pine Council, 1995.

Permanent Wood Foundations, Sure-West Publishing, Red Deer, Alberta, Canada.

3.2 PREFABRICATED FOUNDATIONS

ESSENTIAL KNOWLEDGE

The two major types of prefabricated foundation systems are structural insulated panels (SIPs) and precast concrete panel systems. While these systems are used primarily for new house construction, they may be used to replace damaged sections of existing foundation walls. The SIP foundation systems are virtually the same in detail as the panels used for walls and roofs, and offer an advantage over precast systems in that the components can be easily installed by one or two people without heavy equipment. Precast concrete panels must be craned into place. As is the case for permanent wood foundation systems, both SIPs and precast panel systems can be installed in cold weather, thus permitting flexibility in the project schedule.

1. REPLACE DAMAGED FOUNDATION SECTIONS WITH A SIP FOUNDATION SYSTEM.

In concept, a SIP foundation system is identical to a permanent wood foundation system (Fig. 2). SIPs are commonly 4 by 8 feet or 4 by 9 feet expanded polystyrene (EPS) foam core panels with 1/2 inch pressure-preservative treated plywood exterior sheathing and 7/16 inch plywood or oriented strand board (OSB) interior sheathing. The interior sheathing is normally required to be covered with a fire barrier such as gypsum board, although some recently-developed proprietary coating systems such as AFM Corporation's Firefinish™ meet the requirement of a 15-minute thermal barrier. The ground must be excavated to the level of the existing footings. The SIPs are prefabricated and arrive at the site ready for installation on a 2x footing plate over a crushed stone, gravel, or concrete footing. The SIPs mate with the existing foundation wall with a 2x splice that is fastened with lag screws into the existing concrete or masonry wall.

ADVANTAGES: Work can be conducted in cold weather that limits concrete or masonry construction, giving more flexibility to the construction schedule. SIPs foundations can be built without heavy equipment and in areas of the existing building that have limited access. SIP deliver good thermal performance.

DISADVANTAGES: Standard panel sizes may not accommodate the portion of the wall to be replaced. May require siginificant excavation depending on extent of foundation wall to be replaced.

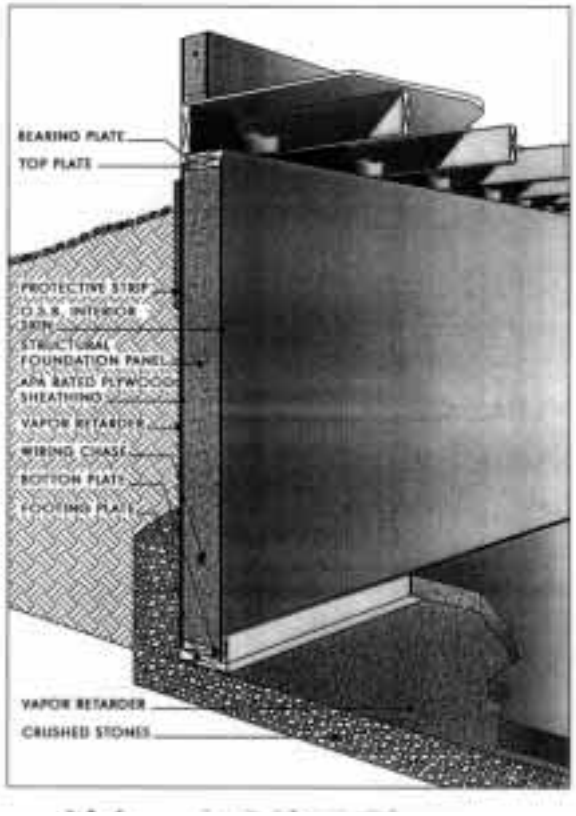


FIGURE 2. PANEL FOUNDATION WALL

2. REPLACE DAMAGED FOUNDATION SECTIONS WITH PRECAST CONCRETE PANEL SYSTEM.

Precast concrete foundation walls, made to order, can be craned into place after the affected section of the existing foundation has been excavated and the damaged portion of the wall is removed (Fig. 3). Precast sections are bolted together and may contain holes or notches in the ribs for plumbing or electri-

FIGURE 3. PRECAST CONCRETE WALL

cal conduits. Superior Walls of America and Kistner Concrete Products, Inc. offer a precast stud wall system that uses lightweight concrete to make the handling of the sections easier, but a crane is necessary to place them. The panels are made with 5,000 psi concrete and the manufacturers state that they usually do not need waterproofing, except at the joints. Insulated concrete wall systems, which are placed on gravel or crushed stone footings, incorporate varying thicknesses of polystyrene insulation with an R-5 per inch rating. Additional insulation can be placed in the cavity between the studs. The inside edge of the concrete studs, which are 24 inches on-center, have factory-installed nailers to accept a finish material. The studs also have predrilled holes for plumbing and electrical conduit. The panels can be bolted to the edge of existing foundation walls.

ADVANTAGES: Allows a concrete foundation wall to be replaced in cold weather; systems include insulation and furring for finished walls.

DISADVANTAGES: Installation requires heavy machinery, such as a crane, and significant excavation, which may not be feasible in affected foundation wall areas with limited access.

FURTHER READING

"Precast Concrete Stud Foundation Wall," *New Building Products*, NAHB Research Center, Vol. 2, No. 5, August/September 1996, p. 1.

PRODUCT INFORMATION

Midwest Panel Systems, P.O. Box 38, Blissfield, MI 49228, 517–486–4844.

Superior Walls of America, Ltd., P.O. Box 427, Ephrata, PA 17522, 800–452–9255.

Kistner Concrete Products, Inc. 8713 Read Road P.O. Box 218 East Pembroke, New York 14056–0218, 716–894–2267, www.kistner.com

4 DRAINAGE

4.1 SURFACE AND SUBSURFACE DRAINAGE

ESSENTIAL KNOWLEDGE

Poor surface and subsurface drainage can lead to ponding of water around the house, leakage of ground water through the basement or crawlspace walls, structural damage to the foundation from the build-up of hydrostatic pressure and the freeze/thaw action of water on the foundation system. Successful drainage requires surface water to be led away from buildings by appropriate grading. The water can be dispersed slowly over the landscape or led offsite through underground gravel drainage ways or piping. Surface runoff is usually not a problem in low-density developments (one to two houses per acre) with porous soils and vegetation that allows water to percolate into the ground. Higher densities, hard surfaces such as roofs and pavement, and poor soil conditions necessitate drainage systems. Successful drainage requires that houses be built above surrounding ground water tables and be protected from ground water migrating through the soils adjacent to the foundation.

TECHNIQUES, MATERIALS, TOOLS

The most successful techniques for improving surface and subsurface drainage around foundations include:

1. GRADE AWAY FROM THE HOUSE.

Ground around the foundation should slope away a minimum of 10 percent for a distance of 8 to 12 feet (codes variously state minimums of 4 to 8.3 percent for 6 to 8 feet, which is not sufficient, according to many experts).

ADVANTAGES: Easily monitored and maintained, allows for the filtration of water-borne pollutants from the land; recharges groundwater tables and aquifers; a natural-appearing technique that requires little or no maintenance.

DISADVANTAGES: Depending on natural slope, site, and soil conditions, achieving natural runoff may be expensive or not possible. May be costly to achieve depending on the existing slope and character of the building's perimeter.

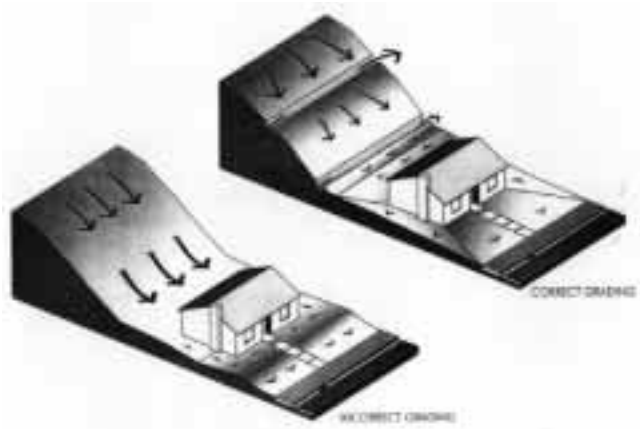


FIGURE 1. SITE GRADING STRATEGIES

2. PROVIDE A "GROUND ROOF" AROUND THE PERIMETER OF THE HOUSE.

This entails the placement of an impervious layer of clay or bentonite under top soil adjacent to the foundation to act as a "ground roof." This layer directs water away from the foundation. Sod in roll form can act as a relatively impervious layer as it is grown on clay soil.

ADVANTAGES: A remedy with a natural appearance, promoting good drainage.

DISADVANTAGES: May be difficult and costly to achieve depending on the slope around the house and the amount of earth-moving necessary.

3. CREATE SWALES TO CHANNEL WATER AWAY FROM FOUNDATION.

Furrows can be cut into the exiting slope to lead surface runoff water away from the foundation walls (Fig. 1)

ADVANTAGES: A natural-appearing technique that requires little or no maintenance.

DISADVANTAGES: May be costly to achieve depending on the existing slope and size of perimeter.

4. TERRACE SLOPE TO REDUCE WATER FLOW.

Where slopes are steep and directed at the foundation wall, they can be terraced to slow and reduce the flow of water (Fig. 1).

ADVANTAGES: A technique that requires little or no maintenance.

DISADVANTAGES: May be costly to achieve depending on the height and character of existing slope.

5. PROVIDE AND MAINTAIN ROOF GUTTERS AND LEADERS.

Clean gutters and leaders (downspouts) that direct water away from the foundation by means of leader extensions, splash blocks, or underground drain lines is the first and most cost-effective line of defense against water-related problems.

ADVANTAGES: Relatively low cost technique to support good foundation drainage.

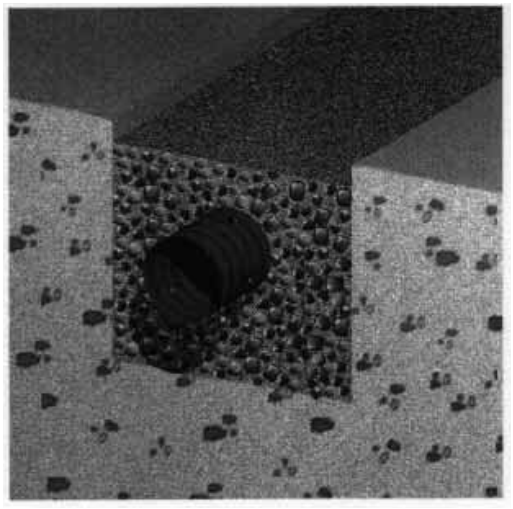
DISADVANTAGES: Requires diligence in keeping gutters and leaders clean; splash blocks in place.

6. PROVIDE TRENCH OR SOIL STRIP DRAINS.

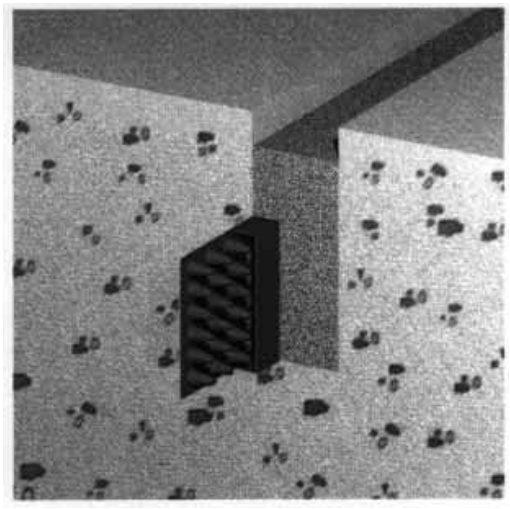
Trench or strip drains placed between the slope and the foundation can intercept and redirect the flow of water from uphill slopes (Fig. 2 and 3).

ADVANTAGES: Preserves natural appearance of slope.

DISADVANTAGES: Can be costly depending on size of drains; need to be monitored and maintained to prevent silting and clogging.



TRENCH DRAIN



STRIP DRAIN

FIGURE 2, 3.

7. PROVIDE GOOD DRAINAGE UNDER BASEMENT WINDOW AREAWAYS.

Particularly at low points around the foundation, areaways can fill up with plant material, debris, and water, causing leaks around basement windows. Keep clean and well drained with a gravel pit that extends down to the foundation drain or leads via a drain pipe to a separate gravel (French) drain.
ADVANTAGES: Relatively low cost and effective.
DISADVANTAGES: Requires maintenance.

8. REPLACE BACKFILL ADJACENT TO HOUSE WITH FREE-DRAINING MATERIAL.

A possible remedy when backfill against the house is overly compacted and non-pourous.
ADVANTAGES: May be cost-effective in some instances, depending on amount of soil to be replaced.
DISADVANTAGES: Requires removal of shrub and plant material; disruptive. Existing footing drains may not be adequately sized or functioning properly.

FURTHER READING

Investigating, Diagnosing & Treating Your Damp Basement, Canada Mortgage and Housing Corp., 1992.

Stormwater Control to Prevent Basement Flooding, Canada Mortgage and Housing Corp., March 1992.

4.2 FOUNDATION DRAINAGE

ESSENTIAL KNOWLEDGE

Wet basements can be an indication of drainage problems around foundations. Most codes require that new housing with habitable basements have an approved foundation drainage system (except in locations with well-drained soils). Houses built within the last 40 years probably have drainage systems similar to current techniques, but may have ceased to properly function due to blockage or a breach in the system. Without the opportunity to inspect a drainage outfall or discharge pipe for flow rate, it is virtually impossible to determine actual conditions.

TECHNIQUES, MATERIALS, TOOLS

Four options to consider after site drainage and roof drainage deficiencies have been corrected and problems persist include:

1. INSTALL AN INTERIOR PERIMETER BASEBOARD "GUTTER" DRAINAGE SYSTEM.

A perimeter baseboard drainage system can be placed on top of the floor slab or cut into the juncture of the wall and the floor and concreted in place (Fig. 4). The system picks up water draining from wall cracks, the cores of concrete block walls, and at the floor/wall intersection, and directs it to a sump pump. Such packaged systems include WaterGuard™ by Basement Systems, Inc., and Basement De- Watering Systems.™ Baseboard systems should be sloped 1/8 to 1/4 inch/ft. to induce flow.
ADVANTAGES: Ranges from relatively simple and inexpensive to moderately expensive, depending on the system used. In combination with sump, reduces water penetration through wall/slab juncture.
DISADVANTAGES: Collects leakage; does not remedy the wall dampness or drainage problems *per se*, as the walls remain moist and the exposed perimeter drains may be considered unsightly in finished spaces. Does not eliminate mold and mildew that can appear on wet walls and in the gutter itself.

