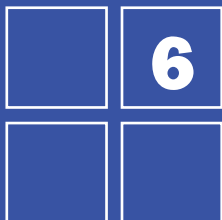


DESIGN OF WOOD FRAME STRUCTURES FOR PERMANENCE



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The American Wood Council (AWC) is the wood products division of the American Forest & Paper Association (AF&PA). AF&PA is the national trade association of the forest, paper and wood products industry, representing member companies engaged in growing, harvesting and processing wood and wood fiber, manufacturing pulp, paper and paperboard products from both virgin and recycled fiber, and producing engineered and traditional wood products. For more information see www.afandpa.org.

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DETAILS FOR CONVENTIONAL WOOD FRAME CONSTRUCTION

INTRODUCTION

Design of durable structures is the result of careful planning and understanding of loads and forces that will likely act upon a building during its lifetime. If these key elements are not taken into consideration, the designer may compromise the ability of the structure to remain fully functional over extended periods of time.

Building codes establish minimum requirements for structural strength, safety from fire, and other hazards. To this end, the American Forest & Paper Association (AF&PA) provides several design standards and construction guides. AF&PA's *National Design Specification® (NDS®) for Wood Construction*, and the related *Wood Frame Construction Manual for One- and Two-Family Dwellings*, provide standards and guidelines for structural design and construction of wood-frame buildings. Likewise, AF&PA's *Design for Code Acceptance (DCA)* series provides building code accepted methods for complying with fire safety provisions of the codes. Yet, building codes do not address all of the issues that promote long-term durability of buildings and structures. This document describes practices to control moisture and protect a building from infestations of living organisms, which can influence the long-term durability of buildings, as can structural loads and fire exposures.

Design of durable structures begins with an understanding of moisture loading and how it interacts with building materials. The designer must be concerned with sources of water, how it is transported, and how it can be controlled and removed. Moisture flows within a building must be managed to prevent water accumulation or storage that may lead to premature deterioration of building products. Quality control is also extremely important in constructing building envelope assemblies to resist the negative effects of moisture.

In many areas, there may also be a risk of insect infestation. In particular, termites may attack wood frame structures and, in turn, reduce the life expectancy of the building.

When properly designed, wood frame structures will resist damage by moisture and living organisms. Recommendations for control of moisture and protection against decay and insect infestations are contained in this document. Many of the recommendations are established practice among architects, engineers, and builders.

PRINCIPLES OF GOOD DESIGN

Protection of wood frame structures to provide maximum service-life involves four methods of control, which can be handled by proper design and construction:

(1) control moisture content of wood, (2) provide effective termite controls, (3) use of durable materials such as naturally durable or pressure treated wood, and (4) quality assurance.

Wood construction maintained at a moisture content of 20 percent or less will not decay. Optimum conditions for decay occur when moisture content is above 25 percent. It should be stressed that when wood is protected from water or from vapor condensation, and exposed to normal atmospheric conditions such as exist inside buildings and outdoors, its moisture content rarely exceeds *15 percent*. Therefore, moisture content control by means of accepted design and construction details is a simple and practical method of providing protection against decay.

Moisture control also contributes to prevention of subterranean termite attack. One of the primary control methods for termites is elimination of sources of water for termites to ingest. Other methods include the use of effective barriers and bait systems supplemented by periodic inspection. Termite barriers are provided by use of accepted construction practices that drive termites into the open where shelter tubes can be detected by inspection and destroyed.

Wood frame structures that properly manage moisture and are provided with a recognized termite control system supplemented by periodic inspections will resist subterranean termite attack and last for many years.

In some cases architectural considerations or use exposures (swimming pools, marine structures, wet process industries, ground contact, or unusual climatic conditions) may complicate moisture control and termite protection and necessitate greater protection. In certain geographical regions, for example, high incidences of precipitation or termite infestation may indicate the need for greater protection. Under these circumstances naturally durable wood of certain species may be used or wood pressure treated with chemicals to prevent decay and termite damage may be required.

THE ROLE OF BUILDING CODES

Building practices described in this document reflect a building science approach to mitigating moisture, pest, and durability problems in new and existing wood construction. State and local codes and ordinances may differ in their approaches to the same issues. In such cases, the local code official having jurisdiction should be consulted and shall have the final authority in determining local requirements.

MOISTURE CONTROL

Sources of Moisture

Sources of moisture include water from rain, snow, high humidity, soils, and water vapor from interior and exterior environments.

The degree to which moisture will load a structure is dependent on a variety of factors including:

- Climatic conditions;
- Site-specific factors, such as location, solar exposure, wind exposure, and relationship to surrounding buildings, vegetation, and terrain;
- Building design features, such as overhangs, cornices, site drainage, and crawl space ground cover.

For design purposes, the probability of external environmental loads can be analyzed according to two climatic zones: rain exposure zones (**Figure 1**), and hygro-thermal zones (**Figure 2**). Microclimate and building design factors also influence the actual exposure level. These additional factors must be accounted for in the design process. To account for moisture loads an understanding of how moisture may be transported into a structure is needed.

Moisture loading will migrate into and through building assemblies through several transport mechanisms including:

- Liquid Flow/Capillarity – Liquid flow is the movement of liquid water under the influence of a driving force, such as gravity, or suction caused by capillary action.
- Air movement – Air movement refers to the transport of water vapor through air leakage in and out of wall, ceiling, and roof envelope cavities.
- Diffusion – Diffusion is the direct movement of water vapor through ceiling and wall surfaces, driven by vapor pressure differentials.

Of these three transport mechanisms, liquid flow generally produces the most significant moisture loads. Thus, it is not surprising that rain penetration and groundwater control has been the primary focus of builders and designers for generations. Air movement and vapor diffusion are also important, though less significant and less obvious contributors to development of moisture problems in buildings.

Principles of Water Management

The primary objective when addressing moisture loads is to keep the building envelope dry by reducing the amount of water transported inside the building envelope and to achieve a balance of the moisture content within the building. To limit the amount of water intrusion and obtain a balance of moisture content, general principles of water management including deflection, distance (separation), drainage, and drying (**Figure 3**) should be followed.

Figure 1 Rain Exposure Zones

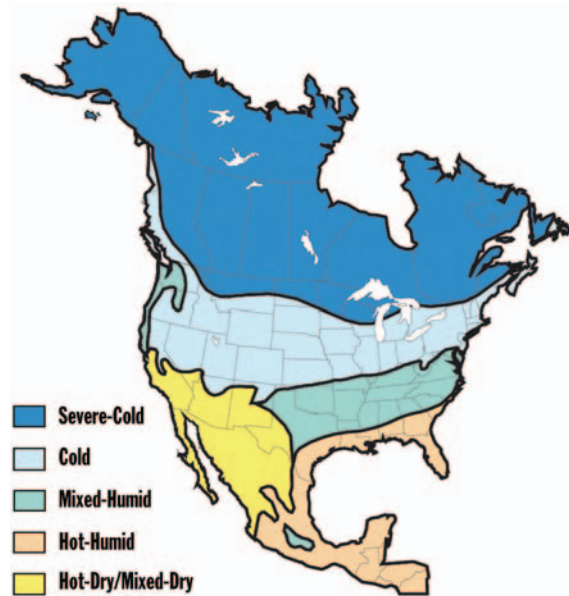
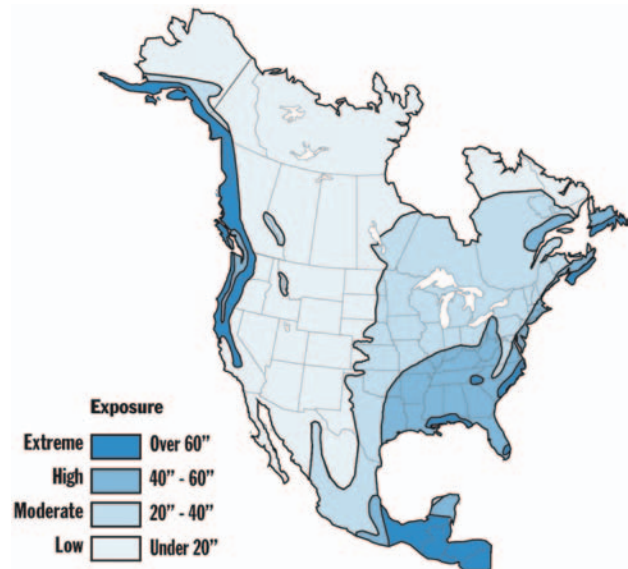


Figure 2 Hygro-Thermal Zones



Following the general principles of water management require that wetting and drying mechanisms be established and maintained to balance moisture content levels at or below the tolerance of building materials being used. Where the tolerance of building materials to moisture is likely to be exceeded, durable materials such as preservative treated wood should be utilized.

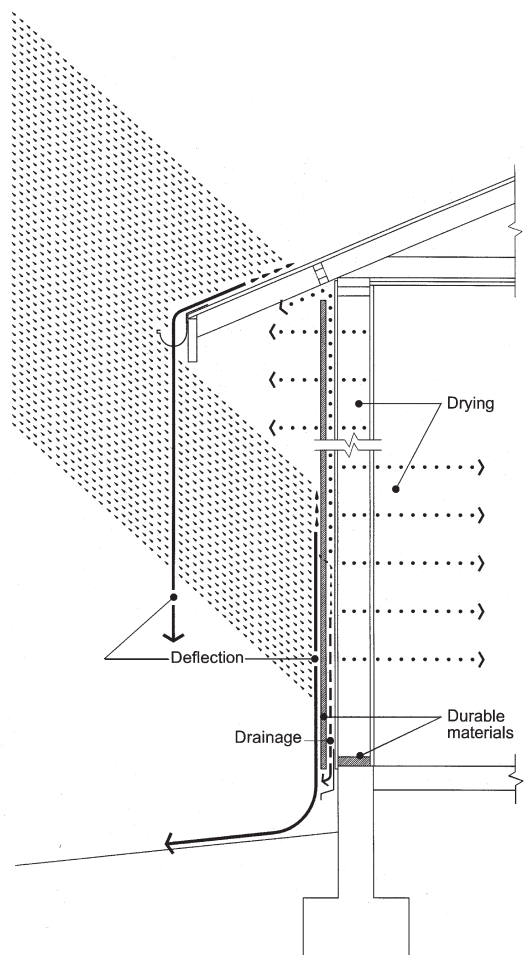
Deflection

Deflection is the first principal and main priority of water management. The intent is to keep rainwater away

from the building and to minimize the potential for water penetration into the envelope. The deflection principle is evident in many building design patterns that have historically proven effective at reducing the amount of rainwater on exterior walls. These include:

- Placing the building so it is sheltered from prevailing winds.
- Providing sizable roof overhangs and water collection systems at the roof perimeters.
- Providing architectural detailing including flashing and caulking that directs rainwater away from the building.
- Providing an approved[†] drainage system around the foundation perimeter to accept roof water runoff.
- Installing permeable bulk vapor diffusion retarders on the exterior of walls and floors, including below a concrete slab or atop the bare soil within a crawl space.
- Providing adequate separation of elements from moisture sources including soil and concrete.

