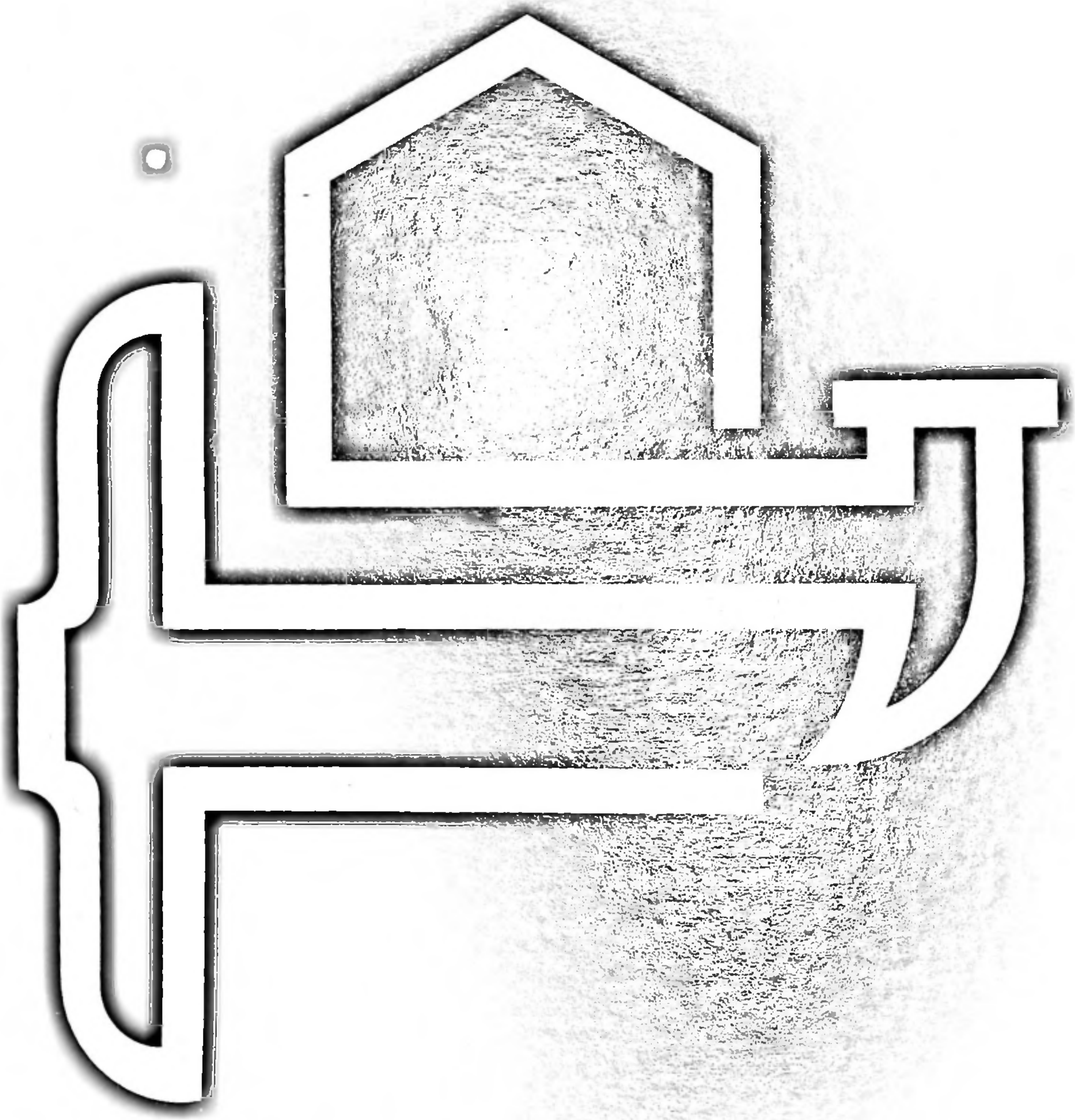
Reducing Home Building Costs with OVE Design and Construction

Guideline 5



PREFACE

Sharp rises in construction costs make it imperative that we develop and adopt new, more efficient ways of using labor and materials in the production of housing. One such way is the Optimum Value Engineered (OVE) building system.

The OVE system, which adheres to sound building practices, reduces direct construction costs through a systematic, integrated approach to building. The use of materials and related labor time are optimized through a process of value engineering, a process that compares alternative materials and methods to determine the least costly combination that will result in a safe and durable product.

This manual, supervised for HUD's Office of Policy Development and Research by Orville Lee, describes the cost-reducing techniques embodied in the OVE system. Whether used selectively or in full, the techniques will readily adapt to residential housing of all types and styles, and to virtually any building operation today.

Some of the techniques may differ from existing local building codes. In such instances, we urge local authorities to consider them carefully. Their use will reduce building costs, increase housing production, and, most importantly, conserve national resources.

The contents of this report do not necessarily reflect the views or policies of the Department of Housing and Urban Development or the U.S. Government.

Other publications in this series are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. They include:

*Guideline 1,	A Design Guide for Home Safety	Stock No. 023-000-00201-9
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**Guideline 3,	A Study of Techniques to Increase the Sound Insulation of Building Elements.	NTIS-PB-222-829/4
Guideline 4,	All-Weather Home Building Manual	Stock No. 023-000-00339-2

*Currently being updated. Revised manual will be available Fall 1980.
**Only available from the National Technical Information Service.

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*Available at cost from NAHB Research Foundation, Inc., P. O. Box 1627, Rockville, Maryland 20850.

ACKNOWLEDGEMENTS

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We also wish to acknowledge the suggestions and ideas obtained from numerous people in Government and industry, and particularly the National Association of Home Builders, National Forest Products Association, National Concrete Masonry Association, American Plywood Association, as well as a number of individual home builders and manufacturers of building products and materials. While acknowledging the advice and suggestions of these individuals and organizations, we wish to emphasize that this in no way implies their endorsement of the contents of this Manual, since the statements, conclusions and other information in the Manual are those of the Foundation.

This Manual was produced under the general guidance of Ralph J. Johnson, President, NAHB Research Foundation, Inc. The project was directed by Donald F. Luebs, Director of Building Systems, with contributions from Hugh D. Angleton, Director of Laboratory Services, E. Lee Fisher, Director of Industrial Engineering, and other professional personnel at the NAHB Research Foundation.

NAHB Research Foundation, Inc.
September 1978

REDUCING HOME BUILDING COSTS WITH OPTIMUM VALUE ENGINEERED DESIGN AND CONSTRUCTION

I. INTRODUCTION

1.1 Purpose of This Manual

The Department of Housing and Urban Development is continually seeking ways to increase housing production and lower costs to better house the people of our Nation. The Optimum Value Engineered (OVE) techniques described in this Manual were developed under contract with HUD by the NAHB Research Foundation, Inc., with this goal in mind.

The purpose of this Manual is to describe the OVE concept to the home building industry and to provide practical instructions for applying OVE cost reducing techniques to the design and construction of homes. Application of the basic planning, engineering and construction techniques embodied in the OVE concept produces a significant reduction in labor and material costs, which makes it possible to provide greater value at a more affordable cost to aspiring home owners.

This Manual is intended for use by builders, subcontractors, designers, architects and engineers, as well as building inspectors, code officials and others concerned with the safe and efficient use of our Nation's resources in the production of housing.

1.2 What is Optimum Value Engineering?

Value engineering is basically a procedure of comparing alternative materials and methods to determine the least costly combination that will result in an acceptable product. This procedure is carried out to a high degree of sophistication in some manufacturing operations.

Home builders regularly practice a form of value engineering when they select certain house designs, materials and products that represent the least costly, marketable combination in their judgment. In the broadest sense, the Optimum Value Engineered concept simply expands on that practice to provide an effective, systematic total systems approach. In a narrower sense, it provides a valuable reference to a wide variety of cost reducing techniques covering the entire design and construction process.

The cost-reducing techniques presented in this Manual are intended to be compatible with wood frame construction, which represents the majority of housing built in the United States.

Although traditional wood frame construction is basically an efficient process, these OVE techniques utilize the same materials and labor skills in an even more effective manner. Indeed, they represent a logical extension of familiar building practices. Some or all OVE techniques will readily adapt to one degree or another to virtually all home building operations today.

Generally, the details in this Manual are presented in relation to single-family homes. In this context, they apply to all types and styles of homes including one- and two-story, split level, etc., from New England colonial to California contemporary. OVE techniques are not necessarily limited to single-family detached homes. Most of the techniques also apply to other housing types such as duplex, fourplex, garden court and town-houses, as well as low-rise (garden) apartments. In addition, most OVE techniques are adaptable to either on-site, shop or prefabricated building methods.

It is central to the OVE concept that this Manual is not simply regarded as a collection of unrelated cost-saving methods. The OVE concept actually includes a whole sequence of planning, engineering and construction techniques, carefully integrated to work together and to complement each other. Together, these techniques provide a systematic approach to cost and value efficient building. The concept is presented in steps beginning with planning and design guidelines, and proceeding through engineering and construction of each portion of the building.

It is apparent that the maximum benefit in cost savings will be obtained by employing the total OVE systems approach. However, it is equally important to note that individual OVE techniques may often be used to advantage in combination with more conventional methods. It is not always necessary to employ the total system to realize a significant cost savings. Designers and builders will find a wide variety of cost-reducing ideas covering the entire design and construction process.

The OVE techniques presented here are practical and suitable for the construction of safe and durable homes. As always, engineered techniques should be applied with good judgment. While most of these techniques do not require detailed engineering analysis, it may be desirable or necessary to obtain professional engineering review in some cases. Technical supplements containing engineering and test data on a number of the techniques described in this Manual, where noted in the text, are also available to assist in obtaining code approvals, etc. (see Table of Contents).

In any event, use of the OVE techniques presented in this Manual presumes adherence to sound building practices. While no new labor skills are required, continuing attention to workmanship is important to assure that housing quality is maintained.

1.3 Where Did OVE Come From?

The Optimum Value Engineered building system was originally developed by the NAHB Research Foundation, Inc., through a contract from the Department of Housing and Urban Development under Operation BREAKTHROUGH, type B programs.*

The purpose was to reduce home building costs through an engineered approach to building, based on familiar and available building materials and labor skills. The objective was to provide the basic system and specific techniques for producing safe, marketable homes at a lower cost, to assist in meeting national housing goals.

The project began with research, review and identification of potential cost-saving techniques relating to structural, finish and mechanical elements of dwelling unit construction. Selected structural subsystems and components were subjected to engineering analyses and loading tests. Concurrently, labor and material costs of alternate assemblies and components were analyzed and compared through the value engineering process. Cost-effective subsystems, details and design principles that complement each other were then integrated to form a total Optimum Value Engineered system.

The OVE system is closely related to conventional wood frame construction. It is based on a 2-foot planning module for full material utilization with adequate design flexibility. All framing members were spaced 24 inches on center for structural continuity, material and labor utilization and simplicity. Some members, such as wall studs and floor joists, were reduced in size through engineering design. Other members, such as foundation sill plates, were deleted entirely when careful analysis showed they served no useful purpose. Trim details were simplified throughout.

Complete plans and specifications were prepared for a small size, single-family detached house to be built as a demonstration (see Figure 1-A). The prototype design incorporated the entire range of planning, engineering and construction techniques included in the OVE system. It was a small house by modern standards — 952 square feet — since this is one means of reducing cost. It was the most basic form of house —single story, built on a crawl space foundation. In geographical regions with a level topography, a slab-on-grade design probably would have been used. It was rectangular in shape, based on a 2-foot module for efficient material utilization. It had only one bath, a compact utility closet and an efficient kitchen, all clustered around a common plumbing wall. Structural components were engineered to their full potential, and construction details were simplified throughout.

An experienced small volume home builder was selected to build

*Optimum Value Engineered Building System, Contract No. H-1315, Dept. of Housing and Urban Development, January 1973.

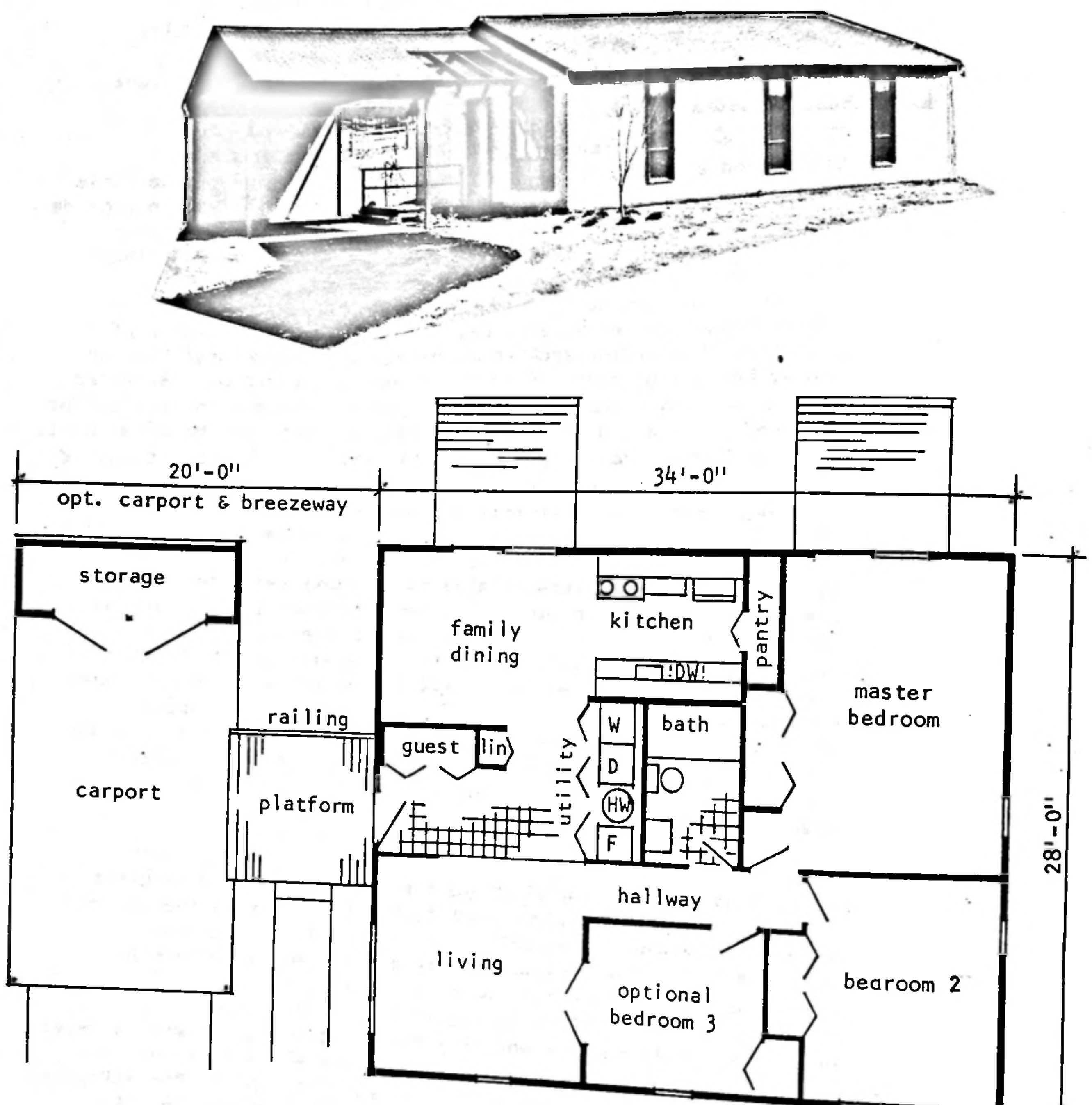


FIGURE 1-A. OVE prototype house built to demonstrate the OVE building system.

the prototype house. Most building code approvals were obtained under the performance provisions of the local prevailing BOCA Basic Building Code on the basis of engineering and test results. A 34-day schedule was prepared for on-site construction of the house. Construction of the house was observed continuously, and material, time and methods studies were conducted by NAHB Research Foundation industrial engineering personnel.

Detailed labor and material requirements for a comparable conventional house were then developed using industrial engineering methods. Labor and material costs for the conventional house were compared with those of the OVE prototype house. Cost determinations for both the conventional and OVE houses were based on direct labor and materials actually required to construct the houses.

A total direct cost savings of more than 12 percent was found for the OVE house. Of this total, 69 percent was in material and 31 percent in labor. Framing and related items, such as sheathing and siding, was the largest major category of savings, representing 65 percent of total savings. This was followed by foundation savings - 13 percent, mechanical systems - 11 percent, and other - 11 percent. The "other" category included such items as interior trim and paint.

If applied universally, this order of reduction in labor and materials would release these limited resources to provide approximately one additional housing unit for every ten presently built. At the same time, it would place all new housing within easier reach of home buyers.

Although the OVE prototype house provides a dramatic example, the cost-reducing techniques employed are by no means limited in application to this particular house design. Modifications of the plan were developed to demonstrate adaptability to other architectural styles and other housing types such as duplex, fourplex, garden court and townhouses. Application to both on-site and prefabricated building methods was also demonstrated.

The versatile nature of the OVE system becomes apparent as it is studied. The "system" is actually a series of complementary planning, engineering and construction techniques that may be used together or separately. This Manual explains each technique so that a builder may fashion his own "system" by selecting the OVE techniques that best suit the conditions under which he operates.

2. MODULAR PLANNING AND DESIGN

2.1 General

Modular dimensioning and coordination is the most fundamental principle to be observed in Optimum Value Engineered design. Standard dimensions of common building materials are considered in the size and shape of the overall plan in order to minimize scrap and waste.

Framing members in the floor, wall and roof are also coordinated with standard material dimensions and with each other in the OVE concept to provide an efficient structure. Openings in the floor, wall and ceiling — such as doors, windows, stairwells, etc. — are in turn coordinated with framing members wherever possible. Similarly, mechanical components are planned to avoid interrupting structural members.

Development of the floor plan is one of the major design requirements. Interior layout is not limited by the OVE concept. The use of clear-span, engineered roof trusses permits maximum freedom in arranging interior nonload-bearing partitions.

Exterior design is another important design requirement. Generally, a functional, no-frills treatment is encouraged for cost-effectiveness, but where the market requires, OVE does not preclude any reasonable design, whether traditional or contemporary, as long as the additional cost is consciously weighed and considered acceptable.

2.2 Material Utilization

Most materials used in home building are produced in some multiple of 2 feet. This includes lumber, plywood, fiberboard, various siding products and other finish items (see Figure 2-A). This fact must be considered in planning for efficient material utilization. A house laid out to utilize available materials to the fullest extent possible will cost less per square foot.

Since most building materials are produced in some multiple of 2 feet, it follows that a plan that is laid out in multiples of 2 feet will provide for efficient material usage in the floor construction as well as exterior walls and roof. For example, a plan dimension that is not a multiple of 2 feet will require just as much material for the floor, walls and roof, and even more labor (for cutting and fitting) than if the dimensions were increased to the next full 2-foot module. Where cutting is necessary with modular dimensioning, the resulting cutoff will be in some multiple of 2 feet and usually may be used elsewhere.

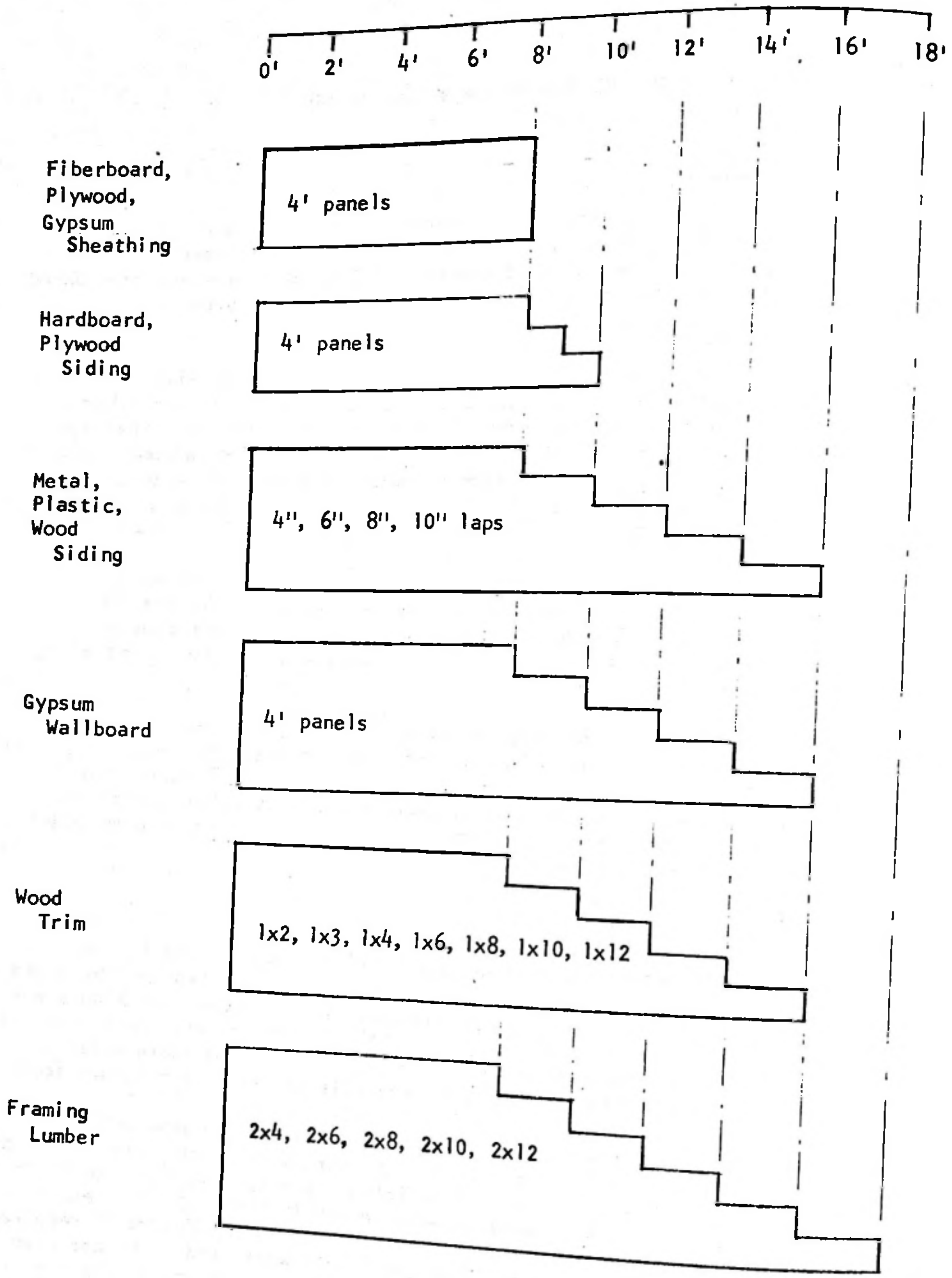


FIGURE 2-A. Standard sizes of common building materials

Since plywood, fiberboard and other 4-foot-wide panel products are generally used to cover the floor, wall and roof, a plan laid out in 4-foot multiples will provide the greatest possible efficiency. A 4-foot multiple is desirable wherever practical; otherwise, the more versatile 2-foot module provides greater design freedom.

2.3 Plan Configuration

A modular planning grid that represents a 2-foot module superimposed on a 4-foot module is shown in Figure 2-B. In practice, the planning module is applied to the overall floor plan so that the outside dimensions of the floor or wall construction are in some multiple of 2 feet. This permits full utilization of floor, wall and roof covering materials. Interior dimensions are not controlled by the 2-foot planning module.

The most efficient plan configuration is a basic rectangle. A rectangular plan has only four corners joined by four straight walls and provides for simple floor and roof structures. Theoretically, the most effective rectangular shape is a square, since it encloses the greatest amount of floor area for a given length of exterior wall. Realistically, however, the depth of a rectangular plan is limited to economical spans for the floor and roof systems, normally ranging between 24 and 32 feet.

With a practical limit on plan depth, length may be extended to the dimension necessary to provide the floor area desired. Figure 2-C shows a series of alternate rectangular shapes, each enclosing approximately 1100 square feet. Plan "C" represents a particularly efficient solution. This plan measures 28'x40', a multiple of 4 feet in both directions. It encloses 1120 square feet of floor area with a comparatively high ratio of floor area to lineal feet of exterior wall. It provides for economical floor and roof spans, the length-to-depth relationship furnishes a desirable scale from a design standpoint, and the 28' depth provides good design flexibility.

A simple rectangular plan will accommodate a wide range of house styles and sizes. In combination with 2-foot modular dimensioning, it greatly simplifies construction and insures efficient material utilization. Any deviation from the basic rectangle creates additional corners and reduces the ratio of floor area to linear feet of exterior wall. It also complicates floor and roof construction. A rectangular plan should receive first consideration and should be used whenever possible.

Where some relief from the basic rectangle is considered desirable from a marketing standpoint, this may often be accomplished by the simple expedient of cantilevering a portion of the floor out over the foundation or lower story. This is a relatively uncomplicated and inexpensive way in which to provide design variation, since it does not alter

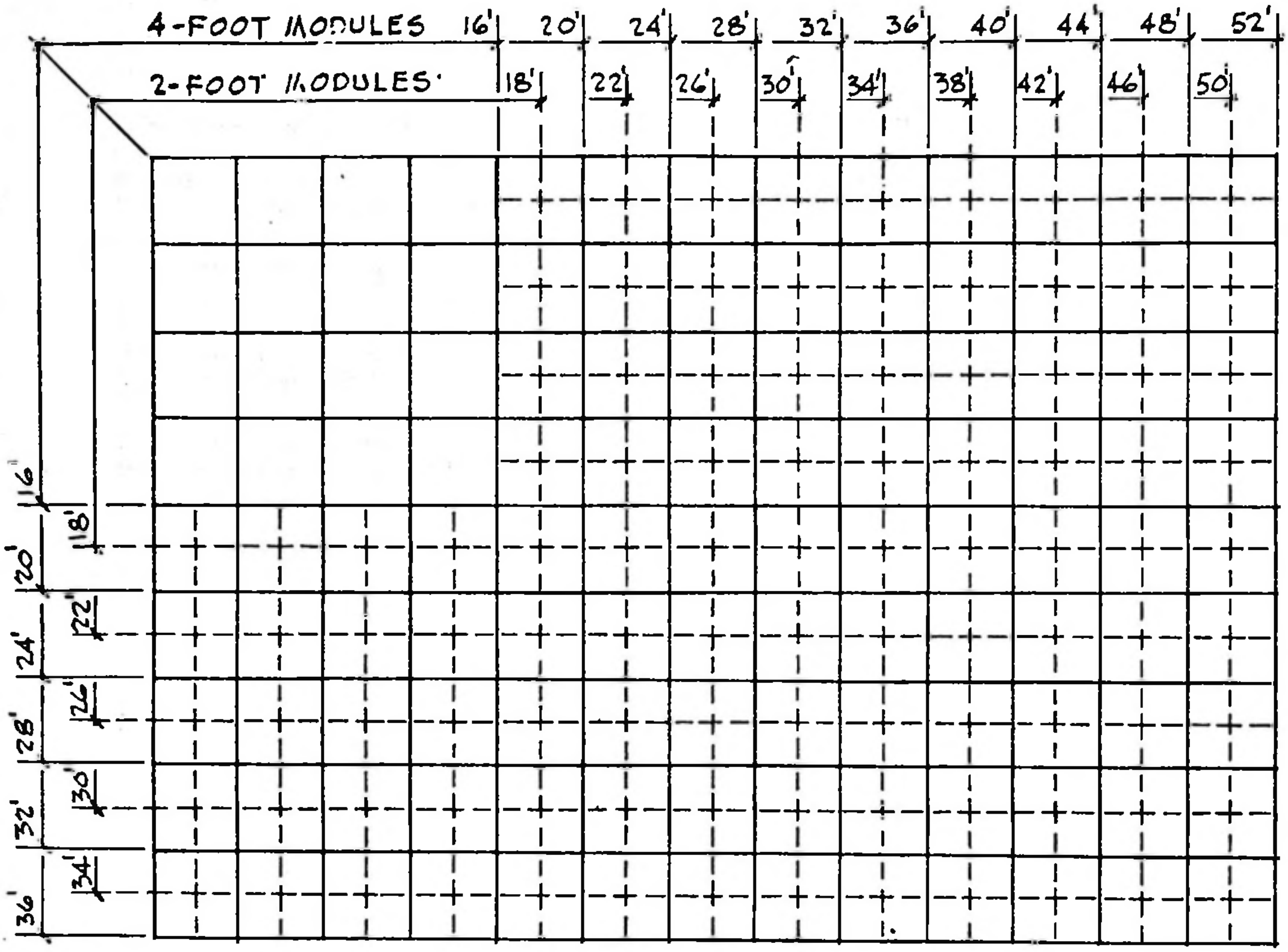
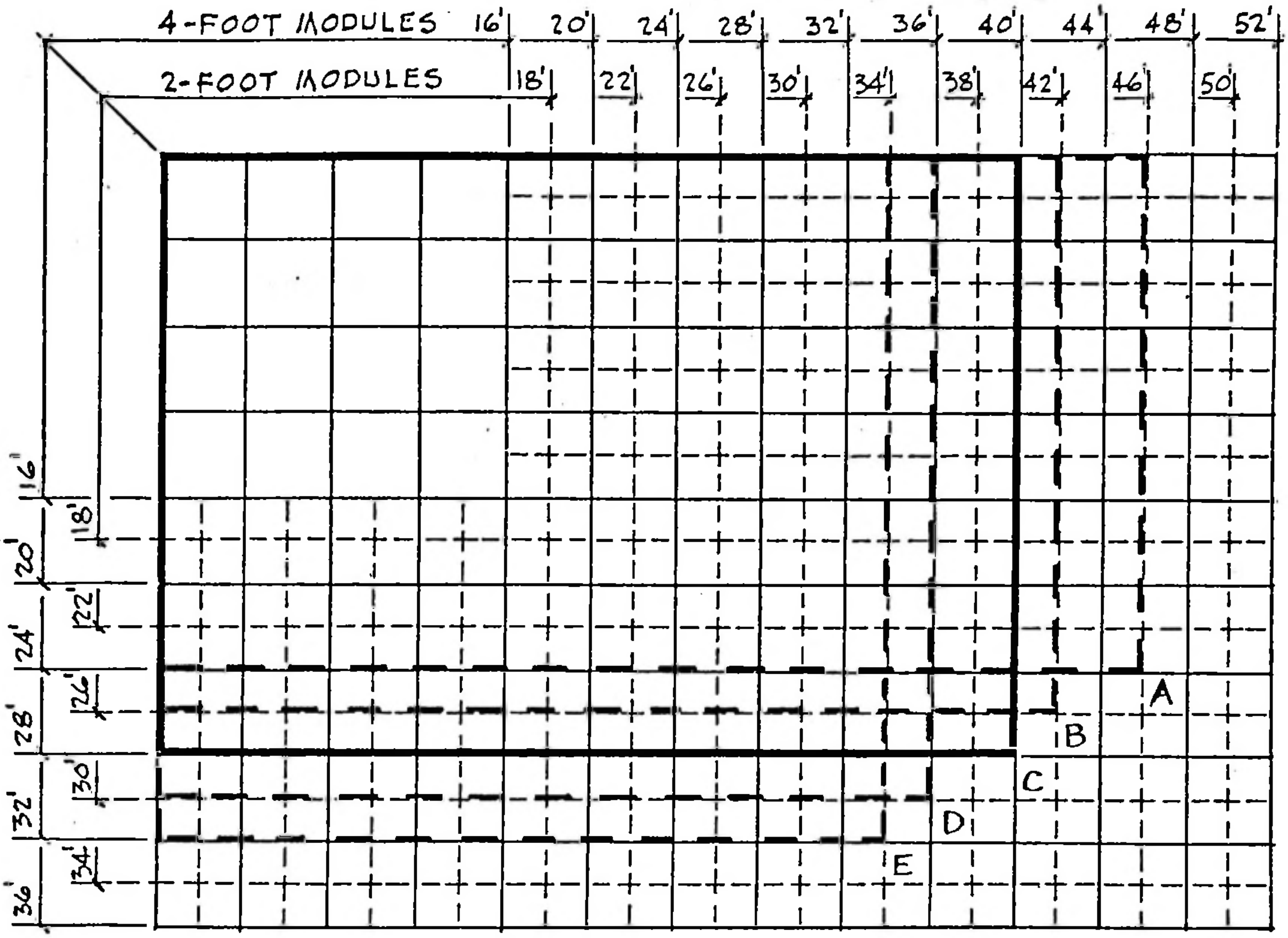


FIGURE 2-B. OVE planning grid provides for both the 4' module, which is the most efficient, and the 2' module, which affords greater design latitude where desirable.



Problem: Select most economical rectangular shape with approximate floor area of 1,100 SF

Alternatives:

Plan	Size		Floor Area		Exterior Wall	Ratio Floor/Wall
A	24x46	=	1104 SF	=	140 LF	7.89
B	26x42	=	1092 SF	=	136 LF	8.03
C	28x40	=	1120 SF	=	136 LF	8.24
D	30x36	=	1080 SF	=	132 LF	8.18
E	32x34	=	1088 SF	=	132 LF	8.24

Selection: Plan C is the most efficient, with a high ratio of floor area to exterior wall, and is based on the 4' module. It provides good scale from a design standpoint, and affords a practical span for floor and roof systems.

FIGURE 2-C. Example of selection of a modular rectangular plan shape

foundation dimensions or spanning conditions of the floor system. A 2-foot overhang is the most practical and is generally permissable structurally (see Figure 2-D).