2. INSTALL A SUMP PUMP.

A sump pump is used to lower the ground water table to a point below the basement slab. It is used when

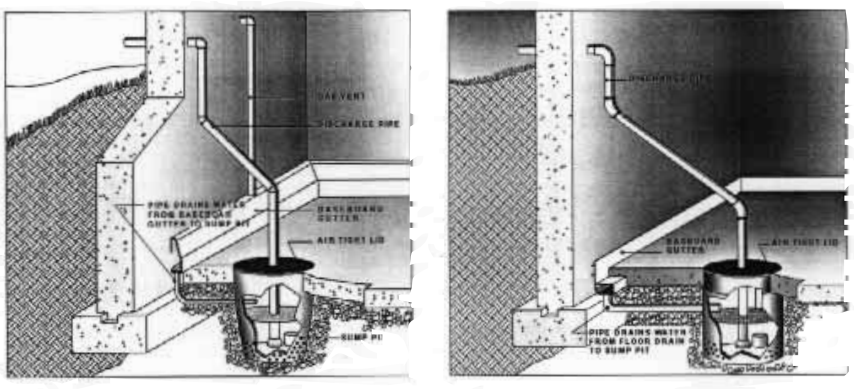


FIGURE 4. INTERIOR BASEBOARD DRAINAGE SYSTEMS

water problems persist and exterior drainage systems are not possible or practicable. If soil gases such as radon or methane exist, sump pumps should be covered and vented to the outdoors. An elaboration of the sump pump solution is to install a radial drainage pipe system, such as that offered by Sanford Irrigation, installed under the slab (Fig. 5) that directs water to the sump. To ensure sump operation in the event of a power outage, water-driven emergency back-up pumps, such as "Home Guard" from HiLo Industries, provide continuous operation with a minimum of 22 psi pressure from a municipal water system.
ADVANTAGES: Least cost alternative to lowering the water-table and reducing water problems in the basement.
DISADVANTAGES: May not be adequate if a major and continuous ground-water problem exists. Sump pump operation is an added household expense, and may be disrupted by power outages.

3. REPLACE THE BASEMENT SLAB AND INSTALL INTERIOR FOUNDATION DRAINS.

A technique to be used when a sump pump alone is not adequate, and where the ground beneath the floor

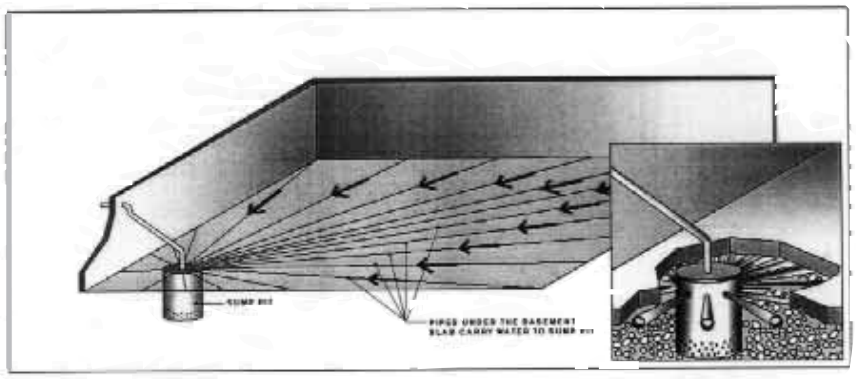


FIGURE 5. INTERIOR RADIAL SUMP SYSTEM WITH SUMP PUMP

slab is relatively impervious and greater drainage area is required. The existing slab perimeter must be removed and new drains installed (Fig. 6), which direct water to a sump pump.
ADVANTAGES: Eliminates the need to remove soil from against the outside of the foundation wall, and from disturbing the foundation.
DISADVANTAGES: Entails removal of at least portions of the existing slab and pouring a new slab, which may be difficult and expensive, based on access to the basement space. Must be carefully designed and built by professionals experienced in these systems. May not work with permanently high groundwater.

4. EXCAVATE THE EXTERIOR FOUNDATION WALL AND INSTALL AND REPAIR OR REPLACE THE EXISTING DRAINAGE SYSTEM.

Soil is removed from against the basement foundation wall and new drainage material is installed next to the wall, which diverts water to new 4 inches (or larger) drainage pipes or other approved system at the base of the wall. In poorly draining soils, a sheet drainage material can be used to enhance the movement of water to the foundation drain and reduce hydrostatic pressure against the outside of the wall.

ADVANTAGES: With a properly drained foundation wall the possibility of leakage through basement walls is reduced significantly and interior wall finishes can be applied with less concern for water damage.

DISADVANTAGES: This work requires removal of the existing plant material and soil, which can be expensive. Solution may be costly, but the best strategy for certain drainage problems.

Corrugated, flexible polyethylene piping has replaced concrete and clay foundation drainage pipe as the industry standard. Some manufacturers, such as Hancor, sell a non-woven filter fabric "sock" that fits over the drain. This may be satisfactory in some areas, but where there are significant fines in the soil that migrate with water, it is preferable to encase the gravel area around the drain tile, as the greater surface

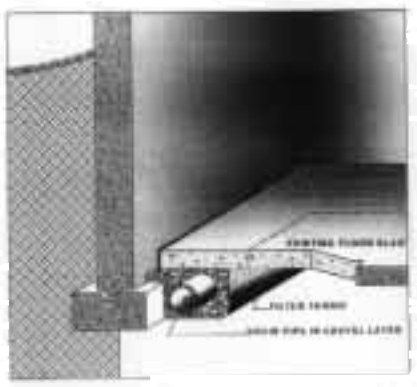


FIGURE 6. INTERIOR FOUNDATION DRAIN

area will extend the life of the filter fabric. Local conditions and codes should be consulted. Considerable interest has been generated in wall drainage systems, called "sheet" or "geocomposite" drains, as they have been successfully used on a large scale in Canada. They are increasingly seen as a cost-effective addition to damp-proofing and water-proofing techniques in the United States, as they are less expensive than corresponding aggregate drainage material. There are four basic types of sheet drainage systems:

1. Dimpled polyethylene or polystyrene sheets used in conjunction with a filter fabric to form a continuous drainage channel. The material is installed with the dimples and filter fabric away from the wall to assure good adherence to it. The sheets, typically used with a damp-proofing or water-proofing membrane, can also be used for under-slab drainage. One manufacturer, American Wick Drain Corp., offers a sheet drain that connects to the foundation drain system (Fig. 7).

2. Formed polyethylene sheets without filter fabric that orient the dimples toward the wall, providing a continuous 1/4" drainage space (Fig. 8). This system, widely used in Canada, does not require damp-proofing to be applied to the foundation wall, and keeps backfill soil and moisture from resting against the wall. The system is sold under the name of "System Platon," manufactured by the Big "O" Co.

3. Matting of various types that forms a wall drainage system to be used with applied water- and damp-proofing systems. Products include: "WARM-N-DRI", a 6-pound-density fiber-glass mat, used in combination with a sprayed "TUFF-N-DRI" polymer modified asphalt, not only drains the channel water, but also has an R-rating of approximately 4 per inch when dry, offered by Koch Materials Co.; Roxul "Drainboard,"

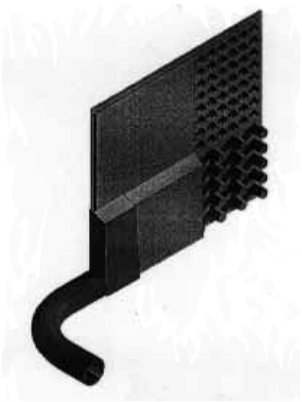


FIGURE 7, 8. AMERICAN WICK DRAIN SYSTEM PLATON

a mineral wool blanket manufactured by Roxul, Inc.; "Enkadrain" drainage matting of geotextile fabric heat bonded to a three-dimensional high-density polyethylene core, which allows water to seep into the core while it holds back adjacent soil, manufactured by Akzo Nobel Geosynthetics.

4. Drainage systems using grooved extruded polystyrene boards to enhance drainage against foundation walls. Among these products is Owens-Corning's INSUL-DRAIN™, which has a network of drainage channels cut into one side of the board which allows ground water to drain away from the foundation wall. Dow's Styrofoam THERMADRY board also has grooves to encourage drainage.

FURTHER READING

Builder's Foundation Handbook, John Carmody, et al., prepared for the U.S. Dept. of Energy by the Underground Space Center, University of Minnesota, 1991.

Investigating, Diagnosing & Treating Your Damp Basement, Canada Mortgage and Housing Corp., 1992.

Methods of Constructing Dry, Fully Insulated Basements, Canada Mortgage and Housing Corp., 1991.

PRODUCT INFORMATION

WaterGuard™ by Basement Systems, Inc., P.O. Box 160, Canton, IL 61520, 800–331–2943.
Basement De-Watering Systems™, 162 East Chestnut Street, P.O. Box 160, Canton, IL 61520, 800–331–2943.
Home Guard, HiLo Industries, P.O. Box 16056, Louisville, KY 40256–0056, 502–778–0234.
Sanford Irrigation, 444 East Highway 79, Elbow Lake, MN 56531; 218–685–4344.
American Wick Drain Corp., 316 Warehouse Drive, Matthews, NC 28105, 800–242–WICK.
Hancor, Inc., 401 Olive Street, P.O. Box 1047, Findlay, OH 45839, 800–537–9520.
System Platon, Big "O" Inc., 254 Thames Road East, Exeter, Ontario, Canada, N0M 1S3, 800–265–7622.
WARM-N-DRI, Koch Materials Co., P.O. Box 2155, Heath, OH 43056–1132, 800–379–2768.
Drainboard, Roxul, Inc., 551 Harrop Dr., Milton, Ontario, Canada, L9T 3H3, 800–265–6878.
Enkadrain, Akzo Nobel Geosynthetics Co., Ridgefield Business Center, Ridgefield Court, Suite 318, P.O. Box 7249, Asheville, NC 28802, 704–665–5050.
INSUL-DRAIN™, Owens-Corning, Fiberglass Tower, Toledo, OH 43659, 800–GET–PINK.
Styrofoam THERMADRY, Dow Chemical Co., 2040 Willard H. Dow Center, Midland, MI, 48674, 800–441–4369.

5 DAMPPROOFING & WATERPROOFING

ESSENTIAL KNOWLEDGE

Dampness in a basement can render it virtually useless, even for storage. Sources of moisture in basements include the intrusion of ground-water through cracks in walls and slabs and their junctures, wicking of moisture through concrete by capillary action, and the infiltration of moist air from outside (this last source is discussed in the "Ventilation" section). Dampness can also be a health hazard. Recent studies sponsored by the Canada Mortgage and Housing Corporation (CMHC), Health Canada, and the National Research Council of Canada as well as Harvard University have established that moisture can lead to increases in a number of biological contaminents including mold, dust mites, and bacterial toxins; some of the molds produce toxins that are harmful to humans.

Building codes generally require that all below-grade basement walls be dampproofed or waterproofed. Dampproofing is used in the absence of hydrostatic pressure and is intended to protect the interior surface of foundation walls from water vapor diffusion, caused by temperature/humidity differentials, and the wicking of moisture through the wall by capillary action.

Waterproofing is designed to bridge nonstructural cracks up to a maximum of 1/16 inch. It is required when hydrostatic pressure exists or is likely to occur due to the presence of ground water at elevations above the basement slab. In such cases, both floors and walls have to be waterproofed and designed to withstand hydrostatic pressure. Waterproofing is usually applied from the top of the footing to not less than 12 inches above the maximum elevation of the water-table. Under some codes, the remainder of the wall can be dampproofed, but it is usually better to continue waterproofing all the way to grade rather than changing materials. Although it is substantially more expensive than dampproofing (sometimes by a factor of 10 or more) waterproofing is increasingly being specified in lieu of dampproofing in mid- to high-end housing because of its static, nonstructural crack-spanning capability and because basements, now more commonly used for living space, are expected to be dry. Materials and applications that come with written performance guarantees are preferred.

TECHNIQUES, MATERIALS, TOOLS

There are a number of techniques and materials for effective dampproofing and waterproofing. The following alternatives consider dampproofing first, and then waterproofing.

Dampproofing materials for walls include those complying with ASTM C887, materials permitted for waterproofing, and other approved materials. There are a number of approaches to dampproofing:

1. APPLY CRYSTALLIZATION PRODUCTS OR CEMENTITIOUS COATINGS TO FOUNDATION WALL INTERIOR.

A variety of coatings are sold as interior (referred to as the "negative" side) waterproofing products, including sealers and paints. Some of these products may work in the absence of hydrostatic pressure, but most interior coating systems are not long-term solutions and will fail under sustained pressure and sub-

strate movement. Products such as Bonsal's Sure Coat™ and Thoro Systems' ThoroSeal™ are represented as being able to prevent water intrusion even under pressure. Crystallization products such as Xypex, Vandex, and Permaquick combine proprietary chemicals with sand and cement. This slurry produces crystallization growth in concrete or masonry substrates that fill open pores and is represented as being able to block the passage of water.

ADVANTAGES: May protect the interior surface of the wall from water wicking from both the exterior wall surface and the foundation base. Can be relatively inexpensive solutions, as compared to exterior work; usually easy to apply. Cementitious and crystalization materials can be applied to damp concrete, allowing water vapor to pass through; non-toxic.

DISADVANTAGES: Often not effective, especially on active cracks and those greater than 1/64 inch. Does not prevent ground water from penetrating the CMU wythe on the exterior side and becoming trapped inside the wall which is a serious problem in cold climates. Finish may not be acceptable and may require paneling or drywall covering. Crystallization products are not effective over control joints.

2. APPLY CEMENTITIOUS COATINGS TO FOUNDATION WALL EXTERIOR.

Commonly known as "parging," these coatings are primarily used for concrete block walls. They should be combined with acrylic modifiers (made by companies such as Bonsal, Thoro Systems and Sonneborn).

ADVANTAGES: A widely used system for many years and may be cost-effective in locations with good draining soils. Protects from moisture wicking from outside the wall. Does not require completely dry substrate or protection boards. Can be combined with polyester reinforcing mesh to enhance performance. Non-toxic materials.

DISADVANTAGES: No crack-spanning capabilities. There have been cracking and spalling problems with some cementitious coatings over time due to water migration behind the substrate, and freeze/thaw cycling. Requires excavation.

3. APPLY ASPHALTIC COATINGS WITHOUT MODIFIERS TO FOUNDATION WALL EXTERIOR.

Asphaltic dampproofing products come in a variety of formulations—solvent- or emulsion-based—with or without fibers to give them body. Hot-applied coatings are necessary in cold weather when emulsion-based coatings may freeze. Both hot- and cold-applied coatings have varying consistencies and formulations, allowing them to be troweled, rolled, brushed, or sprayed. Cold-applied coatings are becoming more common, and can be applied to slightly damp surfaces. Solvent-based materials cannot be applied until concrete has cured sufficiently to meet manufacturer's recommendations.

ADVANTAGES: Available everywhere, economical and easy to install with little skill. Cost-effective when serious water problems do not exist. Used almost exclusively in many regions for starter and low-end housing.