Figure 3 Water Management Principles



Used with permission of the Canadian Wood Council.

Sheltering

Structures exposed to wind are more susceptible to moisture loads. To reduce wind and moisture loads, structures should be located near other structures or be sheltered with natural barriers such as trees or large shrubbery.

Overhangs

A pitched roof with sufficiently wide overhangs can help ensure long-term durability of wood-frame buildings by deflecting precipitation. Detailing of projecting sills, flashings, and drip edges is also a critical component. Cladding and sealants are also part of the deflection line-of-defense.

Flashing

To prevent moisture from entering joints between building elements, flashing is needed at the following places:

- Heads of all openings in exterior walls unless protected by overhanging eaves (**Figure 4**).
- Under window openings where masonry veneer is used (**Figure 5**).
- Where changes in exterior finish materials occur (**Figure 6**).
- At the junction of roof deck and wood siding, at roof valleys, and around chimneys and vent stacks (**Figure 7**).

Vapor Diffusion Retarder

Vapor diffusion retarders should be provided to deflect moisture away from the structure. For walls, this is called a “housewrap” or “building-wrap” and is attached to sheathing underneath the siding. These building wraps need to be breathable by allowing some transfer of water vapor. Without some vapor transfer, the water barrier can easily become a surface for condensation.

Vapor diffusion retarders should also be placed under an exterior floor. In crawl spaces a vapor diffusion retarder should be placed upon the ground within a crawl space to deflect ground moisture.

Where concrete/masonry foundations are used to support a wood-frame building, the natural inclination of moisture to move through the foundation wall must be restricted. Moisture movement through poured concrete foundation walls is controlled by externally applied, water repellant coatings and perimeter drains that reduce soil moisture. Coats of asphalt or tar should also be applied from footing to finish grade. Unit masonry walls require a 1/2-inch layer of portland-cement mortar applied from footing to finish grade, leaving a cove at the junction of the footing and wall. Mortar should then be mopped with asphalt or tar.

Moisture control for concrete slab-on-grade construction is also essential. A high quality vapor diffusion retarder with a 1-perm rating and complying with *ASTM*

[†] Approved, as used in this text, means approved by the authority having jurisdiction.

E 1745 needs to be installed immediately below the concrete slabs. At worst, these vapor diffusion retarders allow only minute amounts of water vapor to pass through into the slab. And, since many soils contain alkali and other chemicals that can cause many plastic products to fail, the vapor diffusion retarders must be capable of resisting chemical attack.

Figure 4 Flashing Over Openings in Exterior Walls

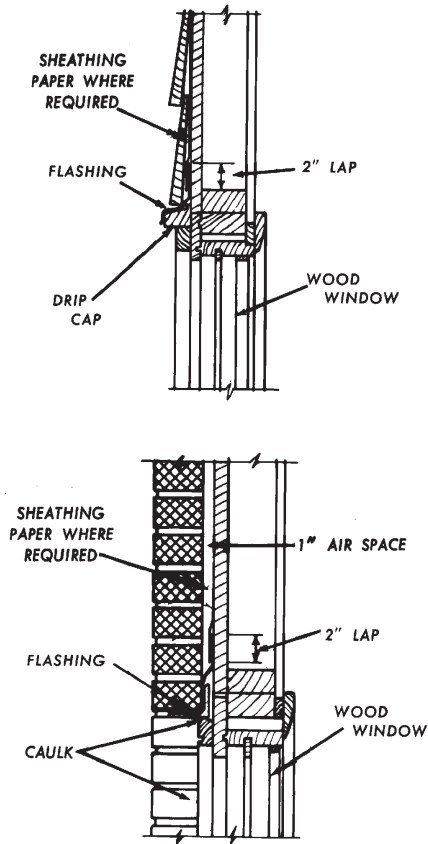


Figure 5 Flashing Under Window in Exterior Wall

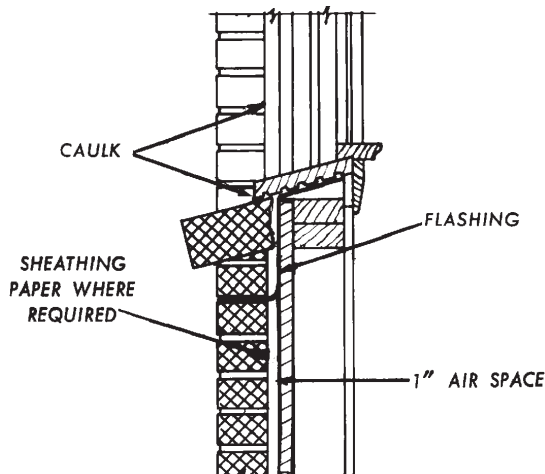


Figure 6 Flashing Where Changes in Exterior Finish Occur

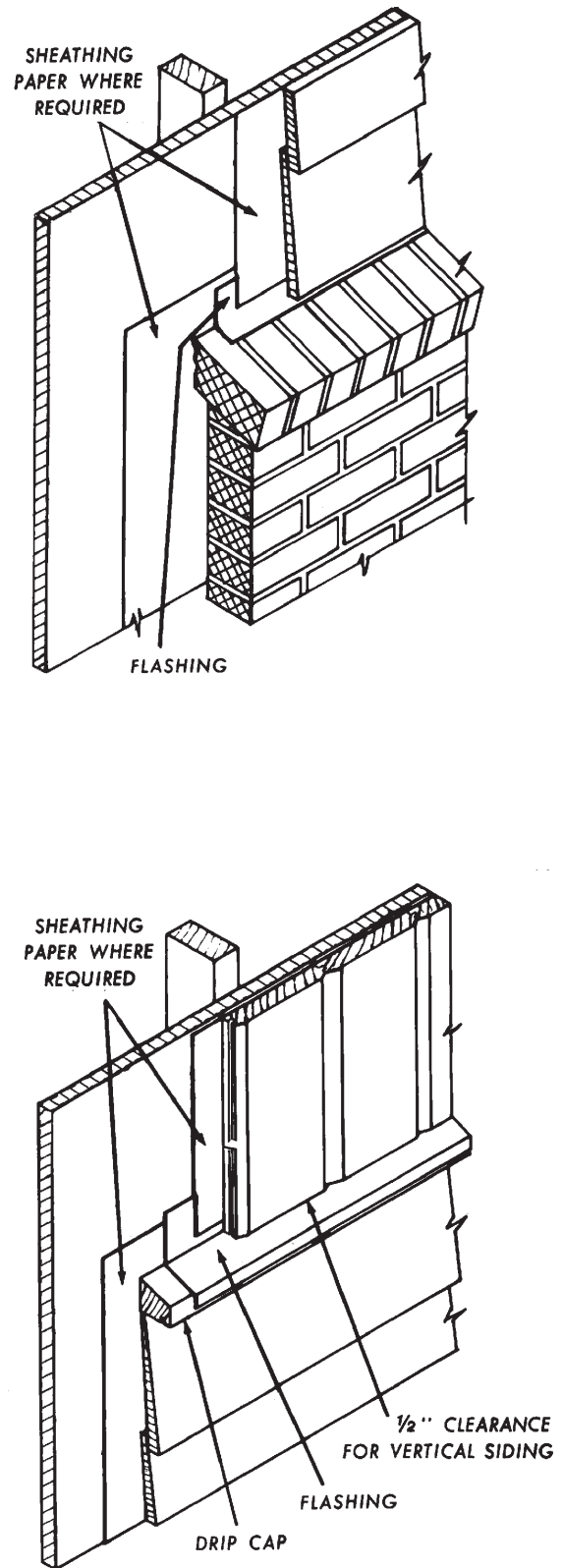


Figure 7 Flashing at Various Points on a Roof

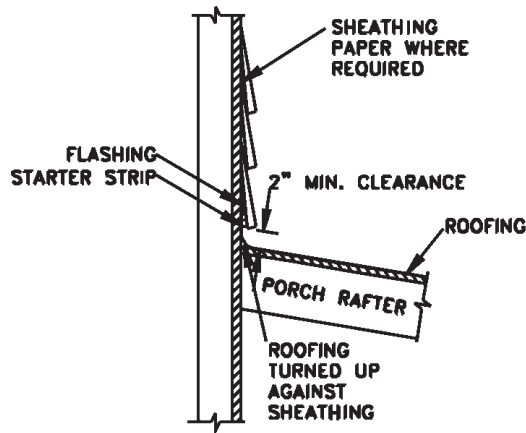
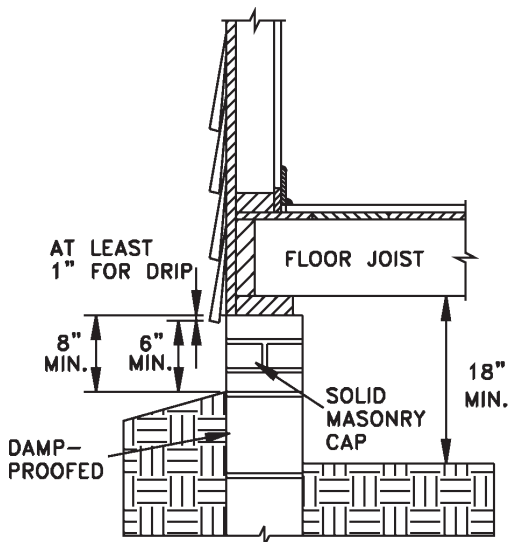


Figure 8 Clearance Between Wood Siding and Earth



Distance - Separation of Wood Elements

Separation of untreated wood from the ground and other sources of moisture and termite infestation is very important. The separations specified in this section are recommended for all buildings and are those considered necessary to *maintain wood elements in permanent structures at safe moisture contents for decay protection*. When it is not possible or practical to comply with the clearance specified, *the use of naturally durable or pressure treated wood is recommended*.