Where a more pronounced variation is desired, two modular rectangles may be joined to form an L-shaped plan. Figure 2-E shows several variations enclosing approximately the same total floor area as the previous plans. Plan "AC" represents an effective solution because it affords a good ratio of floor area to exterior wall with a minimum of additional corners, and furnishes a desirable balance from a design standpoint. Often, an attached garage may be joined to a rectangular house to provide the effect of an L-shape without altering the house itself. The same modular dimensioning principles apply to garages and carports as to houses. Plan configurations such as the T-, U- or H-shape involve numerous corners and complicated floor and roof constructions, and add disproportionately to cost.

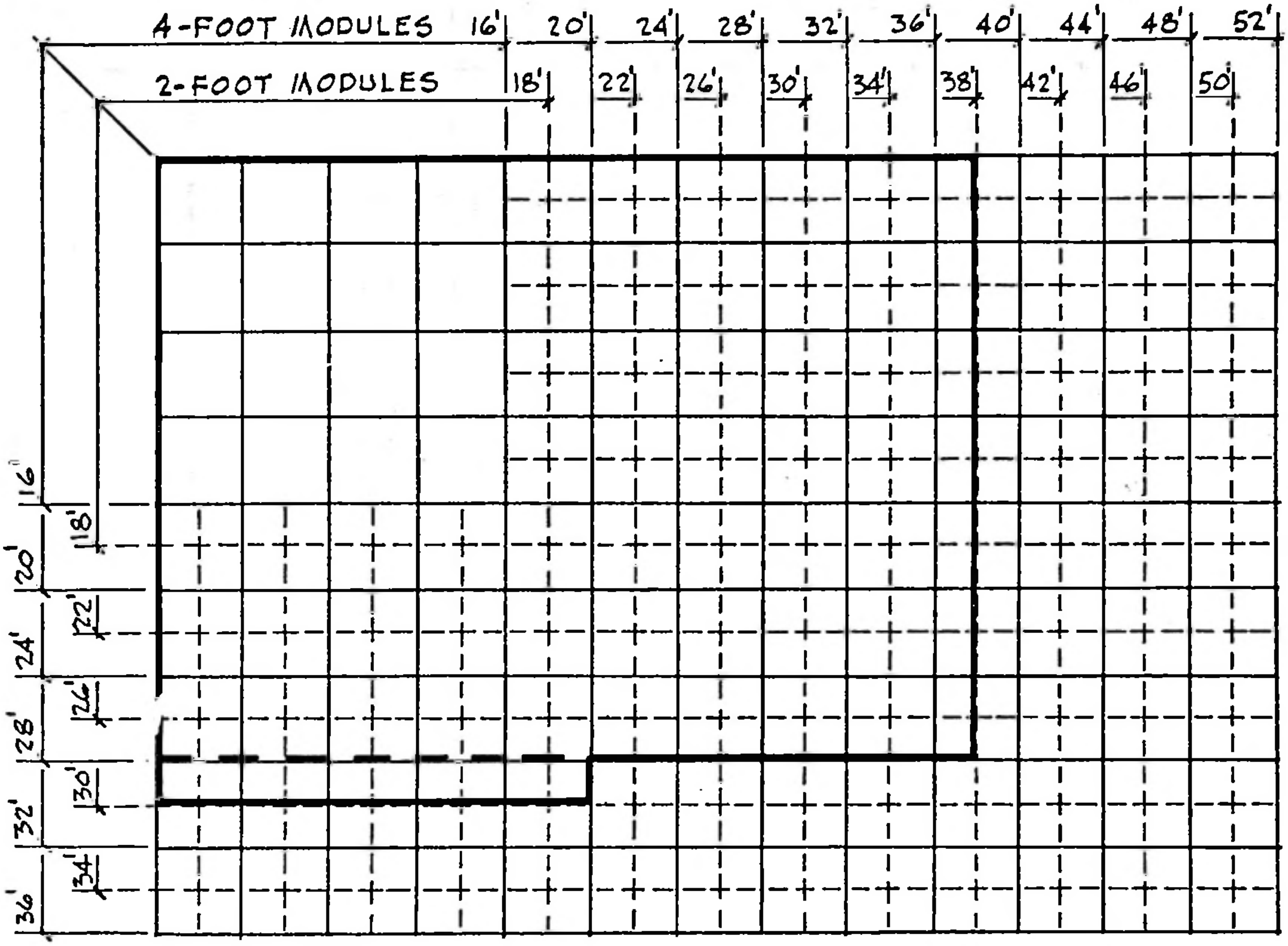
The plan configuration selected in any given case should provide the best possible economy of enclosed area within the limits of marketing requirements. The basic rectangle should always be considered first and discarded reluctantly when cost-to-value ratio is the predominant consideration. Possible floor and roof framing complications should be carefully considered with any plan configuration. To minimize complications, consider solutions that permit all floor joists and all roof trusses to run in the same direction. Do not exceed practical span limitations.

2.4 Framing Coordination

A 24-inch on center spacing is part of the OVE concept for all floor, wall and roof framing. This spacing corresponds to the 2-foot planning module for efficient use of framing materials.

When all floor, wall and roof framing is coordinated at a 2-foot spacing, the respective members bear directly over each other (see Figure 2-F). This results in a more efficient structure and permits reduction or elimination of some framing members used to distribute loads, as will be seen later. Vertical alignment of framing members also simplifies planning of mechanical risers, such as flues and plumbing stacks, that must pass through the structure.

The 2-foot spacing reduces the number of framing members to be handled in the field by one-third compared to the traditional 16-inch spacing. Coincidentally, it reduces by the same proportion the number of fastenings required to attach surfacing materials to the framing. The even 2-foot multiples also greatly simplify layout. Carpenters can think in terms of

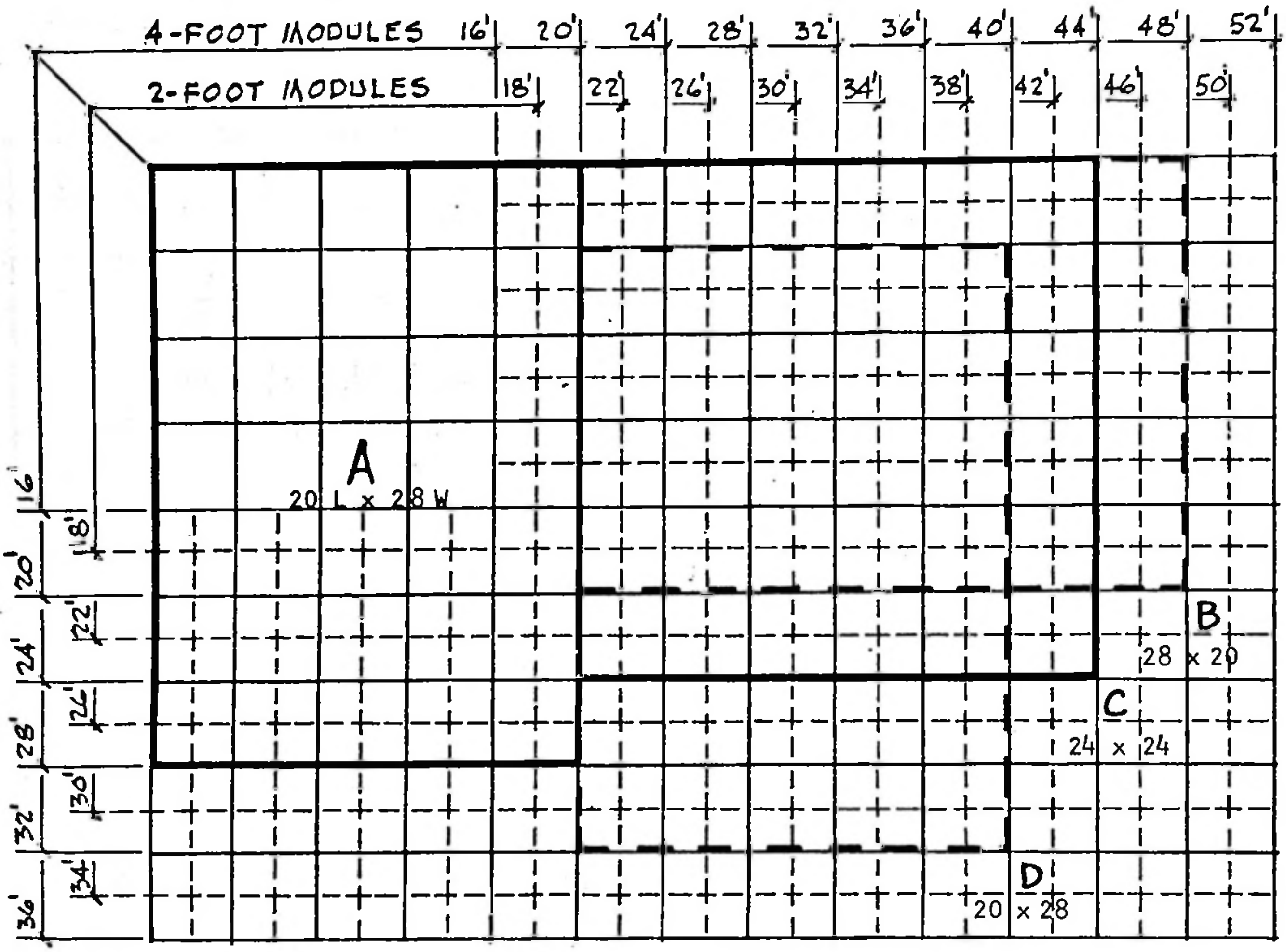


Problem: Provide the least expensive variation on a simple rectangular plan with approximately 1100 SF floor area

Solution: Cantilever a portion of floor 2 feet out over foundation to provide an offset in front elevation

Result: Floor area = 1104 SF
Exterior wall = 136 LF
Ratio Floor/wall = 8.12

FIGURE 2-D. Variation of an OVE rectangular plan formed with cantilevered floor



Problem: Develop economical L-shaped plan with approximately 1100 SF total floor area

Alternatives:	Plan	Floor Area		Exterior Wall	Number Corners	Ratio Floor/Wall
	AB	1120 SF	=	152 LF	6	7.37
	AC	1136 SF	=	144 LF	6	7.89
	AD	1120 SF	=	144 LF	8	7.89

Selection: Plan AC provides greater floor area with minimum number of corners and a favorable ratio of floor area to exterior wall.

FIGURE 2-E. L-Shaped OVE plan formed by joining two modular rectangles.

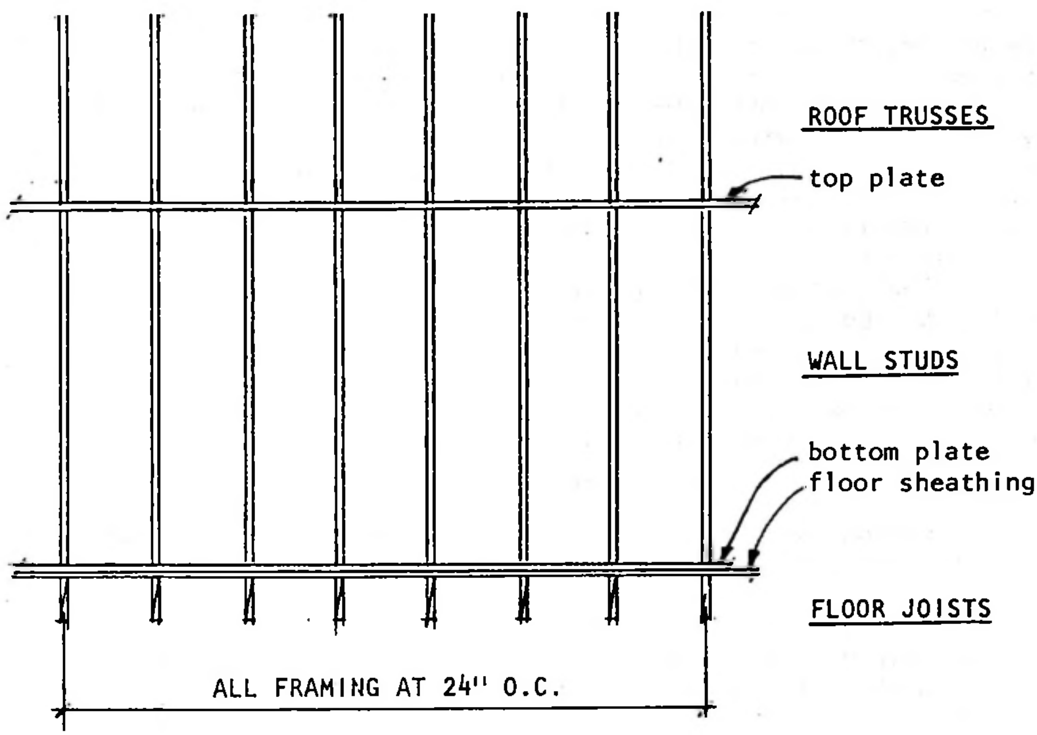


FIGURE 2-F. Coordination of all framing members at 24" on center simplifies framing and permits loads to be transferred directly down through the structure .

2, 4, 6 and 8 feet instead of 16, 32, 48, 64, 80 and 96 inches. It is much easier to make field calculations which reduce the chance for error.

In the OVE system, preliminary layouts are prepared for the floor, wall and roof framing early in the planning stage. This helps in determining the most economical plan configuration, and provides a basis for developing the floor plan and exterior design.

2.5 Developing the Floor Plan

The layout of interior space to create the various rooms, closets, passageways, etc., is a major design responsibility The designer must exercise his skill in preparing a series of preliminary layouts until a particular scheme is agreed upon.

The location and arrangement of partitions is not limited by the OVE concept. Since clear-span roof trusses are considered to be part of OVE design, interior nonload-bearing partitions may be located without regard to structural requirements. There are, however, some practical considerations which should be taken into account in locating and arranging partitions, as noted in the following sections.

Nonload-bearing partitions may be framed with 2x3 studs, as discussed in Chapter 7. The cumulative additional usable floor area thus gained over conventional 4-inch partitions is significant. However, it is sometimes necessary to provide a 4-inch or 6-inch plumbing wall to accommodate the vent stack and other piping.

2.5.1. Mechanical Requirements

One of the primary considerations in a cost-effective plan is the plumbing and heating/cooling layout. An OVE plan should include provision for the necessary equipment and flues, ducts, pipes, vents, etc., to avoid subsequent coordination problems in the field. Electrical requirements should also be considered at the planning stage.

Plumbing facilities, such as for the kitchen, laundry, bathrooms and water heater, are clustered together as closely as possible on the OVE plan to minimize piping and fittings. If there is more than one story, bathrooms and plumbing facilities should be stacked vertically. The kitchen, laundry and bathrooms can all be served with a single vent stack with OVE planning. Where there is more than one story, special care should be taken to align walls in the different levels to provide a clear vertical path for the stack to the roof. It is important to plan the location of the stack to avoid interrupting structural members. It is also best to avoid locating the plumbing stack in an exterior wall because of structural and insulation considerations. If it is possible to concentrate all or most plumbing in one single wall, a prefabricated plumbing wall may be possible.

Generally, OVE planning calls for placing heating/cooling equipment in a central location on the floor plan to provide for good air distribution and to minimize duct runs (assuming a forced air system). Equipment sizing and design of the system itself depend on heat loss and heat gain properties of the total house design. Specifications for insulation, windows, doors, etc., that reduce heating/cooling energy requirements are strongly recommended. Vertical or horizontal chases may be necessary for ducts, flues or returns. These must be incorporated into the plan to avoid subsequent complications. Vertical chases are especially important. Ample space for the necessary flues and ductwork is essential.

The electrical layout is also preplanned in the OVE concept to minimize the number of switches, fixtures and outlets. Switches and fixtures are used only where required. Switches are located close to fixtures and three-way switches are avoided if possible. The service panel is located close to the kitchen and/or utility area to minimize the length of heavy wiring.

2.5.2. Stairway and Access Planning

Stairways and other openings that penetrate the floor or roof structure are particularly important in laying out the floor plan. Such openings should be located so as to interrupt as few structural members as possible for obvious reasons.

Straight run stairs are the most cost effective, and are used in OVE design whenever possible. The stairs should be oriented parallel to floor joists so that only one joist need be interrupted with a 24-inch on center joist spacing. Also, floor framing is simplified if the stair opening is coordinated with a modular joist location on at least one side. The stairway should never interrupt a structural beam or bearing wall in OVE design.

The use of a 7'-6" OVE ceiling height (discussed in greater detail in Chapter 5) will often permit a stair design with only 12 risers and 11 treads, which is one less than with a conventional 8'-0" ceiling height. The resulting shorter stair run affords greater latitude when locating the stairs in tight design situations.

Access openings to attics, crawl spaces and similar spaces should also be located to avoid interrupting framing members. The 2-feet on center spacing of these members generally provides ample clearance for access. However, special attention is necessary to assure that a closet, hallway or other suitable location is available for the access opening so that it may be located between framing members.

2.5.3. Room Size and Arrangement

In the OVE concept the designer strives for a simple, uncomplicated room layout with the minimum number of openings, corners, offsets, etc. The use of "open planning" in living areas helps to reduce the total lineal feet of interior partitions and lends a more spacious feeling, especially important in smaller homes.

Room sizes and other spatial dimensions will vary widely, depending on size of the home and the market preference. However, since one important way to reduce the cost of a home is to reduce the size, it is appropriate to suggest some practical minimums as shown in Table 2-1. Some of these suggested minimum criteria may not conform to prevailing local codes or standards, but they are believed to represent realistic dimensions for basic housing where affordability is of critical concern.

By judicious application of the above minimum criteria, it is possible to design an adequate home having a habitable floor area of less than 900 square feet, with 2 bedrooms, less than 1,000 square feet with 3 bedrooms, and less then 1,200 square feet with 4 bedrooms. Some of the suggested minimums may be applied advantageously in the design of larger homes as well.

2.6 Exterior Design

Architectural design of the exterior elevations is the second major design responsibility. The exterior design, together with the floor plan, determines the character of the total design. Exterior design is a very important marketing factor. However, it is also an important cost factor.

The OVE concept will accommodate a wide range of exterior architectural styles from contemporary to traditional. However, a functional treatment is generally the most cost-effective since it avoids extraneous details and permits materials to be used to their best advantage. Additional costs of more detailed treatments should be carefully weighed against their marketing value. Traditional styles, where required, may often be accomplished at relatively little extra cost through competent design.

2.6.1. Architectural Elements

Exterior design options relate primarily to exterior walls

TABLE 2-1. Suggested minimum space criteria

LIVING ROOM	160 SF - 11'-0" Minimum dimension
KITCHEN	60 SF - 6'-6" Minimum dimension 3'-0" Minimum clear passage Total base and wall cabinet shelving 40 SF, Countertop 15 SF, Drawers 10 SF
COMBINED DINING AREA	70 SF - 7'-6" Minimum dimension
SEPARATE DINING ROOM	100 SF - 8'-4" Minimum dimension
MASTER BEDROOM	120 SF - 9'-4" Minimum dimension
SECONDARY BEDROOMS	80 SF - 8'-0" Minimum dimension
BATH	Enough area to accommodate: 1 - tub 1 - water closet 1 - lavatory 35 SF - 5'-0" Minimum dimension
LAUNDRY	5'-0" minimum space for side-by-side washer and dryer
CLOSETS	BR's - Average 4 LF - 1'-10" clear depth Provide for linen storage "Guest" closet 3 LF - 1'-10" clear depth
GENERAL STORAGE	200 CF Basic - plus 75 CF per BR Accessible attic, basement crawl, excess closets, cabinets, etc., may be included
STAIRS	Width 2'-8" clear Head room - min. 6'-4" Rise - max. 8'-1/4" Run - min. 9" Landing - min. 2'-6"
HALL	Halls - 2'-8" minimum width
DOORS	Primary Entrance 3'-0" x 6'-6" Service 2'-8" x 6'-6" Bath 2'-0" x 6'-6" Closets As required Interior passage 2'-6" x 6'-6"
CEILING HEIGHTS	Habitable area 7'-6" Baths - Utility 7'-0" Basement 6'-8" Halls 7'-0"

and, to a somewhat lesser extent, the roof. The use of a clear span trussed roof is a significant specification in the OVE system. A straight gable trussed roof is the most cost-effective; however, truss systems will accommodate other roof forms where considered necessary.

Architectural elements of concern in exterior walls include siding, trim, doors and windows. The most cost-effective exterior covering is a single-layer structural panel siding fastened directly to studs, as discussed in Chapter 5. However, any nonstructural siding material may be used over a suitable sheathing at some additional cost. Trim at windows, doors, soffit, rake, etc., should be minimized and details simplified. Standard prehung entrance doors save installation time and minimize air infiltration to conserve energy.

Fenestration is probably the most significant factor in adapting the OVE concept to variations in styling. The special 24-inch modular width window units, as discussed in Chapter 5, are designed to fit between studs, and greatly simplify construction where suitable. Horizontal sliders, double hung or other window types, produced in 24-inch modular width increments to fit between framing members also reduce cost by minimizing requirements for extra framing material and labor.

Regardless of the type of window used, variations in size should be minimized. Two or three different sizes generally provide adequate design latitude. The number of door and window openings in the exterior wall should also be minimized to simplify construction and reduce air infiltration. Wall framing is further simplified and made more cost effective if door and window openings are coordinated with modular stud locations on at least one side.

2.6.2. Exterior Design Variation

Although standardization is an important means of controlling costs in production building, not every unit need look identical. There are many opportunities for variation which involve land planning and landscaping as well as design. Table 2-2 represents design variation techniques relating to these environmental factors.

2.7 Working Drawings

The final responsibility of the designer is to prepare a detailed set of working drawings. The primary purpose of working drawings is to convey all necessary information that is pertinent to the construction process.

Working drawings provide the basis for material takeoffs, cost estimating, and subcontractor bidding, as well as construction.

TABLE 2-2. OVE design variation techniques

Land Planning

- street configuration
- lot size and relationships

House Siting

- zero lot line
- varied setbacks
- reverse plan
- 90° turn
- angle to street

House Design

- roof type -- gable, hip mansard, etc.
- roof pitch, overhang
- siding materials
- entrance
- windows
- trim/details
- colors

Attachments/Additions

- carport/garage
- porch/deck
- portico
- L-addition
- stretch addition

Landscaping

- grading
- retaining walls
- fences/screening
- paving — drives, walks, patios, etc.
- rocks, boulders, logs, etc.
- trees, shrubs, ground cover, etc.

Without fully detailed drawings, subcontractors may be expected to bid higher to cover any uncertainties. However, the drawings should not be cluttered with information which is irrelevant to the construction process. It is especially important to avoid extraneous notes, calculations, details, etc., which would tend to confuse the field trades.

Standard sheet sizes used for drawings of single-family home designs include 11"x17", 18"x24" and 24"x36". The smaller size, although convenient to use in the field, will not be adequate in many cases. The larger sheets, on the other hand, are difficult to handle under job-site conditions, and may contain too many details per sheet which can contribute to confusion. A standard sheet size of 18"x24" is generally adequate for single-family house plans, and is used for OVE drawings where suitable.

A typical set of working drawings includes the following sheets:

1. Floor Plan
2. Exterior Elevations
3. Foundation Plan
4. Section and Details
5. Framing Plans
6. Mechanical Layouts

Although the above order is typical, it is not mandatory that the sheets appear in this sequence. In some cases, it will be possible to include more than one of these items on a single sheet. In other cases, certain items may require more than one sheet. The main concern is simply to arrange these essential drawings in a logical fashion without crowding. Insofar as possible, each sheet should include all information required for a particular trade or phase of construction. Details, dimensions, notes, etc., for any given trade or operation should not be needlessly scattered through a set of drawings.

2.8 Specifications

The designer may or may not be called upon to develop a detailed list of specifications for the materials and products required for each house design. The basic specifications for major items - such as framing lumber, concrete, doors and windows, heating/cooling equipment, etc. - should be noted on the appropriate drawing.

Generally, the builder wants to participate directly in decisions concerning more detailed specifications including flooring, cabinets, fixtures, appliances, and other high-cost finish items. The specifications for such items can have considerable impact on building costs on the one hand and marketing objectives on the other. Therefore, the builder's estimating, purchasing, construction and marketing personnel should also be consulted.

In developing a detailed list of specifications, it is advisable to adopt or develop a standard form to insure that all pertinent items are considered in each case. HUD/FHA Form 2005, "Description of Materials," is an outstanding example of such a form which is widely used in the industry, whether or not HUD-insured financing is involved. This specification form, or one modeled after it, is considered to be an important element in the OVE concept.

3. FOUNDATION CONSTRUCTION

3.1 General

Optimum Value Engineered construction begins with the foundation. The foundation is the most variable portion of the structure. The optimum foundation will depend on such factors as climate, soil, topography and building loads. Marketing preferences also need to be considered in determining whether a concrete slab-on-grade, crawl space or basement type foundation is used.

Where primary emphasis is placed on habitable living area, it may be advisable to consider a basementless slab-on-grade or crawl space foundation. The slab-on-grade construction adapts best to fairly level building sites, and may offer the least costly alternative, especially in warmer climates where footings are minimal. The crawl space foundation offers additional flexibility in sloping terrain, and may be preferred where the local market does not favor concrete floors.

In many areas, however, a basement is still preferred. This is particularly true in colder climates where the winter season requires additional space for indoor activities. A basement can offer this type of space at a relatively low cost per square foot, especially where the frost depth requires a deeper foundation.

3.2 Foundation Layout

The accuracy of the whole structure is governed by the foundation. It is worth special effort to assure construction of a foundation that is square, level and accurately dimensioned. This will help to reduce framing and trim labor during construction, as well as air infiltration in the finished structure.

Regardless of foundation type, overall dimensions and layout should be in accordance with modular planning guidelines as discussed previously. However, holding the foundation slightly undersize will permit the balance of the structure to be built to specified dimensions even if there are minor inaccuracies in the foundation.

3.3 Footing Design

Most foundations require some form of footing to distribute building loads to the underlying soil. Conventional footings are generally required to be much larger than necessary.

In OVE design, the total building load at the bottom of the footing should ideally be balanced against the allowable bearing capacity of the soil. Therefore, two factors must be considered to properly engineer the optimum footing size:
1) Total live and dead design load of the building; and
2) Allowable bearing capacity of the soil.

Design loads for any building depend on the weight of the actual structure as well as that of the people, furnishings, etc. which are to occupy the building. Total design load, then, is determined by adding together the dead loads of the structure and the live loads of occupancy, which are assumed for engineering purposes (see Figure 3-A). For wood framed single-family homes, total design load at the foundation wall footing does not generally exceed 1,500 lbs./LF for one story, or 2,000 lbs./LF for two stories and may be much less. Similarly, total design loads on center girder support columns do not generally exceed 9,000 pounds for one story, or 20,000 pounds for two stories.

Soil bearing characteristics may vary substantially from one location to another. Local soil characteristics are often known with sufficient reliability to serve as a basis for footing design. Where it is suspected that locally accepted values are unrealistically low for a particular site, it may pay to obtain more detailed data from on-site tests conducted by a soils engineer. Typically, allowable soil bearing capacities range between 1,500 and 3,000 psf. Soils with an allowable bearing capacity of less than 1,500 psf are not very common, whereas soils with a bearing capacity of more than 3,000 psf are not unusual.

Optimum value engineered footing design for a particular building design load consists simply of balancing the load per square foot of bearing area to the allowable load per square foot bearing capacity of the soil. Table 3-1 shows footing widths for various building loads and soil capacities. Practically speaking, footings at least 2 inches wider than the wall are necessary to provide some field tolerance for wall placement.

Table 3-2 shows footing sizes for center girder support columns or piers for various loads and soil bearing capacities, although accepted engineering practice will often permit a 1/6 reduction in the required bearing area for pier or column footings. Where this is determined to be the case, the values in Table 3-2 may be reduced accordingly.

The thickness of a standard concrete footing is controlled by the amount of projection beyond the wall, pier or column that it supports (see Figure 3-B). A footing thickness of at least 6 inches or the amount of projection on each side of the wall, whichever is greater, is usual with 2,000 psi concrete mix. Thickness may be reduced if the footing is properly reinforced, as determined by a qualified engineer. Reinforcing is particularly advantageous with thicker column footings.

The minimum depth to the bottom of the wall footings is controlled primarily by local frost conditions. Footings normally extend to or below the frost line to prevent destructive heaving action

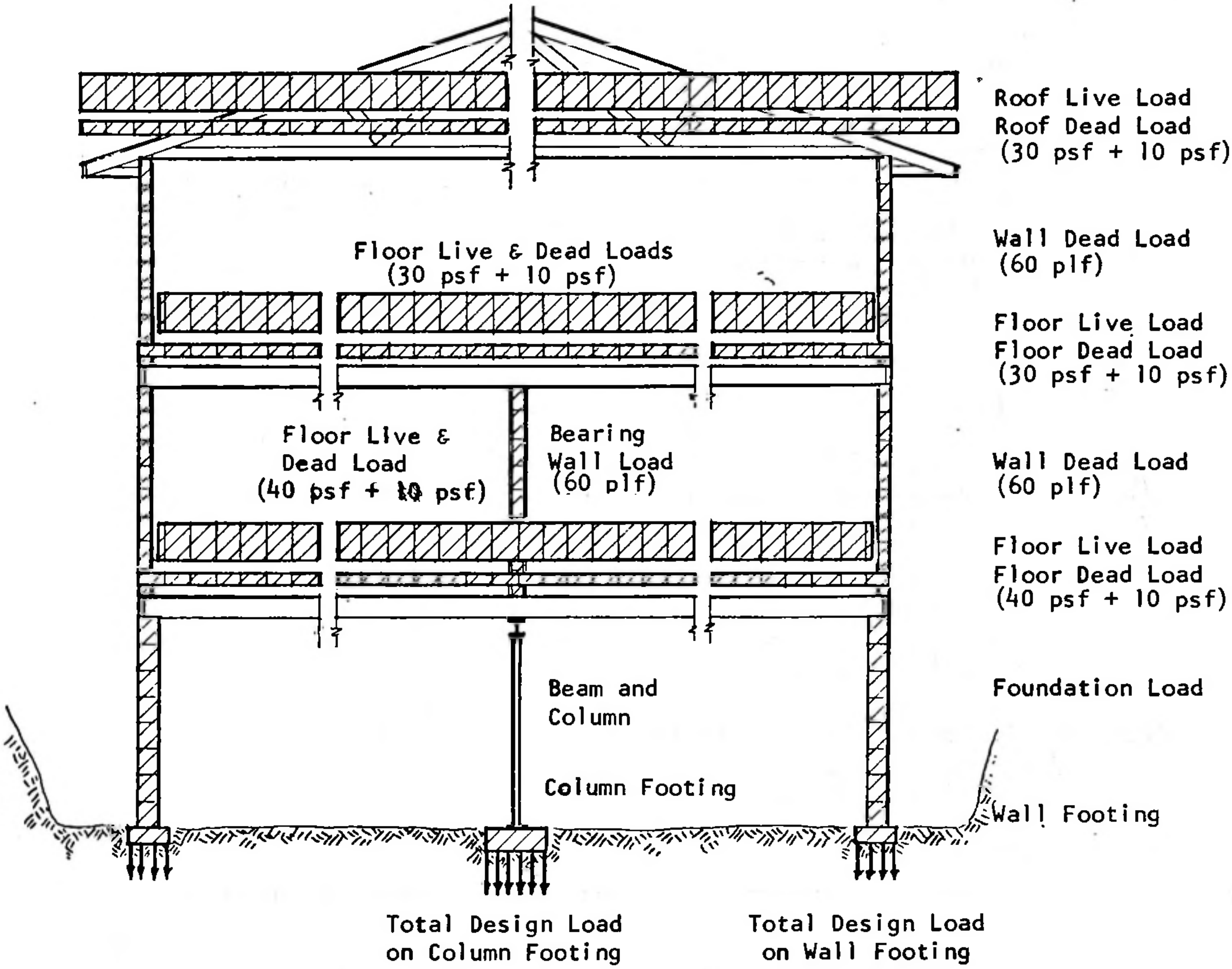


FIGURE 3-A. Example design loads acting on wall footings and column footings. Actual roof live load requirements vary with geographic location and local codes. In addition, earthquake and wind loadings must be considered in some regions.