DISADVANTAGES: Materials can lose their limited elasticity due to aging and freeze/thaw cycling. Will not span cracks. Unattractive when exposed. Requires protection board. Requires excavation.

4. APPLY ACRYLIC OR OTHER APPROVED POLYMER SEALERS TO FOUNDATION WALL EXTERIOR OR SLAB SURFACE.

Some recently developed polymer-based materials are available that have model code approvals for use as dampproofing. One of these products, Poly-Wall™, is an attractive gray, nonasphaltic coating that can be painted to match any color.

ADVANTAGES: Fast-drying and easy to apply by spraying. Can also be used on interior of foundation wall to reduce or eliminate moisture migration in the absence of hydrostatic pressure. Exterior use will qualify as waterproofing when used in conjunction with rubberized asphalt sheet membrane accessory component.

DISADVANTAGES: Without additional membrane, will not span cracks. Solvent based; requires curing period prior to application of sealer on new concrete. More expensive than other dampproofing products, normally used in higher-end housing. Requires excavation.

5. APPLY POLYETHYLENE SHEET BELOW FLOOR SLAB.

Generally required by codes to be not less than 6-mil thick, with joints lapped not less than 6 inches (12

inches is preferred), should be sealed with double-sided asphaltic tape such as that manufactured by Reef Industries, Inc. prior to pour to assure continuity of the barrier, especially in clay soils where capillary action is severe. Fiber-reinforced or high-density polyethylene should be considered. These materials cost a little more, but an undamaged barrier is key to the slab's performance. Dampproofing systems that come with written material and performance warranties are preferred.
ADVANTAGES: If properly installed, provides a continuous, impervious barrier to moisture migrating from below the slab. Can be installed over cracked slabs, with new slab poured on top.
DISADVANTAGES: Care must be taken not to puncture sheet to maintain good performance.

There are a number of approaches to exterior (positive side) waterproofing. Systems are usually required to meet ASTM C-836, which sets elastomeric characteristics.

1. APPLY AN ASPHALTIC-BASED PRODUCT TO THE FOUNDATION WALL EXTERIOR.

These hot- or cold-applied products are similar to those used for dampproofing, but are used in two or more coats in combination with polyester, fiberglass or other types of fabric membranes.
ADVANTAGES: Used extensively in the past, this technique has a proven record. Still preferred and economical in some regions where roofing contractors use similar systems.
DISADVANTAGES: Less environmentally friendly than other products. Does not bridge cracks or weather as well as some other systems. More labor intensive to install than some of the new one-coat products. Requires backfill protection layer. Hot systems are difficult to apply on vertical surfaces due to weight of fabric membrane and viscosity of asphalt.

2. APPLY A RUBBERIZED ASPHALT COATING TO THE FOUNDATION WALL EXTERIOR OR SLAB SURFACE.

These products originated in pipeline protection and commercial building markets, but are increasingly used in residential projects. They are considered higher performing than conventional asphalt products and have become lower in cost in recent years. Made and distributed nationwide by such manufacturers as W.R. Grace, Sonneborn, and Koch Materials Co.
ADVANTAGES: These products often come with material and performance guarantees. Have excellent elastomeric qualities and can span static, nonstructural cracks. Can be spray-applied or installed with self-adhering rolls that eliminate need for seam adhesive. Sheet material guarantees consistent thickness, unlike spray applications. Spray applications require less skill.
DISADVANTAGES: More expensive than non-modified-asphaltic products. Spray applied solvent-based materials should not be applied over fresh concrete. Requires backfill protection layer.

3. APPLY AN ASPHALT-MODIFIED URETHANE COATING TO THE FOUNDATION WALL EXTERIOR.

Asphalt is used as a filler with urethane to lessen the cost of the material, without sacrificing performance. Products have typically been used in commercial applications, but are becoming more common in residential work. Distributed nationally by Sonneborn. Brush or spray applied.
ADVANTAGES: Good elongation; warranties available.
DISADVANTAGES: Require backfill protection layer; more expensive than non-modified asphalt coatings.

4. APPLY A URETHANE COATING SYSTEM TO THE FOUNDATION WALL EXTERIOR.

These systems have the highest elastomeric capabilities of fluid applied membranes. Urethane systems are available in one- or two-component materials. Typically black in color, urethanes are solvent-based, requiring substrates to be completely dry to avoid membrane blistering. Available nationally through Karnak, Sonneborn, Mameco, and GACO Western.
ADVANTAGES: Fluid-applied systems are self-flashing, allowing seamless covering of complicated joints and protrusions. High performance, ease of application. One-coat systems available. Good resistance to chemicals and alkaline conditions on masonry substrates. Warranties available.
DISADVANTAGES: Solvent-based. Materials cost can be as much as three times that of least expensive waterproofing systems, but economical to apply. Requires skilled applicators.

5. APPLY A RUBBER-BASED COATING TO THE FOUNDATION WALL EXTERIOR.

A number of rubber-derived materials—including neoprene, butyl, and hypalon—are used in high-end waterproofing systems. These materials have excellent elastomeric capabilities, but less than that of urethane. They are resistant to most chemicals likely to be encountered below grade. Sheet materials are also available, including EPDM and butyl systems where significant hydrostatic pressure is evident. Used primarily on horizontal surfaces such as slabs. Most manufacturers have experience in commercial applications, and a few new wall waterproofing products, such as Rub-R-Wall™ and Composeal™ have been developed specifically for residential applications.

ADVANTAGES: High performance; resistant to chemicals; warranties available.

DISADVANTAGES: Can be expensive; likely to be cost effective only in high-end housing or when serious foundation water problems are encountered. Sheet systems are not self-flashing at protrusions and changes in plane. Requires backfill protection layer and skilled applicators. Some products are highly flammable and toxic.

6. APPLY A CLAY-BASED WATERPROOFING SYSTEM TO THE FOUNDATION WALL EXTERIOR.

Natural clay systems, commonly referred to as bentonite, typically contain 85 to 90 percent clay and a maximum of 15 percent natural sediments such as volcanic ash. When exposed to water, bentonite swells 10 to 15 percent above its dry volume and becomes impervious to water. Available in panels, sheets, and in combination with urethane-, rubber-, and asphalt-based products to enhance performance. It is also available in mat form with a textile backing similar to carpet. Not widely used in residential construction, but is recommended by some architects and contractors who have used it. A widely distributed product is Volclay Waterproofing, manufactured by American Colloid Co.

ADVANTAGES: Excellent waterproofing material; can be applied to recently poured concrete; not toxic or harmful to the environment; useful in underslab waterproofing; minimal substrate preparation required.

DISADVANTAGES: Requires careful application; hydration and swelling must occur in confined space after backfilling for waterproofing properties to be effective. If space is too confined, bentonite can swell with enough force to raise a floor slab or crack concrete. Subject to premature hydration if not properly protected. Wetting and drying the material will cause it to lose its waterproofing properties. Should not be installed where free-flowing groundwater occurs that could wash clay away from substrate. Not resistant to chemicals.

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Builder's Foundation Handbook, John Carmody, et al., prepared for the U.S. Dept. of Energy by the Underground Space Center, University of Minnesota, 1991.

Control of Moisture Problems Affecting Biological Indoor Air Quality, B. Flannigan and P.R. Morey, International Society of Indoor Air Quality and Climate, 1996.

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Preventing Wet Basements, CTT Vol. 17 No. 1 PL 961, PCA, 1996.

Preventing Water Penetration in Below-Grade Concrete Masonry Walls, TEK 19-3A, NCMA, 1994.

Waterproofing the Building Envelope, Michael T. Kerbal, McGraw-Hill, 1993.

PRODUCT INFORMATION

W.R. Bonsal, 8201 Arrowridge Boulevard., Charlotte, NC 28224–1148, 800–334–0784.

ThoroSeal, Thoro System Products, 8570 Phillips Highway, Suite 101, Jacksonville, FL 32256–8208, 800–322–7825.

Xypex Chemical Corp., 13731 Mayfield Pl., Richmond, British Columbia, Canada, V6V 2G9, 604–273–5265.

Vandex, P.O. Box 1440, Columbia, MD 21044, 800–394–1410.

Permaquick Corp., 1591 Trinity Drive, Mississauga, Ontario, Canada, L5T 1K4, 905–564–6100.

Sonneborn, ChemRex, Inc., 889 Valley Park Drive, Shakopee, MN 55379, 800–433–9517.

Poly-Wall International, 1879 Buerkle Road, White Bear Lake, MN 55110, 800–846–3020.

Grace Construction Products, W.R. Grace & Co., 62 Whittemore Ave., Cambridge, MA 02140–9901, 800–354–5414.

Koch Materials Co., P.O. Box 2155, Heath, OH 43056–1132, 800–379–2768.

Karnak Corp., 330 Central Avenue, Clark, NJ, 07066, 800–526–4236.

Mameco International, 4475 East 175th Street, Cleveland, OH 44128, 800–321–6412

Gaco Western Inc., P.O. Box 88698, Seattle, WA 98138–2698, 800–456–GACO.

"Rub-R-Wall", Rubber Polymer Corp., 1135 West Portage Trail Extension, Akron, OH 44313, 800–860–7721.

Volclay Waterproofing, American Colloid Co., 1500 W. Shure Dr., Arlington Heights, IL 60004,708–392–4600.

Concrete Restoration, Materials and Application Field Guide, STO Concrete Restoration Division, P.O. Box 44609 Atlanta, GA 30336–5609, 800–542–3057.

Reef Industries, Inc./Griffin Vapor Barriers P.O. Box 750250, Houston, TX 77275–0250, 800–231–6074.

6 INSULATION

6.1 INSULATING BELOW GRADE WALLS

ESSENTIAL KNOWLEDGE

Insulation is an important element in controlling thermal comfort of basement spaces. There are two basic approaches to insulating existing concrete or masonry foundation walls: applying insulation to the exterior or interior of the wall. Research has shown that there is not a significant difference in energy savings.

The recent widespread use of foam plastic insulation below grade has increased awareness that foam plastic in contact with the soil can allow undetected access by insects including termites and carpenter ants through the insulation to cellulose (food) material in the structure above. In response to this problem, the *1997 North Carolina State Building Code, Volume III - Residential*, requires inspection and treatment gaps in exterior foundation insulation. In addition, in construction where wood is used as a structural member, the *1997 Standard Building Code* and the proposed *1998 CABO One and Two-Family Dwelling Code* prohibit the use of foam plastics on the exterior face or under interior or exterior foundation walls or slab foundations located below grade in areas where the probability of termite infestation is "very heavy". A reference map indicating these areas includes most of California, eastern Texas, Louisiana, Mississippi, Alabama, Georgia, Florida and South Carolina. A CABO exception is "buildings where the structural members of walls, floors, ceilings, and roofs are entirely of non-combustible materials or pressure-preservative-treated wood."

TECHNIQUES, MATERIALS, TOOLS

1. APPLY EXTERIOR INSULATION.

Covering the upper half only is cost effective in regions with low heating degree-day (HDD) requirements (below 2,000 HDD or in areas with up to 2,400 HDD and low fuel costs). Covering the entire wall (Fig.1) is cost-effective at varying levels of insulation from R-10 to R-15 depending on regional fuel costs.

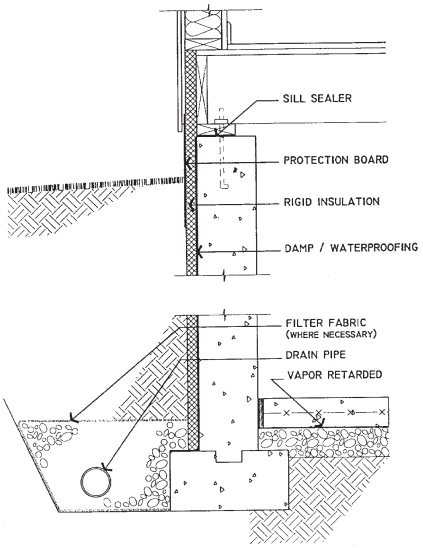


FIGURE 1. CONCRETE BASEMENT WALL WITH EXTERIOR INSULATION

ADVANTAGES: Exterior applications can provide continuous insulation with no thermal bridges; protect and maintain waterproofing/dampproofing at moderate temperatures, thereby extending its life; reduce or eliminate interior moisture condensation problems, since the wall is warm; do not affect interior finishes or reduce useable floor area; will allow inspection of interior walls, sills, and rim joists for insect infestation and mold.
DISADVANTAGES: Some codes now prohibit the use of or require that the insulation be discontinuous so that insect pathways can be detected. Requires excavating the foundation wall for installation.

2. INTERIOR INSULATION COVERING THE ENTIRE WALL FROM FLOOR TO CEILING.
Insulation is applied to the interior wall surface, either as rigid insulation board in combination with furring strips to receive drywall or paneling and accommodate electrical wiring, or in batt form between furring studs. Dow Chemical and Owens Corning have introduced insulation panels with slotted grooves to accept wood furring strips.
ADVANTAGES: Interior applied insulation (Fig. 2) is easier to install than exterior applications; can be fairly inexpensive to install in batt form.
DISADVANTAGES: Interior surfaces of basement walls should be dry, as application of insulation can inhibit

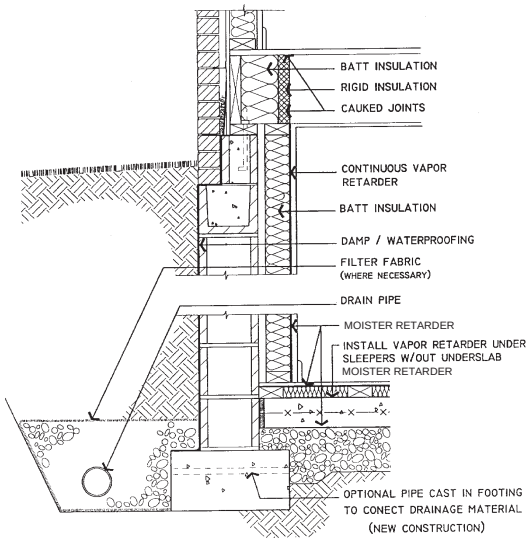


FIGURE 2. CONCRETE MASONRY BASEMENT WALL WITH INTERIOR INSULATION AND WOOD FLOOR ON SLEEPERS

detection of insects and mold within furred wall cavity; most rigid foam insulation requires a 15-minute fire-resistant thermal barrier (usually drywall) to slow the spread of fire to the insulation.