- *In crawl spaces* and other similar unexcavated areas, clearance between the bottom of wood joists, or a wood structural floor without joints, and the ground should be at least 18 inches. Between the bottom of wood girders and the ground, the clearance should be at least 12 inches. Clearance between a post or

column supporting a permanent structure intended for human occupancy and exposed to earth should be at least 8 inches (**Figure 8** & **Figure 9**).

- *When in basements, cellars, or when exposed to the weather, wood columns* which support permanent structures should be supported by a metal or concrete pedestal extending 1 inch above concrete slabs or decks and 6 inches above exposed earth and separated from soil by an impervious moisture barrier (**Figure 10**).
- *Wood joists, beams or girders* framing into exterior masonry or concrete walls should have at least 1/2 inch of air space at top, end, and sides (**Figure 11**).
- *Wood sills* which rest on concrete or masonry exterior walls should be at least 8 inches above exposed earth on the exterior of the building (**Figure 8**).

The bottom of wood joists, girders, and subfloors suspended from foundation walls should be at least 8 inches above the horizontal projection of the outside grade level and should terminate at the interior face of any foundation wall studs.

- *Wood siding and wood trim* should be at least 6 inches above exposed earth on the exterior of a structure (**Figure 8**).
- *Fences and similar items* should be separated from the main structure by at least 2 inches.
- *Exterior wood steps*. Structural portions of wood stairs, such as stringers and posts, should be at least 6 inches above the finished grade (**Figure 12**).
- *Porches, breezeways, and patios*. Beams and headers supporting floor framing should be at least 12 inches above ground. Floor joists or the bottom of a wood structural floor without joists should be at least 18 inches above ground. Posts which rest on wood, concrete, or masonry floors should be supported on metal or concrete pedestals extending at least 1 inch above the floor or at least 6 inches above exposed earth, and separated by an impervious barrier (**Figure 9** & **Figure 10**).
- *Concrete steps, concrete porch slabs, patio slabs or planters* resting on the ground should be below the top of the foundation, and separated from wood in the main structure by at least 2 inches, or otherwise protected from moisture or concealed termite penetration (**Figure 13** & **Figure 14**).
- *Shutters, window boxes, and other decorative attachments* should be separated from exterior siding to avoid trapping rainwater.
- *Moisture permeable floors or roofs* which are exposed to the weather, such as concrete or masonry slabs, should be separated from any wood structural members supporting them by an impervious moisture barrier.

Figure 9 Clearance Between Wood and Exposed Earth in Crawl Space or Other Unexcavated Concealed Areas

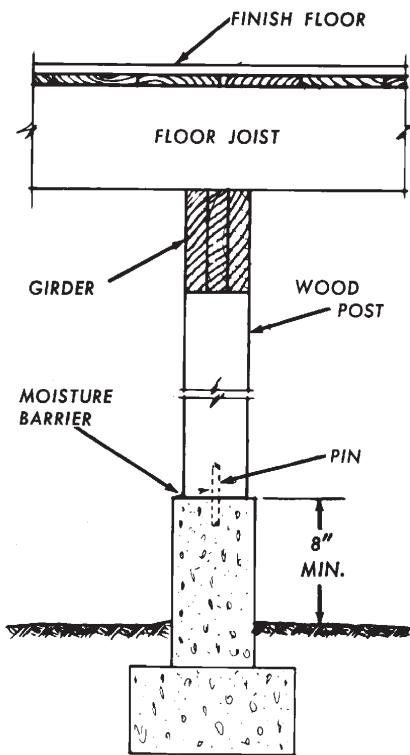
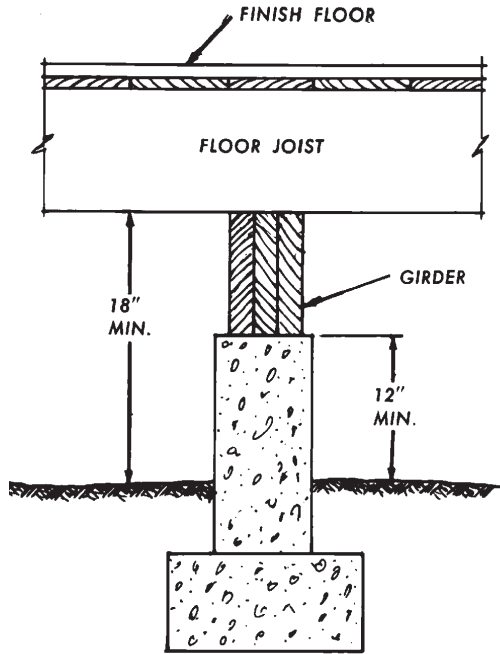


Figure 10 Clearance Between Wood Columns and Floor or Exposed Earth when in Basements or when Exposed to Weather

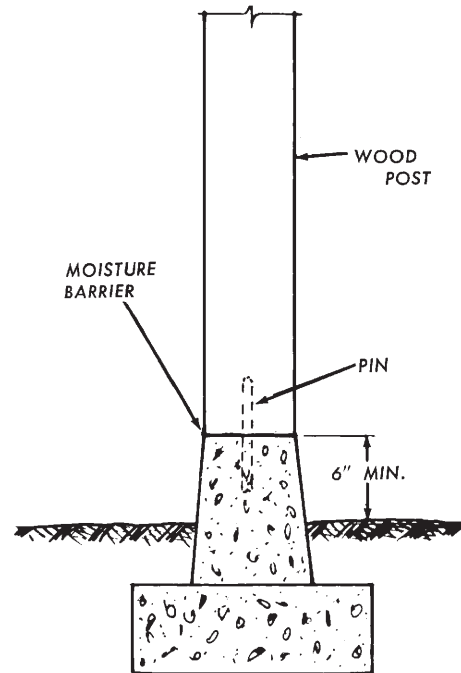
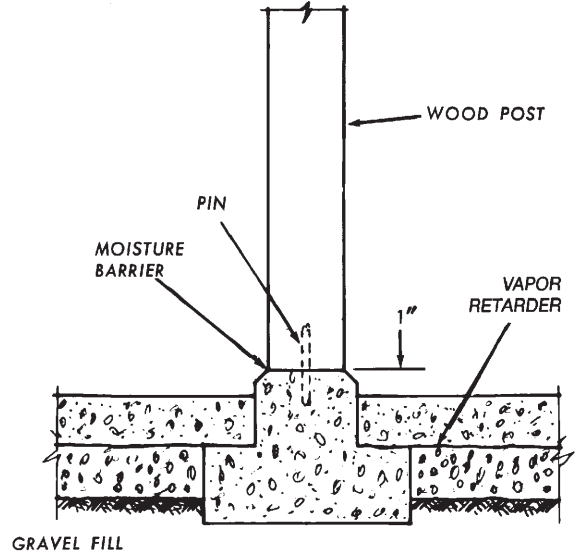