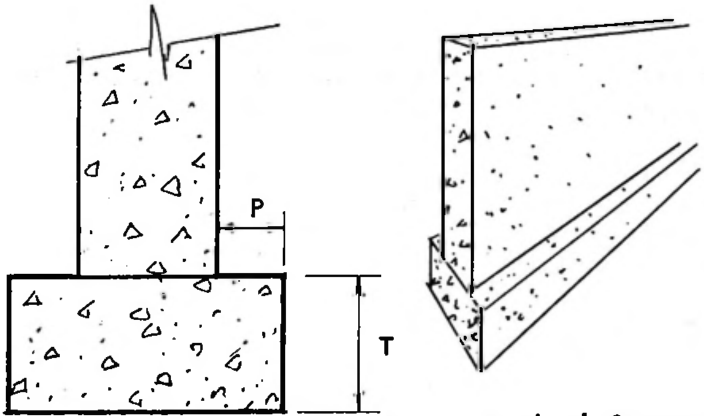
TABLE 3-1. Footing width for typical single-family dwelling loads

Footing Width in Inches				
Total Design Load lbs./LF Footing	Allowable Soil Bearing Capacity, psf			
	1500	2000	2500	3000
1,000	8	6	4.8	4
1,500	12	9	7.2	6
2,000	16	12	9.6	8
2,500	20	15	12	10

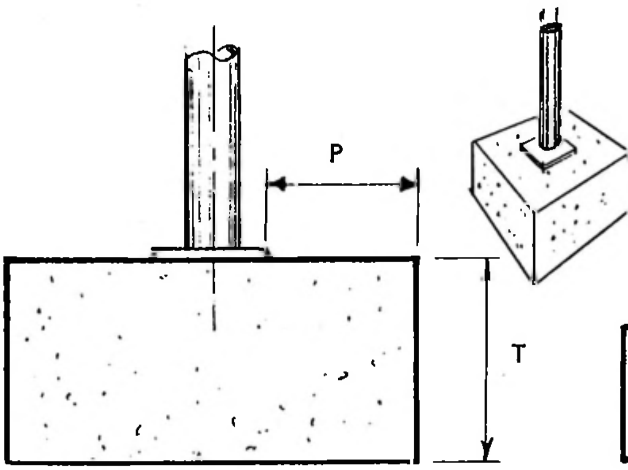
TABLE 3-2. Column footing size for typical single- family dwelling loads

Footing Size in Inches*				
Total Design Load, lbs.	Allowable Soil Bearing Capacity, psf			
	1500	2000	2500	3000
5,000	22x22	19x19	17x17	16x16
10,000	31x31	27x27	24x24	22x22
15,000		33x33	30x30	27x27
20,000			34x34	31x31

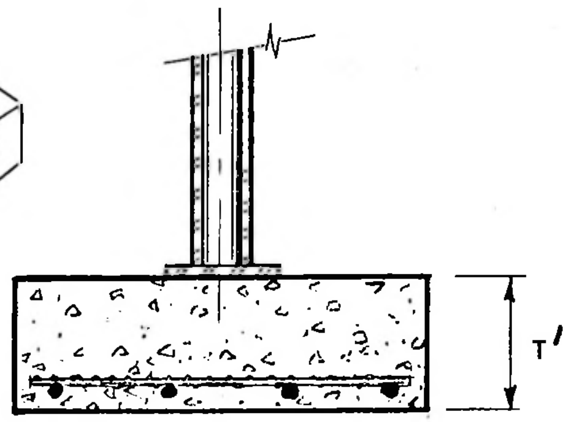
*Note: A one-sixth reduction in these sizes may be permissable under some codes and conditions.



Typical Concrete
Wall Footing



Typical Concrete
Column Footing



Section Through
Reinforced Concrete
Column Footing

FIGURE 3-B. Thickness for typical wall and column footings. Use a minimum 6-inch thickness (T) or the amount of projection (P), whichever is greater. Thickness may sometimes be reduced by the addition of reinforcing.

of frozen soil. Other local factors, such as ground water and certain soil types, may also affect footing requirements. Footings should normally extend down to original undisturbed soil. It may be permissable to bear on compacted fill in certain cases, but this should be determined by a qualified engineer.

Although the most widely used footing consists of a rectangular cross section of concrete placed in a trench, there are other methods of providing the necessary support. If the thickness of a solid concrete wall itself provides sufficient bearing, a separate footing may not be required at all. Where additional bearing is necessary, an integral footing may sometimes be created by flaring the bottom edge of a concrete wall. Pressure treated lumber may also be used as a footing with treated wood foundations. These variations are discussed together with associated foundation constructions in the following sections.

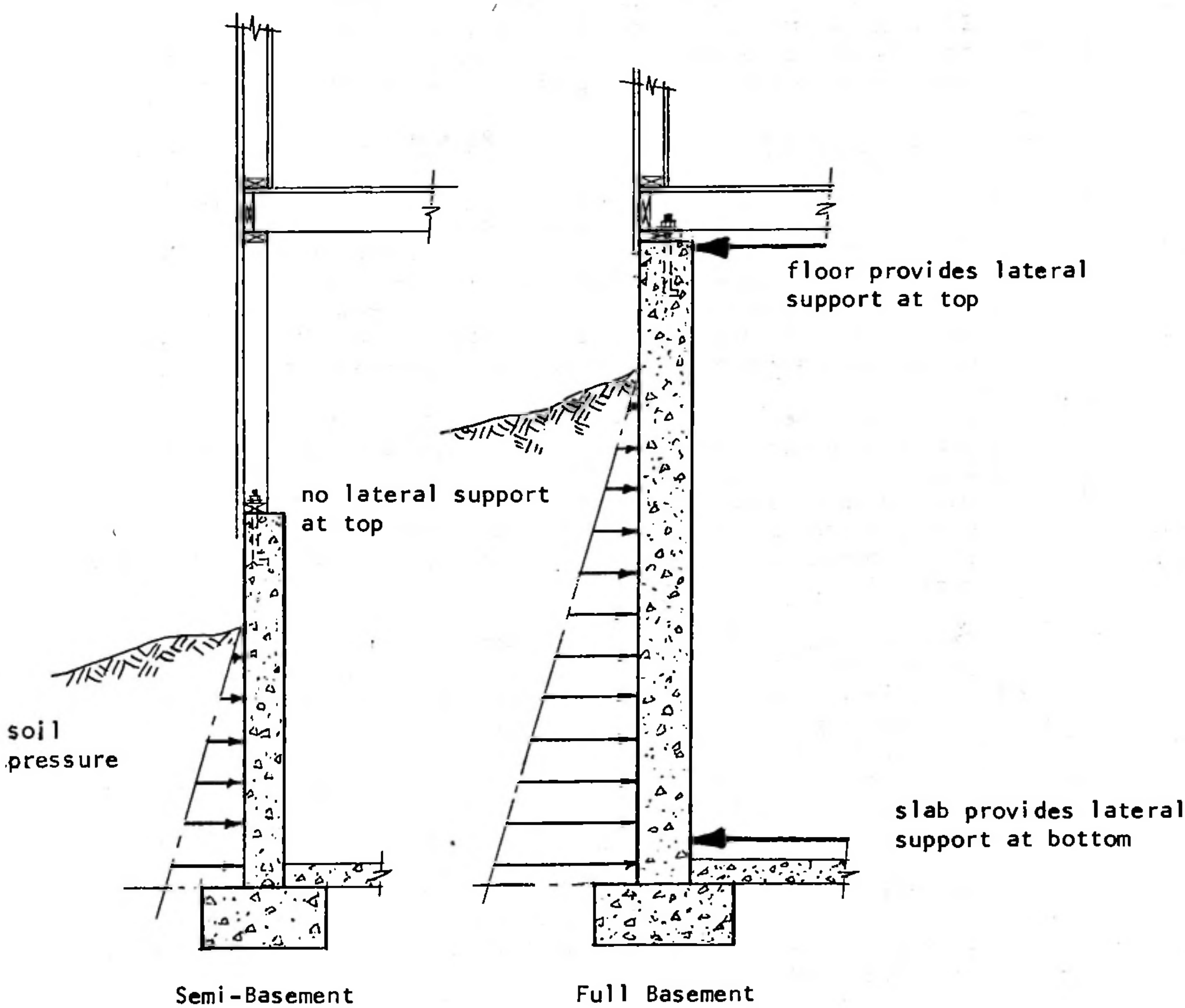
Regardless of what form a footing may take, the primary function is to distribute building loads to the underlying soil. Optimum Value-Engineered footing designs reflect a realistic balance between building design loads and the allowable soil bearing capacity

3.4 Basement Foundations

Basement walls may extend down to approximately 7 feet below finish grade. The controlling factor in structural design is the lateral pressure of backfill against the wall. Of course, the wall must also be capable of carrying the building design loads.

Basement walls are normally laterally supported against the soil pressure by the basement floor at the bottom, and by the first story floor at the top. However, in some semi-basement constructions, such as a split foyer design, the basement wall may not extend all the way up to the above floor, in which case it is not laterally supported at the top. Typical engineering practice assumes the soil pressure of a reasonably well-drained soil to be equivalent to a fluid weighing from 30 to 35 pounds per cubic foot (pcf), although this may range to over 100 pcf with certain soil, groundwater, grade and other special conditions. Therefore, the design load against a basement wall will typically increase from zero at finish grade to 200 psf or more at the level of a basement floor approximately 7 feet below grade (see Figure 3-C). Basement walls in flood-prone areas may be subject to substantially greater loads, requiring special engineering design solutions.

Basement walls in single family homes are usually constructed of either concrete block or plain concrete, although reinforced concrete is sometimes used. More recently a pressure treated wood construction has gained acceptance in some areas. The optimum basement wall design will depend on several factors in any given case. Current costs of alternate materials and labor



Note: Earth pressure at any given point is equal to equivalent fluid pressure of the soil multiplied by the height of backfill above that point

FIGURE 3-C. Earth pressure diagrams showing relation of load to height of backfill

are primary factors to be considered. Some designs may offer other benefits such as faster construction time, less dependency on weather or adaptability to site conditions. All such factors should be carefully weighed in selecting the optimum basement construction for any particular set of conditions.

3.4.1. Concrete Block and Formed Concrete Basements

Certain basement wall constructions of concrete block and unreinforced (plain) concrete have evolved over a long history of use in home building. Where these constructions have demonstrated satisfactory performance under normal conditions engineering design is not required. However, OVE design may include analyzing these "standard" constructions by engineering methods to determine if they are excessive.

Plain concrete constructions that may have 3 or 4 reinforcing bars placed horizontally in the wall should not be confused with reinforced concrete. Although they do contribute somewhat to resistance to lateral loads if properly sized, spaced, and positioned, such horizontal rebars are primarily for control of shrinkage cracking and do not ordinarily qualify as reinforcement.

Reinforced concrete construction has both horizontal and vertical reinforcing, sized and positioned according to specified engineering procedures. Reinforcing requirements are dependent on wall thickness, height of backfill, type of soil, quality of concrete and other factors. Reinforced concrete walls must be laterally supported at the top to allow economical engineering design.

Typical reinforcing requirements for a 6-inch-thick basement wall with 7 feet of backfill with average soil conditions consist of No. 4 (1/2 inch) vertical rebars spaced at 12 inches, and No. 4 horizontal rebars spaced at 24 inches. To be fully effective, the reinforcing should be positioned 1 inch from the inside of the wall.

Standard engineering procedures for reinforced concrete design are oriented toward heavy construction, and often result in overdesign for use in light structures such as houses. This limits the cost-effectiveness of reinforced concrete compared to more traditional constructions. Reinforced concrete basement walls are generally not competitive in home building except under special conditions when their use may be necessary.

Basement wall constructions of concrete block or plain concrete are specified in terms of minimum wall thickness to support a particular height of backfill. Table 3-3 provides examples of laterally supported and laterally unsupported constructions that have proven satisfactory. This table is based on a minimum concrete strength of 2,000 psi and standard hollow core load-bearing concrete block with type M or S mortar.

TABLE 3-3. Minimum suggested foundation wall thickness

Type of Foundation Wall	Minimum Wall Thickness, in.	Maximum Height of Finish Grade Above Basement Floor	
		Foundation Wall Laterally Unsupported At the Top ft. - in.	Foundation Wall Laterally Supported At the Top ft. - in.
Solid Concrete	6	2 - 6	5 - 0
	8	4 - 0	7 - 0
	10	4 - 6	7 - 6
	12	5 - 0	7 - 6
Concrete Block	6	2 - 0	2 - 0
	8	3 - 0	4 - 0
	10	4 - 0	6 - 0
	12	4 - 6	7 - 0

Source: Residential Standards, National Research Council of Canada, 1977

Plain concrete walls should be formed on both sides. Metal forms are available with a brick pattern to change the appearance of formed concrete walls. Special forms are also available with an integral flared footing detail to increase bearing area at the bottom; however, these forms are limited to walls of 5' in height or less, as used in some bi-level house designs.

3.4.2. Treated Wood Basements

More recently a basement construction of pressure treated lumber and plywood has met with considerable acceptance in widely separated areas of the United States and Canada. The U.S. Department of Housing and Urban Development has accepted this construction for FHA-insured loans.

Thousands of homes have been built with this method, which offers some unique advantages. Treated wood basement walls can enhance below-grade living conditions. Electrical wiring is readily installed. Insulation may be installed between the studs, and standard interior wall finish materials are easily nailed over the studs.

Two significant advantages of treated wood foundations are their suitability for construction in cold weather and the potential for prefabrication. Typical wall panels may be fabricated from treated wood, including footing plates (see Figure 3-D). The panels may be erected rapidly on site, reducing construction time and avoiding lengthy delays due to weather. Since carpenters erect the panels, there are fewer trades to coordinate. Where

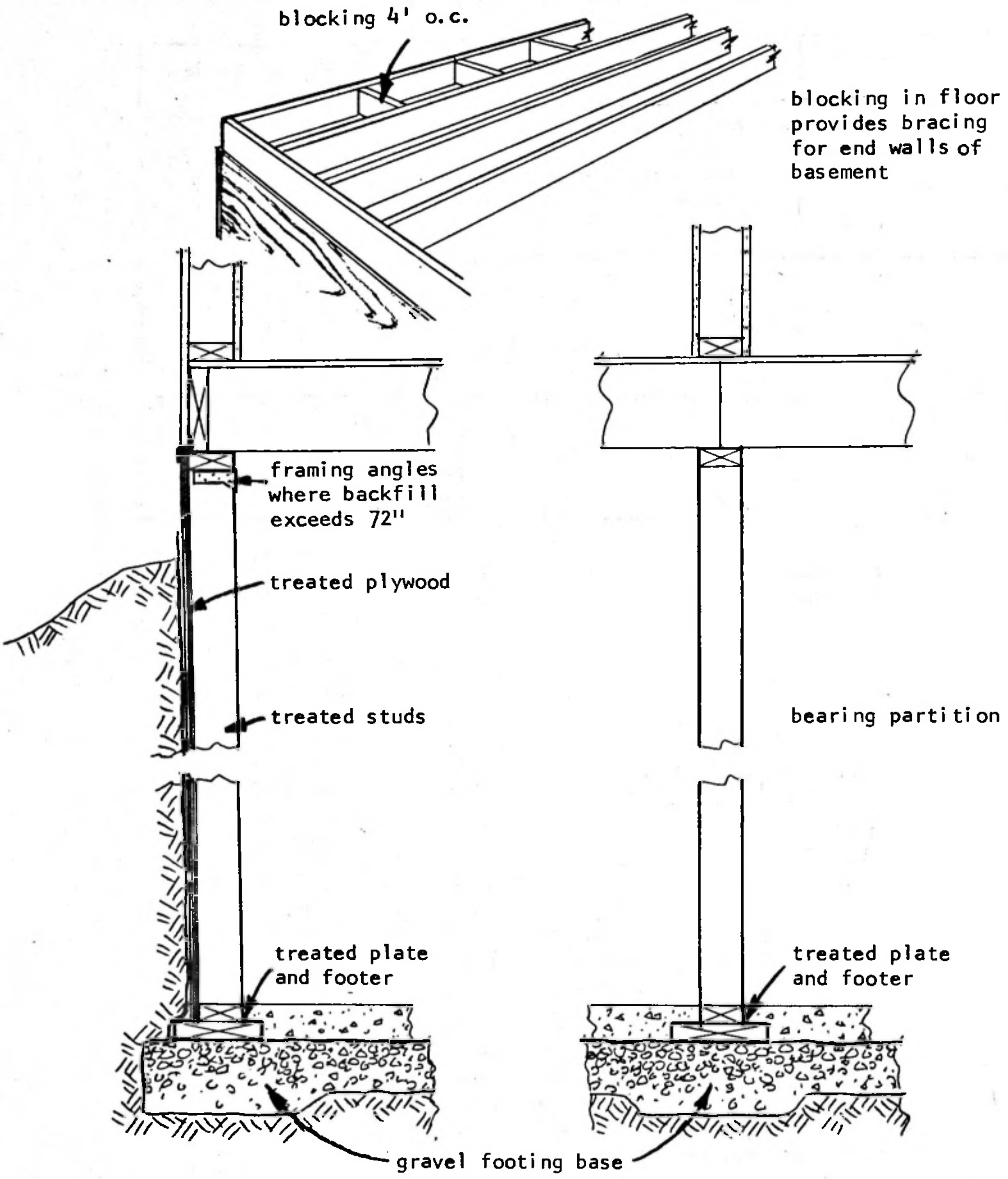


FIGURE 3-D. Pressure treated wood/plywood basement construction suitable for prefabrication

basement walls extend above grade, they are easily painted or covered with the same siding materials as the house walls.

The preservative treatment for this use must be specified and controlled in accordance with American Wood Preservers Bureau Standard AWPB-FDN. Each piece of lumber or plywood must bear the AWPB stamp or that of another approved inspection agency. Lumber and plywood treated in this manner is extremely durable.

Construction of a treated wood basement begins with excavation to the required level in the usual manner. Plumbing lines to be located below the basement floor area are installed as necessary. The entire basement area is then covered with a minimum 4-inch-thick layer of crushed stone or gravel extending approximately 6 inches beyond the footing line. The stone or gravel bed is carefully leveled at all footing locations. The gravel or crushed stone serves to distribute footing loads 4" or more on each side of the footing plate. Wall panels are then installed over the stone, fastened together and braced in place. Joints are caulked and the entire exterior below grade is draped with a continuous sheet of 6-mil polyethylene.

The stone or gravel bed is covered with 6-mil polyethylene over which a standard concrete slab floor is poured. A sump and pump may be desirable to assure a dry basement. The first story floor must be securely fastened to the top of the wood basement walls to resist the inward force of backfill. Where backfill exceeds 72 inches, it is advised to use framing angles at this point. Where backfill exceeds 48 inches, solid blocking should be installed 48 inches on center in the joist space at end walls to transmit foundation wall loads to the floor. The wood foundation should not be backfilled until the basement floor and the first story floor are in place.

Standard engineering procedures may be used in designing treated wood basement walls. As with other basement wall designs, the controlling factors are the height of backfill and soil conditions. Table 3-4 summarizes typical framing requirements for different heights of fill, and typical footing plate sizes required for one- and two-story houses up to 28 feet wide. Pressure treated 1/2-inch-thick standard C-D grade (exterior glue) plywood should be installed with the face grain across studs. Blocking at horizontal plywood joints is not required if joints are at least 4 feet above the bottom plate. These specifications are based on a soil condition with 30 pounds per cubic foot (pcf) equivalent fluid weight.

TABLE 3-4. Framing requirements for treated wood basement walls with studs spaced at 12 inches on center, assuming an equivalent soil pressure of 30 pcf.

No. Stories	Height of Fill	Stud Size	Minimum Required "f"-Value*	Minimum Required "E"-Value*	Footing Plate
1	24	2x4	1150	1,100,000	2x8
	48	2x4	1650	1,600,000	2x8
	72	2x6	1150	1,400,000	2x8
	86	2x6	1750	1,800,000	2x8
2	24	2x4	1650	1,600,000	2x10
	48	2x6	975	1,100,000	2x10
	72	2x6	1450	1,600,000	2x10
	86	2x6	1750	1,800,000	2x10

*See Appendix A for strength properties of different species and grades of lumber; refer to allowable "f"-values for repetitive members.

Reference: All-Weather Wood Foundation System; Design, Fabrication and Installation Manual; National Forest Products Association, June 1976.

3.5 Crawl Space Foundations

There are many traditional variations in crawl space construction. Earlier versions of the inexpensive open pier construction are no longer used in most areas. Later versions incorporate a nonload-bearing curtain wall between piers. These are still used in some areas. However, this construction introduces complications to both foundation and floor construction.

The most cost-effective and widely used crawl space construction is similar to that of a basement except that the foundation wall does not extend as far below grade. The depth of a crawl space foundation is generally determined by local frost conditions. Where the entire area enclosed by a crawl space foundation is excavated, the walls are subject to the same engineering design procedures as with basements. The height of backfill and related soil conditions are the controlling engineering design factors.

Eighteen to 24 inches of headroom is generally adequate for access in a crawl space. Where the frost line requires a deeper footing, the walls may extend down below the level of the crawl space floor, thereby reducing the unbalanced height of backfill acting against the wall from the outside. This permits a less costly wall construction since the height of unbalanced fill under these conditions seldom need be more than 18 inches.

As with basements, crawl space walls are normally supported against lateral soil pressure by the first story floor construction at the top, but they lack the lateral support of a concrete slab floor at the bottom. Where walls extend below the floor level, the earth on the inside of the wall provides lateral support at the bottom. Where the entire crawl space area is excavated, it may be necessary to provide lateral wall support by some other means, such as keying or anchoring to the footing. This is especially important with deeper foundations where the inward soil pressure is greater.

3.5.1. Concrete Block and Formed Concrete Crawl Spaces

Typically, crawl space walls are built of concrete block or plain concrete in much the same manner as basements. Standard concrete footings may be used with either block or plain concrete walls. However, if plain concrete walls are sufficiently thick to provide the necessary bearing at the bottom, a separate footing may not be required. It is also possible to flare the bottom portion of the wall to increase the bearing area by using special forms, as noted in the section on concrete basement construction (see detail, Figure 3-E).

For a given set of conditions, walls are specified in terms of the thickness required to support a particular height of backfill. Table 3-3 in the previous section on basement design provides minimum thicknesses for walls of plain (unreinforced) concrete and concrete block that are laterally supported at the top.

It is apparent that the minimum 6-inch-thick solid concrete walls shown in Table 3-3 are overdesigned for some crawl space constructions. While there is no recognized basis for unreinforced concrete walls of less than 6-inch thickness, a 4-inch thickness has been used successfully in walls which do not exceed a total of 2 feet in height.

Standard engineering procedures may be applied to design of reinforced concrete walls of lesser thickness. Typical reinforcing requirements for a 4-inch-thick reinforced concrete wall with up to 48 inches of unbalanced backfill with average soil conditions consist of No. 4 rebars spaced at 24 inches, both vertically and horizontally. Reinforcing should be positioned 1 inch from the inside face of the wall.

Obviously, reinforcing requirements may be reduced where there is less backfill. In any event, reinforced concrete design should be prepared by a qualified engineer and be based on local job conditions.

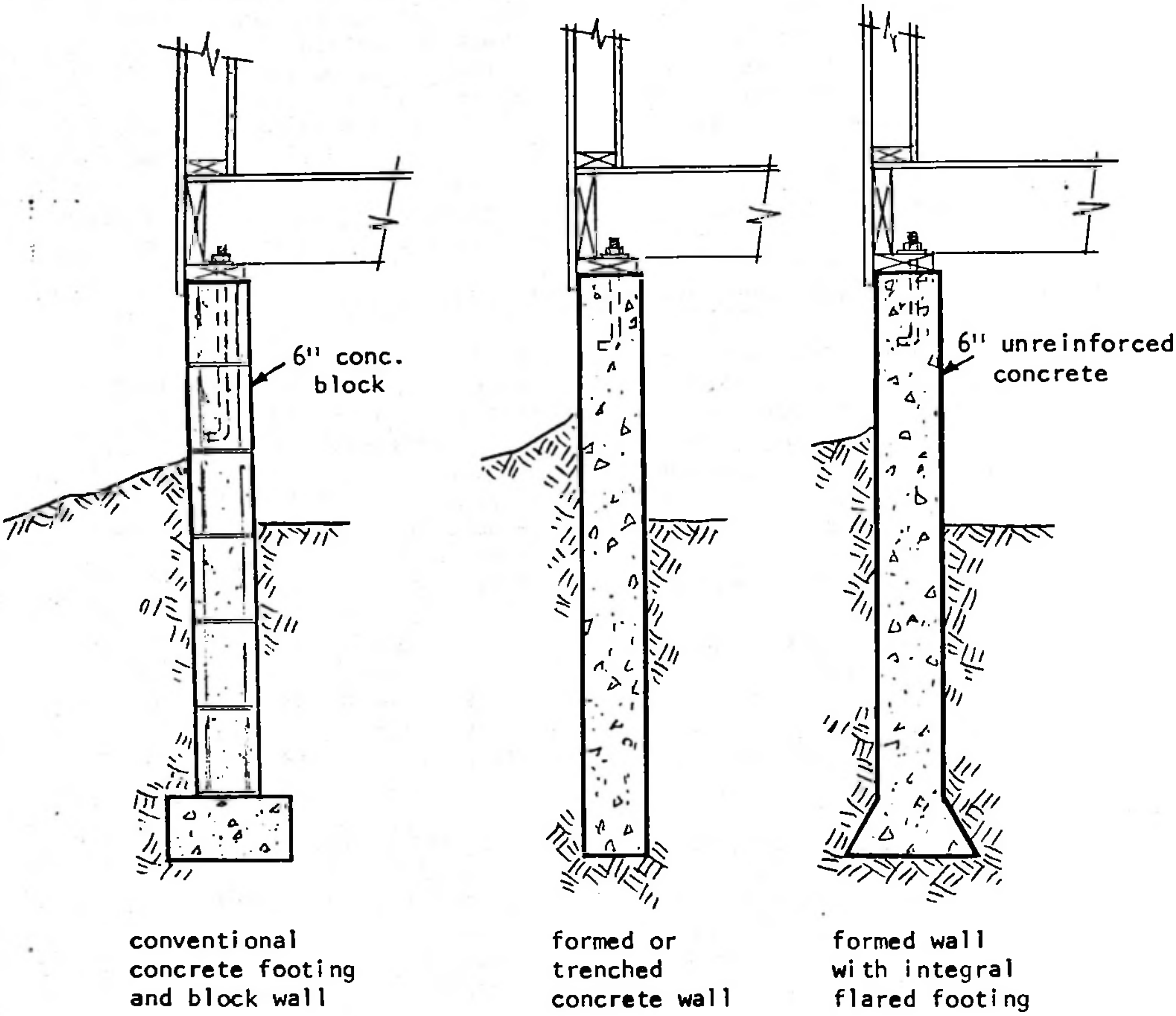


FIGURE 3-E. Alternate concrete and concrete block crawl space foundations

3.5.2. Treated Wood Crawl Space

Crawl space foundation walls may be constructed of pressure treated lumber and plywood as discussed previously in the section on basements. This method offers an opportunity for prefabrication not possible with more traditional foundation materials.

Wall panels are fabricated with integral footing plates. Panels may be erected rapidly on site, even in less desirable weather, and fewer trades are involved. Wall insulation, if specified, is readily installed between studs. Lumber and plywood treated in accordance with American Wood Preservers Bureau Standard AWPB-FDN should be used.

Panels are assembled in the same manner as for treated wood basements, using treated studs, plates and plywood facing. However, since a crawl space requires no more than 24 inches of headroom, the 1/2-inch-thick plywood facing need extend only 2 feet down from the top plate to the level of the crawl space floor, while the unfaced studs continue on down to the frost line (see Figure 3-F). Treated 2x4 studs may be spaced at 24 inches on center for single-story construction. For two stories, a spacing of 12 inches on center is necessary.

Construction begins with excavation of the site to the level of the crawl space floor. If local frost conditions require a greater depth, a trench of appropriate width is dug around the perimeter so that the wall may extend down to the required depth. The bottom of the trench is then covered with a minimum 4-inch layer of crushed stone or gravel which is carefully leveled. Wall panels are installed and braced in place, plywood joints are caulked and the wall is covered with 6-mil polyethylene below grade on the exterior.

A wood frame center bearing wall may also be used. This wall should be assembled from 2x4 studs spaced at 24 inches on center. A plywood facing is not required. The walls may be supported on a stone or gravel bed in a shallow trench as shown in Figure 3-F. As an alternative, center support may be provided by a conventional beam supported on columns or piers.

Additional details are available from the American Wood Preservers Institute, 1651 Old Meadow Road, McLean, Virginia 22101.

3.6 Concrete Slab Foundations

Under suitable site conditions, concrete slab-on-grade construction will often provide the most cost-effective foundation-floor combination. Ground supported concrete slabs are not subject to the span limitations of other floor constructions and footing requirements are minimal, especially in warmer climates.

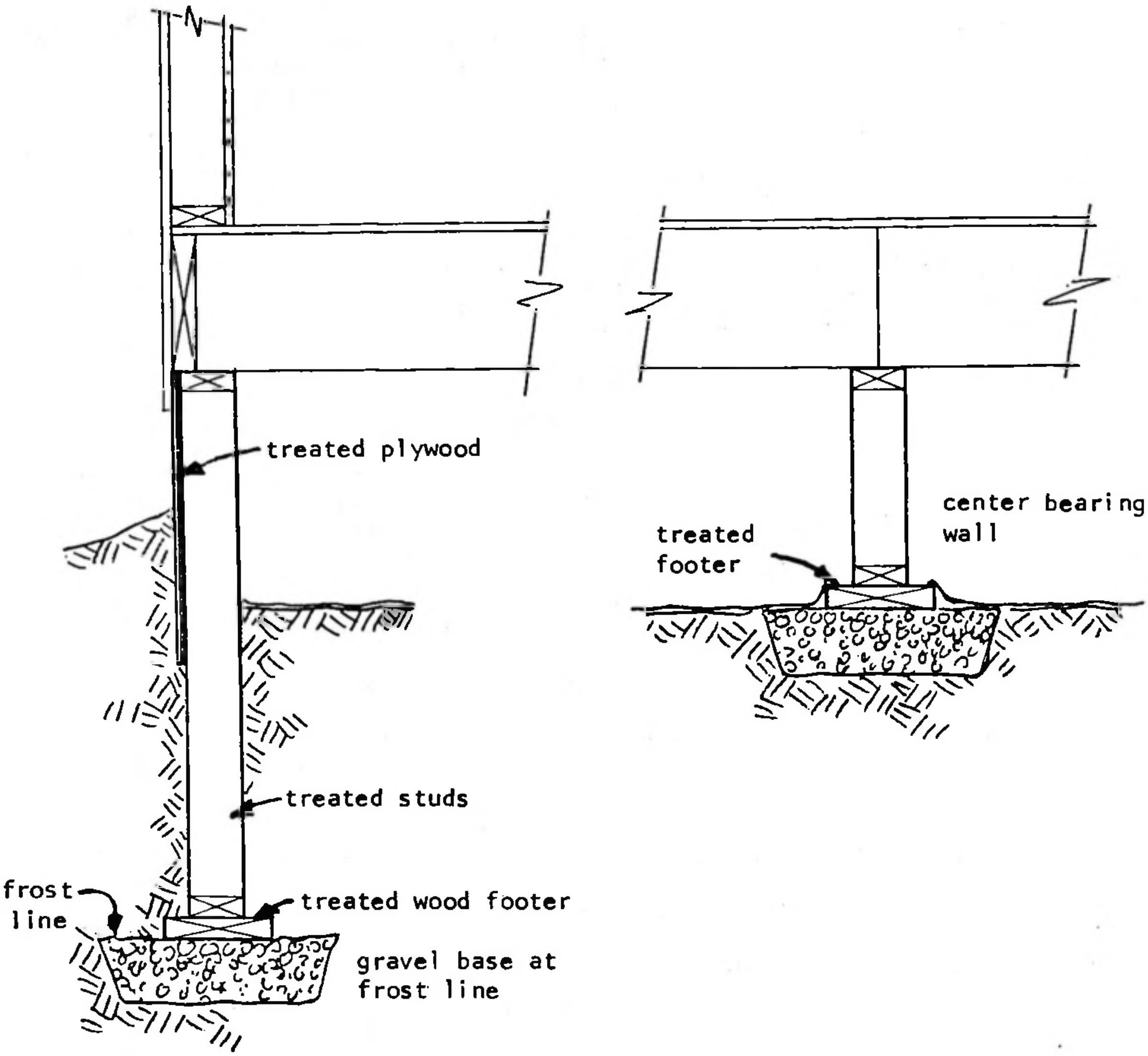


FIGURE 3-F. Pressure treated wood/plywood crawl space construction with "studs" extended down to the frost line

However, there are some practical limitations to concrete slab construction. The greatest limitation is topography. Concrete slab foundations do not adapt well to sloping sites or other conditions which require fill. Although concrete slabs may be supported on compacted fill or intermediate piers if the slab is properly reinforced, the added cost will often favor a crawl space or basement foundation.

There are two basic variations of concrete slab-on-grade construction which are largely dependent on climate. These basic variations are discussed in the following sections and are applicable to typical, reasonably stable soil conditions. Where expansive soils or other unusual conditions prevail, special solutions must be developed on the local level.

3.6.1. Monolithic Slab-On-Grade

A monolithic concrete slab that combines footings and floor in one pour is the least costly of all foundation types where suitable conditions exist. However, it is presently used primarily in warmer climates where frost depth and perimeter heat loss are of little concern.

The basic monolithic slab foundation consists essentially of a 4-inch-thick concrete slab with a thickened edge (see Figure 3-G). The slab itself does not necessarily require reinforcing unless local experience dictates. Where intermediate load-bearing walls require support, the slab thickness may be increased in a section similar to the edge. A concrete strength of 2,000 psi is adequate under normal conditions.

The basic simplicity of this type of foundation minimizes construction time, scheduling delays and other cost-related factors. Topsoil is removed and the site is prepared, perimeter forms are set, a layer of crushed stone or gravel is placed and covered with 6-mil polyethylene, reinforcing bars are positioned and the monolithic slab is poured.

A monolithic slab foundation generally offers the most cost effective solution for level building sites in warm climates, due to its basic simplicity. Even for areas having unstable soils, a special reinforced monolithic slab design may be the most cost effective solution. However, this must be determined on a local basis with a qualified engineer.