Extruded polystyrene (XPS) board has been the material of choice for the exterior insulation of foundation walls due to its superior compressive strength, impermeability, and durability compared to expanded polystyrene (EPS), mineral wool, and polyisocyanurate products. XPS is made by Owens-Corning, Tenneco Building Products and Dow Chemical with a nominal density of 2 pounds/cu. ft. EPS, however, is also promoted in some areas, due to its lower cost. One manufacturer, AFM Corp., has a product called "Perform Guard" that is treated with borate to discourage termite and carpenter ant infestation. Some EPS manufacturers suggest using 1.5- or 2-pound-density board on exterior applications in lieu of 1 pound commonly used for interior and roof insulation, since at higher densities EPS is more durable and easily handled. Mineral-fiber or fiber-glass boards, such as those used in Koch Industries' TUFF-N-DRY system, have performed satisfactorily. EPS and polyisocyanurates can be used for interior applications, along with insulating batts. Polyisocyanurate boards easily absorb water and are damaged with freeze/thaw cycling, so their use should be avoided where water is a problem.

Relatively new developments include vertically grooved extruded polystyrene boards to enhance drainage against foundation walls. For example, Owens Corning's INSUL-DRAIN™ has a network of drainage channels cut into one side of the board which allows ground water to drain away from the foundation wall. Tongue-and-groove edges permit easier board alignment and help seal joints between the boards. Dow's Styrofoam Thermadry™ is also made with drainage channels (see Chapter 4: Drainage).

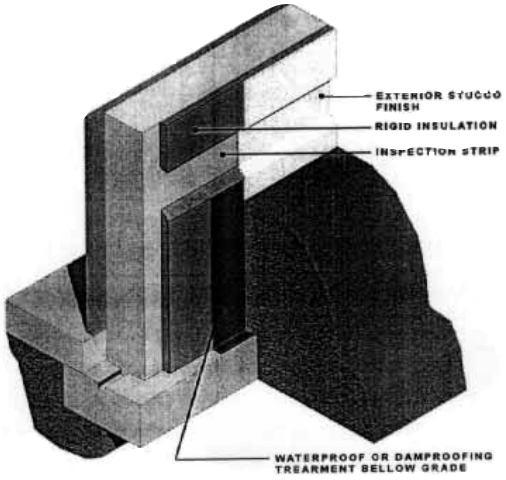


FIGURE 3. INSULATION INSPECTION STRIP

As mentioned earlier, foam board insulation provides a potential pathway for insect (particularly termite) infiltration, into the house. One way to detect this, according to a technical bulletin by LiteForm International, is to provide a "vision strip" by removing a continuous strip of insulation (exposing the concrete) around the entire perimeter of the foundation (Fig. 3) prior to covering or finishing the walls. The strips should be approximately 12 inches above grade level and approximately 8 inches wide. The bottom edge of the cut should be trimmed so that it slopes away from the wall at 45 degrees to shed moisture. It should be noted that this breach in the insulation seriously reduces the overall R-value of the system, and may cause condensation to form on the interior of the wall. The bulletin also recommends a 20 to 22 gauge continuous metal flashing strip (termite shield) be placed at the top of the foundation wall before the wood sill plate is attached. The flashing should overlap the plate by 1 inch and turn down to shed moisture. Termite shields have long been recommended as a way of stopping termite tunnels. Recently, their use has

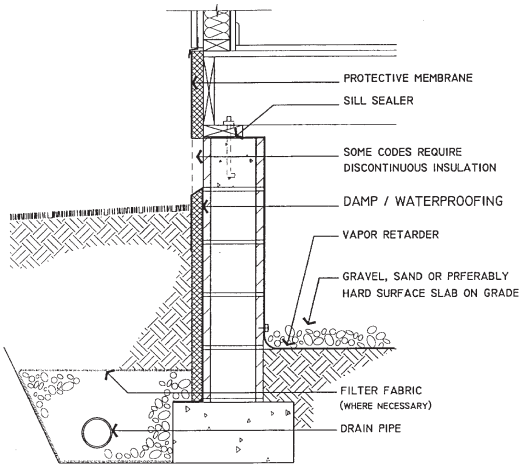


FIGURE 4. CONCRETE MASONRY CRAWL SPACE WALL WITH EXTERIOR INSULATION

decreased because they interrupt exterior finishes and complicate the overlap of sheathing and siding at the juncture of the foundation. When they are used, termite shields are often poorly installed, damaged, or bent in such a way that they do not provide a continuous barrier.

Some code agencies have recent restrictions against the use of foam products below grade. As this requirement continues to be researched, it is important to contact local officials for current use requirements. In addition, most foam product manufacturers are researching the use of insect inhibiting chemical additives in their products. Codes require the protection of insulation board on foundation walls above grade level. DFI Pultruded Composites, Inc., among others, makes a rigid, 1/16 inch-thick fiberglass panel that covers the insulation. The panels come in 12- or 24-inch widths and have a 1 inch lip that goes over the top of the insulation board.

FURTHER READING

Builder's Foundation Handbook, John Carmody, et al., prepared for the U.S. Dept. of Energy by the Underground Space Center, University of Minnesota, 1991.

Building Foundation Design Handbook, Ken Labs et al., prepared for the U.S. Dept. Of Energy by the Underground Space Center, University of Minnesota, 1988.

Concrete Masonry Handbook, Portland Cement Association, 1991.

Fine Homebuilding on Foundations and Masonry, Taunton Press, 1990.

"Preventing Termite Damage," *Lite-Form International Technical Bulletin,* August 1996.

"Should You Insulate the Basement?" *Journal of Light Construction*, June 1992.

PRODUCT INFORMATION

Perform Guard, AFM Corp., 24000 Highway Seven, P.O. Box 246, Excelsior, MN 55331; 800–255–0176.
TUFF-N-DRI, Koch Materials Co., P.O. Box 2155, Heath, OH 43056–1132; 800–379–2768.
INSUL-DRAIN™, Owens Corning, Fiberglass Tower, Toledo, OH 43659; 800–GET–PINK.
Styrofoam THERMADRY™ and Styrofoam Wallmate, Dow Chemical Co., 2040 Willard H. Dow Center, Midland, MI, 48674; 800–441–4369.
DFI Pultruded Composites, Inc., 1600 Dolwick Drive, Erlanger, KY 41018; 606–282–7300.

6.2 INSULATING CRAWLSPACES

ESSENTIAL KNOWLEDGE

Crawlspaces are insulated to protect plumbing and ducting that may run through the space, and to mitigate the effect of temperature swings on the living spaces above. Crawlspaces are either vented or unvented, and insulation strategies vary in each case.

TECHNIQUES, MATERIALS, TOOLS

There are two basic approaches to insulating crawlspaces:

1. INSULATE VENTED CRAWLSPACES.

This approach places batt insulation between the joists, in the underside of the first floor, to protect the living space.

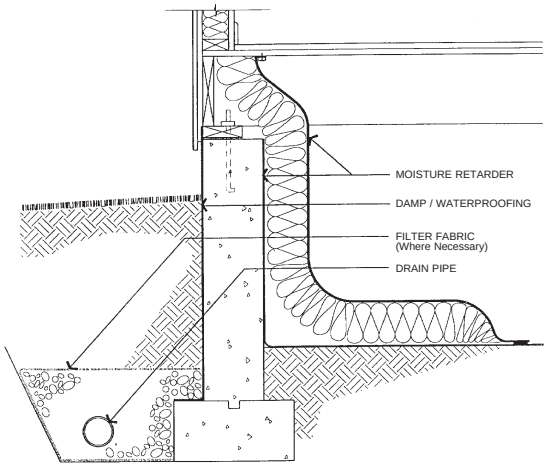
ADVANTAGES: Often the least costly method of crawlspace insulation, accomplished with mineral wool or fiberglass batts; eliminates need to insulate crawlspace walls (required in unvented spaces); protects pipes

and ducts that run in the plenum space between floor joists.
DISADVANTAGES: May be difficult to install if there is limited access to crawlspace. May be difficult to seal the underside of the floor adequately with a vapor barrier due to multiple penetrations. Requires that ducts and pipes below the floor be insulated.

2. INSULATE UNVENTED CRAWLSPACES.

Preferred by many researchers, this strategy of treating the crawlspace as a shallow basement permits the crawlspace to act as an insulated and conditioned plenum space through which pipes and ducts can be run without freezing. It also reduces or eliminate odors, insects, pests, dirt, and debris. Crawlspace walls can be insulated from inside or outside in fashions similar to that for basement walls (Fig. 1, 2 and 4 above, and Fig. 5 and 6 below).
ADVANTAGES: Exterior rigid insulation on crawlspace walls can be relatively easy to apply to the foundation surface, and may be the only insulation alternative where crawlspaces are inaccessible; reduces moisture condensation problems; allows inspection of crawlspace interior walls (if accessible), sills, and rim joists for insect infestation. Interior insulation in the form of boards or batts can be applied without excavation; can be adhered with mastic to foundation wall, or attached to the top of the wall and draped down.
DISADVANTAGES: Insulating unvented crawlspaces can be more costly than insulating a comparable vented crawlspace; can be difficult to install interior insulation in crawlspaces with limited access; harder to inspect insulation-covered walls for insect infestation.

Insulation materials and techniques are discussed in *TECHNIQUES, MATERIAL, TOOLS* in Section 6.1.



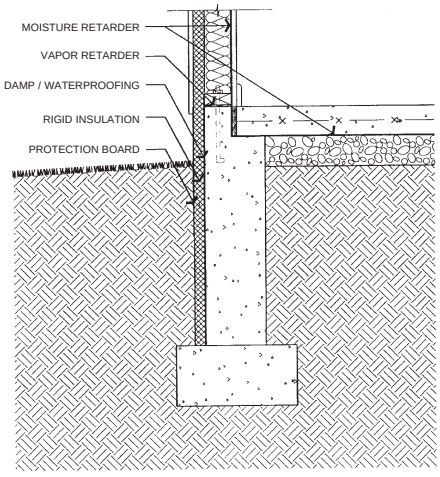


FIGURE 5, 6.

CONCRETE CRAWL SPACE WALL WITH INTERIOR INSULATION

SLAB-ON-GRADE WITH CONCRETE STEM BEAM

FURTHER READING

Builder's Foundation Handbook, John Carmody, et al., prepared for the U.S. Dept. of Energy by the Underground Space Center, University of Minnesota, 1991.

Building Foundation Design Handbook, Ken Labs et al., prepared for the U.S. Dept. Of Energy by the Underground Space Center, University of Minnesota, 1988.

PRODUCT INFORMATION

Refer to Section 6.1.

6.3 INSULATING SLABS

ESSENTIAL KNOWLEDGE

There are two basic types of slab-on-grade foundations: those with conventional footings and concrete or masonry stem walls (Fig. 7) and those with shallow perimeter grade beams (Fig. 8, 9). In rehab work, insulation can be added only to the exterior without disturbing the slab floor.

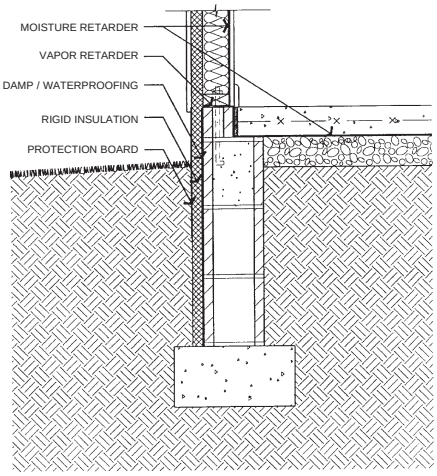
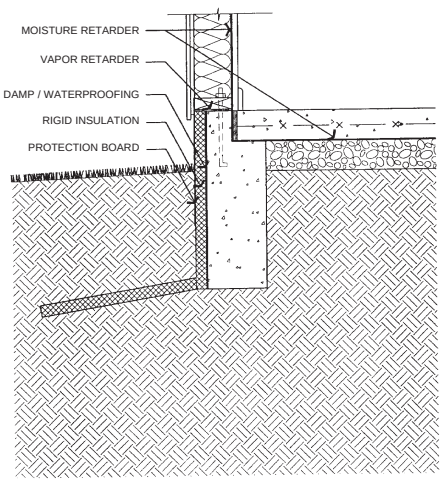


FIGURE 7. SLAB-ON-GRADE WITH MASONRY STEM WALL



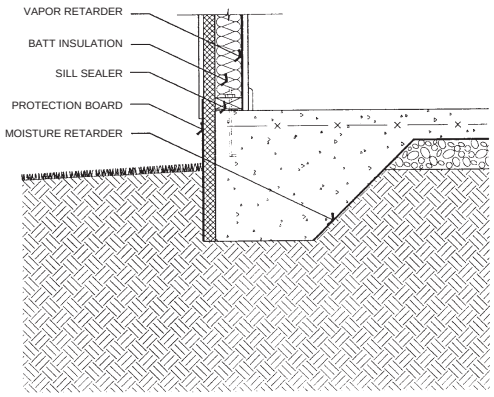


FIGURE 8, 9. SLAB-ON-GRADE WITH FROST-PROTECTED SHALLOW FOUNDATION SYSTEM

SLAB-ON-GRADE WITH PERIMETER "TURN DOWN"

TECHNIQUES, MATERIALS, TOOLS

There are three basic approaches to insulating slabs:

1. EXTERIOR INSULATION FOR SLABS WITH STEM WALLS.

The stem wall depth will typically vary with the frost line. Full depth insulation is recommended in all areas of the country. An alternate insulation strategy is to insulate in accordance with the NAHB *Frost Protected Shallow Foundation* recommendations.

2. EXTERIOR INSULATION FOR SLABS WITH GRADE BEAMS.

This type of slab is typically used in the West, Southwest, and South. Full depth insulation is recommended in areas with moderate or high fuel costs and Heating Degree Days in excess of 2,000.

3. INSULATING BASEMENT SLABS FROM INSIDE.

While not cost effective in terms of energy savings versus first cost, basement slab insulation makes finished floors more comfortable. The traditional method (Fig. 2) is to seal the existing floor with a vapor barrier; fasten pressure-treated wood nailers or sleepers to the floor; cover with another vapor barrier (to prevent moist air from condensing in the floor cavity); install sheathing (plywood or OSB); and finish with wood flooring or resilient tile. An alternate method is to float the new floor over loosely applied insulation and subfloor.

Insulation materials and techniques are discussed in *MATERIAL, TECHNIQUES, TOOLS* in Section 6.1.

FURTHER READING

Concrete Floors on Ground, EB075, Portland Cement Association, 1997.

Slabs on Grade, American Concrete Institute, 1994.

Frost Protected Shallow Foundations, NAHB Builder's Press, 1994.

Design Guide for Frost-Protected Shallow Foundations Second Edition NAHB Research Center, Inc. 1996.

PRODUCT INFORMATION

Refer to Section 6.1

7 VENTILATION

7.1 VENTILATING BASEMENT SPACES

ESSENTIAL KNOWLEDGE

Basement air can suffer from soil gases, mold, and mildew. Soil gases can penetrate the basement through cracks in foundation walls and slabs and through unsealed penetrations. Mold and mildew growth is encouraged by cool surface temperatures, high relative humidity, and by the presence of moisture in walls and floors. Basements are often used to store solvents and fuel tanks, which outgas volatile organic compounds (VOCs). The quality of the basement air also affects the quality of air in the entire house. If the house uses a forced air system for heating or cooling, basement air is induced into the return ducts and at the fan housing and redistributed to other spaces in the house. If the house is heated with a hydronic system or with electric baseboards, the basement air can still migrate to other areas. This type of air movement can be reduced through sealing and caulking, but is unlikely to be eliminated.