Figure 11 Wood Beams or Girder Framing into Masonry or Concrete Wall

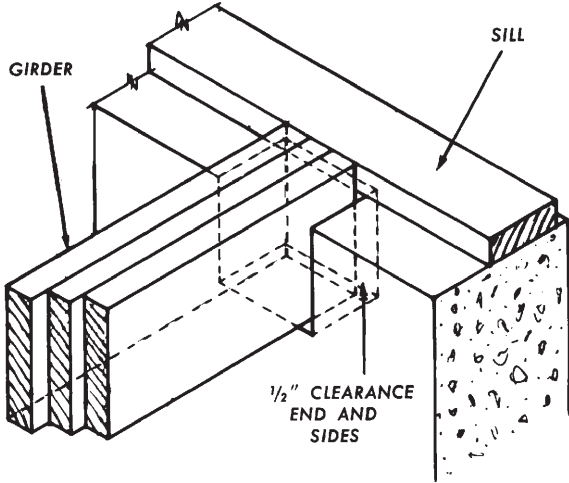


Figure 12 Exterior Wood Steps

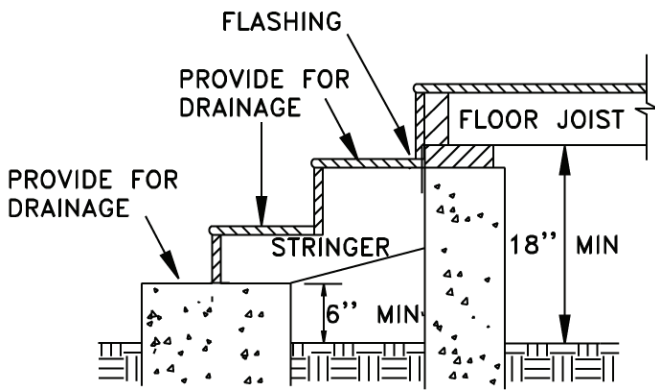


Figure 13 Exterior Concrete Steps

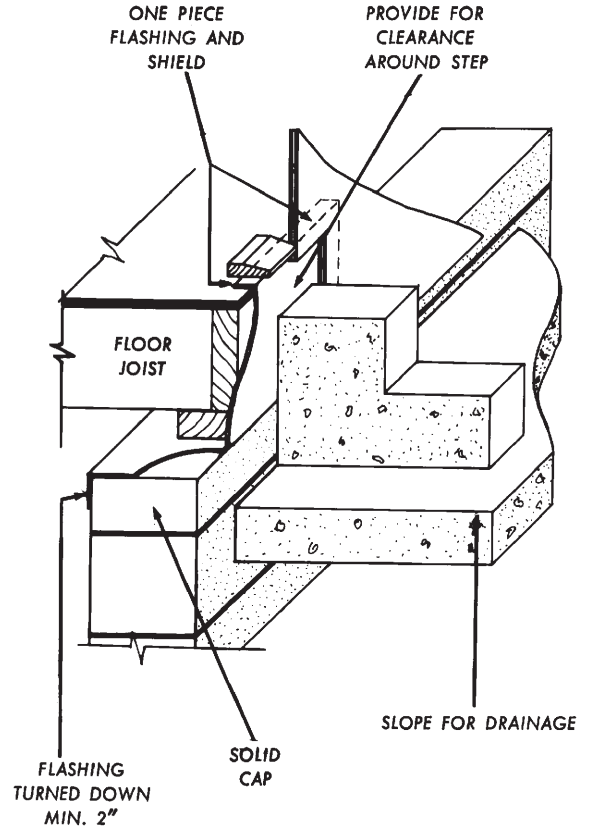


Figure 14 Concrete Porch or Patio Slab

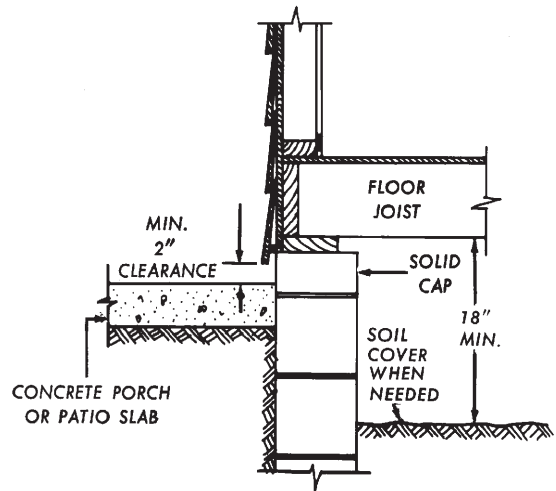
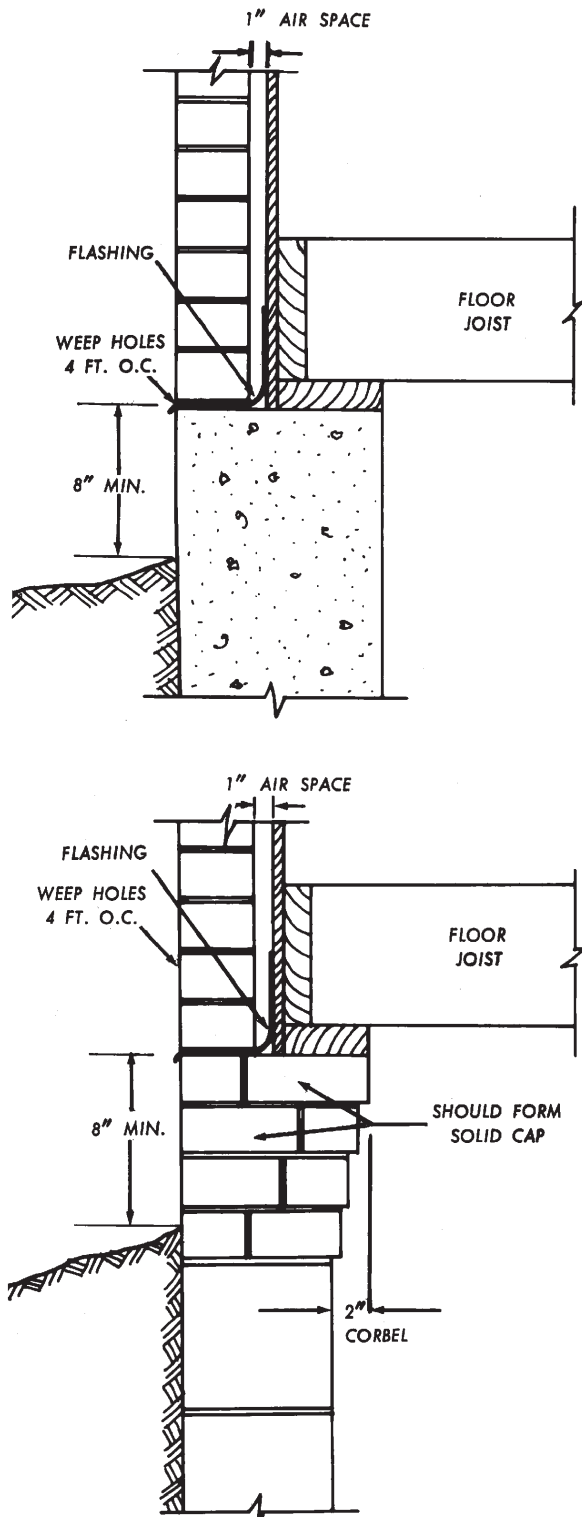


Figure 15 Masonry Veneer Finish Over Wood Framing



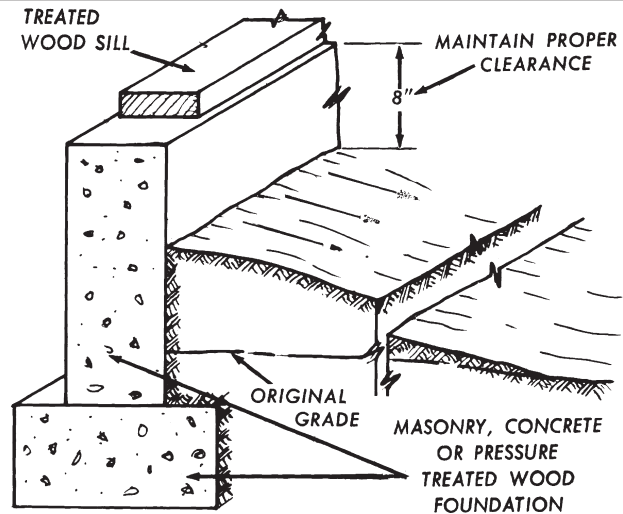
Drainage

Drainage is the next principle of moisture control, second only to deflection in terms of its capacity to manage rainwater. Building design patterns that incorporate drainage principles include pitched roofs, sloped surfaces at horizontal elements, and soil drains around the perimeter of building foundations.

Site Drainage and Sanitation

The building site should always be graded to provide positive drainage away from foundation walls. In determining the height of the foundation, it is important to take into consideration the proposed height of finish grade to assure proper clearance for wood members resting on top of the foundation (Figure 16).

Figure 16 Site Drainage Away from Structure



Building Drainage

All exposed wood surfaces, as well as adjoining areas, should be pitched to assure rapid water run-off. Construction details, which tend to trap moisture in end grain joints should be avoided.

At the detail level, drainage is accomplished by collecting incidental moisture accumulation in the wall assembly and returning it to or beyond the exterior face of the cladding by means of gravity flow. Water is then diverted away from the structure using soil and site drainage.

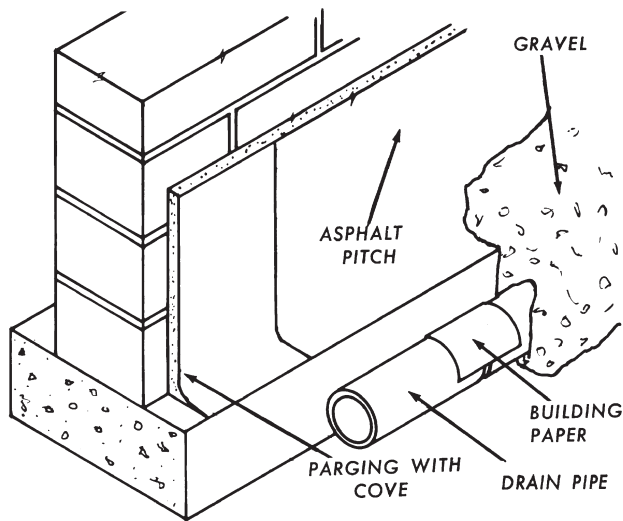
In its simplest form, building drainage is achieved by adding a drainage plane and cavity within the assembly, between the cladding and the sheathing. In wood frame construction, the drainage plane typically consists of a moisture barrier such as building paper, felt, or house-wrap, working in combination with window and door flashings.¹ Drainage is generally the primary means of providing redundancy for moisture control in a wall assembly.

Drainage Cavities introduce an airspace between the cladding and the drainage plane/sheathing. The airspace serves as a capillary break to prevent water from excessively wetting the drainage plane. The airspace, particularly when it provides a pressure equalization function, can also be seen as another means of deflection, in that pressure-equalization neutralizes the primary driving force behind rain penetration (air pressure differential), and thereby reduces the amount of moisture being driven through the cladding into the drainage cavity.

Insulation applied internally or externally to foundation walls helps insure that cold interior concrete surfaces will not condense moisture and promote growth of mold and mildew.

Foundation drainage and damp-proofing of walls below grade are insurance against development of undesirable moisture conditions in crawl spaces and basements (Figure 17, Figure 18, and Figure 19).

Figure 17 Damp Proofing and Drainage of a Masonry Foundation



Footing drains, connected to a positive outfall, should be installed around foundations enclosing habitable spaces below grade (Figure 17).

The gravel drainage system used for wood foundations, described below, may be substituted for footing drains around concrete or masonry foundations when there is provision for drainage from outside the footing to a sump or positive outfall under the basement slab.

Moisture movement around wood foundation walls enclosing basements or other habitable spaces below-grade is controlled by drainage and by applying polyethylene sheeting on the outside of the wall, extending from the footing to finish grade. Drainage is provided by a porous layer of gravel or crushed stone placed below the floor

slab and footer plate and extending at least one foot up the wall for well drained sites or half the total backfill height for poorly drained sites (Figure 18). This gravel layer is drained to a sump or positive outfall. For more detail on wood foundations, see the *Permanent Wood Foundation: Design and Construction Guide*, published by the Southern Forest Products Association.

Drainage may also be needed within a crawl space where excessive moisture prevails (Figure 19).