3.6.2. Insulated Slab-On-Grade

A slab-on-grade construction may also offer a cost-effective solution in colder climates, providing the site is sufficiently level. In colder climates, the floor slab must be separated from the foundation with perimeter edge insulation to prevent excessive heat loss at the slab edge. Also, the independent

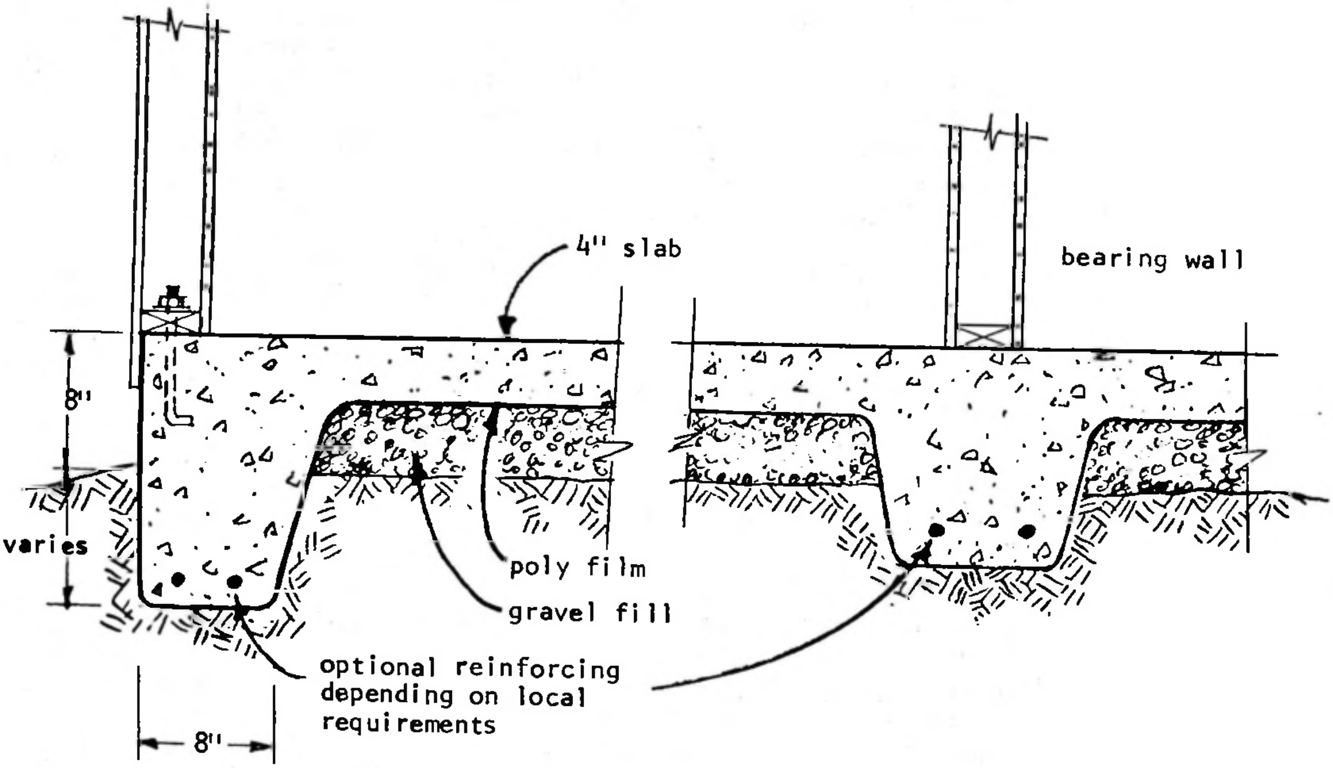


FIGURE 3-G. Monolithic concrete slab foundation suitable for relatively level sites in warmer climates

footing which carries building wall loads must extend down to the frost line.

Several alternate methods of providing for a foundation wall or footing are available. Where soil characteristics permit, a narrow trench filled with concrete may provide the least costly method (see Figure 3-H). The width of the trench at the bottom must provide sufficient bearing area for building design loads. Special trenching machines are available that will excavate a trench with a flared bottom to increase bearing area.

Where soil characteristics do not permit sufficiently accurate trenching for this method, a somewhat wider trench may be excavated to receive a formed concrete wall (with integral flared footing at the bottom, if necessary). Conventional concrete footings may also be used. A 6-inch concrete block wall or formed concrete wall is then erected to the required height as shown in Figure 3-H.

Regardless of the method used, the detail at the top of the wall should accommodate at least 1-inch-thick (R-5) perimeter insulation, depending on climate. Insulation should have an effective width of at least 2 feet. Figure 3-H illustrates the use of a top course of 4" concrete block with 1-inch-thick perimeter insulation. The top of the wall should extend at least 8 inches above finish grade.

A layer of crushed stone or gravel is spread over the floor area and covered with a 6-mil polyethylene moisture barrier. A nominal 4-inch-thick concrete floor is then poured and screeded to the top of the foundation wall. Reinforcing is not required unless local experience indicates the necessity. Where intermediate bearing walls require support, the slab may be thickened and reinforced, as in the monolithic slab described previously. A minimum of 2,000 psi concrete may be used for all footings, walls and slabs under normal conditions.

Heating ducts of one type or another are often incorporated in slab-on-grade construction in colder climates. Installation of these ducts can complicate construction and increase costs unnecessarily. Wherever practical, a heating system that does not require ducts within the slab should be considered.

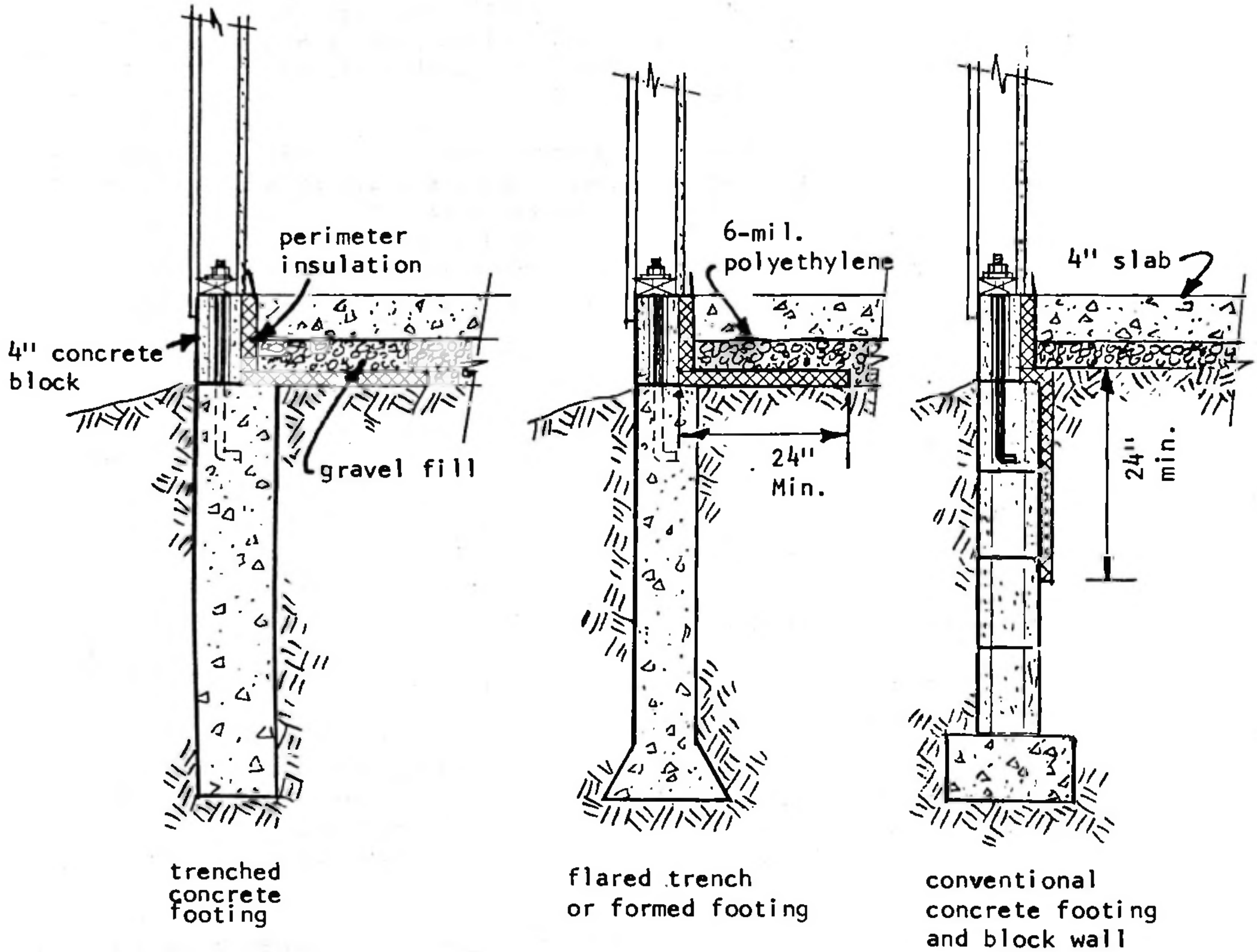


FIGURE 3-H. Alternate concrete slab foundations incorporating perimeter insulation for colder climates

4. FLOOR CONSTRUCTION

4.1 General

There are two basic types of floor construction commonly used in home building — concrete slab and wood frame. Concrete slab floors are discussed in the previous section under foundations.

Most wood frame floors utilize nominal 2-inch-thick joists spaced up to 24 inches on center, bearing on a center beam and covered with plywood sheathing. There are several other variations of wood frame floor construction, but they are basically localized. An efficiently engineered wood joist system is generally recognized as the most universal and cost effective wood floor construction.

This chapter discusses the application of OVE techniques to a wood joist floor system, including center support beams, joists, subfloor and other related members. In all cases a 2-foot on center spacing is used for joists in order to coordinate with other framing members, as discussed in Chapter 2.

4.2 Sill Plate Reduced or Eliminated

A wood frame floor system should be anchored to the foundation to resist wind forces acting on the structure. In conventional practice, a 2x6 sill plate is attached to the foundation with 1/2-inch anchor bolts and floor joists are toe-nailed to the sill plate.

Where a sill plate is used in OVE construction a 2x4 member will generally be adequate with either a solid concrete or a hollow core masonry foundation wall. The sill plate may be attached with anchor straps that are embedded in the foundation in the same manner and at the same spacing as conventional anchor bolts. These devices do not require holes in the sill plate; metal tabs are simply bent up around the plate and nailed. Anchor straps are less exacting, and do not interfere with other framing as conventional bolts often do (see Figure 4-A).

Sill plates may be entirely eliminated where the top of a solid concrete or concrete block foundation is sufficiently level and accurate. Joists may bear directly on a solid concrete wall or on a top course of solid concrete block. They may also bear directly on cross webs of hollow core block or on cores which have been filled with mortar or pea gravel concrete. Where available, standard 2-core, 16-inch-long concrete block will provide a cross web every 24 inches to simplify provision for full joist bearing, as compared with 3-core block.

Where the sill plate is deleted, anchorage of the floor system

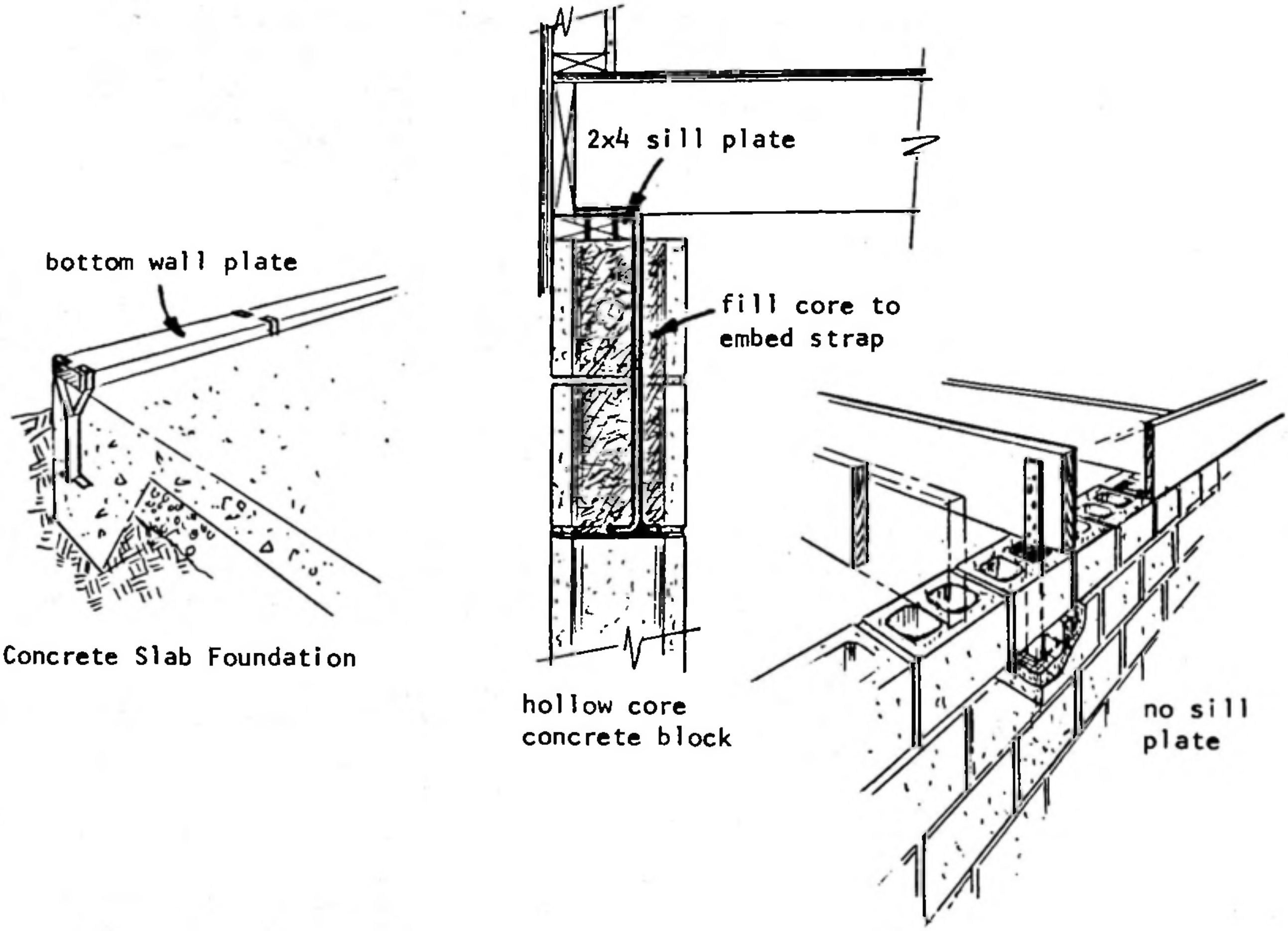


FIGURE 4-A. Anchor straps used for attaching the floor or wall structure to the foundation

may be provided by heavy perforated strapping or anchor strap devices, as described above. The straps should be spaced to coincide with joist locations so that each may be nailed directly to the side of a joist as shown in Figure 4-A.

A treated wood foundation does not require a separate sill plate. Floor joists bear directly on the top foundation wall plate and are toe-nailed to provide anchorage.

4.3 Center Support Beam

Wood frame floor construction typically employs a beam or girder to provide intermediate support for the first floor. In two-story construction, the beam generally supports the second floor as well, via a load-bearing wall extending down the center of the first story.

For maximum benefit in reducing joist spans, center support beams and bearing walls should be located along the centerline of the structure. In some cases it may be desirable to offset the center support one foot from the centerline to provide for even-length joists, as with 26-or 30-foot-deep floor systems. However, this will not be necessary if off-center spliced joists are used, as discussed later.

The center beam usually bears on the foundation at each end and is supported along its length by columns or piers. The spacing of columns or piers is adjusted to the spanning capability of the beam for a particular design load. Two basic types of center beams are commonly used - wood or steel.

The decision on whether to use a wood or steel center beam should be based on a comparison of the total installed cost of each, including intermediate support columns or piers, footings, etc. Other factors such as delivery, scheduling, construction ease, etc. also are a consideration.

4.3.1. Built-Up Wood Beam

Wood beams are typically built up by nailing 3 or 4 layers of dimension lumber together. End joints in each member should be located within 12 inches of the support column or pier, and end joints in adjacent members should be at least 16 inches apart.

Typical allowable spans for built-up wood beams are shown in Table 4-1. Dry lumber should always be used to avoid settlement problems due to shrinkage. A wood plate is not necessary over wood beams, since floor joists may be nailed directly to the beam (see Figure 4-B).

4.3.2. Steel I-Beam

Steel I-beams are often used for center supports because of their

TABLE 4-1. Allowable spans for built-up wood center beams

Width of Structure	Beam Size	Maximum Clear Span			
		1-Story		2-Story	
		1000 f*	1500 f*	1000 f*	1500 f*
24'	3 - 2x8	6'- 7"	8'- 1"	-	4'- 7"
	4 - 2x8	7'- 8"	9'- 4"	5'- 2"	6'- 2"
	3 - 2x10	8'- 5"	10'- 4"	4'-11"	7'- 6"
	4 - 2x10	9'- 9"	11'-11"	5'- 7"	7'-10"
	3 - 2x12	10'- 3"	12'- 7"	6'- 0"	7'- 2"
	4 - 2x12	11'-10"	14'- 6"	8'- 0"	9'- 7"
26'	3 - 2x8	6'- 4"	7'- 9"	-	4'- 3"
	4 - 2x8	7'- 4"	9'- 0"	4'- 9"	5'- 8"
	3 - 2x10	8'- 1"	9'-11"	4'- 7"	5'- 6"
	4 - 2x10	9'- 4"	11'- 6"	6'- 1"	7'- 3"
	3 - 2x12	9'-10"	12'- 1"	5'- 6"	6'- 8"
	4 - 2x12	11'- 5"	13'-11"	7'- 5"	8'-10"
28'	3 - 2x8	6'- 2"	7'- 5"	-	-
	4 - 2x8	7'- 1"	8'- 8"	4'- 5"	5'- 4"
	3 - 2x10	7'-10"	9'- 6"	4'- 3"	5'- 1"
	4 - 2x10	9'- 0"	11'- 1"	5'- 8"	6'- 9"
	3 - 2x12	9'- 6"	11'- 7"	5'- 2"	6'- 2"
	4 - 2x12	11'- 0"	13'- 5"	6'-10"	8'- 3"
32'	3 - 2x8	5'- 5"	6'- 6"	-	-
	4 - 2x8	6'- 7"	8'- 1"	-	4'- 8"
	3 - 2x10	6'-11"	8'- 4"	-	4'- 6"
	4 - 2x10	8'- 5"	10'- 4"	5'- 0"	6'- 0"
	3 - 2x12	8'- 5"	10'- 2"	4'- 6"	5'- 2"
	4 - 2x12	10'- 3"	12'- 7"	6'- 0"	7'- 3"

NOTE: Values shown assume a clear-span trussed roof, and load bearing center partition in 2-story construction. Beam and/or load-bearing partition may be offset from centerline of house up to one foot.

*See Appendix A for "f"-values of different species and grades of lumber. End splits may not exceed one times the beam depth for spans shown.

SOURCE: Based on data from Manual of Lumber and Plywood Savings, NAHB Research Foundation, Inc.

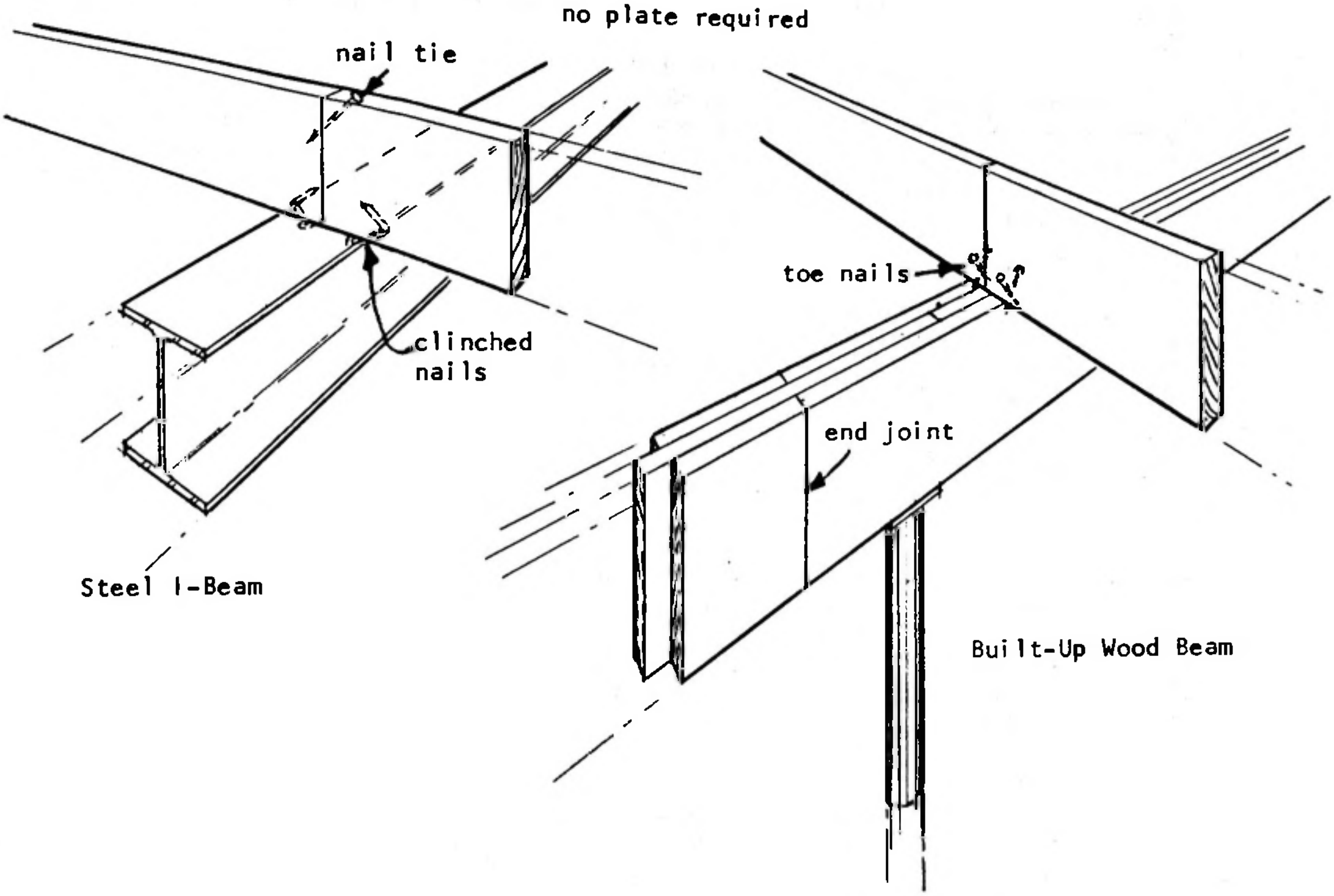


FIGURE 4-B. Alternate wood and steel center beams with plate deleted and floor joists fastened directly to beam

greater spanning capabilities and elimination of possible shrinkage problems with wood. However, steel beams require an additional supplier which can complicate delivery schedules. They are also heavier and more difficult to handle in the field. The total cost of a steel beam, including columns or piers, is generally greater than for a wood beam.

Where steel beams are used in conventional practice, a 2x6 wood plate is normally attached to the top surface by bolting or other means. Floor joists are then toe-nailed to the beam plate to anchor the floor and to provide lateral bracing for the beam. However, a beam plate is not required if the floor joists are secured by other means. Figure 4-B shows a simple but effective method of attachment employing nails driven into the bottom edge of joists and clinched to the steel beam flange.

Where the design requires greater spans, steel beams are often preferred. Allowable spans for steel I-beams are shown in Table 4-2.

4.4 Floor Joist Design

As discussed previously, a 2-foot on center spacing is recommended for floor joists to coordinate with other framing and optimize material use. In-line positioning of joists over the center support is recommended so that joists are located precisely on the 2-foot module on both sides of the support without the 1-1/2 inch offset necessary with conventional lapped joists.

Where conventional joist lengths are installed in-line with joist ends butted over the center support, each joist must have at least 1-1/2 inch bearing. It will usually be necessary to cut each joist to the proper length to accomplish this. In addition, the butted ends must be tied together in some manner. A plywood floor which is continuous over the end joint is sufficient for this purpose. If the floor does not provide a connection, it is necessary to use a wood or metal tie to secure the ends to each other (see Figure 4-C).

If a structural splice is used to join the two joist ends, the end joint need not necessarily be located over the center support. This can actually contribute to the allowable span, as discussed later. It should be possible to obtain preassembled, precut in-line joists from a fabricator, as shown in Figure 4-C.

On the other hand, it may be possible to obtain structural end-jointed lumber for full-length joists. Either of these variations of full length in-line joists may be installed more rapidly and accurately than conventional joist lengths.

Regardless of the joist design used, spanning capabilities are increased by gluing the plywood floor in place, as

TABLE 4-2. Allowable span between columns or piers for typical steel center beams*

Width of Structure	Beam Designation			Maximum Clear Span	
	ht. - in.	Type	lbs./ft.	1-story	2-story
24'	8	B	10.0	13'- 9"	10'- 0"
	10	B	11.5	16'- 0"	11'- 8"
	8	W	17.0	19'- 4"	14'- 1"
	10	B	17.0	20'- 9"	15'- 2"
	10	W	21.0	23'- 2"	17'- 5"
26'	8	B	10.0	13'- 3"	9'- 8"
	10	B	11.5	15'- 5"	11'- 3"
	8	W	17.0	18'- 7"	13'- 7"
	10	B	17.0	20'- 0"	14'- 7"
	10	W	21.0	22'- 8"	16'- 9"
28'	8	B	10.0	12'- 9"	9'- 4"
	10	B	11.5	14'-10'	10'-10"
	8	W	17.0	17'-11"	13'- 1"
	10	B	17.0	19'- 3"	14'- 1"
	10	W	21.0	22'- 2"	16'- 2"
32'	8	B	10.0	11'-11"	8'- 9"
	10	B	11.5	13'-10"	10'- 2"
	8	W	17.0	16'- 9"	12'- 4"
	10	B	17.0	18'- 0"	13'- 2"
	10	W	21.0	20'- 9"	15'- 2"

*Based on a continuous beam over two equal spans with maximum ½" deflection at design load, and assuming a clear span trussed roof.

Source: Steel Beam Stress and Deflection Estimator for use in calculating sizes of laterally supported beams for residential and light construction, United States Steel Corp.

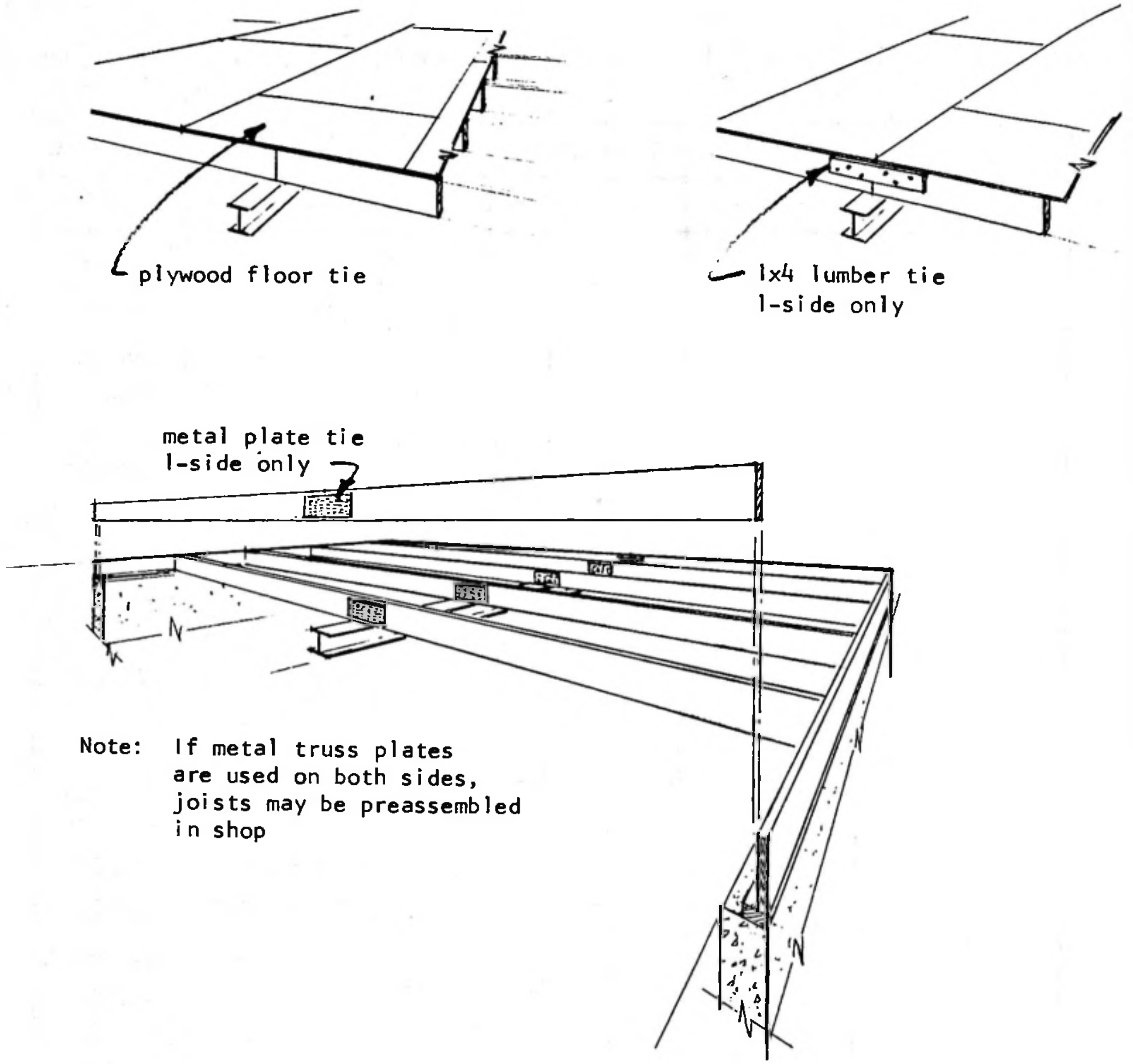


FIGURE 4-C. Alternate methods of tying in-line joists that butt over the center beam

discussed later. Floor joists may also be cantilevered over the foundation at least 2 feet in most cases to increase their effective span.

4.4.1 Simple In-Line Joist Design

Existing span tables for floor joists generally provide allowable spans for 24-inch on center joist spacings. Allowable spans for a given size of joist depend on the strength properties of the wood and the design loads.

A dead load of 10 psf is generally assumed for wood frame floors. The standard live load used for single-story homes or the first floor of two-story homes is 40 psf. A 30 psf live load is often used for the second story of two-story homes, assuming lighter load conditions in bedroom areas.

The strength properties of wood depend on species and grade. Strength properties of common species and grades are shown in Appendix A. Using the appropriate "E" and "f" values for the selected species and grade, allowable clear spans for simple joists butted over a center support may be determined from Table 4-3 for live load conditions of 40 psf and 30 psf.

4.4.2 Glued Floor Design

When a plywood subfloor is properly glued to floor joists with a construction adhesive, they act together as a single structural member. The composite T-beam thus formed will span a greater distance than if the floor is fastened only with nails.

Using the appropriate "E" and "f" values for the selected joist lumber, Table 4-4 provides allowable spans for joists spaced at 2 feet with 3/4-inch-thick glue-nailed plywood subfloor. Research conducted by the NAHB Research Foundation, Inc. for HUD indicates that 5/8-inch-thick Group 1 tongue and groove plywood may also be used over joists spaced at 2 feet on center when properly glue-nailed to joists and glued at the grooved joint (see Technical Supplement A). Table 4-5 provides allowable spans for joists spaced at 2 feet with 5/8-inch-thick glue-nailed subfloor. The data presented in both Tables 4-4 and 4-5 were developed for HUD by the NAHB Research Foundation, Inc. in a previous program to evaluate the contribution of a glued floor in reducing bending stresses in joists (see Technical Supplement B).

Glue-nailing of the plywood subfloor is recommended as a cost effective method of increasing the stiffness and/or allowable span of a floor. Glue-nailing is also highly effective in reducing floor squeaks and loose nails which may otherwise occur at a later time due to shrinkage of joists.

TABLE 4-3. Allowable spans (ft-in) for simple floor joists spaced at 2' on center

"E"-Value* 1,000,000 psi	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
40 Lbs. Per Sq. Ft. Live Load											
Min. Reqd. "f"-Value*	1050	1120	1190	1250	1310	1380	1440	1500	1550	1610	1670
2x6	7-3	7-6	7-9	7-11	8-2	8-4	8-6	8-8	8-10	9-0	9-2
2x8	9-7	9-11	10-2	10-6	10-9	11-0	11-3	11-5	11-8	11-11	12-1
2x10	12-3	12-8	13-0	13-4	13-8	14-0	14-4	14-7	14-11	15-2	15-5
2x12	14-11	15-4	15-10	16-3	16-8	17-0	17-5	17-9	18-1	18-5	18-9
30 Lbs. Per Sq. Ft. Live Load											
Min. Reqd. "f"-Value*	1020	1080	1150	1210	1270	1330	1390	1450	1510	1560	1620
2x6	8-0	8-3	8-6	8-9	8-11	9-2	9-4	9-7	9-9	9-11	10-1
2x8	10-7	10-11	11-3	11-6	11-10	12-1	12-4	12-7	12-10	13-1	13-4
2x10	13-6	13-11	14-4	14-8	15-1	15-5	15-9	16-1	16-5	16-8	17-0
2x12	16-5	16-11	17-5	17-11	18-4	18-9	19-2	19-7	19-11	20-3	20-8

*See Appendix A for strength properties of different species and grades of lumber; refer to allowable "f"-values for repetitive members.