If the basement is used as a living space, it especially needs to be properly ventilated. Without proper ventilation, indoor pollutants can reach high concentrations. Even if the basement is mostly used for storage or mechanical equipment, ventilation is important because complete separation of basement air from house air is not feasible. Basement ventilation is usually provided directly through operable windows, vents, or fans, or indirectly through air infiltration. Air infiltration is not a good method of ventilation because the rate of infiltration varies with wind and temperature and cannot be relied upon to provide sufficient outside air at all times. The best solution is to have an airtight basement that is well-ventilated.

For basements with boilers or furnaces, good ventilation also helps reduce the potential for depressurization. When a basement furnace or boiler pulls air from the rest of the house for combustion, and exhausts it out the flue, a low pressure zone is created in the basement, which can pull soil gases into the space. If the equipment is placed in an area open to the rest of the basement, depressurization will usually be negligible; if the equipment is enclosed in an airtight room depressurization is more significant. The basement can also have more than one combustion appliance (a furnace plus a hot water heater). The effect of these appliances firing at the same time is additive. For air systems, return ducts usually pull air from the basement, causing depressurization. Ducts should be sealed and taped, but some leakage will remain. A separate supply of outside air to the combustion area is beneficial. The basement can also be pressurized by the air system to keep soil gases out.

Since ventilation has many positive effects, it is important that it be provided effectively. In many residences, supply of outside air to the combustion equipment is achieved by windows left open in the basement space that contains the furnace or boiler, or by a vent with insect screening installed in the foundation wall. These methods will induce cold air into the basement during winter and moist air during summer, increasing the energy cost. Additionally, the window that provides combustion air could be closed accidentally. For this reason, windows are not recommended as a means to provide combustion air.

Combustion air can be ducted in close proximity to the boiler or furnace. This method is not that different from creating a screened opening in the wall. The best solution is to purchase equipment that is certified as direct-ventilation (sealed-combustion), and that draws the outside air directly into the combustion chamber. This method raises the energy efficiency of the heating system and increases the safety of operation. If sealed combustion is not feasible, it is preferable to provide a fan that brings in air to the combustion equipment only when this equipment operates.

There are a number of approaches to providing adequate ventilation to basements and sufficient combustion air for a furnace or boiler, without creating low pressure zones that draw soil gases:

1. PROVIDE DIRECT-VENTILATION (SEALED-COMBUSTION) BOILERS OR FURNACES.

This type of mechanical equipment provides outside air for combustion through a duct that leads directly from a wall vent to the combustion chamber of the boiler or furnace.
ADVANTAGES: Warm air from the house is not used for combustion and exhausted through the chimney; the risk of incomplete combustion and of flue gas backflow into the house is eliminated.
DISADVANTAGES: Requires extra cost to purchase a sealed-combustion boiler or furnace.

2. PROVIDE A FAN WITH A MOTORIZED DAMPER TO INDUCE OUTSIDE AIR INTO THE BOILER OR FURNACE ROOM ONLY WHEN THE EQUIPMENT FIRES.

This method provides combustion air, and is similar to the sealed combustion technique, except that the combustion air is not ducted directly to the equipment and has to cross the boiler or furnace room. When the equipment does not fire the damper closes over the fan and does not allow cold air to seep in.
ADVANTAGES: Warm air from the house is not used for combustion and exhausted through the chimney; the risk of incomplete combustion and of flue gas backflow into the house is eliminated.
DISADVANTAGES: Extra cost and somewhat higher complexity than for a window or vent.

3. PROVIDE A SCREENED, OPEN VENT TO ALLOW OUTSIDE AIR INTO THE BASEMENT NEAR THE FURNACE OR BOILER.

The constantly opened vent allows outside air into the boiler/furnace area of the basement at all times (operable windows are not a recommended alternative, because they might be closed). To mitigate the intrusion of cold or moist air throughout the basement, the furnace or boiler should be enclosed in its own room.
ADVANTAGE: A low-tech, low-cost solution.
DISADVANTAGES: The equipment must be located next to an exterior wall with vent opening above grade; if located close to exterior grade level, the vent will require maintenance to keep it free from debris or snow. The air in the boiler/furnace room can get cold, increasing the heat loss from the equipment and therefore increasing the fuel use. Also, it is possible (even if not likely) that under strong wind conditions a supply vent placed on the leeward side could *exhaust* air, rather than admit it.

4. SEPARATE THE BASEMENT AIR FROM THE AIR IN THE REST OF THE HOUSE.

Separation of basement air from house air is desirable when the basement is not used for living space. The purpose is to minimize mixing basement air, that could be polluted by dust, mold, or VOCs, with conditioned air for the house. The basement space is separated from the rest of the house with doors and continuous floor. Basement ventilation is provided by adequately sized windows or mechanical intake and exhaust fans. The basement is heated with a hydronic system, electric baseboard heat, or with a separate air heating system that keeps the air from the basement from mixing with the rest of the house. Containers that can outgas VOCs are stored in an airtight, enclosed room. This room should have continuous exhaust to the outdoors. Fan housings and ducts in the basement that serve the house must be sealed and taped to avoid drawing basement air into the rest of the house.
ADVANTAGES: The basement is well ventilated, and the air in the rest of the house is cleaner.
DISADVANTAGES: If a heated air system is used for the house, there will be significant added cost for a separate, decoupled air system for the basement (or for a separate hydronic or electric heat system). Extra costs are incurred to carefully seal fan housings and ducts in the basement that serve the living area.

5. TREAT THE BASEMENT AS CONTIGUOUS, CONDITIONED SPACE OPEN TO THE REST OF THE HOUSE.

This method is recommended when the basement is maintained to the same standards of cleanliness as a living space. Separate ventilation for the basement can be provided with windows, or mechanical intake

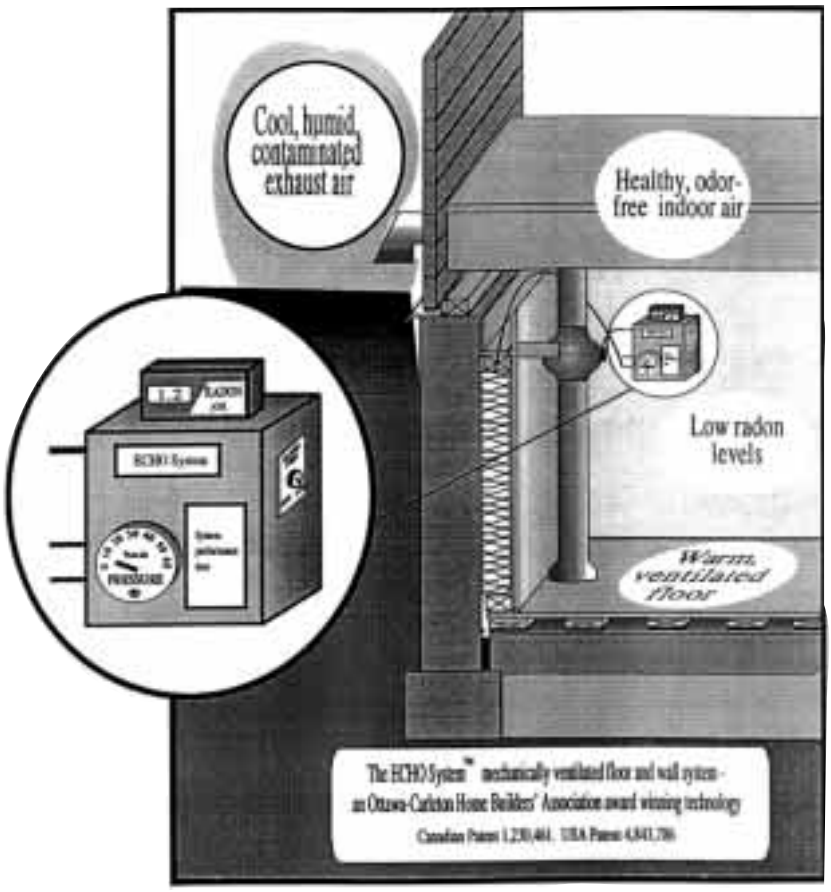


FIGURE 1. ECHO SYSTEM PERFORMANCE CHARACTERISTICS

and exhaust systems. The basement can also be ventilated using outside air brought in by the air system that serves the house. If an air system is used for the entire house, ducts located in the basement must be well-sealed to avoid pressure imbalances that could lead to the suction of soil gases. An additional step in avoiding soil gas seepage is to pressurize the basement. This condition can be achieved by supplying outside air at the upper floors and by exhausting at the basement level.

ADVANTAGES: Can provide proper ventilation in the basement at all times.

DISADVANTAGES: Possible discomfort at times as warm air rises and the upper spaces overheat, while the basement remains cooler. Adjustable dampers in the ducts leading to each floor, or mechanical destratification ducting, will remedy this problem at added cost. Also, tight basement walls will reduce the air infiltration rate in the basement, and will reduce the airflow from basement into other spaces.

6. PROVIDE A VENTILATED "ROOM WITHIN A ROOM."

When walls are continuously moist from water penetration, or when radon cannot be satisfactorily controlled with EPA-recommended techniques (see Section 7.3), rooms or areas within the basement space can be built that have continuous air exhaust under the floor and in the wall cavity between the room's walls and the basement walls. This innovative technology, called the ECHO system (Fig. 1) is sold by Indoor Air Technologies, Inc. Ideally, the furnace, boiler, or domestic hot water heater nearby should have sealed combustion, with a ducted outside air supply. More important, the return ducts and fan housing need to be well sealed to avoid air being drawn from the basement, creating negative pressure that can reduce the effectiveness of this system.

ADVANTAGES: Addresses several aspects of basement air quality. Effective when exterior source problems cannot be eliminated. The insulation installed on the interior walls (not on the foundation walls) remains

dry even if the basement walls leak.
DISADVANTAGES: Requires monitoring of equipment and conditions in ventilated wall spaces. Can be costly.

FURTHER READING

Clean Air Guide, Canada Mortgage and Housing Corp., 1993.

Control of Moisture Problems Affecting Biological Indoor Air Quality, B. Flannigan and P.R. Morey, International Society of Indoor Air Quality and Climate, 1996.

Moisture Control Handbook, Joseph Lstiburek with John Carmody, U.S. Dept. Of Energy, 1991.

Moisture Control in Buildings, Heinz R. Trechsel, ed., ASTM, 1994.

Indoor Air Quality And Climate: Investigation, Evaluation and Remediation, Indoor Air Technologies, Ottawa, ON, Canada KIVOW2

PRODUCT INFORMATION

ECHO System, Indoor Air Technologies, Inc., P.O. Box 22038, Sub 32, Ottawa, Ontario, Canada K1V 0W2, 800–558–5892.

7.2 VENTILATING CRAWLSPACES

ESSENTIAL KNOWLEDGE

The venting of many existing crawlspaces is inadequate and moisture and odor problems are frequently apparent. Moisture encourages mold, mildew, and wood rot, and degrades insulation R-value. There is currently much debate about the ratio of ventilation area to floor area. Building codes typically require that crawlspaces be provided with ventilation openings in the surrounding walls with a net free area of 1 square foot for each 150 square feet of crawlspace area, or reduced to $^1/_{1,500}$ of the crawlspace area when an approved moisture retarder is used over the ground surface. Natural ventilation is useful during dry winter months, but can actually increase the moisture in the crawlspace during humid winter spells and during the cooling season, in areas with humid summers. Crawlspaces that are not ventilated with foundation vents must be equipped with a mechanical ventilation system conforming to an approved mechanical code.

TECHNIQUES, MATERIALS, TOOLS

There are a number of approaches to ventilating crawlspaces and mitigating moisture problems:

1. NATURALLY VENTILATE THROUGH REQUIRED-SIZED OPENINGS IN THE FOUNDATION WALL.

Ventilation can be achieved through the existing foundation wall by removing portions of the block or concrete wall and installing ventilation grilles. The floor above the crawlspace must be insulated, as temperatures inside the crawlspace will be seasonal (see Section 6.2: Insulating Crawlspaces). Special care must be taken to insulate water and waste piping located below the floor insulation. Dirt floors are a major source of moisture in crawlspaces and should be covered with a polyethylene moisture retarder. A concrete slab, or other protective surface, can be placed over the polyethylene to protect the sheet against damage.
ADVANTAGES: Compared to mechanical ventilation, this approach is relatively inexpensive in terms of operating costs; requires little maintenance.

DISADVANTAGES: Requires insulation of floor above crawlspace, which may be difficult or impossible to achieve. Insulation must be tightly packed between floor joists; any air spaces between the insulation and the joists promote air convection, which short circuits the insulation. Removing portions of the existing foundation walls may not be possible or practicable, such as with rubble stone walls or concrete walls with rebar. Natural ventilation may not always provide enough airflow to remove moisture, and may induce moisture in summer and during humid winter periods. Removable covers for the grilles can address this problem, but add a maintenance cost.

2. MECHANICALLY VENTILATE THE UNCONDITIONED CRAWLSPACE.

This option is similar to the one discussed in 1 above (natural ventilation), except that the ventilation is mechanically provided. There are ventilation systems on the market, such as the CellarSaver by Tamarack Technologies, that can be adjusted to activate at a certain humidity level. They also have insulated dampers that close when the fans are not in use.

ADVANTAGES: Ensures a minimum ventilation rate even when there is no breeze. Dampers, manual or automatic, close the crawlspace to humid outside air when the fans are off.

DISADVANTAGES: Same construction drawbacks as option 1; additional cost of operating and maintaining the fans.

3. MECHANICALLY VENTILATE THE SEMICONDITIONED CRAWLSPACE.

This strategy essentially treats the crawlspace as a basement space, ventilating it similarly through mechanical means. The crawlspace is mechanically heated in addition to being ventilated. The foundation walls are insulated (see section 6.2: Insulating Crawlspaces).

ADVANTAGES: Ensures that ventilation is timely and sufficient. When the crawlspace is properly insulated, this technique saves money in fuel costs and extends the life of the floor structure.

DISADVANTAGES: Higher initial cost. Requires access to crawlspace for installation and to observe condition of space and equipment.

FURTHER READING

"Investigation of Crawl Space Ventilation and Moisture Control Strategies for British Columbia Homes," Canada Mortgage and Housing Corp., 1991.

Moisture Control Handbook, Joseph Lstiburek with John Carmody, U.S. Dept. Of Energy, 1991.

Moisture Control in Buildings, Heinz R. Trechsel, ed., ASTM, 1994.

"Recommended Practices for Controlling Moisture in Crawl Spaces," Technical Data Bulletin, Vol. 10, No. 3, January 1994 ASHRAE Symposium.