Figure 18 Damp-Proofing and Drainage of a Wood Foundation

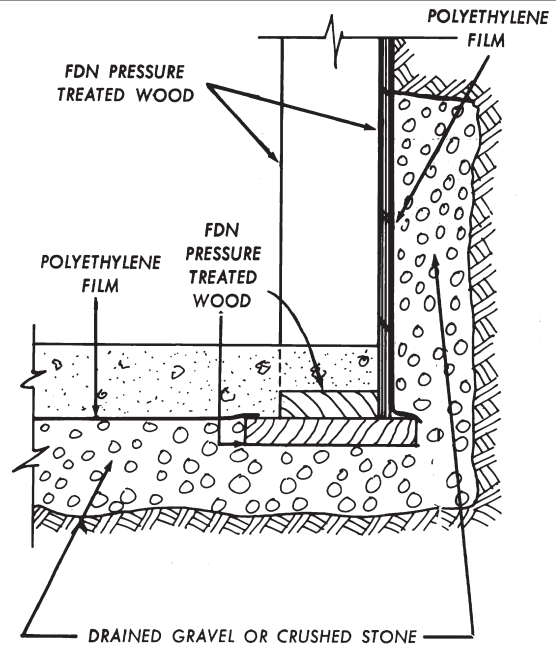
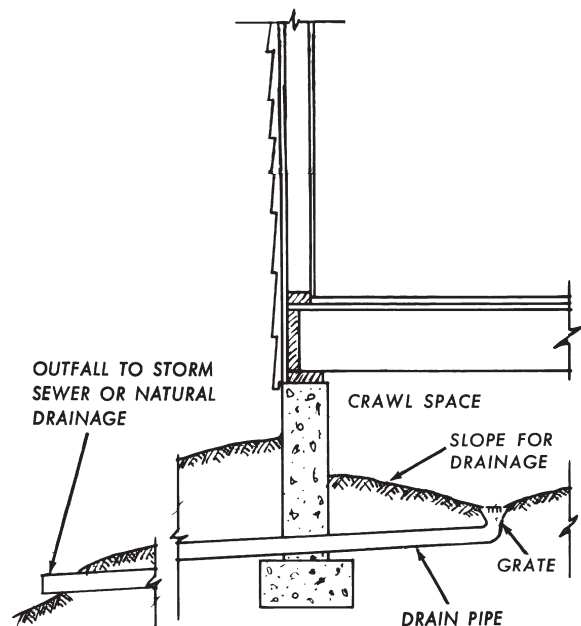


Figure 19 Drainage of a Crawl Space



For slab-on-ground construction and basement floors, earth should be covered with not less than 4 inches of coarse gravel or crushed stone over which a separating membrane is placed before pouring the slab. In slab-on-ground construction and where basements contain living space, this membrane should be a vapor diffusion retarder having a permeability not greater than one perm.

Siding. Exterior wood siding should extend at least 1 inch below the top of the foundation to provide a drip line protecting the sill from rainwater (Figure 8).

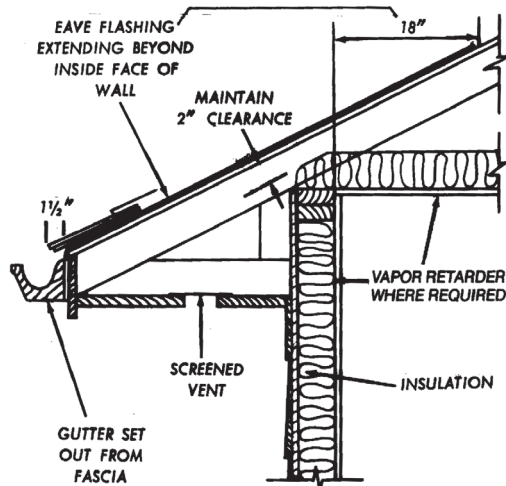
Where the exterior finish is masonry veneer, a one-inch space should be provided between sheathing and the veneer extending down to at least the bottom of the sill plate. Weep holes and flashing should be provided at the base of the veneer wall to allow for drainage (Figure 15).

Roofs. Shingles should project at least 1/2 inch beyond the roof sheathing to provide a drip line. When asphalt shingles are used, a starting course of wood shingles is desirable. Gutters and downspouts are needed unless eave projection is 24-inches or greater. Roof run-off should be drained away from the structure.

In northern areas, melting snow may result in ice dams on roof overhang and gutters to the extent that water may work back under shingles and drip into attic spaces or walls. Protection is provided by applying eave flashing consisting of 55-pound roll roofing or 6-mil polyethylene extending over the roof sheathing from the edge of the eave to a point 18 inches inside the inner face of the exterior wall (Figure 20).

Exposed Structural Members. Exposed structural members should be designed to provide sufficient ventilation and drainage away from end joints to allow rapid drying. In instances where proper detailing of such joints may not provide sufficient protection, the designer can specify naturally durable or pressure treated wood.

Figure 20 Shingles and Flashing at Eave



Drying

Drying is the mechanism by which moisture accumulations are removed by venting (air movement) and vapor diffusion (direct movement through wall and ceiling coverings). Moisture originates from both inside and outside the structure. Excessive moisture may condense on the underside of roof decking and inside walls, which can lead to mold and decay. Adequate ventilation and properly placed vapor diffusion retarders help provide solutions. The latter should always be located on or near the warm side of walls, floors, and ceilings. However, vapor diffusion retarders are typically omitted in ceiling assemblies where attics are well ventilated. The permeability of cladding, moisture barriers, vapor diffusion retarders and interior finish materials will greatly affect overall drying potential. Vapor diffusion retarders should be carefully installed to provide a complete envelope preventing moisture vapor produced inside the structure from entering enclosed spaces where condensation may occur.

Local climate conditions, types of occupancy, and design methods determine the requirements for control of vapor movement and ventilation. Some energy-saving practices, such as reducing air leakage or adding insulation, may increase the potential for moisture condensation. Good construction practices (attention to detail) must be followed to prevent problems caused by condensation. Care should be taken to dry-frame cavities to a moisture content of < 20% prior to enclosure. General code provisions are largely based on houses where heating of the building is the primary concern. To build long-lasting, energy-efficient, healthy houses in areas where cooling of the building, not heating, is a primary concern, the climatic conditions of the area must be considered.

Ventilation, vapor diffusion retarders, and ground cover requirements may vary. Consult the local building department to confirm specific requirements.

Crawl Spaces

Ventilation. Crawl spaces under buildings, and other unexcavated concealed spaces under porches, breezeways, patios or other appendages, should be naturally ventilated by openings in foundation walls or by suitable mechanical means. Such spaces should be provided with access panels so that they may be easily inspected. Crawl spaces must be designed to allow sufficient drying to prevent build-up of moisture to levels where water vapor will condense or where fungal growth can occur. In some hot and humid climates, local or state codes may restrict crawl space ventilation.

Minimum ventilation requirements for crawl spaces are specified in the codes. The requirements are usually based on the ratio of the free ventilation area to the area to be ventilated. Typically, the required ratio is 1 to 150. When a vapor diffusion retarder is placed over the ground

within a crawl space, the ventilation ratio may be reduced to 1 to 1500.

Ventilation openings should be arranged to provide cross ventilation. They should be kept clear of shrubbery and should be covered with corrosion resistant wire mesh, with mesh openings not less than 1/4 inch nor more than 1/2 inch in any dimension. Vents should be at least 3 inches above outside grade and below the bottom of floor joists, or wells with 6 inches of clearance around the vent should be provided. No unventilated, inaccessible spaces should be permitted.

It is very important that ventilation should not be cut off at any time during the year when it is the only means of moisture control in crawl spaces. Ventilation openings are not necessary when crawl space walls are insulated, an approved vapor diffusion retarder is provided over the ground, and conditioned air is provided to the crawl space. Ventilation requirements are based on the assumption that outside air has a lower absolute humidity than air in the crawl space. In hot and humid climates where exterior air has a high absolute humidity, use of natural ventilation may not be the best option for drying the crawl space.

Vapor Protection. Except in arid or semi-arid areas, soil should be covered with a fungi resistant vapor diffusion retarder having a permeability of 1 perm or less, such as 6 mil polyethylene lapped approximately 4 inches at joints. The vapor diffusion retarder should conform to ASTM E1745 and be resistant to chemicals in the soil. Laps should be sealed. The vapor diffusion retarder should lap-up onto the foundation so the concrete slab is isolated from soil and the foundation. Seam tape should be used to seal the retarder to any pipes or other objects that penetrate the retarder and the slab. The ground surface should be leveled and the cover turned up at walls and piers.

Multi-Family and Nonresidential Buildings

For multi-family or nonresidential buildings where crawl space configuration or building location may reduce the efficiency of natural ventilation, the required net area of vent openings should be increased. A vapor diffusion retarder is also recommended for such installations.

Concrete Slab Foundations. Soil is a constant source of moisture, so deflection of soil moisture is important. The use of a sturdy vapor diffusion retarder beneath slabs prevents ground-based moisture from migrating up through the concrete by capillary action or diffusion. Lapping of joints in the vapor diffusion retarder and liberal use of tape and other sealants around pipe penetrations is critical. However, care should be taken in hot climates to slow the rate of concrete surface curing. Vapor diffusion retarders placed under the slab slow the rate of drying in the lower depth of the concrete. When the upper depth is exposed to high heat and dries too fast, it shrinks relative to the deeper concrete that can not disperse its moisture as fast because

of the vapor diffusion retarder. Surface cracking can result. After the surface initially hardens, some means of covering the slab to slow the rate of curing is advised.

Attics

Natural Ventilation. To eliminate the problem of moisture condensation on roof framing in cold weather and to permit escape of heat in hot weather, ventilation of all attic spaces is required by model building codes (**Figure 21**). In some hot and humid climates, local codes may restrict attic space ventilation.