Source: Span Tables for Joists & Rafters, National Forest Products Association, 1977.

TABLE 4-4. Allowable spans (ft.-in.) for 24" o.c. joists with 3/4 glued plywood floor

Joist Size	Joist Modulus of Elasticity, "E", in 1,000,000 psi*							
	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
40 lbs. per Square Foot Live Load								
2x6	8-1 1100	8-8 1270	9-2 1415	9-7 1545	9-11 1655	10-2 1755	10-6 1855	10-9 1950
2x8	10-3 1025	11-0 1180	11-7 1310	12-2 1430	12-7 1535	13-0 1630	13-4 1725	13-8 1810
2x10	12-9 970	13-8 1110	14-4 1230	15-0 1345	15-7 1445	16-0 1535	16-6 1625	16-11 1710
2x12	15-2 925	16-2 1060	17-1 1175	17-10 1280	18-6 1380	19-1 1470	19-8 1560	20-2 1640
30 lbs. per Square Foot Live Load								
2x6	8-11 1340	9-7 1540	10-1 1715	10-6 1865	10-11 2005	11-3 2130	11-7 2250	11-10 2360
2x8	11-4 1245	12-2 1430	12-10 1590	13-4 1730	13-10 1860	14-3 1975	14-8 2085	15-0 2190
2x10	14-0 1170	15-0 1345	15-10 1495	16-6 1625	17-1 1745	17-9 1860	18-2 1970	18-8 2070
2x12	16-8 1120	17-10 1280	18-10 1425	19-7 1550	20-4 1670	21-0 1780	21-8 1890	22-2 1985

NOTE: Associated minimum required "f"-value for repetitive members shown with each span.

*See Appendix A for strength properties of different species and grades of lumber.

Source: Performance of Glued Single-Layer Plywood-To-Wood Joist Floor Systems, NAHB Research Foundation, Inc., for HUD, June 1973

TABLE 4-5. Allowable spans (ft.-in.) for 24" o.c. joists with 5/8" glued plywood floor

Joist Size	Modulus of Elasticity, "E", in 1,000,000 psi*							
	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
40 lbs. per Square Foot Live Load								
2x6	7-9 1010	8-3 1155	8-9 1285	9-1 1395	9-5 1500	9-9 1595	10-0 1685	10-3 1770
2x8	9-10 940	10-6 1075	11-1 1195	11-7 1300	12-0 1400	12-5 1495	12-9 1580	13-1 1660
2x10	12-2 885	13-0 1010	13-9 1125	14-4 1230	14-11 1325	15-5 1415	15-10 1500	16-4 1585
2x12	14-6 850	15-6 970	16-4 1080	17-1 1180	17-10 1280	18-5 1365	19- 1455	19-6 1535
30 lbs. per Square Foot Live Load								
2x6	8-6 1220	9-1 1400	9-7 1555	10-0 1690	10-4 1815	10-8 1930	11-0 2040	11-3 2140
2x8	10-10 1140	11-7 1305	12-3 1450	12-9 1575	13-3 1695	13-8 1810	14-0 1910	14-5 2015
2x10	13-5 1075	14-4 1230	15-2 1365	15-10 1490	16-5 1605	17-0 1720	17-6 1820	17-11 1920
2x12	15-11 1025	17-1 1175	18-0 1310	18-10 1430	19-7 1545	20-3 1655	20-11 1760	21-6 1860

NOTE: Associated minimum required "f"-value for repetitive members shown with each span.

*See Appendix A for strength properties of different species and grades of lumber.

Source: Performance of Glued Single-Layer Plywood-To-Wood Joist Floor Systems, NAHB Research Foundation, Inc., for HUD, June 1973

4.4.3 Off-Center Spliced Joist Design

If two unequal joist lengths are spliced together so that the splice occurs at a certain point off-center, joist spans may be increased significantly. This arrangement provides structural continuity over the center support as compared to the use of individual joists which start at the center support (see Figure 4-D). It can provide up to a forty percent increase in joist stiffness — the basis for residential floor joist design.

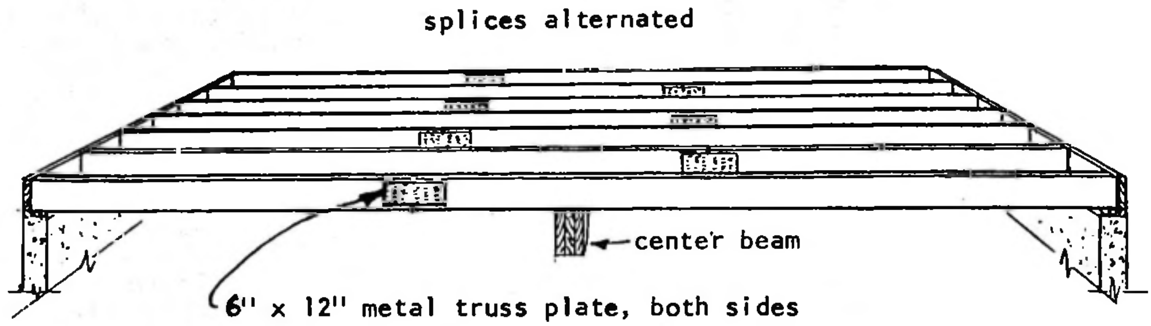
Under theoretical uniform load conditions for common residential floor spans, the bending stress on a continuous joist is zero at a point several feet from the center support. A spliced joint located at or near this point is subjected to minimal bending moment. This permits use of a splice having less moment resistance than the joist itself. The splice may be formed with plywood or metal plates applied to both sides of the joist.

Research conducted by NAHB Research Foundation, Inc., for HUD showed that properly designed 2x8 spliced joists, spaced at 2 feet on center and with glue-nailed 5/8" plywood sheathing, are structurally adequate for a 28-foot-deep house with center bearing. A floor section constructed of spliced joists in combination with a glue-nailed plywood subfloor was tested in the laboratory. Full-scale loading tests showed this floor system to be substantially stiffer and stronger than commonly used code requirements (see Technical Supplement C).

This floor system was used in the OVE demonstration house described in Chapter 1. Full-length 28-foot joists were preassembled from No. 2 Hem-Fir lumber by splicing a 2x8-10 to 2x8-18. The splice was formed with standard 6"x12" truss plates applied to both sides. Joists were installed 2 feet on center, with the splices alternating on either side of the center support (see Figure 4-D). A 5/8 inch thick tongue and groove plywood sheathing was glue-nailed to the joists with the tongue and groove joint glued. The full length spliced joists handled well under field conditions and greatly simplified floor construction to provide a significant reduction in labor cost. The resulting floor proved satisfactory in every respect.

Based on this experience, a 2x8 off-center spliced joist floor system, as described, is considered suitable for houses up to 28 feet in depth with center bearing. Spliced joists for other typical house depths may be fabricated from standard lengths of the same quality of 2x8 lumber, as shown in Figure 4-D.

Additional research to develop more complete span tables for off-center spliced joists with glued subfloors is now under consideration. Off-center spliced joists offer all of the benefits of an in-line joist layout, plus a significant increase in spanning capability over conventional joists.



Note: Use lumber with minimum "E" = 1,400,000 and "f" = 1,150 (repetitive member).
Use glue-nailed plywood floor

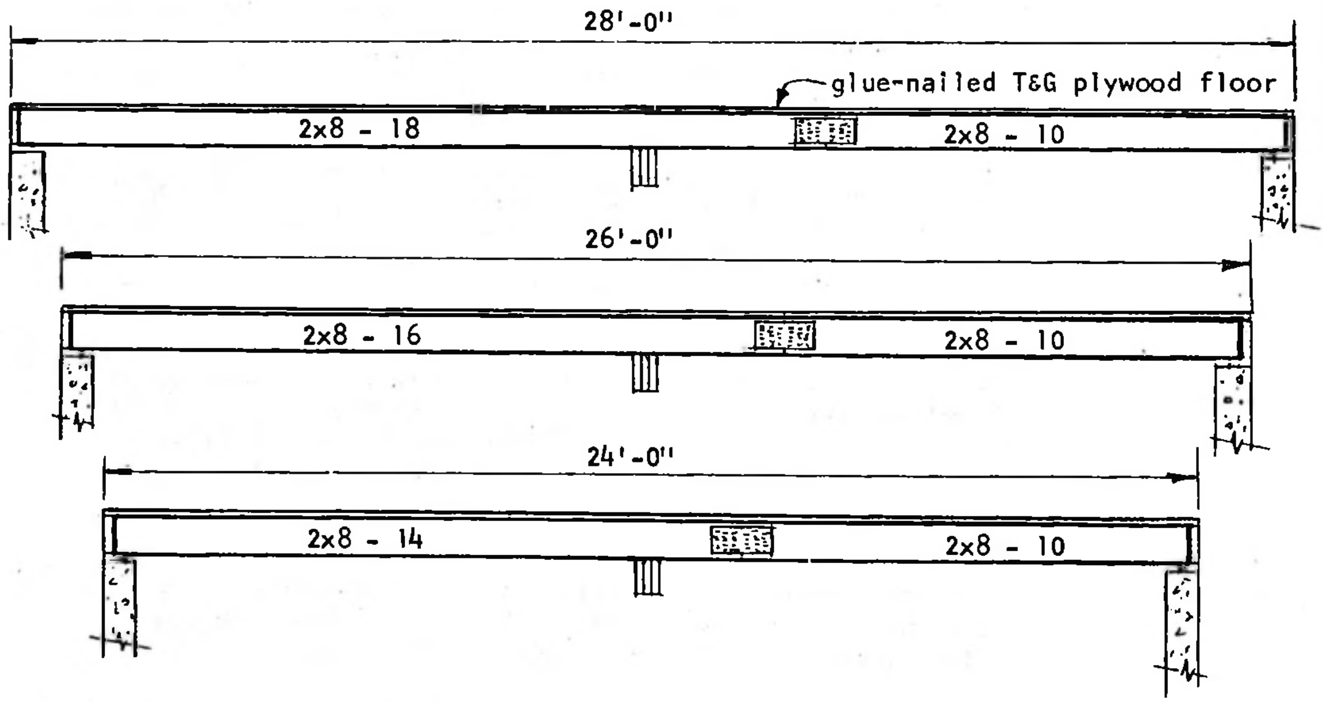


FIGURE 4-D. Off-center spliced joist designs span further than simple joists of the same dimension

4.5 Framing Openings in the Floor

Floor joists spaced at 2 feet on center provide ample clearance for mechanical ducts and flues, crawl space access doors and other smaller openings in the floor, if these openings are located between joists. The required opening may be framed with simple 2x4 blocking, leaving structural joists intact.

Larger openings such as stairwells may require disruption of one or more joists. Such openings should be planned so that their long dimension is parallel with joists in order to minimize the number of joists that are interrupted. Special care should also be exercised to avoid disrupting the center beam or bearing partition which supports the floor, by the stair opening Wherever possible, the opening should be coordinated with the normal joist spacing on at least one side to avoid the necessity for an additional trimmer joist to form the opening.

A single header is generally adequate for openings up to 4 feet in width. A single trimmer joist at each side of the opening is usually adequate to support single headers which are located within 3 feet of the end of joist spans (see Figure 4-E). Tail joists under 6 feet in length may be fastened to the header with 3 - 16d end nails and 2 - 10d toe nails, or equivalent nailing. Tail joists over 6 feet in length should be attached with joist hangers. The header should be connected to trimmer joists by the same means as tail joists are connected to the header.

Where wider openings are unavoidable, double headers are generally adequate up to 10 feet, as shown in Figure 4-F. Tail joists may be connected to double headers in the same manner and under the same conditions as specified above for single headers. Tail joists which are end-nailed to a double header should be nailed prior to installation of the second member of the double header to provide adequate nail penetration into the tail joist. A double header should always be attached to trimmer joists with a joist hanger.

Trimmer joists at floor openings must be designed to support the concentrated loads imposed by headers where they attach to the trimmer. As noted previously, a single trimmer is adequate to support a single header located near the end of the span. All other trimmers should be at least doubled, and should be engineered for specific job conditions.

4.6 Bridging Between Joists Eliminated

Cross bridging or solid blocking between joists is still used in some conventional construction. However, such bridging does not contribute to the performance of the floor and, in fact, detracts from floor performance by increasing the effect of vibrations from walking on the floor. It is no longer required by FHA and the major model codes in normal residential floors. Bridging may be totally eliminated between floor joists

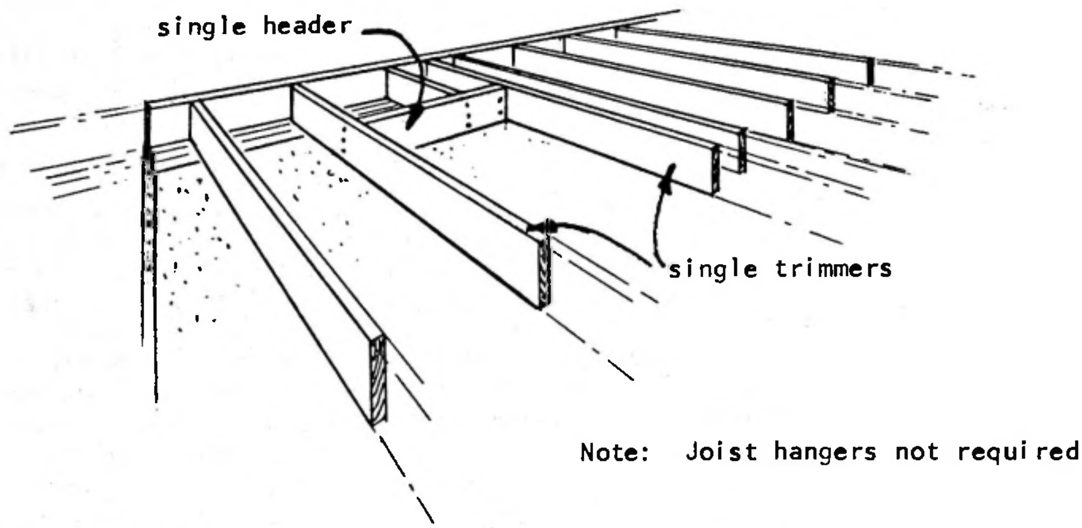


FIGURE 4-E. Single header used across openings less than 4' in width. Single trimmer used to support single header which is located within 3' of the end of joist span

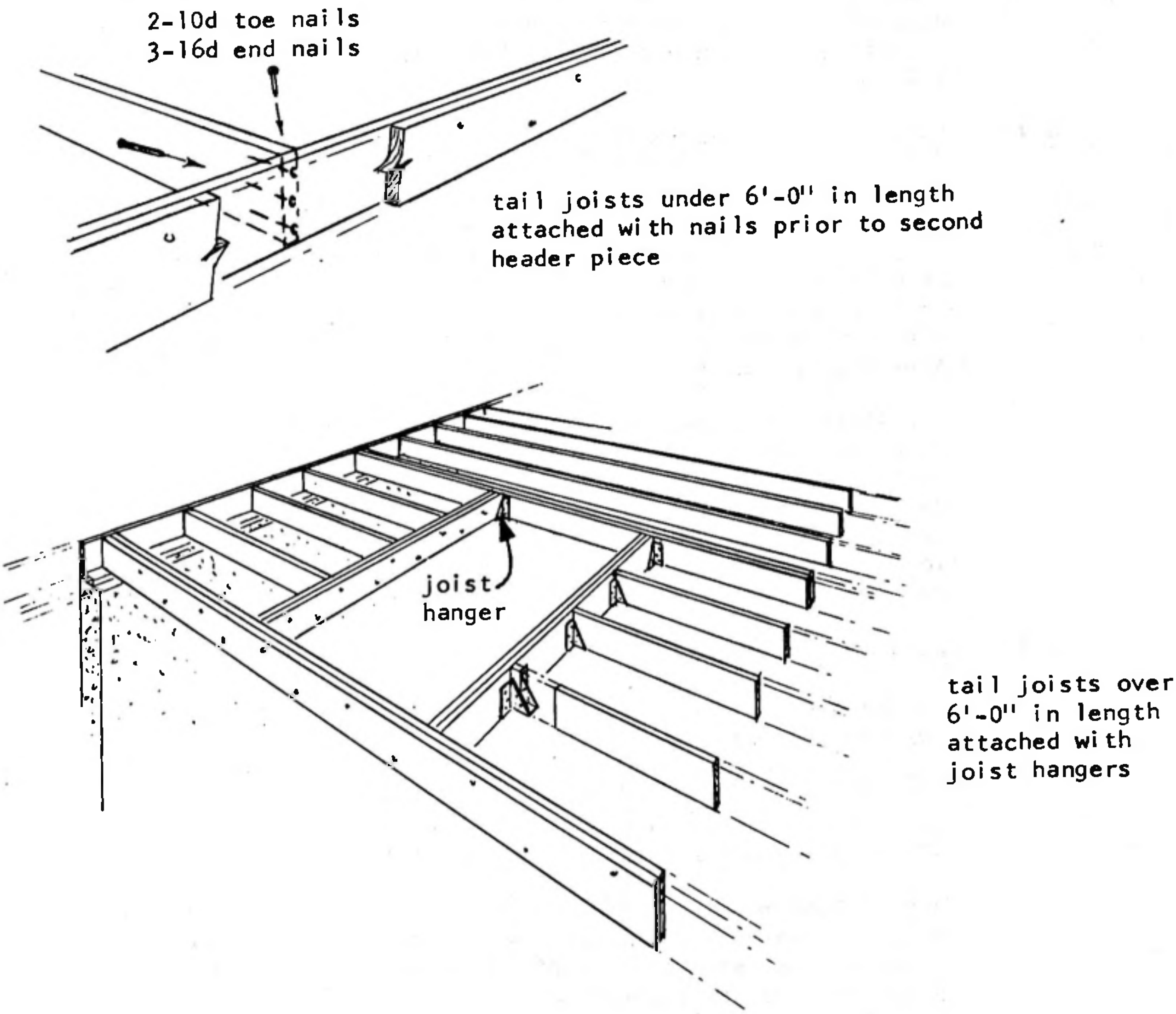


FIGURE 4-F. Double header used across openings up to 10' under normal conditions; must be attached to trimmer joists with joist hanger. Trimmer joists should be at least doubled, depending on load conditions

up to and including 2x12's.

Use of dry lumber for framing members retards nail pops and warping. With lumber which has a higher moisture content and a known tendency to warp, it may be desirable to provide some means of lateral restraint. The subfloor itself serves to restrain the top edge of joists. A finished ceiling applied to the underside of joists will serve to restrain the bottom edge. Where no ceiling finish is used, restraint at the bottom edge of joists may be provided with a 1x3 fastened across the joists at mid-span with 2 - 8d nails at each joist (see Figure 4-G).

4.7 Supporting Nonload-Bearing Partitions

Conventional construction typically employs doubled floor joists under nonload-bearing partitions that are parallel to the floor joists. However, where 5/8 or 3/4 inch thick plywood flooring is used over joists spaced at 24 inches o.c., no extra support is required. Nonload-bearing parallel partitions may be nailed directly to the floor with no additional floor framing required* (see Figure 4-H).*

Parallel partitions may be anchored at the top to overhead floor or roof framing using 2x3 or 2x4 blocking installed flatwise, spaced 2 feet apart to provide adequate backing for ceiling drywall (also shown in Figure 4-H). Blocking which is precut in 22-1/2 inch lengths for this purpose will contribute to convenience and accuracy. Precut blocking of this type has many applications throughout the structure.

4.8 Band Joist Reduced or Eliminated

The band joist used across the ends of floor joists traditionally has been the same size as floor joists. One function of a band joist is to temporarily brace floor joists in position prior to application of the subfloor. The band joist also helps to support stud loads in conventional construction, where wall studs do not necessarily align with floor joists.

With 2-foot modular OVE planning, however, each wall stud bears directly over a floor joist. A nominal 1-inch-thick band may therefore be used in place of the traditional band joist to provide temporary support and positioning of joists. A 1x band uses less material and is easier to install using 8d nails (see Figure 4-I).

In certain cases the band joist may be entirely eliminated with OVE planning. Where a sill plate is used, it will serve to position the bottom edge of joists which are toe-nailed to it. The top edge of joists may be aligned and fastened as the subfloor is installed, precluding the necessity for a band altogether. The siding and/or wall sheathing is then extended down over the

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* Technical Note No. B 429, "Non-Load-Bearing Partitions on Plywood Floors", American Plywood Association.

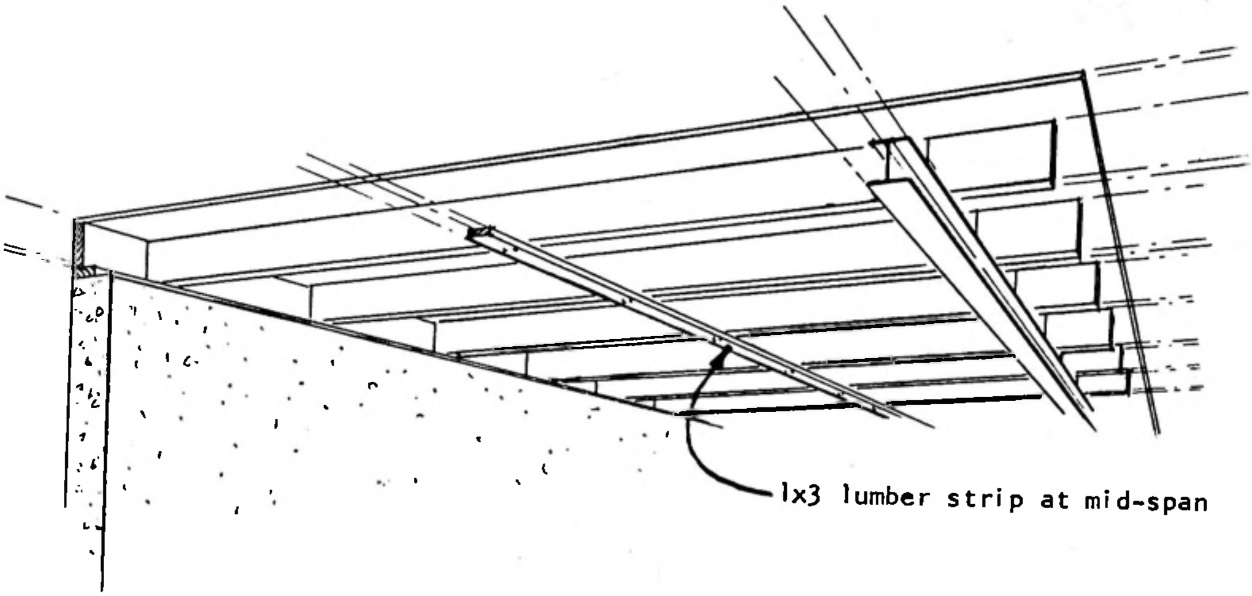


FIGURE 4-G. Floor bridging is not normally required, however, where greenjoists have a known tendency to warp, a 1x3 strip of wood will provide restraint where the ceiling is otherwise unfinished.

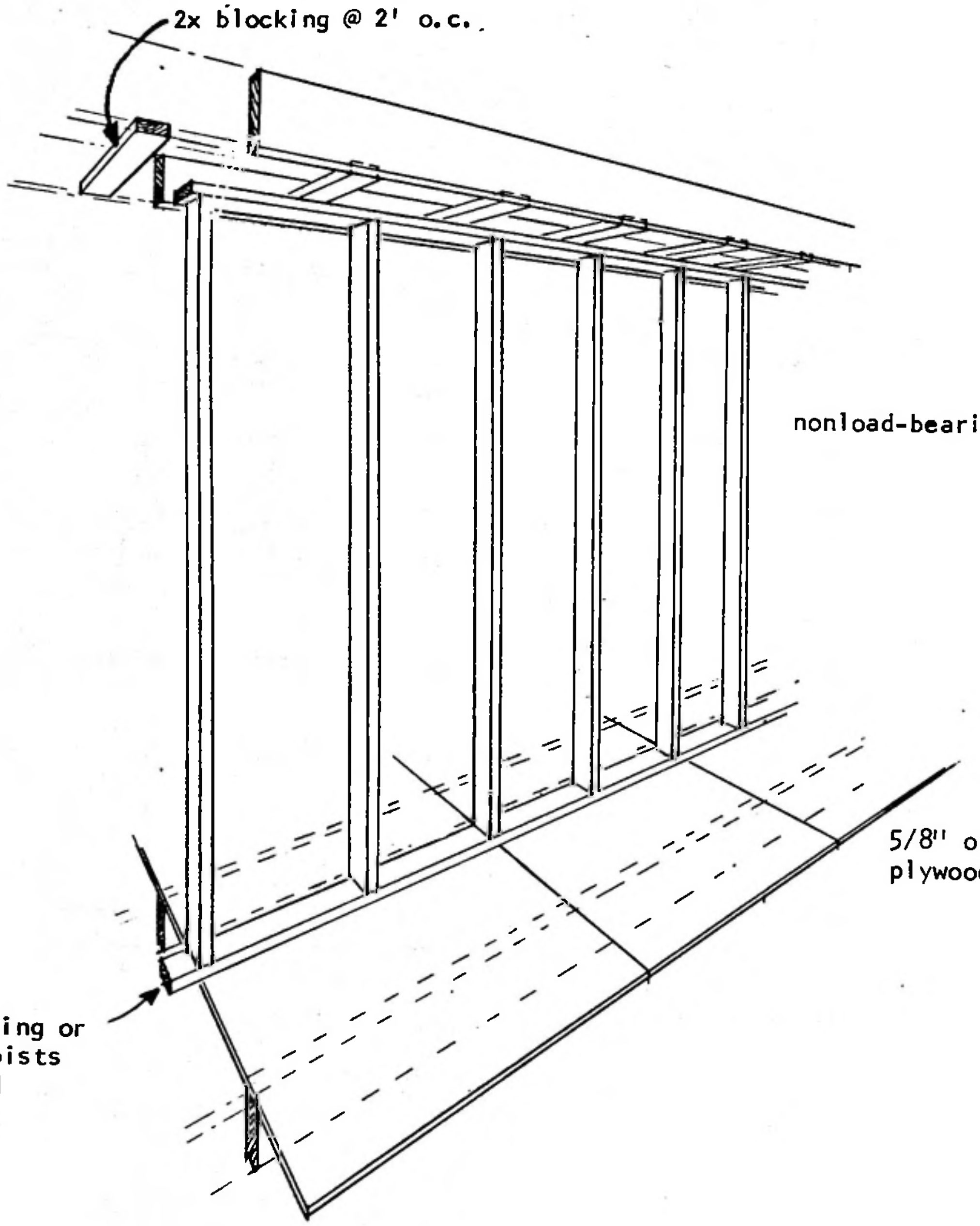
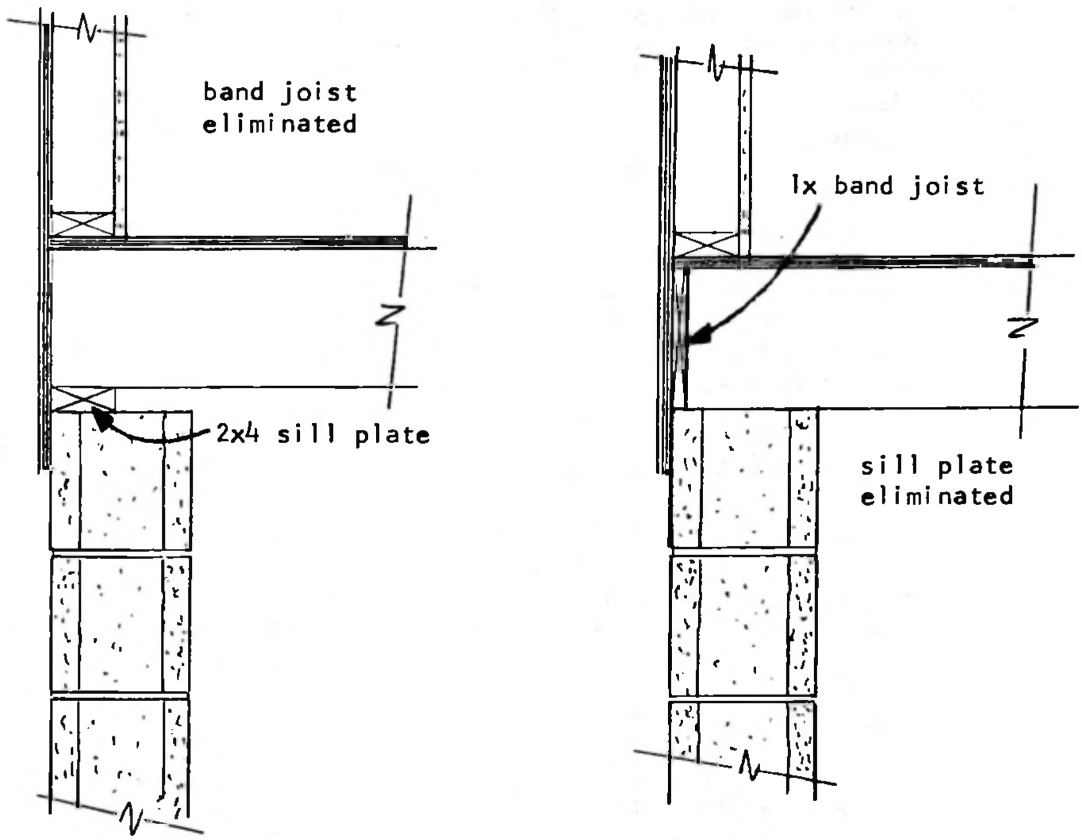


FIGURE 4-H. Precut 22½"-long blocks used to support parallel partitions between framing members at the ceiling, no extra framing or blocking is required at the floor with a 5/8 or 3/4 inch plywood floor.



Note: Wall studs aligned over floor joists

FIGURE 4-1. Band joist reduced or deleted in OVE construction where each wall stud bears directly over a floor joist open joist ends as shown in Figure 4-1.

4.9 Single-Layer Plywood Flooring

In the past, conventional practice has typically employed a double floor construction consisting of subfloor and finish floor or underlayment. However, where carpet and/or resilient floorings are used throughout, a single layer of tongue and groove plywood, designed as a combination subfloor and underlayment, may be applied directly to floor joists. A substantial savings in labor and material is possible by combining these functions in one material.

Tongue and groove, 3/4-inch-thick Group I underlayment grade plywood is recommended for single-layer floors installed over joists spaced 2 feet on center where the plywood is fastened only with nails. Either 8d common nails or 6d deformed shank nails may be used. Nails should be spaced 6 inches apart at panel edges and 10 inches apart across the panel face. Edge blocking is not required with tongue and groove plywood.

Although nailing as above will provide adequate attachment, the use of an approved construction adhesive provides additional benefits for application of single-layer plywood floors. Nail spacing may be increased to 12 inches, both along edges and across the face, where glue is used. Glue should also be used in the grooved joint of tongue and groove plywood for the best results.

As discussed previously, glue-nailing of the plywood floor to joists will increase the stiffness and/or allowable span of the entire floor system. Glue-nailing will also eliminate or reduce loose nails and squeaks which can otherwise develop with even a small amount of joist shrinkage.

Research conducted by the NAHB Research Foundation, Inc., for HUD showed that glue-nailed application of a plywood floor also increases the stiffness of the plywood between joists. As noted previously, tests indicate that 5/8-inch-thick Group I underlayment grade plywood will provide a satisfactory floor when properly glue-nailed to joists spaced at 2 feet on center (see Technical Supplement A).

5. EXTERIOR WALL CONSTRUCTION

5.1 General

The great majority of homes built in the United States have exterior walls framed with wood studs. The conventional wood frame wall is essentially a very efficient construction, but its full potential is not often realized.

There are many opportunities to engineer wood frame walls to reduce both the material and labor content. This chapter discusses the application of OVE techniques to wood frame exterior walls, including studs, plates, headers, siding and other related elements. A 24-inch on center stud spacing is emphasized to coordinate with the 2-foot planning module and coordinated framing principle discussed previously.

Tilt-up wall construction reduces labor content and construction time. It is beneficial to assemble wall sections to the greatest extent possible prior to erection, including framing and sheathing (if used) as well as siding, windows and exterior trim, wherever practical. This may be accomplished by using shop fabricated wall panels or by field fabrication of walls lying flat on the floor deck, or any combination of these.

5.2 Reduced Wall Height

A rough wall height slightly over 8 feet is generally used in conventional homes to produce an 8-foot finished ceiling height after installation of floor and ceiling finish materials. A full 8-foot-high ceiling is not necessarily required, however. Most building codes accept a 7'-6" finished ceiling height in habitable rooms. Where used, it has been found that occupants are rarely concerned or even aware of the difference.

A 7'-6" ceiling height offers several advantages compared to the standard 8-foot height. The lower wall height reduces the amount of material required for studs, insulation and siding. It simplifies construction, since workmen can more readily reach that height for framing and finishing work. A 7'-6" ceiling height often eliminates one step in two-story construction, thereby providing more space for locating stairways. In addition, the lower ceiling height provides an enhanced exterior profile and tends to increase the apparent room size on the interior, because the scale of horizontal-to-vertical dimensions is greater (especially significant in smaller homes). A 7'-6" ceiling height also reduces heat loss and heat gain by reducing total wall area.