PRODUCT INFORMATION

CellarSaver, Tamarack Technologies, Inc., 11 Patterson's Brook Road, P.O. Box 490,
West Wareham, MA 02576; 800–222–5932.

7.3 VENTILATION FOR SOIL GASES

ESSENTIAL KNOWLEDGE

In the past few years, awareness of the dangers of soil gases, especially radon, has grown. According to the U.S. Environmental Protection Agency, 14,000 cancer deaths in the U.S. are caused by radon each year. The

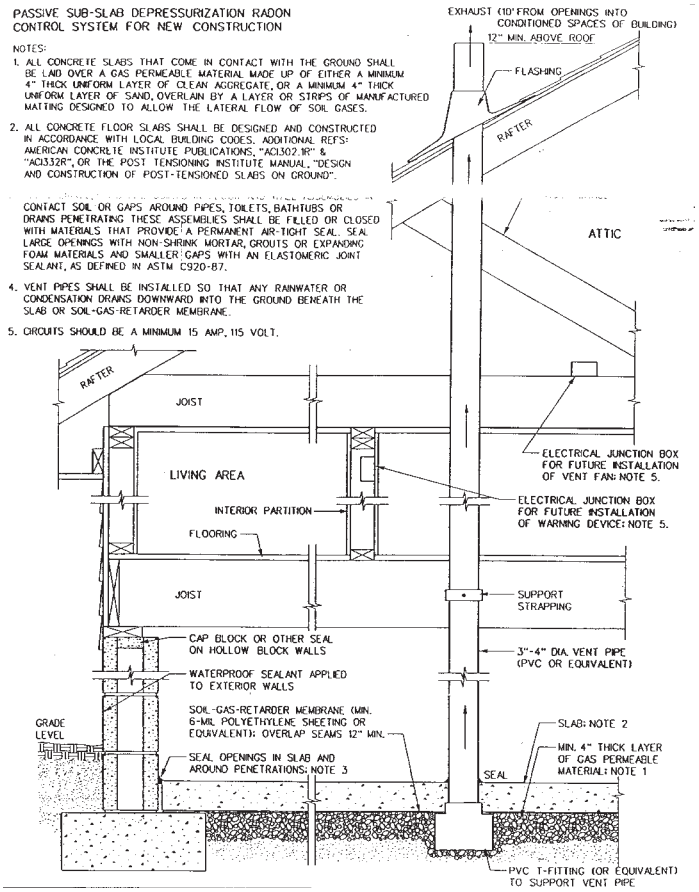


FIGURE 2. PASSIVE SUB–SLAB DEPRESSURIZATION RADON CONTROL SYSTEM

EPA estimates that one out of every 15 houses has elevated radon levels, with concentrations heavier in some regions than in others. A colorless, odorless, radioactive gas, radon is most often found in basements, entering through crawlspaces, dirt floors, cracked foundation floors and walls, and openings around drain pipes and sump pumps.

TECHNIQUES, MATERIALS, TOOLS

The EPA has released details of techniques for radon abatement in basements and crawlspaces. Consideration should also be given to the mechanical ventilation system's effect on radon control:

1. PROVIDE SUB-SLAB VENTILATION OF SOIL GASES IN BASEMENT SPACES.

Vent pipes penetrating the slab can run vertically through the house, and be vented out the roof or a side wall. The vent pipe has a continuously operating exhaust fan that maintains negative pressure. All cracks and penetrations through the slab, and junctures between the slab and the walls, should be sealed with caulking or grout. New slabs should be poured on a 4-inch layer of gravel or sand, overlaid with a gas-retarder membrane (Fig. 2, 3).

ADVANTAGES: An approved technique, endorsed by EPA, that effectively exhausts gases below the slab.

DISADVANTAGES: Can be costly, depending on size of basement and configuration of house. Less effective when the basement walls are made of hollow core concrete masonry units (CMU), since radon could find points of entry into such walls. In cold climates, there is the possibility of frost heaving due to the cold air introduced under the slab.

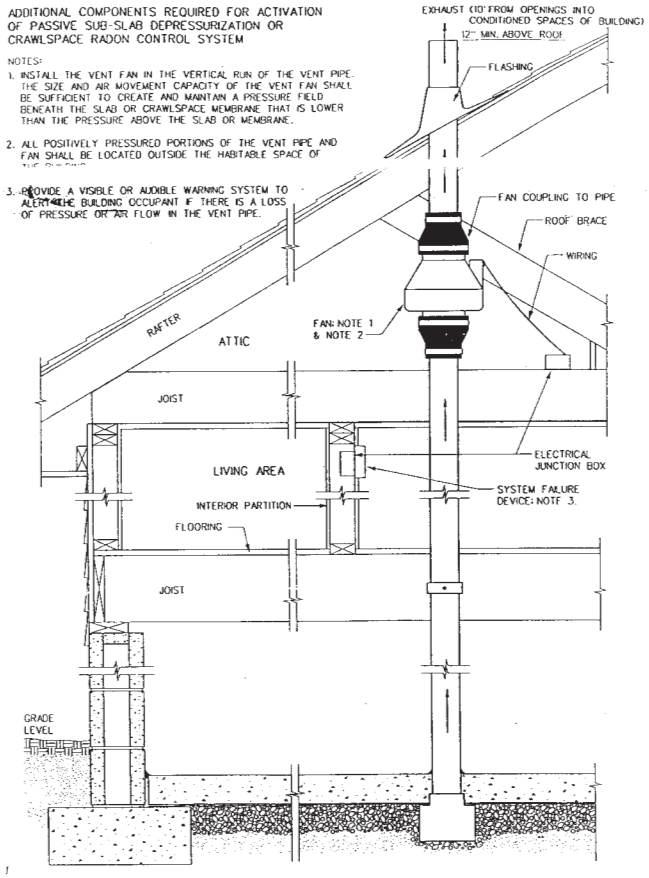


FIGURE 3. ADDITIONAL COMPONENTS REQUIRED FOR ACTIVATION OF DEPRESSURIZATION RADON CONTROL SYSTEM

2. PROVIDE FOUNDATION WALL DEPRESSURIZATION.

The foundation wall is depressurized through weeping tiles (drain tiles). A continuously operating exhaust fan maintains negative pressure. All cracks and penetrations at the wall should be sealed with caulking or grout.
ADVANTAGES: Relatively easy to implement.
DISADVANTAGES: The area protected by this technique is limited; fan must operate at all times; ineffective if weeping tile is connected to the sewer system or to roof leaders.

3. PROVIDE BASEMENT HEATING AND VENTILATION, SEPARATE BASEMENT AIR FROM THAT OF THE REST OF THE HOUSE, AND PRESSURIZE THE SPACE TO KEEP OUT SOIL GASES.

This approach, similar to that discussed in section 7.1, is useful to supplement the EPA-recommended radon mitigation techniques described above. Pressurization is achieved via a dedicated air system for the basement, with an outdoor air intake. This technique ensures that the basement is always at a positive pressure with respect to air spaces in the basement walls and in the cavities below the slab. This approach is most useful in basements with CMU walls with hollow cores, through which radon can enter. If a furnace, boiler, or domestic hot water heater is located in the basement, combustion air must be ducted to a sealed appliance, or outside air must be supplied using a fan with damper (the fan operates only when the appliance fires). Open windows or screened vents are not recommended because they can compromise positive pressure. If the house has an air system, fan housings and ducts must be sealed and lapped to avoid entraining basement air.
ADVANTAGES: Ensures good ventilation; increased effectiveness in keeping radon out.
DISADVANTAGES: Significant cost required to achieve a tight basement/house separation; significant cost in supplying a dedicated air system, such as a furnace with outside air supply; additional cost for a ducted out-

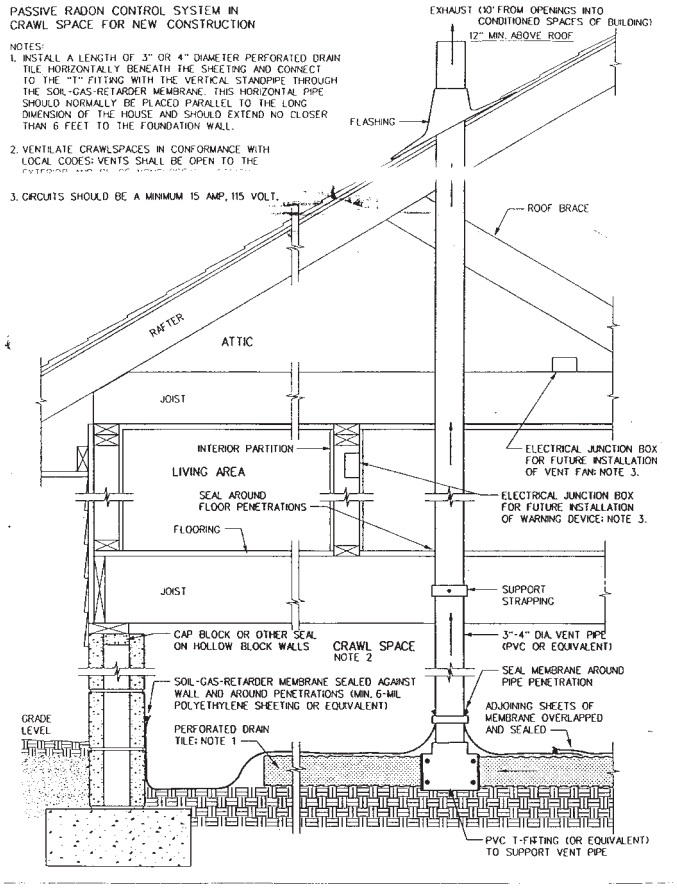


FIGURE 4. PASSIVE RADON CONTROL SYSTEM IN CRAWL SPACE FOR NEW CONSTRUCTION

side air system for combustion (although such system is a good idea even if the basement has no radon problems; see Section 7.1).

4. PROVIDE VENTILATION OF SOIL GASES FROM CRAWLSPACES.

Where a crawlspace slab exists, the technique is similar to that described for basement spaces (above). For dirt-floor crawlspaces (Fig. 4) perforated pipe should be laid over the soil, parallel to the house's long dimension, and should extend no closer than 6 feet to the foundation wall. A T-fitting joins the perforated pipe to an exhaust stack that extends through the roof. The pipe and crawlspace floor are then covered with a gas retarder membrane, and sealed against the foundation wall and all vertical penetrations.
ADVANTAGES: An approved technique sanctioned by the EPA that effectively exhausts soil gases.
DISADVANTAGES: Can be costly, depending on size of crawlspace and configuration of house.

5. PROVIDE A VENTILATED "ROOM WITHIN A ROOM."

Refer to Section 7.1, option 6. The ECHO system described there is also effective in reducing radon penetration into basement and into other occupied spaces.

FURTHER READING

Guide to Radon Control, Canada Mortgage and Housing Corp., 1990.

"Model Standards and Techniques for Control of Radon in New Residential Buildings," March 1994.

"Radon-Resistant Construction Techniques for New Residential Construction: Technical Guidance," U.S. Environmental Protection Agency, 1991.

"Selected Detail: Radon Abatement," Michael J. Crosbie, *Progressive Architecture*, Nov. 1994, p. 125.

8 SHORING, UNDERPINNING, & REPAIR

ESSENTIAL KNOWLEDGE

When a foundation settles or is displaced laterally, cracks appear, water may intrude, and the building's basic structure is compromised. Foundation walls may crack, settle, move upwards from freeze/thaw cycling or expansive soils, or move sideways. The primary causes of such foundation failures are: problematic sites; poor soil conditions; seismic activity; water migration through soils or flooding; poor foundation design, engineering, or construction materials. Problematic site conditions include steep slopes beyond the soil's natural angle of repose; lack of terracing under fill; sites with high water tables, springs, or underground streams; and sites adjacent to bodies of water or within flood plains. Poor soil conditions include highly expansive soils; organic (peat or discarded plant material) or silty soils; and poorly compacted fill that was not layered when it was placed. Seismic activity can damage inadequately reinforced brick, concrete, concrete block, or stone foundations. Water-related damage includes the migration of fines under foundations, decreased soil cohesiveness (which causes settlement), and hydrostatic pressure against foundation wall and floors (which can lead to cracks and displacement). Poor design and engineering may result in improper materials, under-reinforcement, or lack of attention to many of the conditions mentioned above.

Foundation settlement usually happens over time, and is not a dramatic event; there is usually time to prepare a proper fix. The cause of the settlement should be carefully and deliberatively researched, as remedial work is expensive and care should be taken to understand the nature of the problem. A structural engineer or a soils (geotechnical) engineer who specializes in such work should be consulted.

TECHNIQUES, MATERIALS, TOOLS

There are a number of approaches to stabilizing and re-positioning foundations, which are applicable to all types, including stem walls, piers with grade beams, and slabs on grade. Some of these systems are commonly used to repair commercial or industrial building, but they can also be used for residential multi-family and single-family housing rehab. Repairs should be undertaken by experienced contractors under the direction of a professional engineer.

1. STABILIZE AND UNDERPIN SETTLED FOUNDATION WITH REINFORCED CONCRETE PIERS.

This process involves auguring a pier excavation next to the settled portion, in some instances (such as with granular soils) inserting round cardboard forms, placing reinforcing steel , and pouring a concrete pier including an elbow or cap under the existing footing. Concrete piers can bear on rock or can be designed as friction piers. Once the concrete is cured, a hydraulic jack can be set between the newly formed elbow or cap and the underside of the footing (Fig. 1). The jack distributes the load to the new pier and raises the settled portion. Shims are then inserted to hold the raised foundation in place so that the jack can be removed and the joint packed with a no-slump mixture of sand and cement (drypack). The number of piers is determined by the type of foundation and the size of the settled portion. If the loads are small and

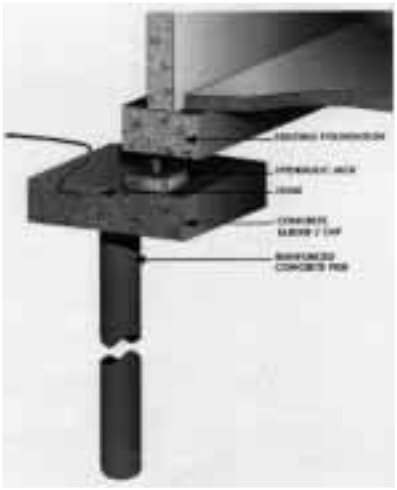


FIGURE 1, 2. REINFORCED CONCRETE PIER "MINI" PIER

the soil's capacity is good, the jack can be eliminated and the loads transferred through the shims directly.
ADVANTAGES: A conservative approach, with a proven track record.
DISADVANTAGES: Limited in depth in sandy soils that will collapse the auger hole. May not work as friction piers in soil with poor bearing capacity. Requires concrete to cure sufficiently before load is applied. Difficult to raise the foundation more than a few inches. More disruptive to landscaped areas adjacent to the building than mini or helical piers.