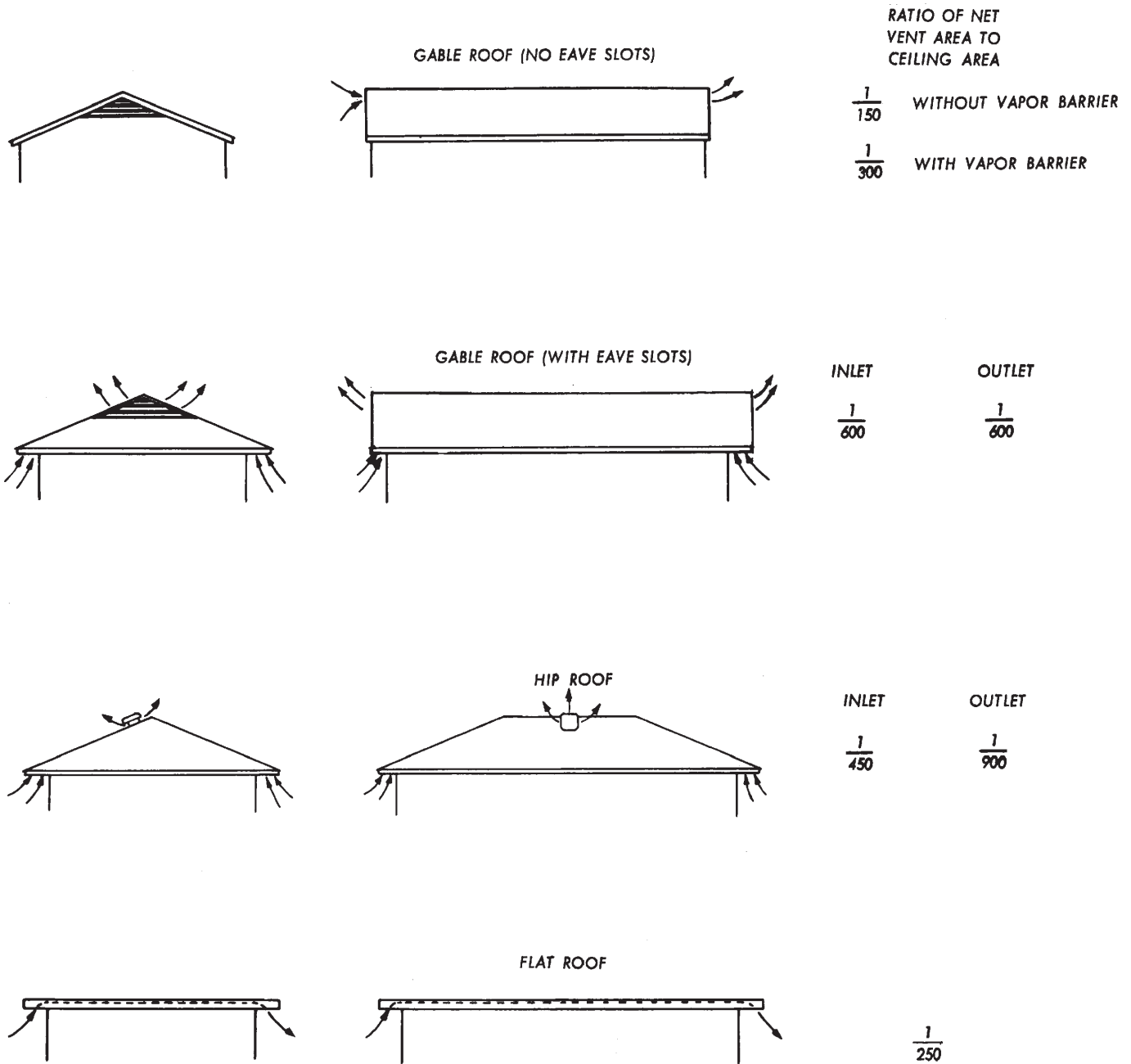
For gable roofs that depend upon screened louvered openings for ventilation, a net open area of 1/150 of the area of the ceiling below should be provided. The free ventilating area may be reduced to 1/300 when a 3/4 inch slot is provided beneath the eaves in addition to the screened gable-end louvers (1/600 inlet and 1/600 outlet vent areas), or when a vapor diffusion retarder having a permeability of 1 perm or less is installed on the warm side of the ceiling (**Figure 20**). For hip roofs, it is customary to provide a 3/4 inch slot beneath the eaves and install ventilators near the peak, to obtain net inlet and outlet open areas of 1/450 and 1/900, respectively, of the area of the ceiling below.

In hot and humid regions, attic spaces can heat up to 130°F or more on a hot summer day. Eventually, that heat transfers through the ceiling insulation into living spaces below, increasing the cooling load. To counter this problem, it is suggested that twice the recommended roof ventilation be used and it is recommended that a radiant barrier be installed, such as labor-saving roof sheathing with foil laminated directly to it. The radiant barrier blocks transfer of heat from the roof to the attic. The radiant barrier should be applied to the underside of the roof, not on the attic floor, with adequate openings along the ridge and below the low-profile vents so that attic air can exhaust. Light colored roofing may also be used to slow heat transfer into the attic space.

For flat roofs, blocking, bridging, and insulation should be arranged to permit unobstructed movement of air for ventilation. Such roofs may be ventilated along overhanging eaves on the basis of net open area equal to 1/250 of the area of the ceiling below. A vapor diffusion retarder having a maximum permeability of 1 perm should be applied to the warm side of the ceiling below flat roofs.

Mechanical Ventilation. In lieu of natural ventilation of attic spaces described above, mechanical ventilation may be used. Such ventilation should provide minimum air changes of 0.7 cu. ft./min. (at 0.03" standard pressure) per sq. ft. of the ceiling below. Air intakes of 1 sq. ft. of free openings per 300 cu. ft./min. of fan capacity should be provided. Mechanical ventilation should provide adequate protection against harmful condensation throughout the year.

Figure 21 Methods of Ventilating Roof Spaces and Amount of Ventilation Required



In dwellings having roof slopes less than 3 in 12 or in cold weather climates, a vapor diffusion retarder having a permeability of 1 perm or less should be applied on the warm side of the ceiling. Where exposed interior wood roof decking is used, a vapor diffusion retarder should be installed between the wood roof decking and any insulation used on the exterior side of the roof decking. A vapor diffusion retarder is not necessary in unconditioned buildings where wood roof decking is not insulated.

Walls

Vapor Protection of Walls. The principle of vapor protection is to make the warm side of the wall as vapor tight as possible, and the cold side permeable enough to permit passage of moisture vapor to the outside of the wall.

Placement of the vapor diffusion retarder is dependent on climatic conditions. In cold climates, the vapor diffusion retarder should be placed on the interior of the wall. In hot humid areas the vapor diffusion retarder should be

on the exterior of the wall. A permeability of at least 5 times the vapor diffusion retarder permeability should be maintained between the vapor diffusion retarder and the cold-side face of the wall. In cold climates where the 5 to 1 ratio of warm-side to cold-side permeability rating cannot otherwise be obtained, such as may occur with rigid foam plastic or foil faced sheathing, use of foilback gypsum board, polyethylene sheathing, or other special vapor diffusion retarder treatment located at the warm-side of the wall may be needed to avoid condensation in the wall cavity. In tightly sealed dwellings, use of dehumidifiers may be necessary to prevent objectionable condensation of moisture in kitchen, bathroom, laundry and similar areas. In regions of extreme heat, it is highly recommended not to place an impermeable vapor diffusion retarder under gypsum board, or cover gypsum board with vinyl wall paper. In regions where extreme heat and cold may occur, inclusion and placement of vapor diffusion retarders should be carefully considered. Local codes may allow vapor diffusion retarders to be excluded all together in such climates.

Where batt insulation with an integral vapor diffusion retarder is used in walls, care should be taken to insure that the retarder is face-stapled to studs to prevent movement of moist air into the enclosed wall space and avoid batt compression. Where batt insulation does not have an integral vapor diffusion retarder and such a retarder is required, a separate vapor diffusion retarder should be provided.

In wall construction, the drying potential of both the cladding and the wall sheathing/framing must be considered. Air spaces introduced for drainage purposes also offer a means to dry material by back-venting. Drying of sheathing and framing is often a separate matter and is greatly affected by the selection of moisture barrier and vapor diffusion retarder materials.

TERMITE CONTROL

Termites attack above the ground by means of shelter tubes attached to foundation walls, piers, and other elements in contact with the ground. However, *only* under conditions which permit the insect to establish and *maintain* contact with moisture, is a colony able to penetrate and consume wood in-service.

There are more than 2,000 species of termites. The most damaging are roughly 20 species called “subterranean” termites because of their nesting and foraging habits. Of the subterranean termites, Formosan are by far the most damaging in the U.S. Formosan termites, which were introduced to Hawaii and the southeastern United States from Southeast Asia at the end of World War II, can cause more damage than domestic termites and at a faster rate. Formosan colonies also tend to be larger than those

of domestic subterranean termites.

The general information given below concerning protection against termites is applicable to Formosan as well as domestic termites. However, given the increased level of damage possible from Formosans, additional precautions should be taken where they exist. Those geographic areas near enough to current infestations to be reasonably threatened by existing Formosan termite colonies or by migration in the near future are considered to be areas of severe risk. Those areas elsewhere would be considered to be intermediate and low risk areas.

- *Suppression.* Formosan termite colonies should be contained in their current geographic region of infestation. Precautions should be taken to assure that logs, soil, landscape timbers, mulch, and other transportable sources of infestation are free of termites.
- *Site Management.* Construction sites must be managed to assure that nothing exists that promotes establishment of colonies. All construction debris should be removed from the site, along with dead trees, foliage, stumps and other sources of food for termites.
- *Soil Barriers.* Soil barriers that kill or restrict movement of termites should be introduced based on the severity of infestation. In areas of severe risk, the use of barriers such as graded gravel or termite-resistant steel mesh is appropriate along with the use of chemical soil treatment or bait systems. In low-risk areas, soil barriers are not required.
- *Foundation Details.* In all risk areas, the use of preservatively treated or naturally durable wood and termite barriers as discussed below is necessary. It is also important that foundation design be done with care. Depending on the type of foundation, use of graded gravel or termite-resistant steel mesh at points where piping penetrates slabs is reasonable. Where concrete masonry units are used as elements of the foundation, the bottom of the units should be protected with graded gravel or termite-resistant mesh, or the units should be filled with concrete.
- *Structural Protection.* In areas of severe risk, an increased level of protection of structural elements of the building is justified. The structural frame – including posts, poles, columns, joists, girders, rafters, structural sheathing, and bracing – should be either preservatively treated wood or naturally durable.

Prevention of subterranean termite attack is typically achieved using a barrier separating wood from earth, the application of chemical termiticide to the soil under and around the building, or through use of baiting systems which poison termite colonies.

The termite hazard will vary from one region to the next. In all areas, structures should still be designed to provide adequate and accessible clearance between earth and wood in order to permit periodic inspection for termite shelter tubes and wood damage. Where clearances recommended under the heading "Distance - Separation of Wood Elements" is provided, no additional protection is required, unless a specific termite hazard is known to exist. However, all foundations and piers of hollow masonry units should have solid masonry caps in which all joints or voids are filled with mortar.

In addition, all roots, wood forms, stakes, and scraps of wood should be removed from the immediate vicinity of the house before back-filling and before placing a floor slab. Particular care should be taken to remove all scraps of wood from enclosed crawl spaces.