In addition to the benefits noted above, a 7'-6" ceiling height increases the structural capacity of the studs by reducing their length (they become shorter columns). This is an important factor in engineering design for 2-foot on center stud spacing. A nominal 7'-6" finished ceiling height with a 7'-7" rough dimension is therefore considered to be an effective OVE design and construction principle.

5.3 Top and Bottom Wall Plates

Where all floor, wall and roof framing members are coordinated on a 2-foot module and aligned vertically, building loads are transmitted directly downward through roof trusses, studs and floor joists. Top plates are no longer required to act as structural beams to distribute concentrated loads from roof trusses to adjacent studs. Likewise, bottom wall plates are not required to act as structural beams to distribute concentrated loads from studs to adjacent floor joists.

Wall plates of some sort are a practical necessity in the layout, assembly and erection of wall panels, and attachment to the floor and roof structure. However, the traditional doubled 2x4 top plates are not required in OVE design. Where roof trusses are aligned over studs, a single top plate is adequate to provide for attachment of trusses. It should be noted that it is unnecessary to tie top plates at corners and other wall intersections, since attachments between the studs, sheathing, siding, and the roof system provide sufficient structural connection.

In certain cases, it may be feasible to substitute nominal 1-inch-thick lumber for top and bottom plates where suitable grades of lumber are available at a favorable price difference. However, a 1x top plate does not provide a suitable base for attachment of roof trusses without special framing connectors. Also, 1x lumber widths sometimes vary from stud dimensions, which may produce dimensional problems in the wall construction.

An effective OVE exterior wall construction, then, consists of studs spaced at 2 feet on center with a single top and bottom plate of the same dimension as studs. A rough wall height of 7'-7", including plates, will provide a 7'-6" finished ceiling height after installation of floor and ceiling finish materials, leaving a net stud length of 7'-4" (see Figure 5-A).

5.4 Wall Stud Design

As discussed previously, a 2-foot on center spacing is used for all framing members to coordinate with the OVE planning module and to transmit concentrated loads directly to the next framing member below.

Many building codes and standards specifically permit 2x4 studs to be spaced up to 24 inches on center in single story homes and in the second story of two-story homes. Several codes also permit a 24-inch stud spacing in the first story of two-story homes. Even so, the building official may require engineering

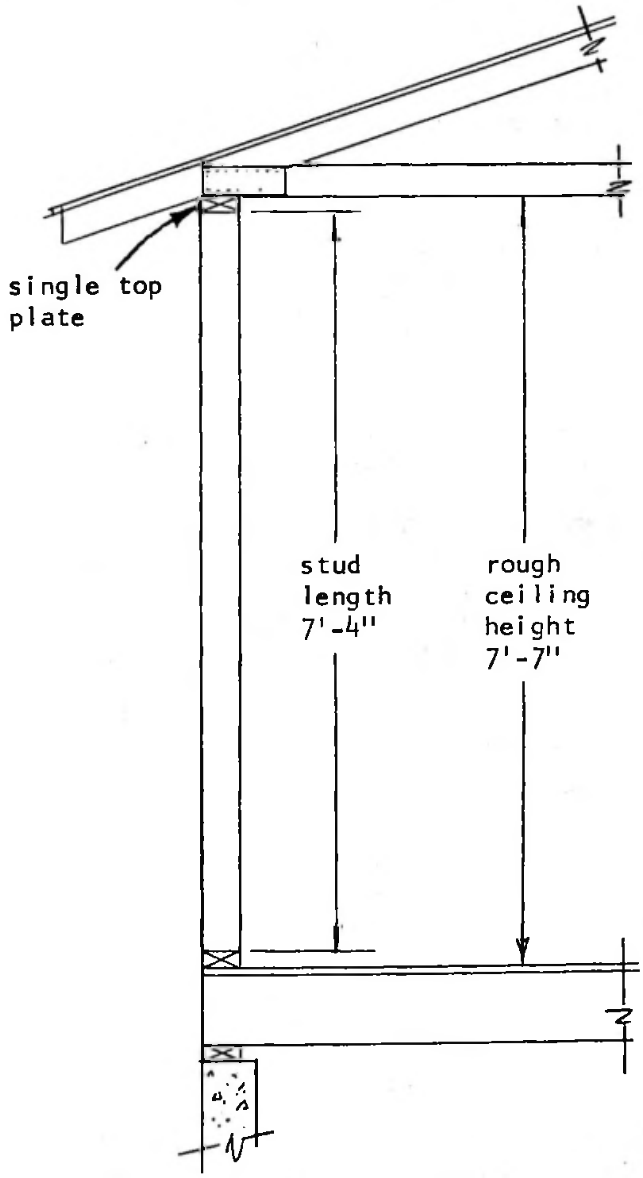


FIGURE 5-A. Suggested OVE exterior wall construction having 2' on center studs vertically aligned with other framing members and a single top and bottom plate, with a 7'-7" rough ceiling height.

calculations to substantiate the use of 2x4 studs spaced 2 feet on center in any particular application.

The most critical factor in designing wood studs is usually the horizontal wind load. On buildings that are 50 feet or less in height, the wind pressure on exposed vertical surfaces is normally assumed to be 15 psf, except in geographical localities subject to severe wind conditions.

5.4.1 Engineered 2x4 Studs

Conventional engineering procedures for determining the load carrying capacity of wood frame walls are generally based on the structural skeleton alone. The only contribution normally credited to exterior and interior coverings is prevention of sidewise buckling of the studs.

Research conducted by the NAHB Research Foundation, Inc., however, demonstrates conclusively that even so-called "non-structural" interior and exterior sheet materials (such as gypsum drywall and low density fiberboard) contribute substantially to the strength and stiffness of wood frame walls.

Based on laboratory research data, a recommended design procedure was developed recognizing approximately one-half of this contribution (see Technical Supplement D). A simplified procedure for checking the structural adequacy of 2x4 studs, based on this work, is shown on the following page.

5.4.2 Engineered 2x3 Studs

Although 2x3 studs are nor normally used for load-bearing walls in conventional building, they may be suitable in certain areas having lesser design loads for wind and snow. Research conducted by the NAHB Research Foundation for HUD indicates that exterior load-bearing walls with 2x3 studs spaced at 2 feet on center are adequate for some single-story homes up to 28 feet in depth under moderate wind and snow loads.

In laboratory tests conducted for HUD, full scale wall panels were subjected to simultaneous horizontal and vertical loads to simulate combined wind load and roof loads. Wall panels were constructed of nominal 7'-6" long 2x3 studs spaced at 2 feet on center, covered with conventionally nailed 3/8-inch plywood siding on the exterior face and 3/8-inch gypsum drywall on the interior face. Test panels showed satisfactory performance under a combined horizontal (wind) load of 15 psf and vertical (roof) load of 1,000 pounds on each stud, equivalent to 30 psf total roof load for a 28' truss with a 2-foot overhang at the eaves (see Technical Supplement E). This wall construction was used in the OVE demonstration house described in Chapter 1.

SIMPLIFIED PROCEDURE FOR CHECKING STRUCTURAL ADEQUACY OF 7'-4" LONG 2x4 STUDS SPACED AT 2 FEET ON CENTER

A. Determine the total vertical design load acting on each stud due to live and dead roof, wall and/or floor loads (lbs.).

B. Determine local horizontal wind design load requirements for walls (normally 15 psf, unless unusual wind conditions prevail).

C. Calculate compressive stress due to vertical load:

$$\frac{\text{Total Vertical Load per Stud (A)}}{5.25}$$

D. Calculate bending stress due to horizontal load:

$$\text{Wind Load (B)} \times 52$$

E. Determine allowable compressive stress parallel to grain for species and grade of 2x4 stud from Appendix A.

F. Determine allowable bending stress ("f") for repetitive members for same species and grade of 2x4 stud from Appendix A.

G. The species/grade of 2x4 stud selected is acceptable from a stress standpoint if:

$$\frac{(C)}{(E)} + \frac{(D)}{(F)} \text{ Does } \underline{\text{not}} \text{ exceed } 1.0$$

H. If the above exceeds 1.0, try a higher stress rated species or grade of 2x4 stud until an acceptable one is found.

Based on this experience, 2x3 studs spaced at 2-feet on center are considered adequate for exterior load-bearing walls in single story homes or the second story of two-story homes where:

- House depth does not exceed 28 feet
- Design wind load does not exceed 15 psf
- Design snow load does not exceed 20 psf
- Allowable fiber stress ("f") of 2x3 material is at least 800 psi
- 4'x8' sheet materials such as gypsum board, fiberboard sheathing or their structural equivalent are used on both exterior and interior faces

5.5 Exterior Wall Corners

Conventional practice generally employs a 3-stud "corner post" at exterior wall corners. This practice is not dictated by structural considerations. The third member serves only as a backer for the interior wall facing, usually 1/2-inch-thick gypsum drywall.

Since the maximum load on the corner studs is one half or less than the load on a regular stud, two stud corners are adequate structurally. The corner may be formed from the end studs in each of the two wall panels which meet at the corner. They are simply nailed together in conventional fashion as the wall panels are erected. No other special means of attachment is required at the typical corner.

Several alternate methods of providing the necessary drywall back-up at corners in place of the third stud are shown in Figure 5-B. One alternative consists of a 4-foot-long 1x3 lumber strip nailed to the back of the inside corner stud. Another alternative is to use small wood or plywood cleats spaced no more than 2 feet apart. A third alternative utilizes special metal clips spaced up to 2 feet apart. Clips of this type are preferred for ease of installation with limited accessibility. They are now widely available at building hardware suppliers.

It should be noted that gypsumboard is not actually fastened to the metal clips or wood backers. The sheet resting against the backers is installed first so that the second sheet, which is nailed to the stud, will lock the first in place. This provides a "floating joint," which is recommended practice to reduce stresses and cracks at the corners. The 2 stud corner is also an energy saver since the wall insulation can fill the space normally occupied by the third stud.

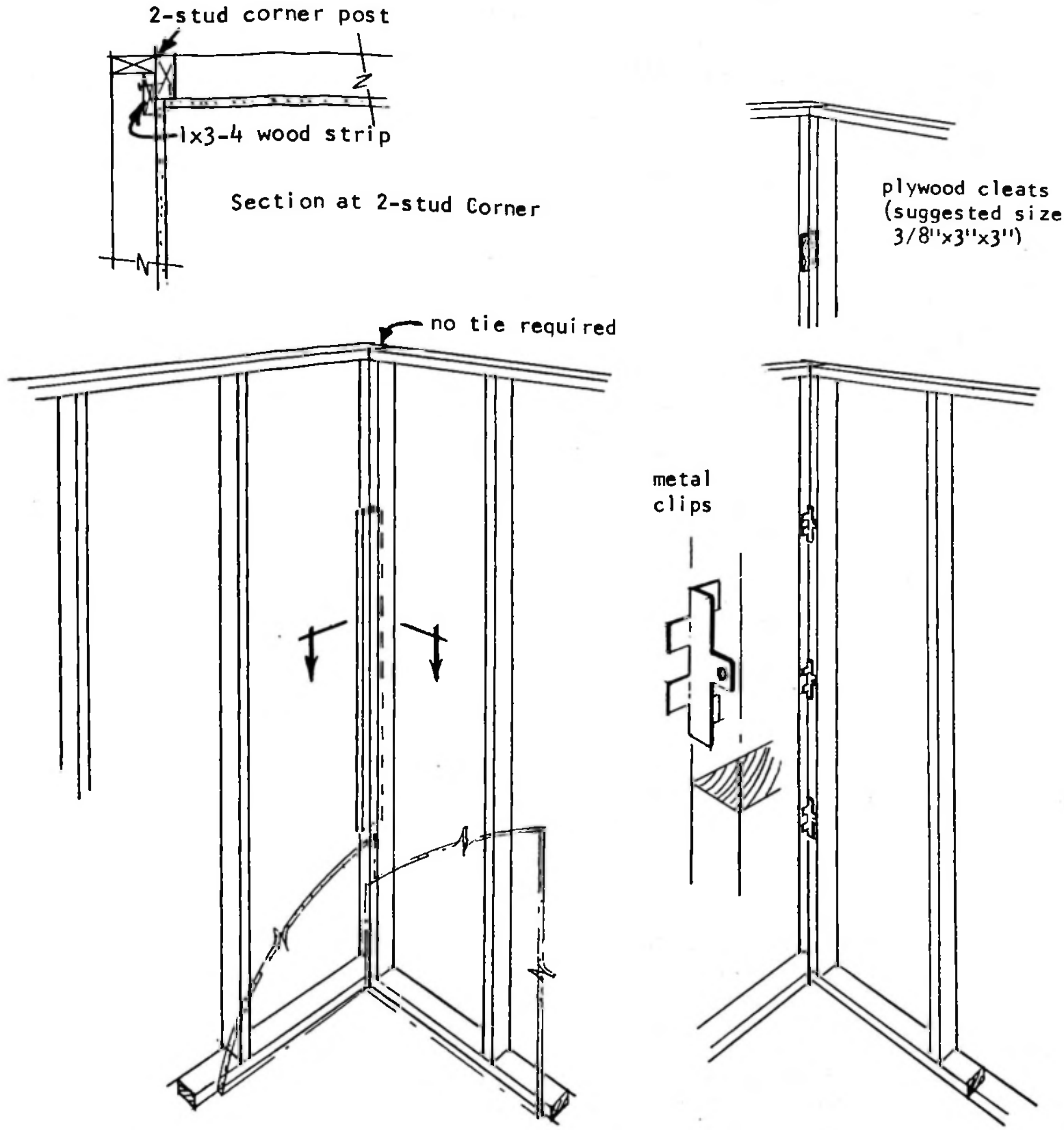


FIGURE 5-B. Alternate methods for providing drywall back up with a 2-stud "corner post."

5.6 Partition Posts Eliminated

Similarly, a 2-stud "partition post" need not be built into the exterior wall for attachment of partitions. There is no structural requirement for anchorage of partitions to the exterior wall. A partition post as such is not required.

Partitions which intersect the exterior wall at a point sufficiently close to a normal stud location may be nailed directly to the exterior wall stud. No other attachment is required. Where partitions fall between normal stud locations, a mid-height block may be installed between the exterior wall studs to provide for attachment of the end partition stud (see Figure 5-C).

It is also necessary to provide back-up support for drywall at the intersection. This may be provided by lumber strips, plywood or wood cleats or metal clips, as shown for exterior wall corners.

5.7 Mid-Height Blocking Eliminated

Blocking between studs at approximately 4 feet above the floor is not necessary with platform framing, as used in the OVE system. It is unnecessary from either structural or fire considerations.

Wall studs are adequately braced laterally by even minimal wall covering materials. Top and bottom plates act as firestops with platform framing. Modern building codes do not require such blocking.

5.8 Framing Door and Window Openings

Wherever possible, the location of door and window openings in the exterior wall should be coordinated with the modular stud spacing on at least one side. This will simplify construction and eliminate at least one extra stud at each opening.

When architectural design considerations allow the use of windows in 24-inch modular width increments, windows can be coordinated with the modular stud spacing on both sides. This is especially effective where nominal 48-inch-wide windows are also coordinated with 4-foot-wide siding panels.

Structural headers are required only in load-bearing walls where a stud is interrupted. Either lumber or a plywood box beam construction may be used for structural headers. The plywood box beam uses less material and is an energy saver since the cavity may be filled with regular wall insulation.

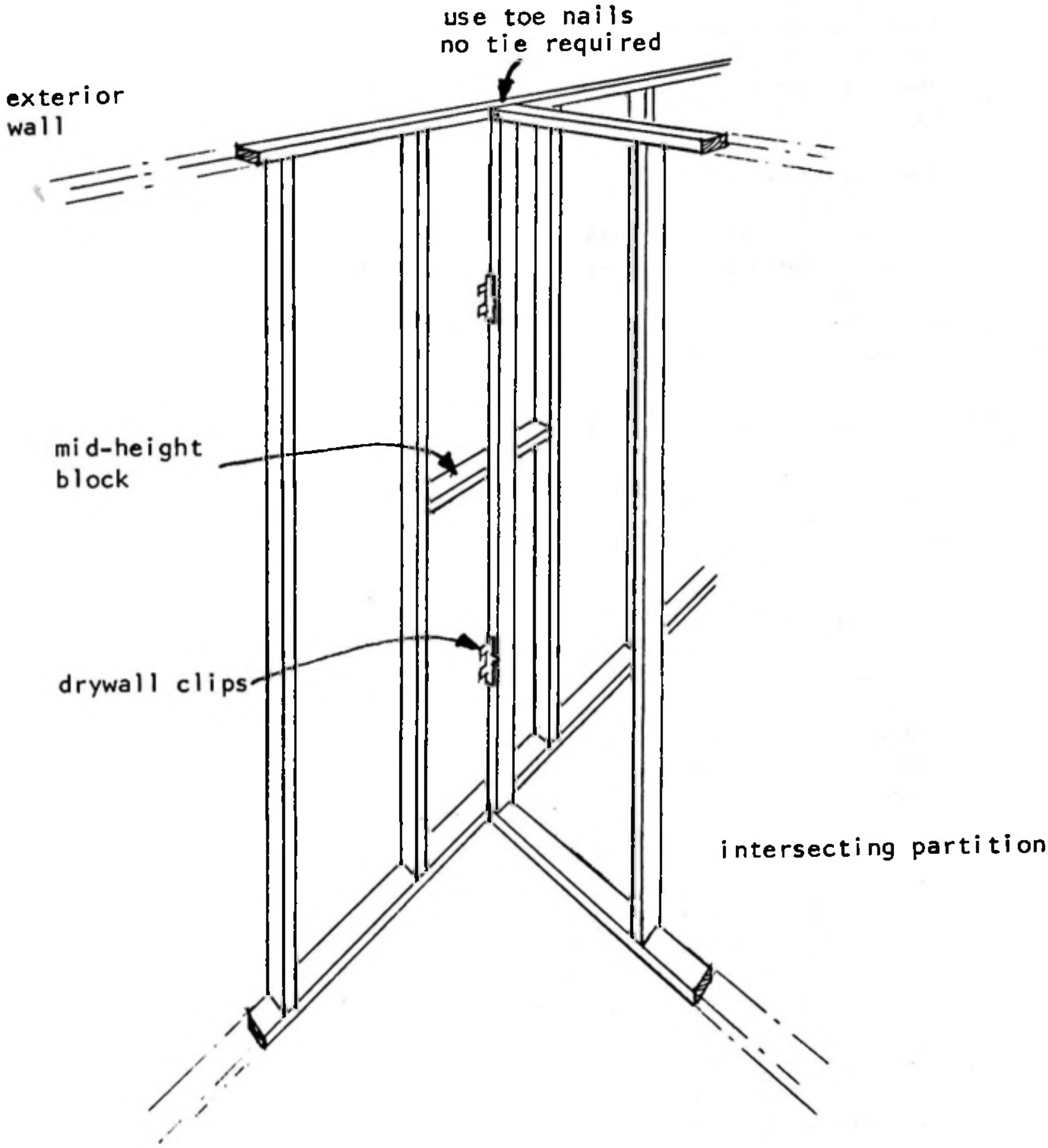


FIGURE 5-C. Attachment of partitions and drywall backup at exterior walls without using a partition "post".

5.8.1. Openings in Nonload-Bearing Walls

The purpose of a structural header is to carry roof or floor loads over an opening in a wall. Where there are no floor or roof loads to be carried over the opening, there is no reason to use a header or supporting "jack" studs.

The end walls of houses with trussed roof systems are essentially nonload-bearing (assuming that roof trusses and floor joists bear on front and rear walls). Structural headers are not required over door and window openings in exterior nonload-bearing walls of this type. The openings may be single framed with one stud at each side and a single member across the head (see Figure 5-D).

5.8.2. Window Opening Between Studs

A nominal 24-inch-wide window opening may be formed between regular studs by simply installing precut blocks at the proper height for the head and sill. Since no studs are displaced, this type of opening may be used in either load bearing or nonload-bearing walls without requiring a structural header, jacks or extra studs.

In rooms where a more expansive window width is desired, two or more adjacent stud spaces may be utilized in this manner to form a multiple opening window. In this application, regular studs remain in place between individual units to function as load bearing mullions (see Figure 5-E).

Where compatible with architectural design, nominal 24-inch wide windows will simplify construction and reduce both labor and material requirements. For maximum effectiveness they should be used consistently rather than mixed with other widths. Although the width remains standard, the height may be varied to provide different window opening areas.

5.8.3. 2x8 Lumber Headers

A structural header is necessary over openings in load-bearing walls where one or more load-bearing studs are displaced. A 2x8 header installed directly beneath the single top plate of the recommended 7'-7" rough wall height will provide the normal 6'-10" rough opening height.

Where a conventional double 2x8 header is used in a 2x4 wall, it is not necessary to shim or nail the two members together if the members are positioned flush to the inner and outer faces of studs as they are nailed. Where loads and span conditions permit, a single 2x8 header may be used in a 2x4 stud wall by addition of a 2-inch-thick block along the bottom edge. Similarly, a single 2x8 header may be adapted to a 2x3 load

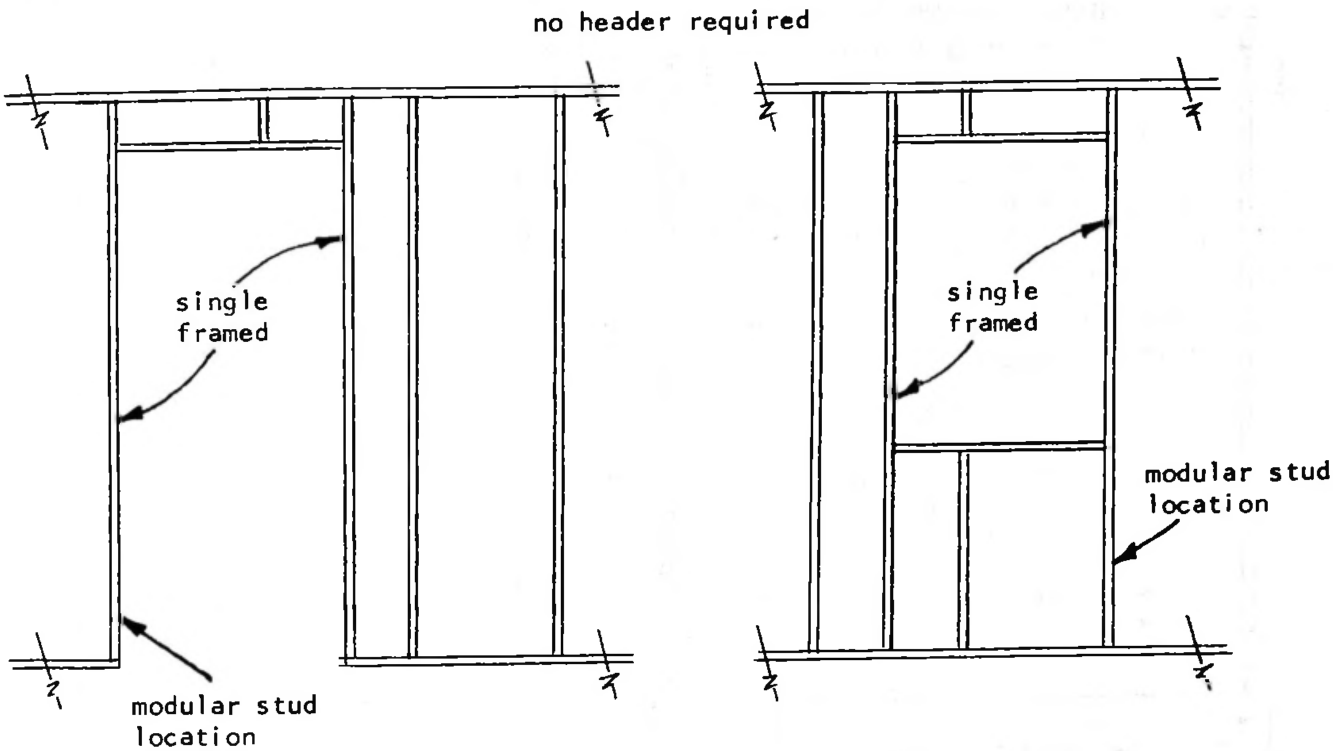


FIGURE 5-D. Single-framed openings in nonload-bearing exterior walls.

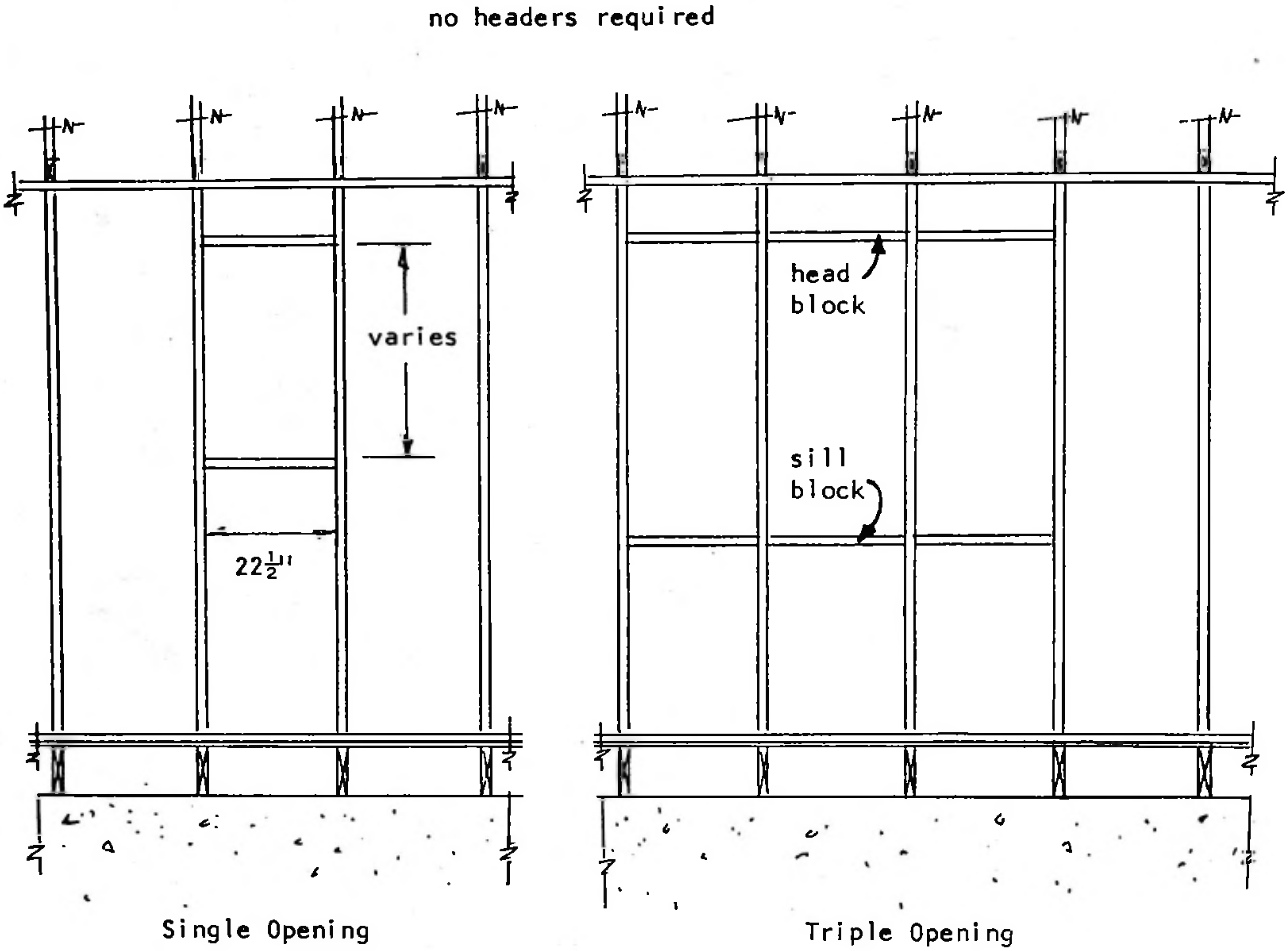


FIGURE 5-E. Nominal 24-inch wide window opening between studs eliminates requirement for headers, jacks and cripples in a load-bearing wall.

bearing wall by adding a 1-inch-thick block along the bottom edge (see Figure 5-F for details).

Total roof design load consists of the dead load or weight of the structure itself, plus the live load or snow load. The dead load of the roof/ceiling will usually range between 8 psf and 15 psf, depending on the particular construction and combination of materials. Snow loads for different regions of the country are presented in Figure 6-B, Chapter 6. Floor design loads are described previously in Chapter 4. Normally a 10 psf dead load is assumed, and either a 30 psf or 40 psf live load is used, depending on building code stipulations.

Several different roof and floor load combinations are depicted in Figure 5-G. Allowable spans for 2x8 headers with different roof and floor load conditions are shown in Table 5-1. It is important to note that when a window or door opening occurs directly beneath an opening in the story above, the lower header may be carrying floor loads only. It is therefore advantageous to align openings vertically in multistory construction to minimize header loads.

It is apparent from Table 5-1 that 2x8 headers are capable of spanning a substantial range of door and window openings meeting most residential requirements. A single jack stud supporting each end of the header is adequate for the spans shown.

Where a greater effective window width is desired, two or more individual window units may be installed next to each other. The header should be continuous across the adjacent openings, with intermediate jack studs installed between units to act as load-bearing mullions, as shown in Figure 5-F.

5.8.4 Glue-Nailed Plywood Box Headers

A structural header may be formed by glue-nailing a plywood skin to framing members above openings in a load-bearing wall. Performance tests were conducted on two designs of this type by the NAHB Research Foundation, Inc., for HUD (see Technical Supplement F).

For houses up to 28 feet deep, plywood box headers up to nominal 3 feet in length which carry only roof loads or floor loads may be constructed of a single layer of 3/8-inch or thicker Group 1 exterior grade plywood glue-nailed to either the inside or outside face of framing above the opening. Face grain of the plywood must be oriented horizontally across the opening, and the top plate must be continuous over the opening. No jack studs are required for this opening width (see details Figure 5-H).