2. STABILIZE OR RAISE SETTLED FOUNDATION WITH STEEL MINI-PIERS.

Usually hydraulically driven, mini-piers range from 2 to 8 inches in diameter. The smaller sizes, 2 to 4 inches, are typically used in residential projects. The piers are set adjacent to the interior or exterior face of the footing at intervals of 6 to 8 feet, depending on the condition and reinforcement of the footing (Fig. 2). They are then hydraulically or pneumatically installed through a drive frame mounted on the foundation wall to rock or an adequate bearing strata. The building's dead weight, plus the weight of the soil adhering to the footing and foundation wall, provide the resistance/reaction during installation of the mini-piers. The piers are usually driven to depths of 15 to 25 feet, and can go as deep as 150 feet, but are increasingly uneconomical and difficult to drive over 60 feet. A number of companies including Atlas Systems, Inc. and Perma-Jack hold patents on mini-pier product installation systems. Another variant, called the Mini-Pile™ system, developed by Heywood Baker, Inc., employs an over-sized point that concentrates resistance at the end of the pipe pile. The pile is hollow, and if bedrock is not encountered a grout bulb can be pressure injected at the end of the pipe to supply the necessary bearing. There are two attachment systems—one used in expansive soil attaches to the foundation by means of a steel bracket; the other employs a 12-inch thick reinforced concrete pile cap/ jacking pad that is used to seat a hydraulic jack that is in turn used to raise the footing. The space between the surface of the jacking pad and the footing underside is then filled with concrete to complete the pilecap.
ADVANTAGES: Time-proven, economical, and stable, where bearing layer is within 50 to 60 feet of grade. No heavy equipment required; can be installed in limited access areas and be used to raise slabs.
DISADVANTAGES: Can crack foundation and slab if used incorrectly. Economical use requires bearing layer to be relatively near to grade, and 2- to 3-foot square access pits, which can disturb the foundation perimeter if multiple pits short distances apart are used.

3. STABILIZE OR RAISE SETTLED FOUNDATION WITH HELICAL PIERS.

A patented system that screws a steel shaft with a helical plate into stable soil. The steel shaft attaches to the footing and foundation wall by means of a bracket. The rotation of the helical plate by a hydraulic jack will eventually cause enough resistance to stabilize the foundation or raise it, if necessary (Fig. 3). Installers of the helical pier system are trained and licensed by such companies as A.B. Chance Co. and Atlas Systems,

Inc., which provide geotechnical support. Warranties are available.
ADVANTAGES: A proven, versatile, technically sound system. Economical and not as disruptive as some other methods. No heavy equipment required. Can be installed in limited access areas; can be used for shallow pier foundations, as a wall anchor to pull back and hold basement walls, and to raise slabs. Hydraulic jack torque can be measured, thereby determining actual bearing capacities of helical piers.
DISADVANTAGES: Will not work in soils of limited bearing capacity. May disturb building perimeter, including walks and planting, if on-center spacing of piers is close. Requires notching the footing to apply the bracket.

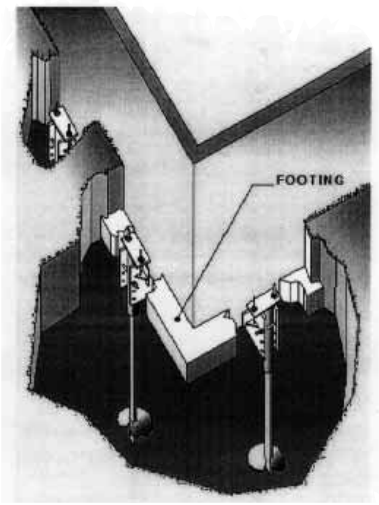


FIGURE 3. HELICAL PIER

4. STABILIZE OR RAISE SETTLED FOUNDATION BY "PRESSURE GROUTING" OR "MUD GROUTING."

This technique pressure injects a slurry of cement, water, and sand into the soil to stabilize the foundation or to raise the basement slab. This method is difficult to control, and the location of the grout and its effect are impossible to determine. It is more commonly used for slab stabilization and less for foundation shoring, where other techniques are considered more reliable and cost effective.
ADVANTAGES: An economical solution, if it works.
DISADVANTAGES: Often not effective; difficult to control and evaluate; may crack slabs; grout may travel well beyond the desired treatment area.

5. STABILIZE OR RAISE FOUNDATION WITH COMPACTION GROUTING.

Compaction grouting involves the pressure injection of a very low slump grout through a buried pipe to displace and compact soils. Major uses include: densifying loose and poorly compacted soils; filling voids including large sink holes; preventing liquification of soils due to seismic activity by densifying the soil beyond the liquification threshold; re-leveling settled structures; using compaction grout bulbs as structural elements for mini-piles or underpinning. The key to the system's success is that the pumped grout remains local to the area around the buried pipe and does not migrate, as less controlled forms of pressure grouting do.
ADVANTAGES: Relatively controllable; wide variety of applications. Remains in a mass and can displace poor soils. Can be used to raise foundations and slabs. Cost-effective primarily for large projects such as townhouses and multi-family buildings.
DISADVANTAGES: Too expensive for some single-family house foundation repairs. Requires access by heavy machinery. Not recommended in saturated clay soils or in soils containing high amounts of organic material.

6. STABILIZE, WATERPROOF, OR RAISE FOUNDATION OR SLAB WITH VARIOUS HIGHLY SPECIALIZED GROUTING TECHNIQUES.

A variety of other specialized grouting techniques exist to stabilize foundations in larger buildings, such as multi-family housing. Commonly used by foundation repair specialists around the country, these techniques include *jet grouting*: high pressure liquid grouting to form a soil cement called soilcrete used for sophisticated underpinning work; *chemical grouting*: injecting sodium silicate into sandy soils to stabilize them and make akin to sandstone; *urethane grouting*: to waterproof under slabs and difficult-to-access spaces; *vibro-compaction*: uses probe-type vibration to densify granular soils; *injection systems*: for expansive soils, injecting potassium, lime, and water to limit movement.

ADVANTAGES: Sophisticated, site-specific techniques that can solve difficult problems.

DISADVANTAGES: Expensive and not normally used in residential rehab.

7. UNDERPIN MASONRY OR CONCRETE STEM WALL WITH ENLARGED FOOTING.

If the settlement of a foundation wall is localized, it may be possible to underpin the foundation directly by increasing the footing size in order to distribute the wall loads over a greater area. This process involves jacking a portion of the house to take the load off the foundation wall, excavating a portion of the footing (in alternating 3- to 6-foot sections, for example), adding steel reinforcement, and filling the footing excavation with concrete). After the concrete has cured sufficiently (usually 7 days) the intermediate sections can be excavated and the process repeated. Alternatively, if the wall is seriously deteriorated, a new wall and footing can be erected alongside the existing wall.

ADVANTAGES: Relatively inexpensive, expedient local repair if affected area of the foundation is restricted to a relatively small perimeter.

DISADVANTAGES: Work should be designed by an engineer so that the new footing is sized and reinforced for the existing soil conditions. A dangerous procedure that should be undertaken by experts. May not work in silty or expansive soils as the new footing mass may continue to settle. Not cost effective over long wall lengths.

8. BUTTRESS STONE FOUNDATION WALLS.

Freeze/thaw action, expansive soil, migrating water, and hydrostatic pressure can all raise havoc with stone foundation walls, particularly those laid without mortar. In some cases walls may be repointed or stabilized from either inside or outside. In other cases, the pointing may not be cost effective and may not be easily waterproofed due to irregular surfaces. A repair that can both stabilize and waterproof stone walls is shown in Fig. 4. In this case, a new concrete surfacing is poured into the cavity between plywood forms and the

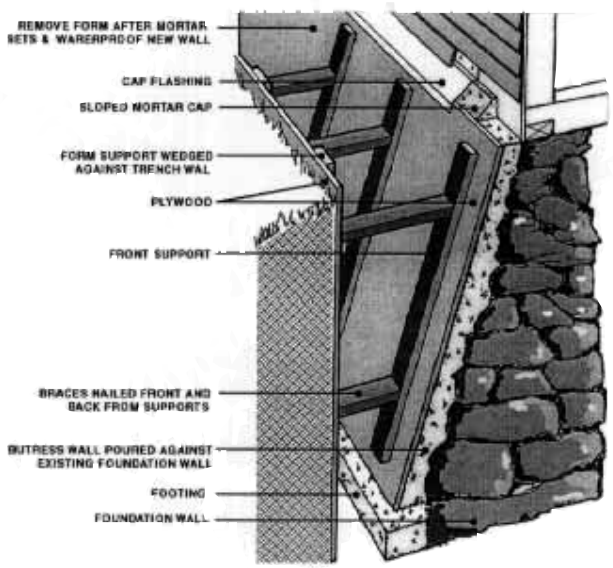


FIGURE 4. BUTTRESSING STONE FOUNDATION WALL

existing wall face, consolidating the wall and providing a smooth surface on which to apply waterproofing.
ADVANTAGES: Allows the existing wall to remain; reinforces and waterproofs the wall.
DISADVANTAGES: Requires excavation and formwork; can be expensive.

9. REPLACE THE FOUNDATION.

Extensive settlement; unsightly, cracked, or displaced foundation walls; rotting sill plates; or the need to gain additional height in a basement may necessitate the replacement of all or part of the foundation. When only one foundation wall is to be replaced, platform framing offers several options. If the first floor framing is perpendicular to the wall, it may be possible to place a supporting girder just inside the exterior wall, parallel to it (Fig. 5). In structures where the joists run parallel to the exterior wall, needle beams can be placed perpendicular and under the wall to support it while the foundation is replaced (Fig. 6). If the entire house is being raised, a system of carrying beams, cribbing, and jacks should be designed to support the critical load-carrying members of the house. An alternative to using cribbing and jacks is to install helical piers to provide the footing for a column support to temporarily underpin portions of the structure. Professional guidance should be sought.
ADVANTAGES: Provides the opportunity to build new, dry living/storage space while fixing a number of basic problems.
DISADVANTAGES: Can be expensive. Requires changes to all plumbing and electrical service connections; requires skills beyond those of most house-building contractors.

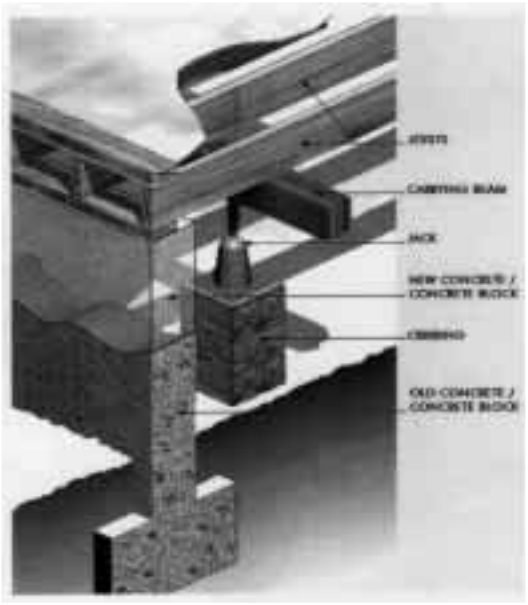


FIGURE 5. JACKING A WALL WITH PERPENDICULAR JOISTS

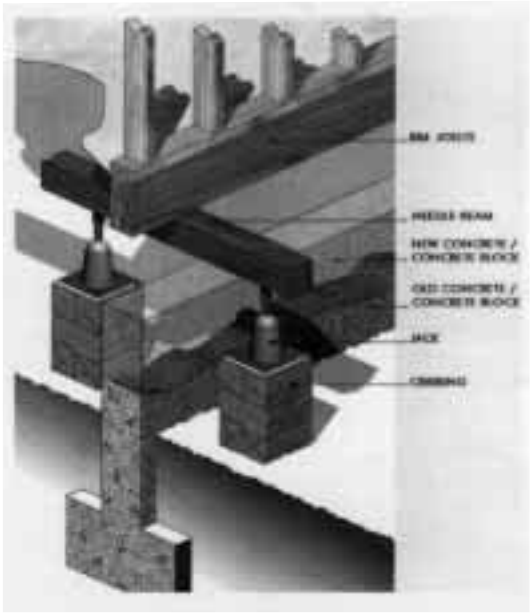


FIGURE 6. JACKING A WALL WITH PARALLEL JOISTS

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Renovation: A Complete Guide, Michael W. Litchfield, Prentice-Hall, 1991.

So Your House is Built on Expansive Soil, edited by Warren K. Wray, American Society of Civil Engineering Press, 1995.

The Day the House Fell, Richard C. Handy, Ph.D., American Society of Civil Engineering Press, 1995.

PRODUCT INFORMATION

A.B. Chance Company, 210 North Allen Street, Centralia, MO 65240; 573–682–8414.
Atlas Systems, Inc., 3114 Weatherford Road, Independence, MO 64055; 800–325–9375; www.atlassys.com
Heywood Baker Geotechnical Engineers and Drilling Contractors, 1875 Mayfield Road, Odenton, MD 21113; 410–551–8200.
Perma-Jack of Kansas, 201 South Haverhill, El Dorado, KS 67042; 800–736–9255.

9 CRACK REPAIR, COATINGS & FINISHES

9.1 CRACKS IN WALLS AND SLABS

ESSENTIAL KNOWLEDGE

Basement wall and floor cracks can be caused by a variety of factors, including drying shrinkage, thermal contraction, restraint (internal or external) to shortening, subgrade settlement, and applied loads, including those due to expansive soils, hydrostatic pressure from high water tables, and in some parts of the country, seismic activity. Factors that can contribute to cracking problems include inadequate reinforcement in concrete, concrete block, and stone walls, incorrect/lack of construction and control joints, and improperly mixed or placed mortar or concrete. Stationary hairline cracks (those 1/16 inch and less in width) are usually nonstructural and are primarily cosmetic concerns unless they are associated with moisture problems. Cracks 1/8 inch in width and greater may also be nonstructural, but may reflect significant wall settlement or displacement. Repair should not be undertaken until the principal cause of the cracking has been determined (see Chapter 8: Shoring, Underpinning, and Repair).

TECHNIQUES, MATERIALS, TOOLS

1. REPAIR CRACKED AND OUTWARDLY DISPLACED FOUNDATION WALL BY EXTERIOR JACKING.

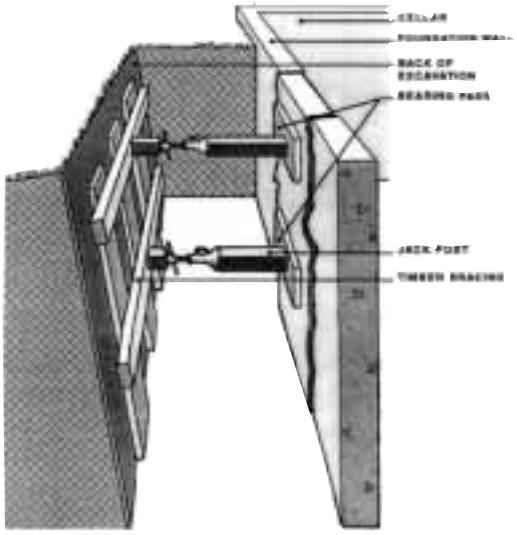
If a section of a foundation wall has been outwardly displaced beyond the plane of the adjacent walls, it may be possible, rather than rebuilding that section, to move it back into place. This can be accomplished by excavating in front of and to the side of the affected section and jacking the displaced wall by means of hydraulic ram jacks (Fig 1). Care must be taken to provide a jacking pad of sufficient area so that the jack doesn't punch through the wall. It is also important to shore up the excavation against which the wall is jacked, and to provide drainage from the excavation in the event of rain.