Where local experience indicates that additional protection against termites is required, one or more of the following systems should be specified depending on the degree of hazard:

Termite Barrier

The most common method of control is a termite barrier which is considered to be any building material or component which is impenetrable to termites and which drives the insect into the open where its activities can be detected.

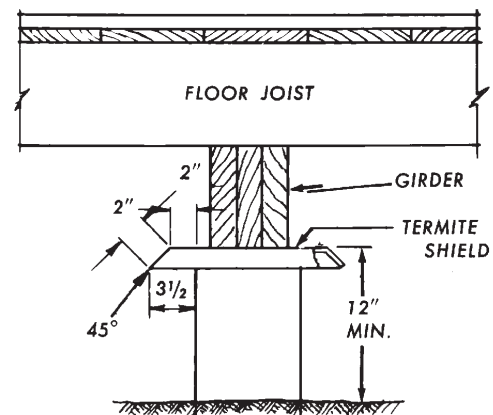
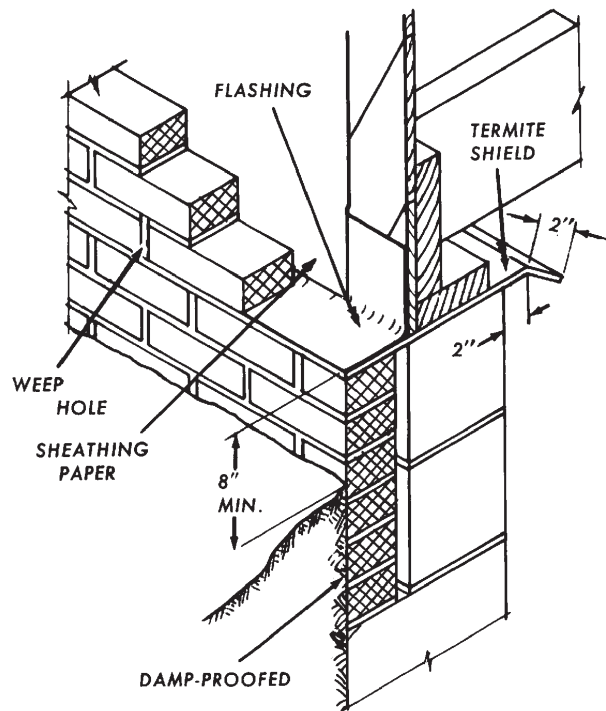
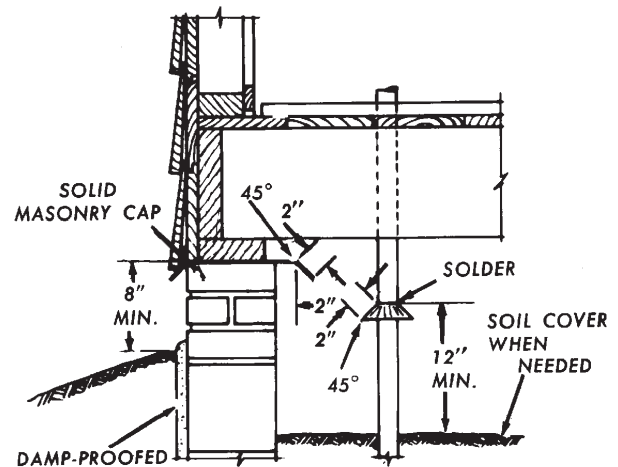
Properly installed termite shields should be of not less than 26 gauge galvanized steel, or other suitable metal of proper thickness, installed in an approved manner on top of all foundation walls and piers, and around all pipes leading from the ground (Figure 22). Longitudinal joints should be locked and soldered. Where masonry veneer is used, the shield should extend through the wall to the outside face of the veneer (Figure 22).

Any of the barriers mentioned can be installed without major changes in established construction methods. *However, periodic inspection is essential to the successful function of any of the barrier types recommended.*

Chemical Soil Treatment

Chemical soil treatment has been a standard practice for preventing termite infestation of structures for some time. A termiticide is placed into the soil under and around a structure to create a continuous chemical barrier that blocks potential routes of termite entry. Typically, a trench is dug around slabs, piers, or other supports touching the soil, which is then saturated with termiticides. Soil below the slab is also treated with the termiticide. Application of soil treatments should be carried out by a licensed professional in accordance with requirements of the authority having jurisdiction. The typical effective life of a soil treatment varies between products.

Figure 22 Installation of Termite Shield



Application of chemicals and precautions involved in their use should be in accordance with manufacturer's recommendations (**Figure 23**). For permanent wood foundations, soil treatment should be in accordance with the recommendations for poured concrete foundation walls, except that the treatment should extend below the wood footing.

Construction Details

A critical element in controlling termite access to the structure is proper detailing during the building design process, particularly in those areas at ground level. For foundations:

- Poured concrete foundation walls may allow access when cracks greater than 1/64 inch are present.
- Poured reinforced concrete caps, which should be at least 4 inches thick, on unit masonry foundations, may allow access when cracks greater than 1/64 inch occur.
- Slab-on-ground construction requires special consideration in areas where a termite hazard exists. Concrete slabs vary in their susceptibility to penetration by termites and cannot be considered to provide adequate protection unless the slab and supporting foundation are poured integrally (monolithic slab) to avoid cracks or holes through which termites may enter (**Figure 24**).
- Where other types of slab construction are used, termites may penetrate joints between the slab and wall. They may also enter through expansion joints or openings made for plumbing or conduit. Thus, it is necessary to provide a barrier at these points by use of termite shields or by chemical soil treatment (**Figure 22 & Figure 23**).

Stucco, masonry veneer, and other non-wood siding in contact with the ground may provide access for termites in infested areas. For this reason, the veneer or siding should be kept at least 8 inches above finished grade, unless termite shields are installed in an approved manner or the soil on the exterior has received a chemical treatment (**Figure 22**).

Rigid expanded polystyrene or polyurethane insulation used against foundations can provide concealed access and are easily penetrated by termites. Where such foundation wall insulation is used and a particular termite hazard is known to exist, it is important that soil treatment, shields, or pressure treated wood be used as appropriate to the design.

In-Ground Bait Systems

In-ground bait systems are a relatively new technology for treating subterranean termites. In-ground bait

stations are placed around a house in the soil. Untreated cellulosic material is placed in several of the stations and monitored several times a year for signs of termite activity. Once termite activity is found in the station, the cellulosic material is replaced by termiticide-treated, cellulosic material that the termites will return to their colonies. In order for this system to be effective, it must be maintained and serviced.

Fumigation

Structures subjected to a fumigation system are covered with a tent and a lethal gas is released into the structure. This treatment kills termites in the structure, but not termites in the soil. This system is effective in killing drywood termites as they infest and live self-contained in the wood of a structure. Fumigation is not recommended without other treatments for controlling subterranean termites because termites in the soil may re-enter the structure as soon as 24-hours after fumigation.

DURABLE MATERIALS

Another principle involves selection of materials. Durable materials must be selected for use at all locations where moisture tolerance is necessary or where termite infestation is likely. Where deflection, drainage, and drying cannot effectively maintain moisture content of wood components below 28%, decay resistant wood must be selected. For most wood framing components, this is achieved using preservative-treated wood. For some applications, this is achieved through selection of naturally durable species of wood.

Approved durable and preservative-treated wood is usually recommended when location of the member in question may be such that it cannot be maintained at a safe moisture content and when climatic or site conditions in certain areas may not permit control of decay or termites by construction practices alone.

The use of naturally durable or preservative-treated wood in a particular condition depends on the exposure and importance of the given member. Recommended uses for naturally durable and pressure treated wood are given in the section entitled "Conditions of Use for Pressure Treated and Naturally Durable Wood."

Naturally Durable Wood

Substances deposited by the living tree makes the heartwood of certain species resistant to decay or termite attack. The following commercial species of naturally durable wood should consist of 100% heartwood, except that an occasional piece may have corner sapwood if 90% or more of the width of each side on which it occurs is heartwood:

Figure 23 Application of Soil Treatment

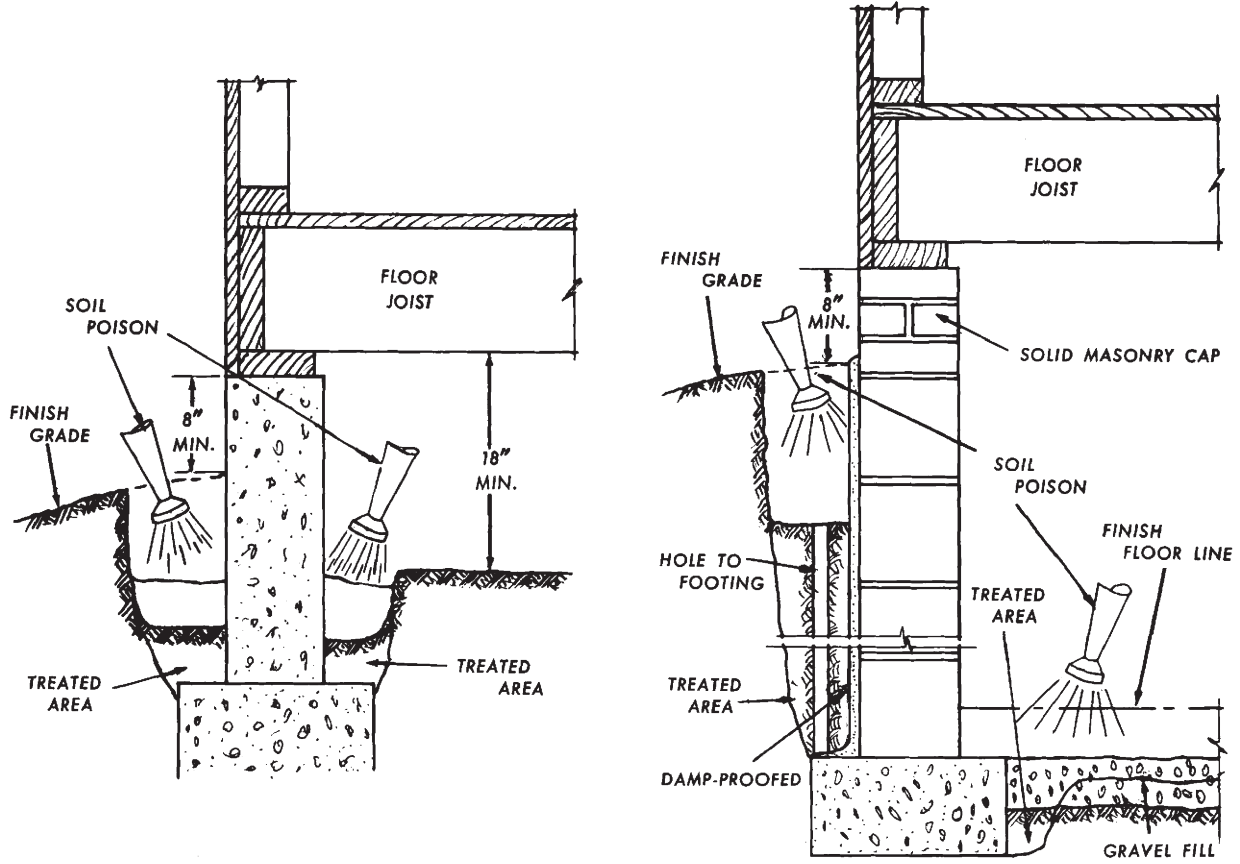
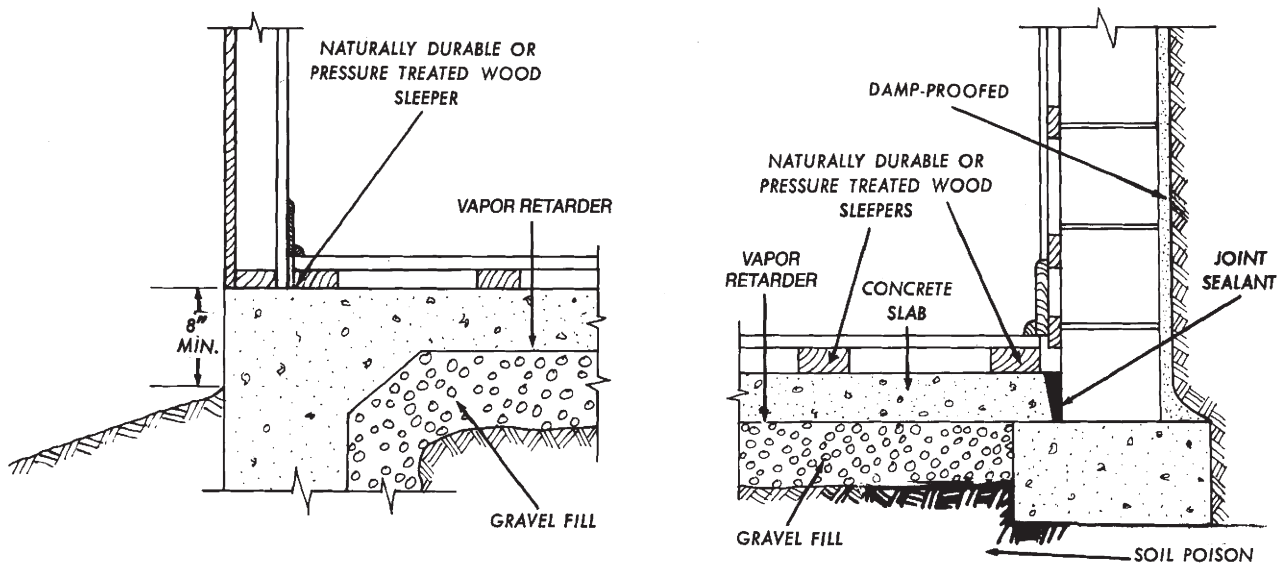


Figure 24 Termite Control for Slab-on-Ground Construction



- Decay Resistant Species: Redwood, Cedars, and Black Locust.
- Termite Resistant Species: Redwood and Eastern Red Cedar.
- In addition to the applications recommended under “Conditions of Use for Pressure Treated and Naturally Durable Wood,” naturally durable wood may be used wherever untreated wood is used.

Pressure Treated Wood

The effectiveness of preservative treatment is dependent upon the following factors: (a) type of chemical used, (b) amount of penetration, (c) amount of retention, and (d) uniform distribution of preservative. The expression “pressure treated wood” refers to wood meeting the retention, penetration and other requirements applicable to the species, product, treatment, and conditions of use in the approved standards of the American Wood Preservers Association (AWPA). Since penetration and retention may be controlled in the pressure treating process, it is important to select the right preservative and to specify the correct retention for the intended exposure. All wood required to be pressure treated should bear the quality mark of an approved inspection agency which maintains continuing supervision, testing, and inspection over the quality of the product. The mark should identify whether the pressure treated wood is suitable for use in contact with the ground, or is limited to above-ground use.

Wood members selected for pressure treatment should be dimensioned and machined prior to preservative application. When such precutting is not feasible, all untreated surfaces exposed by sawing, planing, boring, or routing, must be treated with a liberal application of preservative. Wood pressure treated with a water-borne preservative and used in enclosed locations where drying cannot readily occur should be at a moisture content of 19% or less before being covered with insulation, interior wall finish, floor covering, or other material.

Applications for pressure treated wood are not limited; it may be used where naturally durable or non-pressure treated wood is used. However, it should be required for members which are exposed to severe service conditions. Where members are to be painted or when finished materials will be nailed to, or placed in direct contact with treated wood, water-borne or water-repellent preservatives should be specified.

Conditions of Use for Pressure Treated and Naturally Durable Wood

Where recommended clearances between wood and earth are not maintained for wood joists or girders, or the bottom of wood structural floors without joists, the floor assembly, including posts, girders, joists, and sub-floor,

should be approved naturally durable or pressure treated wood. Naturally durable or pressure treated wood should also be used when recommended clearances cannot be maintained between the earth and sills which rest on concrete or masonry exterior walls, and between the earth and wood siding and posts or columns. When ends of wood girders entering exterior masonry or concrete walls are not provided with the recommended clearance, or when posts or columns cannot meet the recommended clearance between the wood and concrete or masonry floors, those members should also be approved naturally durable or pressure treated wood.

Sleepers and sills on a concrete or masonry slab, which are in direct contact with soil should be approved naturally durable or pressure treated wood. Pressure treated wood should be used for:

- members in contact with the ground (except when completely below the permanent ground water table or continuously submerged in fresh water);
- posts or columns embedded in concrete which is in direct contact with the earth; and
- members not separated by an impervious moisture barrier from moisture permeable (concrete, masonry slabs) floors or roofs which they support.

Retaining or crib walls should be approved pressure treated wood except that such walls of approved naturally durable wood up to 4 feet in height and of untreated wood up to 2 feet in height may be used when separated from the property line or a permanent building by a minimum distance equal to the height of the wall. Retaining or crib walls not more than 2 feet in height located on the property line also may be of approved naturally durable wood.

In geographical areas where experience has demonstrated a specific need for protection against termites and decay, approved pressure treated or naturally durable wood should be used for those portions of wood members which form the structural supports of buildings, balconies, porches or similar permanent building appurtenances when such members are exposed to the weather without adequate protection from a roof, eave, overhang, or other covering to prevent moisture or water accumulation on the surface or at joints between members. In addition to providing preservative treated floor framing members where suggested elsewhere, the use of treated sub-flooring is recommended for increased termite protection.

Wood furring strips or other wood framing members attached directly to the interior of exterior masonry or concrete walls below grade should be approved naturally durable or pressure treated wood.

Fasteners for naturally durable and preservative-treated wood shall be resistant to corrosion or protected to resist corrosion. Fasteners used in preservative treated wood should be of a type recommended by the treating

industry and by the manufacturer of the chemical used in the treatment. When sacrificial coatings are applied to fasteners, a minimum coating thickness capable of protecting the fastener for the expected service life of the structure shall be provided.

Non-Pressure Treated Wood

Non-pressure treatments are intended to provide resistance to decay in moderate exposures and, in the case of the water-repellent preservative, to retard liquid moisture absorption as well. They provide little, if any, protection against termite damage. Their effectiveness is based on the ability of the wood to absorb the preservative. While the end grain of wood readily absorbs the preservative to a sufficient depth for adequate protection, penetration into side grain is usually less than that obtained by pressure treatment.

Moderate exposure implies that the wood is dry most of the time but occasionally may be damp enough to permit decay to occur. In general, non-pressure treatments are effective for protection where the thinness and dryness of the member permits sufficient penetration and retention.

Non-pressure treatments have been widely used for window sash and doors and their frames, as well as for wood siding and miscellaneous exterior trim. The water-repellent preservatives have the extra advantage of providing better paint performances on these items. Other applications include: fence parts not in contact with the ground; and exterior stairs, porch framing, and trim. Where wood members are exposed to the weather, ends which abut or are held by fastenings which tend to retain moisture may be protected by non-pressure treatment.

Wood may be preservatively treated by one of the following non-pressure processes: (a) cold soaking or dipping in which immersion time is dictated by the desired retention and end penetration; and (b) vacuum process or hot-and-cold-bath method using treating cycles designed to produce the desired retention and penetration.

Preservatives used for non-pressure treated wood are petroleum based. The water-repellant preservative should meet the standards of the Window & Door Manufacturers Association or the American Wood Preservers Association *Standard for Oil-Borne Preservatives (P8)*. The treatments prescribed in *AWPA P8* have a heavier concentration of preservatives and are not recommended for painting.

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Selected References:

1. American Society of Testing Materials, ASTM E1745 Standard Specification for Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs, *Annual Book of ASTM Standards* v. 04.12.
2. American Forest & Paper Association. *National Design Specification for Wood Construction*. Washington, DC.
3. American Forest & Paper Association. *Wood Frame Construction Manual for One- and Two-Family Dwellings*. Washington, DC.
4. International Codes Council. *International Building Code*. Falls Church, Virginia.
5. Southern Forest Products Association. *Permanent Wood Foundation Design and Construction Guide*. Kenner, Louisiana.

ENDNOTE

1. §1403.2 of the *International Building Code* specifically requires the exterior wall envelope to be designed and constructed in such a manner as to prevent the accumulation of water within the wall assembly by providing a water-resistive barrier behind the veneer. In some exterior wall applications, a double layer of felt paper may be required. The designer should check with the listing or the Evaluation Report for specific installation requirements beyond those specified in the building code.

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