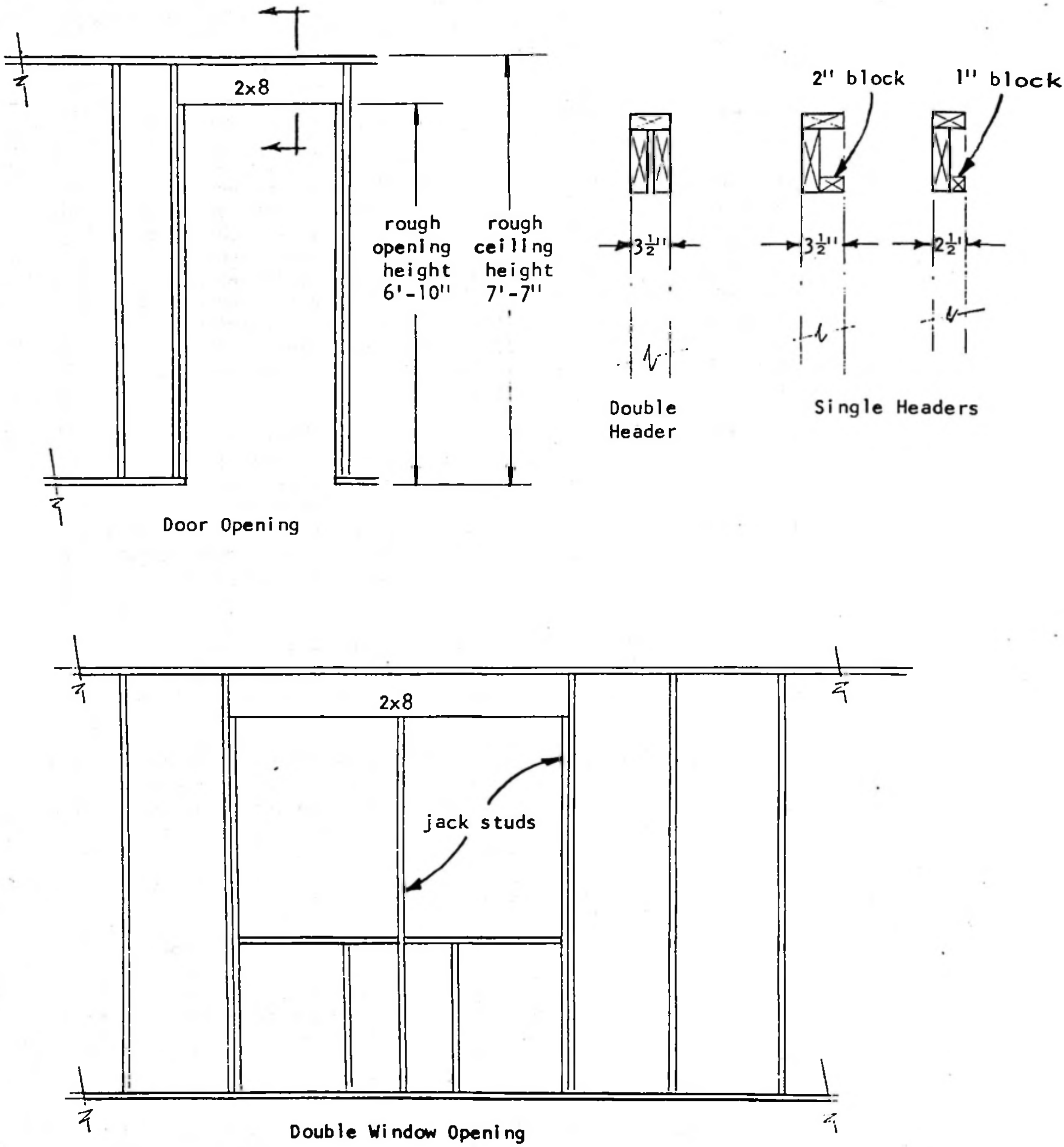


FIGURE 5-F. Single and double 2x8 headers used with 7'-7" OVE rough ceiling height in exterior load-bearing wall

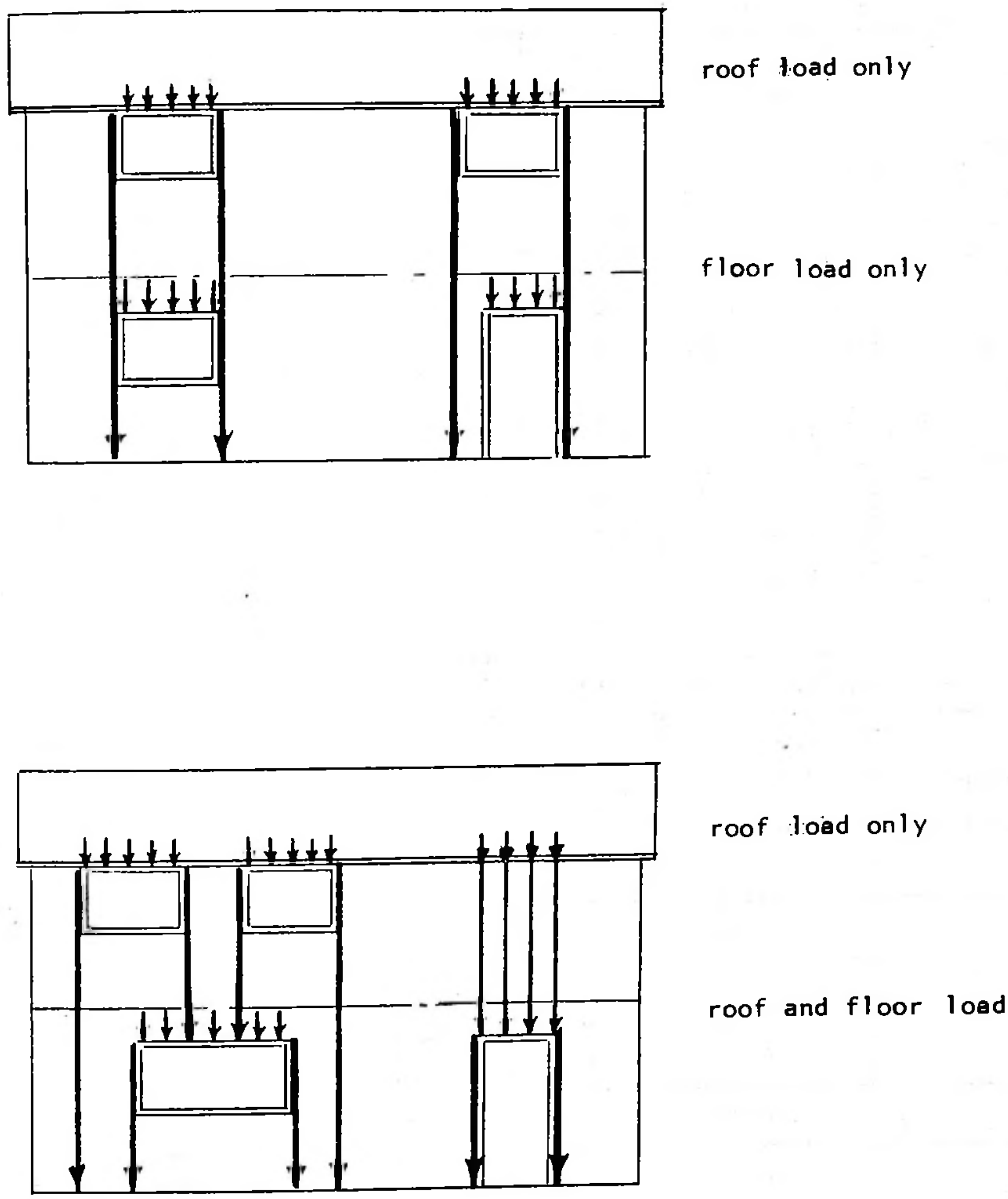
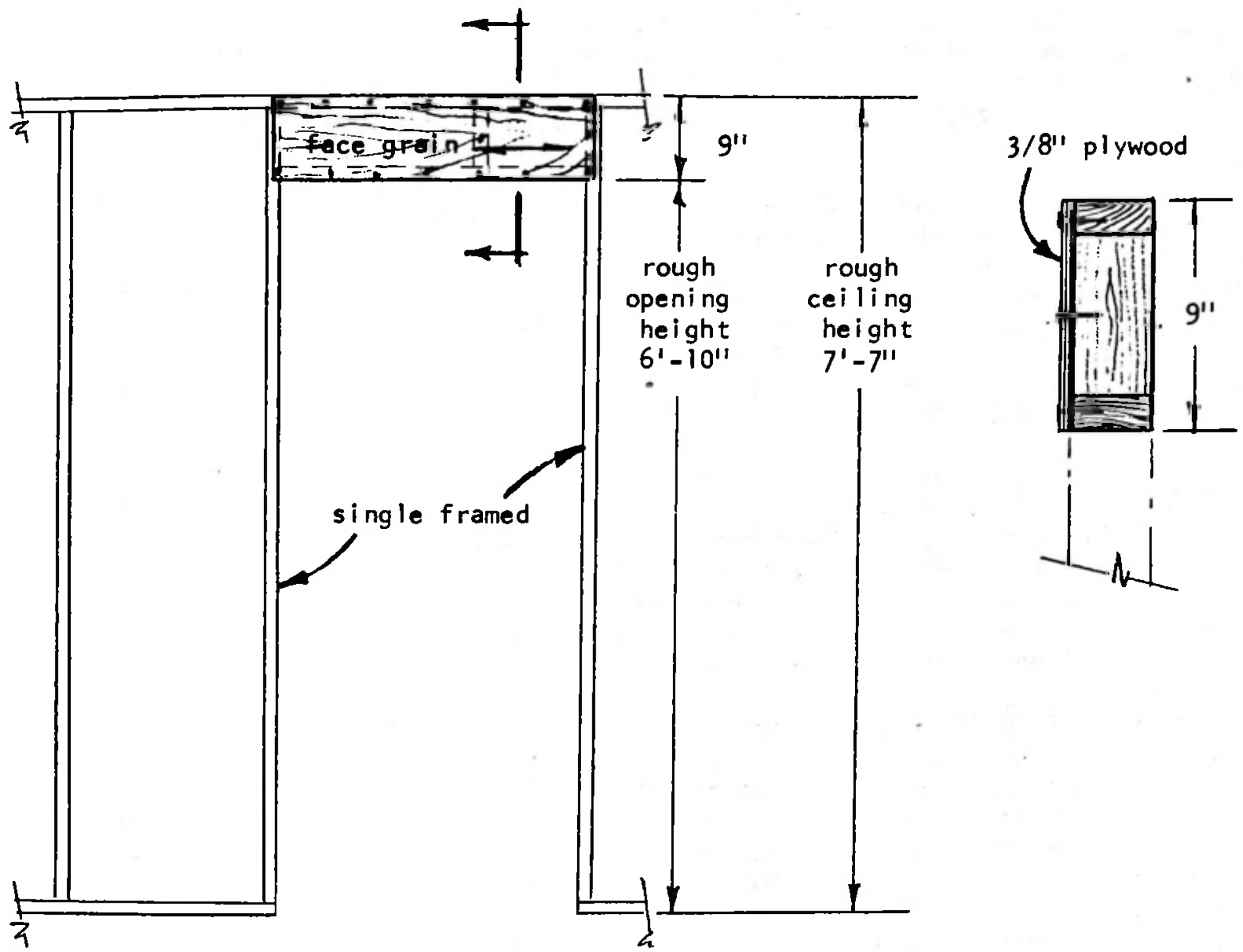


FIGURE 5-G. Possible combinations of roof and floor loads acting on different headers in a 2-story structure.

TABLE 5-1. Allowable 2x8 header spans (ft.-in.) for different load conditions

Load Condition	Min. Lumber Strength*	Header Size	House Depth (ft.)				
			24	26	28	30	32
50 psf Live & Dead Load							
Floor Only	1000 f	1-2x8	3-8	3-5	3-3	3-1	2-11
	75 H	2-2x8	6-8	6-6	6-3	6-1	5-10
	1500 f	1-2x8	4-5	4-2	3-11	3-8	3-6
	90 H	2-2x8	8-2	7-11	7-8	7-5	7-0
30 psf Live & Dead Roof Load — 50 psf Live & Dead Floor Load							
Roof Only	1000 f	1-2x8	4-0	3-9	3-6	3-3	3-1
	75 H	2-2x8	7-0	6-9	6-6	6-4	6-2
	1500 f	1-2x8	4-10	4-6	4-2	3-11	3-8
	90 H	2-2x8	8-6	8-3	8-0	7-9	7-6
Roof and Floor	1000 f	1-2x8	2-1	2-0	-	-	-
	75 H	2-2x8	4-3	4-0	3-9	3-6	3-4
	1500 f	1-2x8	2-6	2-4	2-3	2-1	2-0
	90 H	2-2x8	5-0	4-9	4-5	4-2	4-0
40 psf Live & Dead Roof Load — 50 psf Live & Dead Floor Load							
Roof Only	1000 f	1-2x8	3-0	2-10	2-7	2-5	2-4
	75 H	2-2x8	6-0	5-7	5-3	4-11	4-7
	1500 f	1-2x8	3-7	3-4	3-2	2-11	2-9
	90 H	2-2x8	7-3	6-9	6-3	5-11	5-7
Roof and Floor	1000 f	1-2x8	-	-	-	-	-
	75 H	2-2x8	3-7	3-4	3-2	3-0	2-10
	1500 f	1-2x8	2-2	2-0	-	-	-
	90 H	2-2x8	4-4	4-0	3-9	3-7	3-4
50 psf Live & Dead Roof Load — 50 psf Live & Dead Floor Load							
Roof Only	1000 f	1-2x8	2-5	2-3	2-1	2-0	-
	75 H	2-2x8	4-9	4-6	4-2	3-11	3-8
	1500 f	1-2x8	2-10	2-8	2-6	2-4	2-3
	90 H	2-2x8	5-9	5-4	5-0	4-8	4-5
Roof and Floor	1000 f	1-2x8	-	-	-	-	-
	75 H	2-2x8	3-2	2-11	2-9	2-7	2-5
	1500 f	1-2x8	-	-	-	-	-
	90 H	2-2x8	3-9	3-6	3-4	3-1	2-11

*See Appendix A for strength properties of different species and grades of lumber.
Note: End splits may not exceed one times header depth.



Note: Group I exterior grade plywood glue-nailed with approved structural adhesive

FIGURE 5-H. Plywood box header for openings up to 3'-wide, carrying only roof loads or floor loads which do not exceed 500 lbs. per lineal foot over the header.

For openings up to nominal 6 feet in width carrying only roof loads or floor loads in houses up to 28 feet deep, a layer of 3/8-inch or thicker Group 1 exterior grade plywood should be glue-nailed to both the inside and outside face of framing over the opening. The face grain of both plywood skins must be oriented horizontally, and the top plate must be continuous over the entire opening width. It is necessary to use jack studs for openings greater than 4 feet in width (see Figure 5-I for details).

The plywood thickness for either design may be selected to blend with other wall covering materials. The plywood skins may be considered as sheathing or finished as an accent panel on the exterior, or may be taped and spackled as drywall on the interior. A water resistant structural adhesive of the casein, urea formaldehyde, urethane or phenol-resorcinol type should be used to glue the plywood. Nails should be spaced at a maximum of 6 inches along all framing members.

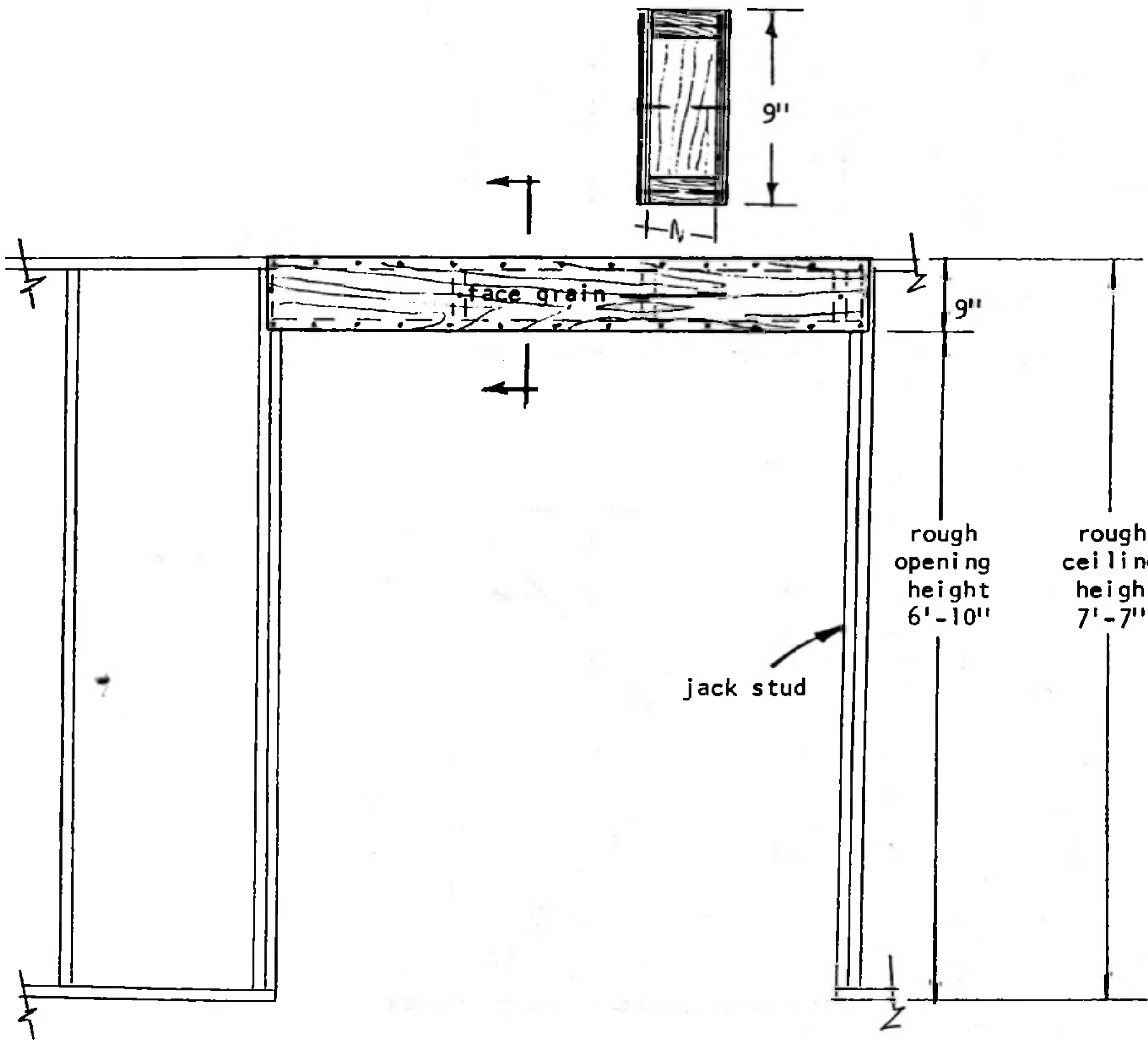
The 9" deep box beams in this application are designed to provide the standard 6'-10" rough opening height when used with a 7'-7" wall height. The beams may be used with either a 2x3 or 2x4 wall construction. They are suitable for houses up to 28' in depth where they carry either floor loads or roof loads, but not both. In neither case should the total design load exceed 500 pounds per lineal foot over the beam.

5.9 Exterior Wall Siding/Sheathing

There are several methods of providing the necessary racking strength in exterior walls to resist wind and earthquake loads. Where consistent with architectural design, 4-foot-wide structural siding panels generally offer the most cost effective solution.

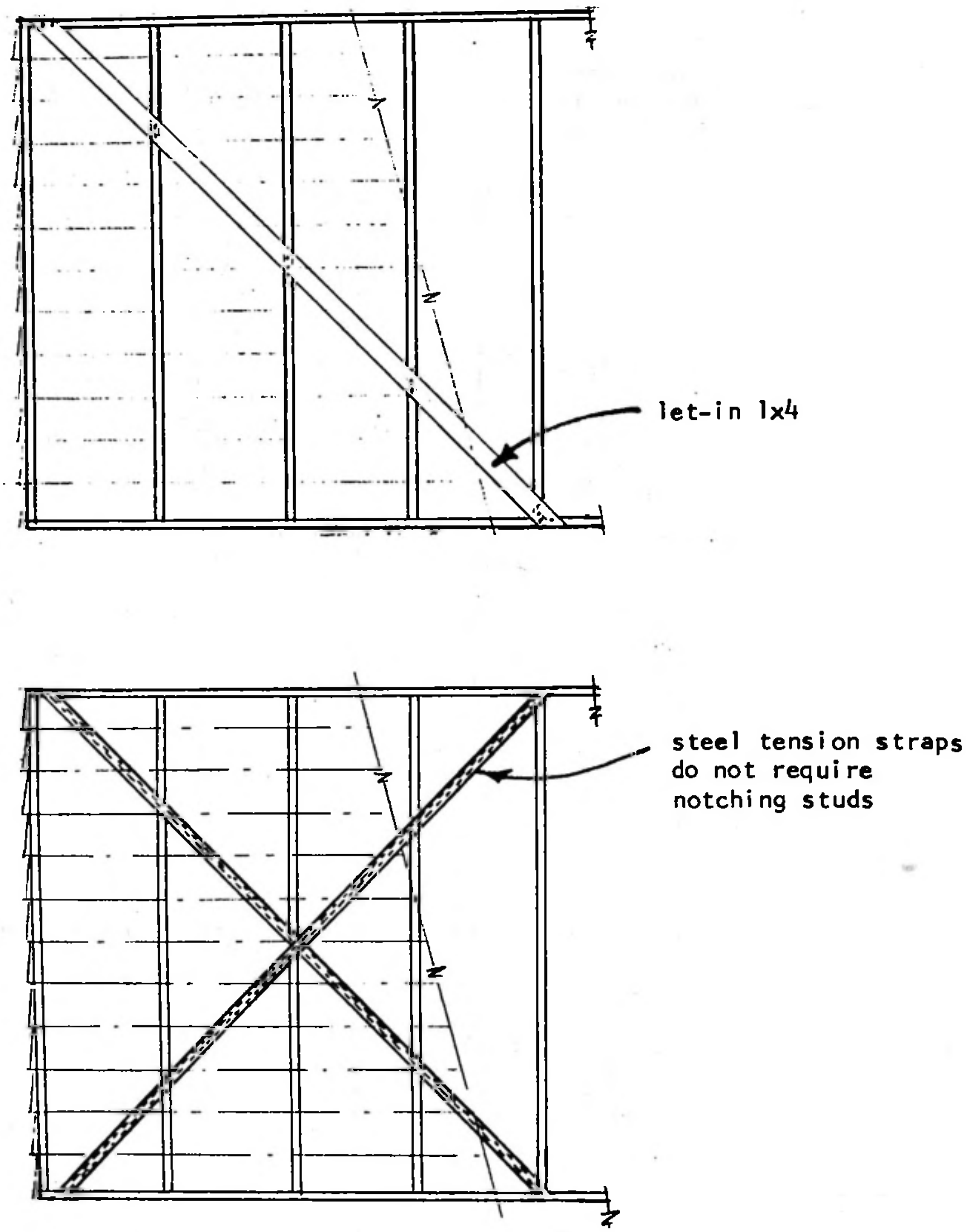
There is a wide variety of decorative plywood, hardboard and high density fiberboard siding products which may be applied directly over studs spaced at 24 inches on center. Although not recommended by the manufacturer, a 3/8-inch-thick saw-textured plywood siding product used on the OVE demonstration house proved satisfactory. Structural siding panels installed directly to studs combine the functions of siding, sheathing and structural bracing in a single layer.

Certain siding products such as horizontal wood or plywood strip siding may be suitable for application directly to studs or over sheathing paper, but do not provide necessary racking strength. Let-in 1x4 diagonal corner bracing may be used to provide the required racking strength with this type of application. Each wall should contain at least one 8-foot- or three 4-foot-wide braced sections. Let-in bracing is not permissible with 2x3 studs. Metal tension straps are also available for diagonal bracing. They must be installed diagonally in both directions to provide the required racking strength (see Figure 5-J). Metal



Note: Group I exterior grade plywood glue-nailed with approved structural adhesive

FIGURE 5-1. Plywood box header for openings up to 6'-wide, carrying only roof or floor loads which do not exceed 500 lbs. per lineal foot over the header.



Note: Diagonal bracing not required where an approved panel siding or sheathing product is used.

FIGURE 5-J. Alternate methods of providing diagonal bracing where required for racking strength in exterior walls

straps do not require letting in, and may be used with any size stud. Either type of diagonal bracing may be used with non-structural sheathing such as plastic foam insulating sheathing products.

Some siding materials, such as aluminum, require wall sheathing for back-up support, even though they are nailed at studs. Where this type of siding is used, 1/2-inch-thick intermediate density fiber board sheathing will provide the required racking strength to the wall as well as back-up for siding. Higher density 1/2-inch-thick "nail-base" fiberboard sheathing is also available for sidings such as wood or asbestos shingles, which must be attached directly to the sheathing.

Wherever possible, the sheathing and/or siding should be applied to the wall framing before the wall is tilted up. Almost any siding product can be installed in this manner, especially on full length walls. Special wall jacks are available where completed walls are too heavy to lift by hand.

Regardless of the type of siding selected, a prefinished product saves on-site labor time and contributes to quality control. Exterior painting is difficult to control, and quality can suffer from unskilled labor, inferior paints or delays in application. Most types of siding are available in a prefinished form, or they may be prefinished prior to delivery.

5.10 Exterior Door Units

Prehung exterior door units are used in OVE construction to simplify construction and to maintain quality. Both prehung wood doors and insulated steel door units are available.

Steel doors are generally prehung in a wood frame with weather stripping and threshold installed, and the units are prime painted. The foam-filled steel doors have gained a reputation for being stable, weathertight, and generally trouble free. Analyses show that storm doors are not cost effective from an energy conserving standpoint when prehung weatherstripped foam filled steel doors are used.

5.11 Window Units

The choice between wood or aluminum window units depends on the house design, market preference, performance, cost and, of course, availability.

The least expensive windows are usually aluminum. However, the lowest cost aluminum units usually have high rates of air infiltration, which is poor from an energy conservation standpoint. Thermalized aluminum windows have a thermal break that reduces heat loss and heat gain through the metal. Although better quality aluminum windows may cost as much or more than a comparable quality wood window, they are sometimes preferred because they do not require field finishing. However, it is important to specify aluminum windows that have been anondized, coated or treated for corrosion resistance. "Mill finish" aluminum provides little corrosion protection.

Prefinished wood window units are also widely available. These range from factory painted to plastic clad finishes with varying degrees of durability and cost. Regardless of the type of unit selected, a window which does not require additional finishing on the exterior is a part of the OVE concept to avoid this troublesome field operation.

Aluminum windows carrying the label of the Architectural Aluminum Manufacturers Association (AAMA) meet industry standards, including lower levels of air infiltration. Wood windows carrying the label of the National Woodwork Manufacturers Association (NWMA) meet industry standards for wood windows.

Wood and aluminum window units are normally produced in standard widths which do not necessarily correspond to the 2-foot modular stud spacing. Where window openings are coordinated with wall framing members on both sides of the opening, as discussed previously, it will generally be necessary to obtain special window widths. This is not necessarily a problem, however, since window units are often fabricated on a local or regional level. Many fabricators can provide special sizes at little or no extra cost, depending on quantity.

Whether stock or special window sizes are used, it is beneficial to limit the number of different sizes required. With proper planning, three window sizes will often be sufficient for an entire series of house designs to provide for the kitchens, living rooms and bedrooms, respectively.

Either wood or aluminum window units may be installed before the wall is erected. As with siding, this will reduce labor costs, especially where subsequent installation would require ladders or scaffolds.

5.12 Exterior Trim and Finish

Minimizing exterior trim is part of the OVE concept. However, trim around doors and windows, at corners and other critical points often serves an important purpose. Aside from appearance, the primary function of exterior trim is to cover construction joints and small inaccuracies. Properly placed exterior trim pieces provide needed construction tolerances.

Many architectural styles lend themselves to natural or rustic materials on the exterior. This permits the use of less expensive lumber for trim. Figure 5-K shows basic trim details using common lumber strips. A rough sawn surface, knots and other natural characteristics become an asset rather than a reflection on quality. Costly moldings and millwork are discouraged under

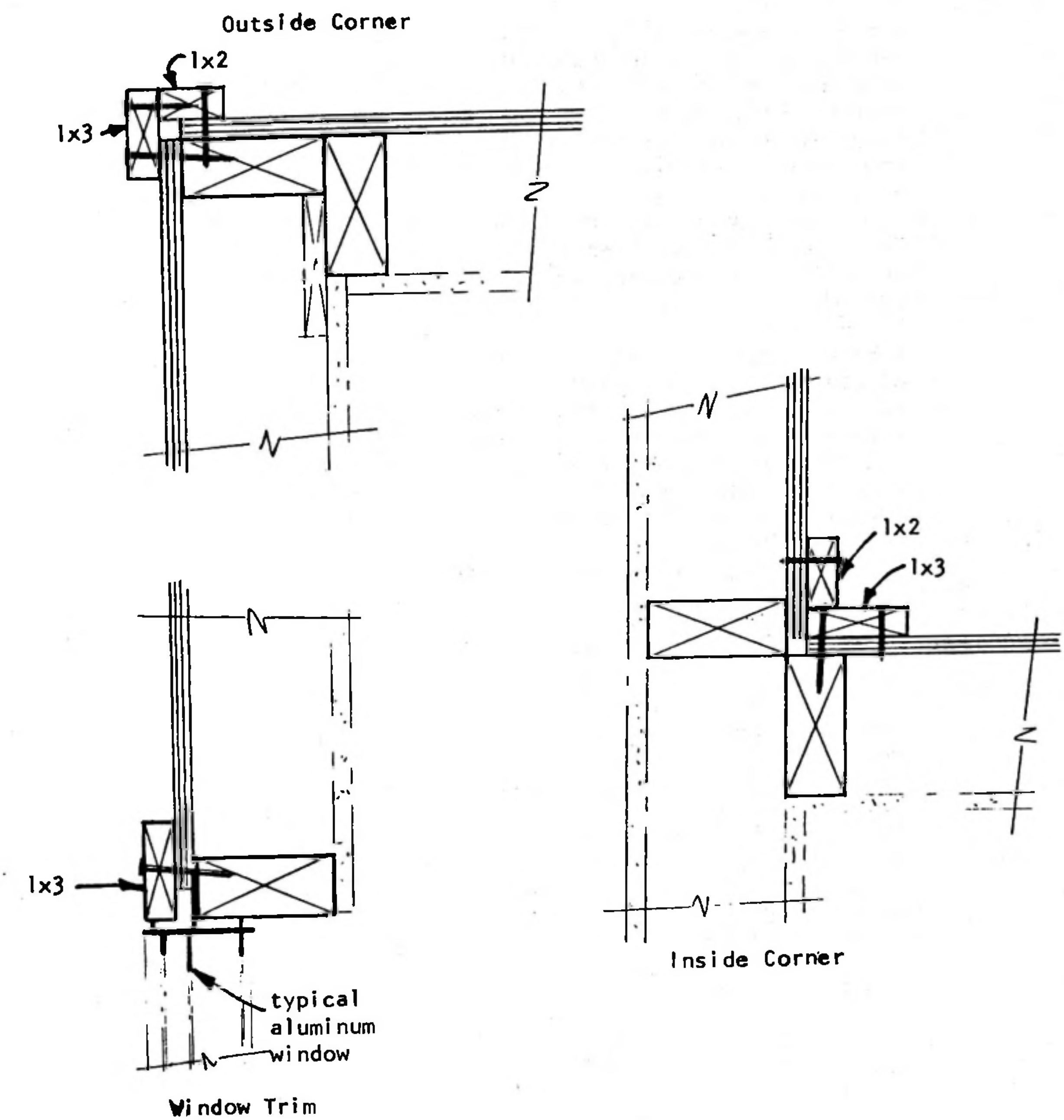


FIGURE 5-K. Less costly lumber strips used as exterior trim for natural or rustic appearance

the OVE concept. Where the design calls for a colonial entrance detail, consider the molded plastic units that are now available.

With prefinished siding, door and window units as noted before, use of prefinished trim will totally eliminate exterior painting as a separate operation. Prefinished trim and other accessories are available with most prefinished siding products to cover normal trim requirements at windows, corners, etc. Where they are not available, or where the siding is prefinished locally, the required trim items can be prefinished by the builder or fabricator in a similar manner. Accessories, such as colored caulk and siding nails, are widely available to complete the package.

A heavily pigmented stain finish may be considered in lieu of conventional paint for trim. These stains are not as sensitive to temperature conditions during application, and they provide good coverage. They are not subject to cracking and peeling as are many conventional paints. In some cases one coat will be sufficient, especially where saw-textured wood is used. The characteristic low gloss of heavy-bodied stains of this type is appropriate for either traditional or contemporary designs.

A stain finish of this type is also suitable for wood-based siding products, especially saw-textured wood or plywood siding materials. The stain may be applied by brush, roller or spray, either on-site or off-site. Some fabricators use sophisticated "curtain" or "flow" coating equipment for a more uniform application. Freshly finished panels can usually be stacked after an initial surface drying.

Corrosion resistant nails should always be used with exterior siding and trim. Stainless steel, aluminum or hot-dip galvanized nails are recommended for this use. Electro-plated galvanized nails, plain painted nails and resin coated nails will corrode and stain trim and siding.

6. ROOF CONSTRUCTION

6.1 General

The use of standard wood roof trusses spaced at 2 feet on center is part of the OVE concept. For optimum cost-effectiveness, trusses should be used in conjunction with a straight gable, rectangular roof design.

Light-weight wood trusses are the most highly engineered component used in house construction today. They form the basis of a very efficient roof system. This chapter discusses the application of OVE principles to trussed roof construction, including sheathing, roofing and vents, as well as trim details at the rake and eave.

6.2 Engineered Roof Trusses

Roof trusses are widely accepted and used, and are readily available in most areas. They are easy to install, requiring only basic carpentry skills, and provide a means of rapidly enclosing the building shell.

Trusses will adapt to almost any design situation including hips, L-shaped plans and other variations. However, the most cost-effective design is a straight gable rectangular roof, as discussed in Chapter 2. A 4/12 or 5/12 roof pitch assures adequate drainage. Steeper pitches are more difficult to work on and increase safety problems.

Trusses are normally designed for 24-inch on center spacing which integrates ideally with the 2-foot OVE module. When installed directly over wall studs, also spaced 2 feet on center, a single top plate on the wall provides ample anchorage by conventional toenailing under normal conditions. In high wind regions (30 psf or more wind design load) additional anchor straps may be required to tie trusses to wall studs.

Several basic types of trusses are available, depending on architectural and engineering design factors (see Figure 6-A). The "Fink" or common "W" truss is the most widely used type. The arrangement of web members in a Fink truss is structurally efficient, and allows good access through the center portion.

The "Howe" truss is also very efficient structurally. However, the additional web member adds slightly to cost and the arrangement of web members tends to interfere with attic access during construction.