ADVANTAGES: Less expensive than completely replacing portions of the wall. Allows visual inspection of wall conditions and provides an opportunity to waterproof the wall and inspect drainage.

DISADVANTAGES: Wall condition may not permit jacking. The wall may not be aligned when jacking is complete. Cracks will require patching, grouting, and waterproofing. This technique will disturb grounds and plantings adjacent the affected wall portion.

2. STABILIZE CRACKED AND INWARDLY BOWED FOUNDATION WALL BY USE OF "EARTH ANCHOR" AND WALL PLATE.

If an upper section of the foundation wall has been inwardly displaced, usually at the midpoint of the wall, it may be possible to stabilize or straighten the wall with an "earth anchor" (Fig. 2). Typically installed in an exterior trench approximately 6 feet on center horizontally and below the average frost depth. The "Grip-



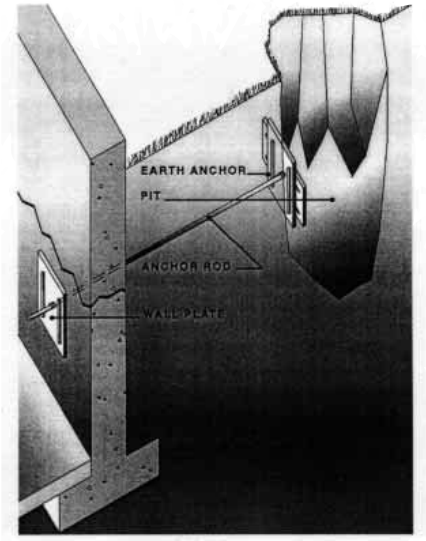


FIGURE 1, 2. JACKING CRACKED FOUNDATION WALL EARTH ANCHOR

Tite" wall anchor system utilizes an anchor rod that is pushed through the soil by means of a hammer drill/rotary hammer from a reinforced wall plate through a 1 1/8 inch hole in the foundation wall to an earth anchor plate set at a distance of 7 to 8 feet from the face of the exterior wall. The anchor rod has a nut and washer that is tightened with a torque wrench against the wall plate, usually during dry seasons. The wall can be brought back to a more vertical position in a process that takes, according to the manufacturer, one to three years. An offset trencher or narrow bucket backhoe are occasionally used to excavate 12 inch-wide trenches alongside the wall to relieve soil pressure and to allow for faster vertical realignment.

ADVANTAGES: Stabilizes and straightens walls without the need for a complete excavation along the length of the exterior wall. Can, in some instances, reduce the size of wall cracks and bring the wall to a more vertical position. Less expensive than wall replacement or side wall excavations. Can prevent further wall displacement.

DISADVANTAGES: Not capable of bringing wall back to a fully vertical position, something which could only be accomplished if the soil on the outside of the wall was removed. Requires exterior excavation for the wall plate. Wall anchor plates are exposed on the inside wall surface.

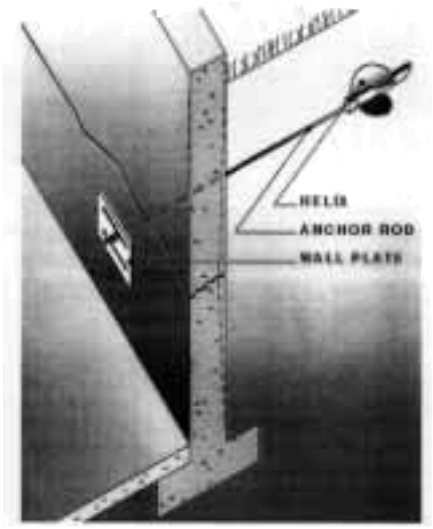


FIGURE 3. HELICAL WALL ANCHOR

3. STABILIZE CRACKED AND INWARDLY BOWED FOUNDATION WALL BY USE OF HELICAL SCREW ANCHOR.

An alternative technique to the "earth anchor" includes the use of a helical screw anchor. Installed at intervals along a wall depending on the job site conditions, helical screw anchors are similar in concept to earth anchors described above, except that the helical plate is a part of the anchor rod itself, and is screwed into the soil bank rather than placed in a pit (Fig. 3). Once the rod develops the appropriate resistance, a plate is placed on the inside of the wall and a nut tightened with a torque wrench to secure and possibly straighten the wall. The two largest manufacturers of helical systems are A.B. Chance Co. and Atlas Systems, Inc. Their anchors are installed by certified dealers throughout the U.S.

ADVANTAGES: Stabilizes and may straighten walls without the need for continuous excavations. May reduce the size of wall cracks by bringing walls to a more vertical position. Less expensive and disruptive than wall replacement or continuous excavation.

DISADVANTAGES: May not straighten walls significantly; interior anchor plate is exposed.

4. REPAIR WALL CRACKS WITH CONVENTIONAL GROUTING TECHNIQUES.

If cracks are not expanding in size and water penetration is not an issue, conventional grout repairs may be possible. The limitations of grouting systems are inherent in their material consistency as fairly stiff; dry mixes typically used for repair work cannot easily flow into cracks, especially thin ones. Most cracks must be chipped open on the surface for the patch to be effective. Even in this case, however, the patch depth is only 1 to 2 inches, and is more cosmetic than structural in nature. A number of grouting materials are available through a wide variety of suppliers, including conventional portland cement and sand, with or without acrylic admixtures to enhance the bond to existing material, various proprietary low slump "dry pack" mixtures, and fast-acting hydraulic cements that set up fast and can be used to plug holes and wide cracks where water seepage is a problem. In addition, fiber-reinforced cements, called surface-bonding cements, are designed to strengthen block walls and can even be used on both surfaces to form a structural skin on walls laid "dry" without mortar.

ADVANTAGES: Inexpensive repairs that do not require a high degree of skill to complete.

DISADVANTAGES: Essentially surface repairs, non-structural; except for hydraulic cements, will not usually prevent water penetration. Will not work where there is crack movement.

5. REPAIR CRACKED WALL WITH EPOXY INJECTIONS.

Epoxy injections can be used to restore structural soundness when foundations have been stabilized and

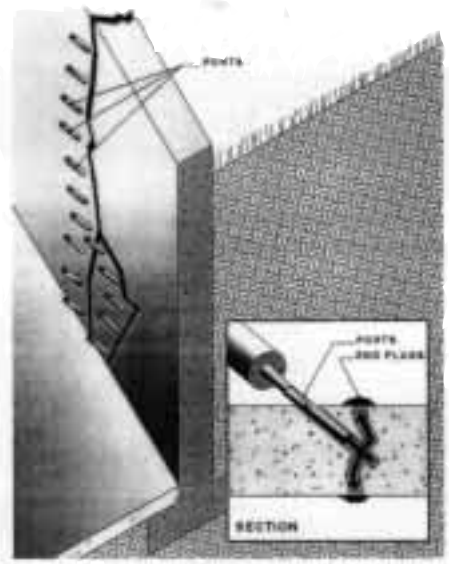


FIGURE 4. EPOXY OR URETHANE GROUTING

when cracks are not growing in size. Cracks as narrow as 0.002 inch can be bonded by the injection method. The typical technique involves drilling holes at close intervals along the crack and installing tubes (ports) in the holes into which epoxy is injected under pressure (Fig. 4).
ADVANTAGES: A proven and widely used technique. Can create a structural bond that is stronger than the concrete itself. Epoxy grout materials are available from a wide variety of manufacturers.
DISADVANTAGES: Will not prevent wall from cracking adjacent to the repair if further movement occurs. Cannot be used if cracks are leaking water. While moist cracks can be injected, water or contaminants in the crack will reduce the effectiveness of the repair. Works best with concrete rather than concrete block walls, because the cores in the block reduce the contact area. Expensive. Requires skilled applicators.

6. REPAIR CRACKED WALL WITH URETHANE INJECTIONS.

Urethane grouts are used to stop water infiltration and to fill cracks in foundation walls when there is substantial seepage through the wall. Urethane grouts are also flexible, which makes them suitable for repairing cracks with limited movement (up to 1/8 inch with some grouts). Urethane grouts are not structural (as epoxy grouts are) but will serve to help bond materials together. Grouts are either hydrophillic (which chemically react with water and can dehydrate in the absence of water) or hydrophobic (which do not dehydrate). Both grouts expand to create a dense, closed-cell foam through which water will not pass. Specific applications should be reviewed with the manufacturers, some of which include the 3M Co., Green Mountain International, Prime Resins, and the DeNeef Co. The application of urethane grout is similar to that of epoxy, pumped through a series of injection ports that are drilled to intercept the crack. Urethane sealant manufacturers also have developed fast-acting formulations that are applied directly to holes in concrete to stop leaks.
ADVANTAGES: State-of-the-art products used in critical situations where water and crack movement conditions exist. Developed for commercial projects such as municipal water and sewer lines, tunnels, and other large-scale projects.
DISADVANTAGES: More expensive than other kinds of products. Nonstructural. Requires skilled applicators and careful attention to installation instructions. Not recommended for concrete block walls, as expansion of urethane may crack block.

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PRODUCT INFORMATION

W.R. Bonsal 8201 Arrowridge Boulevard, Charlotte, NC 28224–1148; 800–334–0784
3M Construction Markets Division, 3M Center Building, 225–45–08, St. Paul, MN 55144–1000; 800–480–1704
A.B. Chance Company, 210 North Allen Street, Centralia, MO 65240; 573–682–8414
Atlas Systems, Inc., 3114 Weatherford Road, Independence, MO 64055; 800–325–9375; www.atlassys.com
Abatron, Inc., 5501 95th Avenue, Kenosha, WI, 53144; 800–445–1754
DeNeef Construction Materials, P.O. Box 1219, Waller, TX 77484; 409–372–9185

Green Mountain Inc., P.O. Box 97, Waynesville, NC 28786; 800–942–5151
GRIP-TITE Manufacturing Co., Inc., P.O. Box 111, Winterset, IA 50273–0111; 515–462–1313
Prime Resins, 2381 Rockaway Industrial Boulevard, Conyers, GA 30207; 800–321–7212

9.2 COATINGS AND FINISHES

ESSENTIAL KNOWLEDGE

Surface treatments for concrete and concrete block walls repel water, which helps to control exterior surface staining as well as the migration of water through the wall, which can lead to efflorescence, staining, mold, and other problems on interior surfaces. In general, exterior surface treatments should allow for vapor transmission to ensure that humidity within the wall can escape. Treatments that are impermeable to water vapor tend to fail by blistering and peeling when moisture builds up behind the exterior surfaces. (Special water retarding coatings are discussed in Chapter 5: Dampproofing and Waterproofing.)

Typical interior coatings include a wide variety of latex paints that use polyvinyl acetate as a binder. These paints are not subject to weathering and are less expensive than exterior vinyl acrylic paints. Most exterior coatings can be used on interior applications. As is the case with all paints, manufacturers' recommendations as to surface preparations and applications should be followed carefully. Manufacturers estimate that up to 80 percent of paint failures are due to improper surface preparation and application.

Clear treatments, which can be used to enhance the water resistance of walls without siginificantly altering their appearance, are made with either silicone, silicate or acrylic resins. Epoxy paints are used in some interior wall and floor commercial applications, such as in schools and hospitals, where corrosive chemicals are present or high traffic is anticipated, but are not normally used in residential applications.

TECHNIQUES, MATERIALS, TOOLS

1. APPLY CEMENTITIOUS COATINGS.

Cementitious coatings include conventional parging and stucco coatings, and specially formulated cement-based products that include latex binders and other additives that enhance performance. Included in this category are surface bonding cements meeting ASTM C887 requirements that contain glass fiber reinforcements that can strengthen walls.

ADVANTAGES: Can change color and texture of existing wall; can enhance water resistance; fiber reinforcements enhance strength.

DISADVANTAGES: Subject to cracking and delamination due to weathering and expansion and contraction of walls.

2. APPLY ELASTOMERIC COATINGS.

A number of manufacturers produce elastomeric polymer coatings that are formulated to bridge static cracks up to 1/16 inch. These products are often used as the final coating on exterior insulation and finish systems (EIFS) and can be applied directly on concrete and concrete block walls. These coatings are also used in conjunction with other brush- or trowel-applied elastomeric underlayment products that fill cracks up to 1/4 inch.

ADVANTAGES: Can change color and texture of existing wall; can cover and protect exterior surfaces subject to deterioration from expansion and contraction.

DISADVANTAGES: Significantly more expensive than other coatings.

3. APPLY PAINT COATINGS.

The currently preferred exterior paints are latex, breathable, water-based paints. Latex paints typically come with acrylic or polyvinyl acetate binders. Paints with all-acrylic binders are recommended for exterior use

as they have the greatest durability and flexibility. Most paint manufacturers offer a variety of crack fillers that can be applied before the finish paint to smooth out surface irregularities in walls. Alkyd paints use chemical compounds made from vegetable oil and synthetic resins as binders and are more difficult to apply and clean up than water-based latex paints. They are also adversely affected by alkaline surfaces, especially new concrete and concrete block construction. Recently developed acrylic paints have a number of superior characteristic to alkyd paints, including easier workability, better breathability, flexibility, color retention, resistance to chalking, and better resistance to mildew.

ADVANTAGES: Can alter color and surface texture with use of aggregate additives; can increase water resistance of wall; relatively economical.

DISADVANTAGES: Will not bridge active cracks; requires on-going maintenance and renewal.

FURTHER READING

Painting Concrete, 15134, Portland Cement Association, 1992.

"Preventing Masonry Failures With Proper Coating Choices," Tom Smead, *Construction Specifier*, July 1996, pp. 48–53.

"Specifying Quality Architectural Paints," Walter J. Gozdan, *Construction Specifier*, July 1996, pp. 44– 47.

Water Repellents for Concrete Masonry Walls, TEK 19-1, National Concrete Masonry Association, 1995.

PRODUCT INFORMATION

W.R. Bonsal Company, 8201 Arrowridge Boulevard, P.O. Box 241148, Charlotte, NC 28224–1148, 800–334–0784.

Sherwin-Williams Company, 101 Prospect Avenue N.W., Cleveland, OH 44101; 800–321–8194.

APPENDIX

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