Several variations of "scissors" truss designs are sometimes used to provide a sloped ceiling. Scissors trusses may be mixed

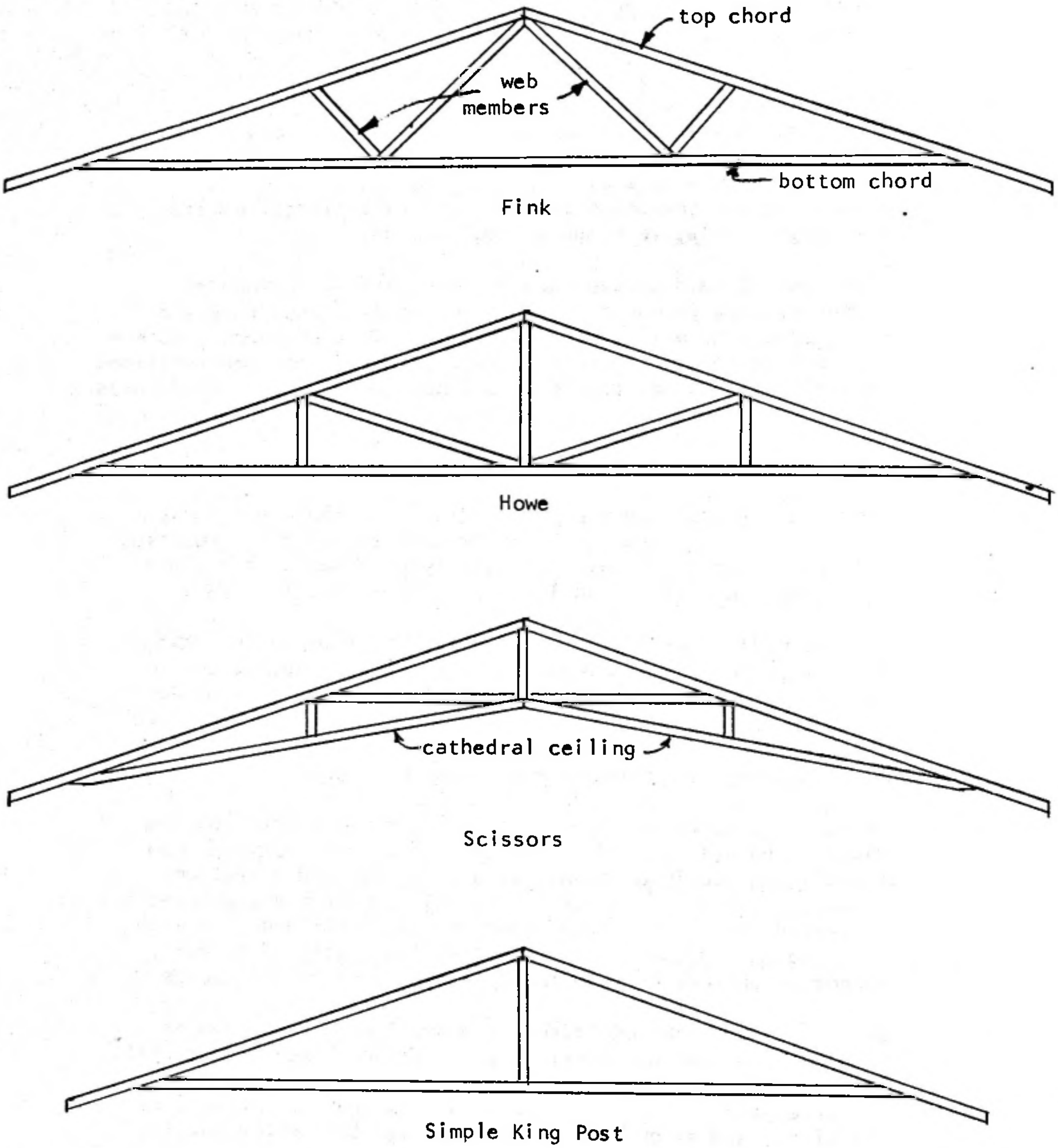


FIGURE 6-A. Basic roof truss designs used for clear span roof construction spaced at 2' on center

with standard trusses in the same roof system to provide a "cathedral" ceiling feature over a portion of the house at some extra cost.

A basic "king post" truss is less efficient structurally, but may be useful under certain load and span conditions. For example, when exposed in a carport, the clean appearance of this basic design is desirable.

Normally, truss fabricators provide the necessary engineering design, relieving the builder of this responsibility. The critical factor in truss design is usually the snow load, which varies considerably by region. A map showing 50-year recurrent snow loads across the United States is presented in Figure 6-B. The snow load together with the dead load of the roof/ceiling construction, which normally ranges between 8 psf and 15 psf, determines the allowable span of a given truss design.

Allowable spans for typical Fink designs are shown in Table 6-1. Allowable spans for Howe designs are in the same range. Fink or Howe trusses with 2x4 top and bottom chords are normally adequate for houses up to 26 or 28 feet in depth; 2x6 top and/or bottom chords are usually required for greater spans. Scissors truss designs vary and are not as easily typified but, in general, will not span as far as a Fink or Howe truss of the same basic design. Simple king post trusses are not well suited to spans exceeding 24 feet.

Regardless of the truss design used, it is desirable to hold the length of the top chord to a multiple of 2-feet or slightly less in order to permit maximum utilization of truss lumber as well as roof sheathing material. A minor adjustment in the overhang dimension will often accomplish this, although sufficient overhang to shade south facing glass in the summer is desirable to reduce heat gain loads.

6.3 Prefabricated Gable Ends

Prefabricated gable ends are generally available as part of the truss package. These resemble a truss, but have vertical members spaced at 2 feet on center in lieu of truss web members (see Figure 6-C). Therefore, they are not a true structural truss and should not be used over a clear span.

Rough openings for attic vents are usually built into gable end trusses. Some fabricators also preapply the sheathing, where used. Either siding or sheathing are applied directly to vertical members of the gable truss, as over studs. Installation of gable end sheathing, siding, vents and rake trim prior to erection of the gable end truss will reduce labor costs.

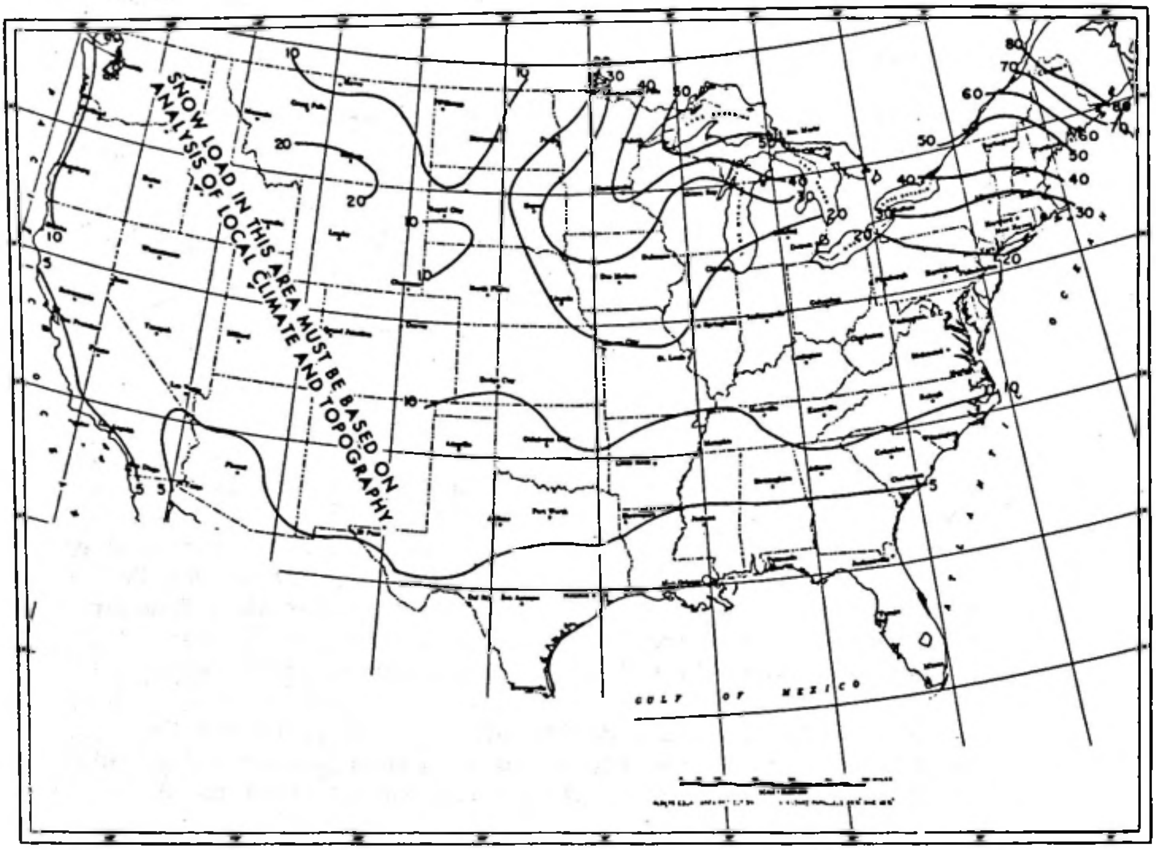


FIGURE 6-B. Snow load in lbs/sq ft used in determining roof design load based on data supplied by the Environmental Science Services Administration, Environmental Data Service.

TABLE 6-1. Allowable out-to-out spans for typical Fink truss designs spaced at 2-feet on center with a 40 psf total design load

Roof Pitch	Lumber Grade	2x4 T.C. Max. Spans		2x6 T.C. Max. Spans	
		Using 2x4 BC	Using 2x6 BC	Using 2x4 BC	Using 2x6 BC
Southern Yellow Pine					
4/12	No. 2	26'-5"	27'-3"	27'-7"	39'-7"
	No. 2 MG	28'-10"	29'-8"	30'-4"	43'-11"
	No. 1	31'-10"	32'-9"	34'-0"	48'-5"
	Sel. Str.	33'-2"	33'-11"	38'-7"	50'-3"
5/12	No. 2	27'-6"	28'-2"	29'-7"	40'-11"
	No. 2 MG	29'-11"	30'-7"	32'-4"	45'-3"
	No. 1	32'-3"	33'-0"	36'-1"	49'-0"
	Sel. Str.	33'-8"	34'-4"	40'-8"	51'-0"
Douglas Fir-Larch					
4/12	No. 2	28'-10"	29'-8"	30'-4"	43'-11"
	No. 1	32'-0"	32'-11"	34'-10"	48'-5"
	Sel. Str.	33'-2"	33'-11"	38'-2"	50'-3"
5/12	No. 2	29'-11"	30'-7"	32'-4"	45'-3"
	No. 1	32'-6"	33'-2"	36'-10"	49'-0"
	Sel. Str.	33'-8"	34'-4"	40'-4"	51'-0"
Hem-Fir					
4/12	No. 2	25'-0"	25'-9"	26'-0"	38'-5"
	No. 1	28'-7"	29'-5"	29'-7"	42'-10"
	Sel. Str.	30'-6"	31'-5"	33'-0"	46'-6"
5/12	No. 2	26'-0"	26'-8"	27'-11"	39'-9"
	No. 1	29'-7"	30'-3"	31'-7"	44'-3"
	Sel. Str.	30'-11"	31'-7"	35'-1"	47'-0"

Source: Span Tables for Light Metal Plate Connected Wooden Trusses, Truss Plate Institute, 1972.

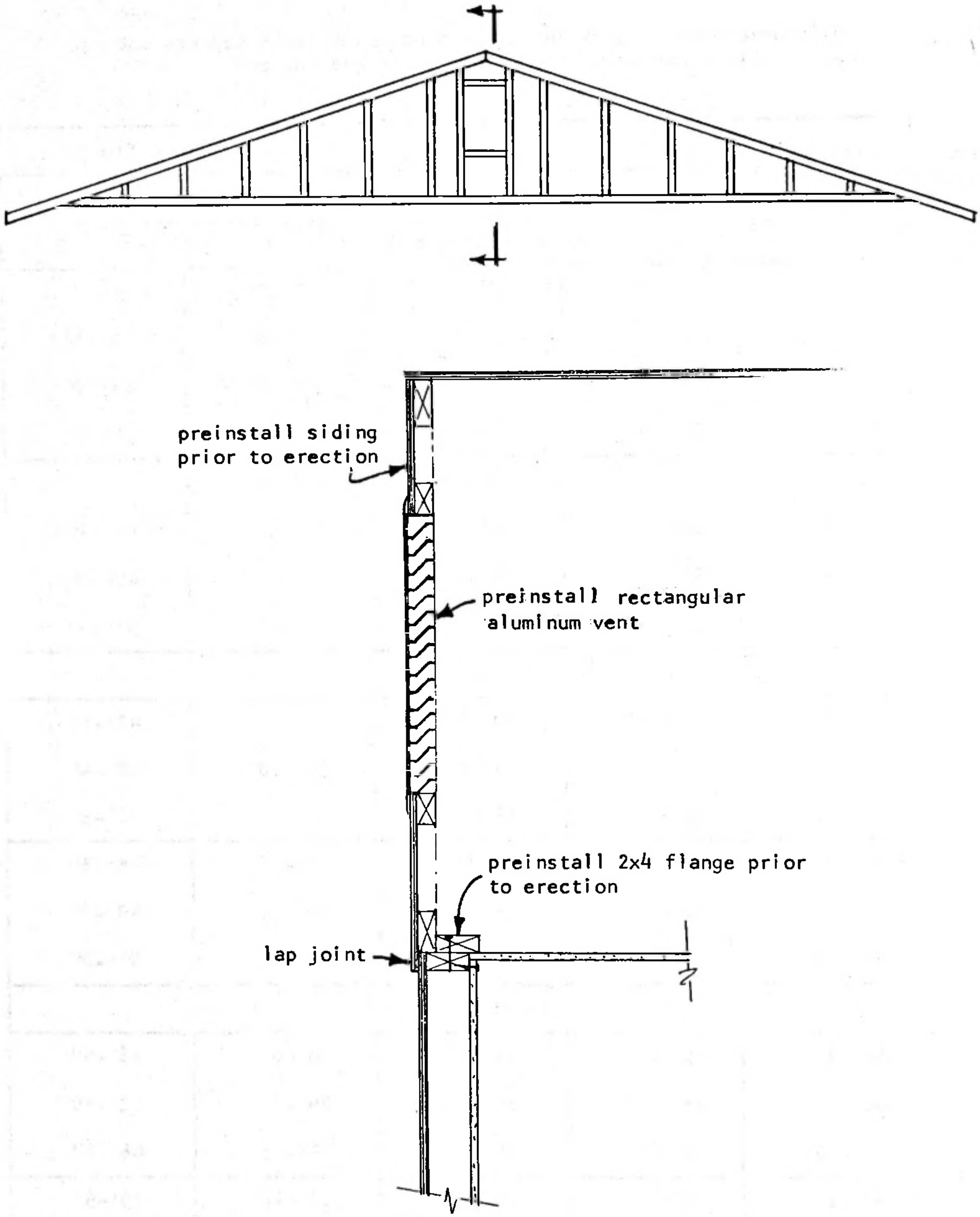


FIGURE 6-C. Typical prefabricated gable end and installation detail.

Attachment of a 2x4 "flange" along the bottom chord is recommended prior to erection, as shown in Figure 6-C. The gable end is then installed by nailing down through the flange into the top plate of the wall. Note that the flange also serves as backup blocking for the ceiling drywall.

A lap joint detail over wall siding is used to provide an effective weather-tight joint with ample field tolerance (also shown in Figure 6-C).

6.4 Attic Vents

Gable end vents of adequate size are the least costly means providing necessary attic ventilation to avoid buildup of excessive heat or moisture. A simple rectangular aluminum vent is generally the most cost-effective solution. As noted above, the required rough opening for the vent is usually built into the gable end truss by the fabricator.

A vent size providing a total of 50 square inches of net free area for every 100 square feet of ceiling area (one square foot for every 300 sq. ft. of ceiling area) is recommended if a vapor barrier is used in the ceiling (recommended procedure). If no vapor barrier is used in the ceiling, the total net free area of ventilation should be increased to 100 square inches per 100 square feet of ceiling.*

6.5 Plywood Roof Sheathing

Plywood is the most common roof sheathing material in use today. Thicknesses up to 5/8 inch are commonly used in some localities. However; it is well established that, under normal conditions, 3/8-inch-thick Group I plywood sheathing is suitable for application over trusses spaced at 2 feet on center if the edges are supported between trusses.

The least costly and most widely used method of providing the required edge support is with metal "H" clips designed for this purpose (see Figure 6-D). It is not necessary to support edges at the ridge. Blocking between trusses at the ridge is unnecessary. When 3/8 inch plywood is used on trusses 2' on center, workmen should stand or kneel over the trusses until the plywood is fastened, thus avoiding "nailing in" a permanent set or deflection in the plywood between trusses.

It should be noted that it is unnecessary to stagger plywood end joints over alternate trusses. Full sheets of plywood may be applied starting from either end. This will simplify roof sheathing layout and application, and may reduce the number of cuts required. Preplanning the plywood layout will avoid waste.

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*Insulation Manual - Homes, Apartments, NAHB Research Foundation, Inc., P. O. Box 1627, Rockville, Maryland 20850.

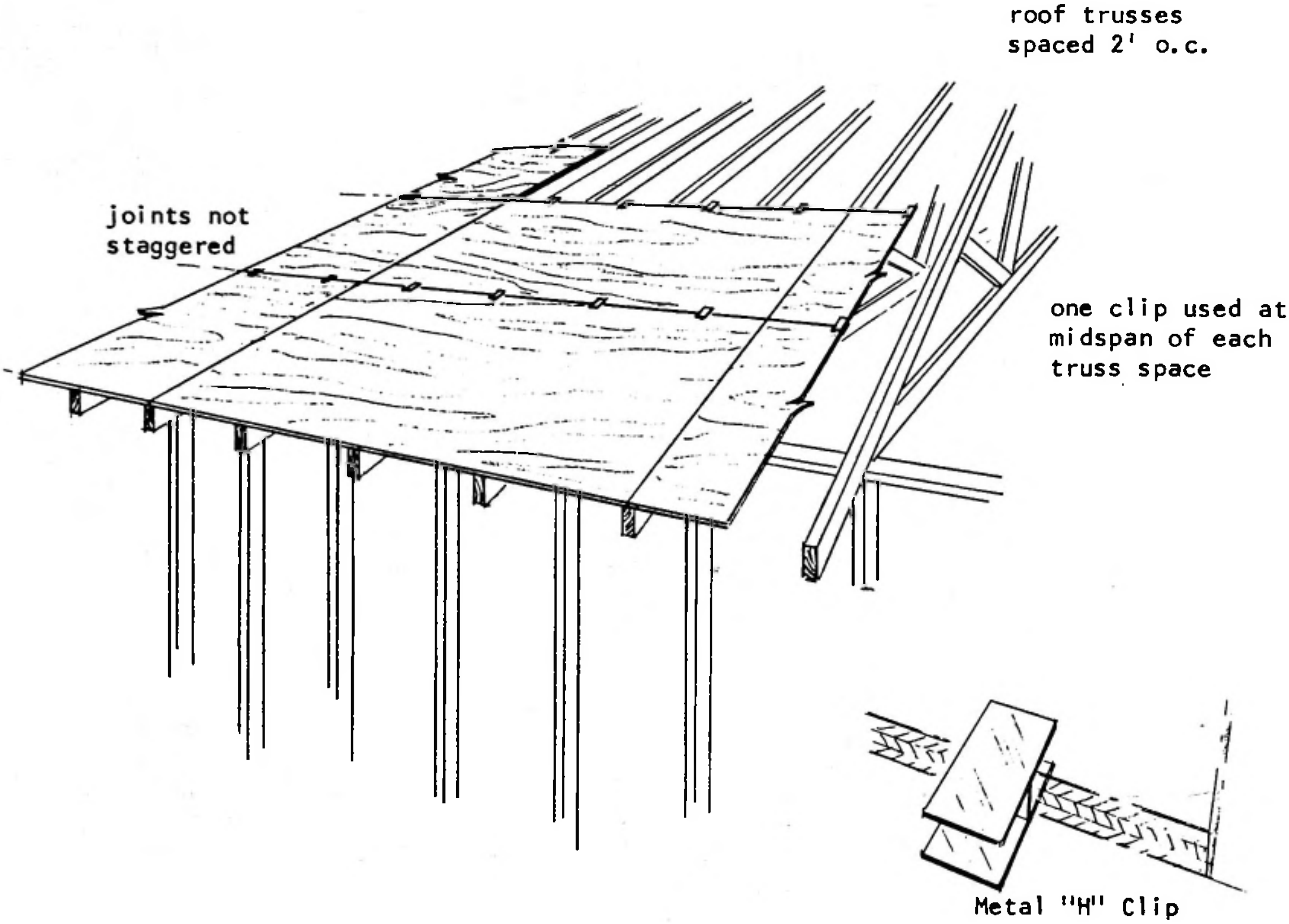


FIGURE 6-D. Group 1, 3/8"-thick plywood sheathing used over roof trusses spaced at 2' on center with metal "H" clips for edge support.

6.6 Roof Trim Details

The OVE concept includes simplification of roof trim details to the maximum extent possible, consistent with the design and required functions. Traditional details may include a fascia, soffit and required blocking, frieze, various moldings and other special details. Many of these details may be simplified or eliminated with no loss in function.

As with other exterior trim, less expensive lumber may be used for rake and eave trim when the natural characteristics of the wood are treated as an architectural feature. Rough sawn lumber is especially appropriate in this type of application, but it should be dry. A heavy-bodied stain finish may also be considered for rake and soffit trim. As discussed in the previous chapter this type of finish is not as sensitive to job conditions, and complements natural materials well. It is particularly advantageous to prefinish roof trim items, either on-site or off-site, in order to reduce field labor and to avoid paint lines and runs on the siding.

Color-matched 8d siding nails are well-suited for applying trim, although unpainted casing head or finish nails may also be used. In either case, high-quality corrosion resistant nails should be used, as with other exterior trim and finish.

6.6.1 Basic Rake Trim

Trim details at the rake edge of the roof are essentially nonfunctional. If gable end siding is carefully fitted to the underside of roofing, rake trim may be entirely eliminated or limited to a metal drip edge (see Figure 6-E).

However, some trim may be applied along the rake to enhance appearance. A trim strip at this point also contributes to field tolerance by covering the rough edge of gable end siding. A simple fascia board, anywhere from 1x2 to 1x6 in size, will conceal inaccuracies in fitting gable end siding, and will provide a more finished appearance as shown in Figure 6-E.

6.6.2 Simplified Gable Overhang

A gable overhang is essentially nonfunctional. However, where it is considered desirable, an open soffit detail may be created at minimal cost by simply extending roof sheathing out over the gable end and attaching a "rake board" along the outer edge. A maximum 12-inch overhang is possible with 3/8-inch plywood roof sheathing using this method. A 2x4 or 2x6 of sufficient length may be used as a trim board as shown in Figure 6-E.

Roofing nails which penetrate the exposed roof sheathing are not considered to be a problem where open soffits of this type

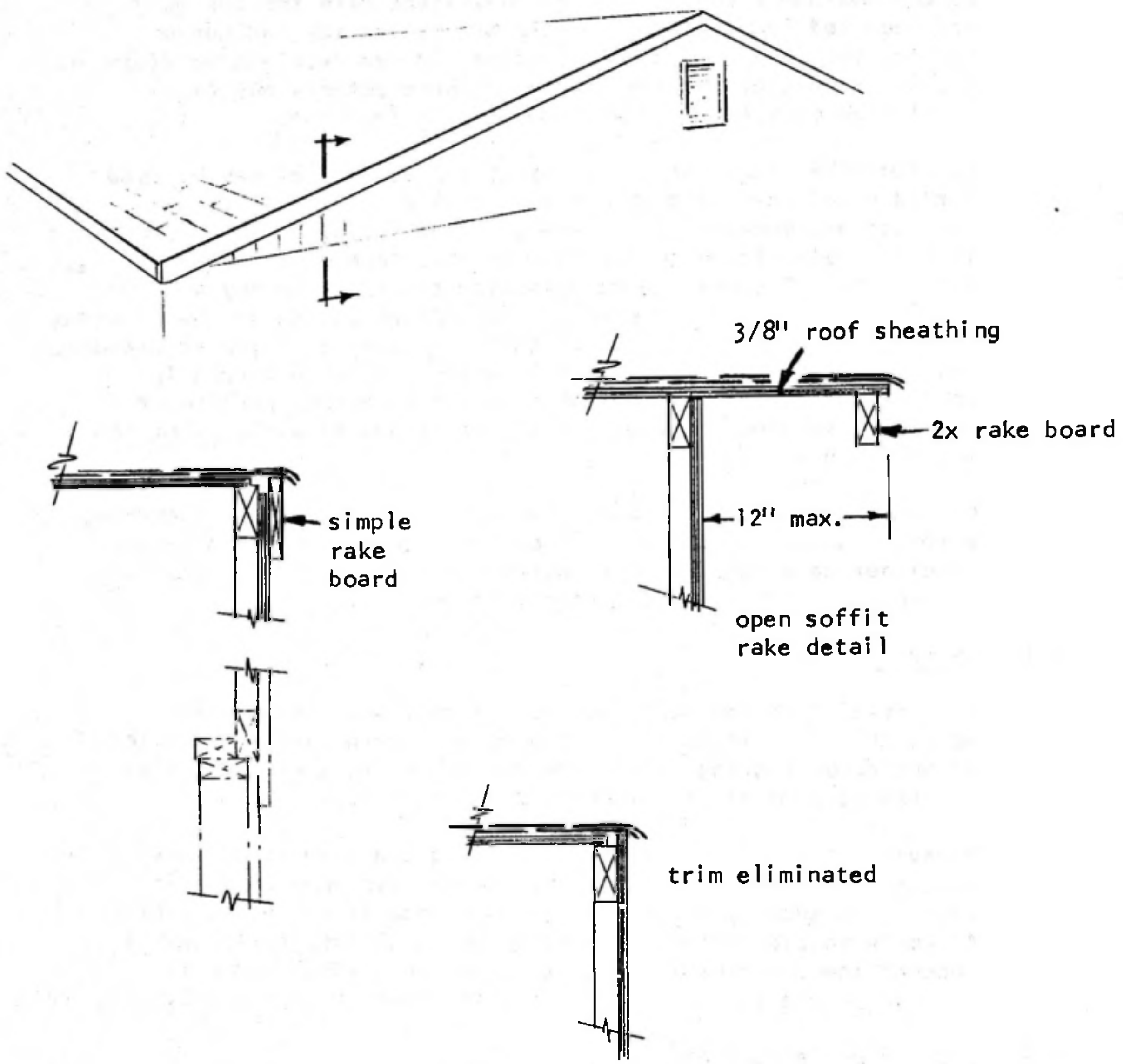


FIGURE 6-E. Simplified rake trim details, with and without overhang.

are presently used. Nail tips are not readily noticeable in the shaded recess of the soffit. A dark stain or paint provides additional concealment.

6.6.3 Basic Eave Trim

The primary function of the trim detail at the eave edge of a roof is to cover openings between roof framing members and to provide for proper water runoff from the roof. If the siding is extended upwards to cover truss ends, eave trim may be entirely eliminated or limited to a metal drip edge (see Figure 6-F).

However, as with the rake detail, it may be desirable to provide some trim along the eave for appearance. Where no overhang is required, eave trim may be limited to a simple fascia board applied directly to truss ends. A 1x6 or 1x8 fascia is sufficient to cover truss ends, depending on whether a 2x4 or 2x6 truss is used, as shown in Figure 6-F.

Where no eave overhang is used, a gutter will prevent problems from water running down the sidewall. The gutter also becomes a part of the trim detail at the eave.

6.6.4 Simplified Soffit Overhang

A soffit overhang is often desirable to provide summer shading at windows and protection from rain. Where an overhang is used, an inexpensive open soffit detail will eliminate much of the cost of a conventional "cornice".

All trim details on the underside of the soffit may be eliminated, leaving the truss tails exposed. Precut 2x4 or 2x6 blocks are then installed to close off the openings between trusses. A 1x6 or 1x8 fascia used across truss ends will help support the roof edge and provide a more finished appearance, as shown in Figure 6-F. In some rustic designs, with thicker plywood used at the roof overhang, the fascia board may be eliminated.

The amount of overhang may vary, but should be selected with the truss design and summer shading in mind. The overhang may often be adjusted so that the length of the top chord is a multiple of 2 feet (or slightly less). This will also provide for efficient utilization of plywood roof sheathing. Truss ends are plumb cut to provide for installation of a gutter. However, a gutter is not absolutely essential with an overhang of at least 12 inches.

As noted previously, roofing nails that penetrate the exposed underside of roof sheathing do not necessarily present a problem. Nail tips are not readily visible in the shaded recess of the soffit, and a dark stain or paint will provide additional concealment where considered necessary.

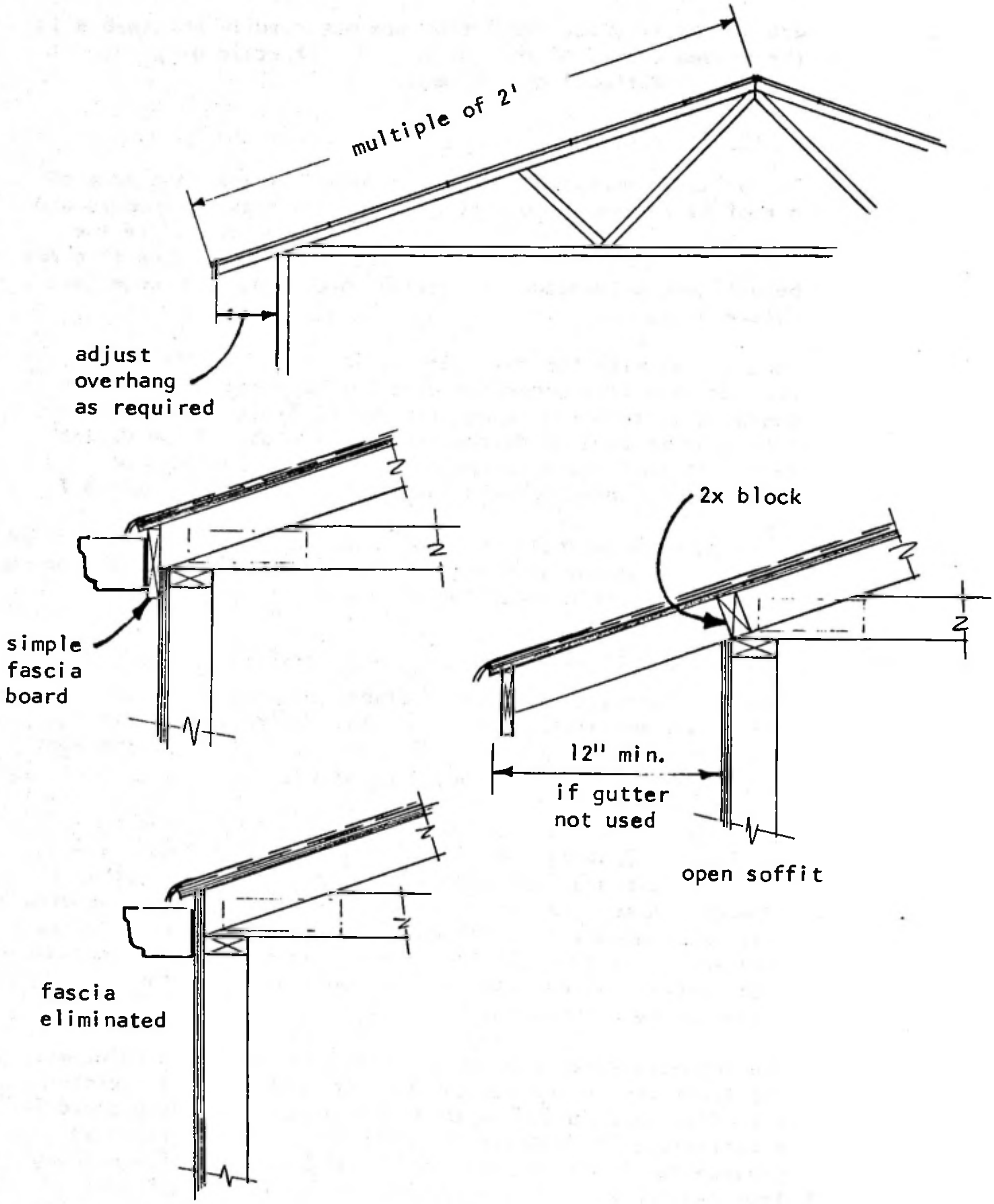


FIGURE 6-F. Simplified eave/soffit details, with and without overhang.

6.7 Roof Covering

A 15-pound asphalt impregnated roofing paper is often applied over roof sheathing to provide temporary weather protection. Such temporary protection is advisable if shingles are not installed soon after completion of the roof structure. In this case the roofing paper should be well-nailed with large washer-head nails in order to adequately resist wind. However, if roof shingles are installed soon after roof sheathing, roofing paper is not required. Field experience suggests that such a roofing underlay is unnecessary with "seal-down" shingles where the roof pitch is 4 in 12 or greater.

Asphalt strip shingles are the most widely used roofing in residential construction today, and are consistent with the OVE concept. The standard asphalt shingle is in the form of a 12-inch- by 36-inch-long strip having three tabs with a weight of 240 pounds per square (100 square feet of installed coverage) including seal-down tabs. A comparable 210-pound fiberglass reinforced asphalt shingle is also becoming available.

Asphalt strip roofing is the least expensive, most versatile roofing available. It is highly tolerant to field conditions and does not require a high degree of skill for installation. Asphalt shingles readily adapt to various roof design conditions including eaves, ridges, hips, valleys, chimneys, vents, etc., with virtually no accessories required and very little waste. The typical life expectancy of standard 240-pound asphalt shingles is up to 25 years depending on climate, and the self-sealing tabs provide extra protection against wind damage.

7. INTERIOR PARTITIONS AND FINISH

7.1 General

Interior load-bearing partitions are framed with essentially the same studs, plates and headers as exterior load-bearing walls. However, the primary function of nonload-bearing partitions is to divide interior space and provide a desirable degree of privacy; structural requirements are minimal.

This chapter discusses the application of OVE principles to nonload-bearing partition framing, interior surfaces, trim and other finish items required to complete the interior in a cost-effective manner. Information is included on interior wall and ceiling finish, stairs, doors, closets, cabinets and floor coverings.

7.2 Nonload-Bearing Partition Framing

Basic wood stud framing is the most widely used of partition construction because of its relative cost effectiveness. It is simple and efficient, and requires no special fastening or finishing procedures. Since structural requirements are minimal, the size of framing members may be reduced compared to load bearing walls.

The use of 2x3 studs spaced at 24 inches on center for nonload-bearing partitions is acceptable under most building codes. This construction meets the performance requirements of nonload-bearing interior partitions and has been well-accepted wherever used. The useable floor area is increased perhaps 12 to 14 square feet in a typical home, and occupants are generally unaware of any difference compared to a traditional 2x4 wall.

Since the studs in a nonload-bearing partition do not carry vertical loads, it is not necessary to coordinate their positions with structural members in the floor or roof. Nonload-bearing partitions may be located as desired, and the studs need not bear directly over other framing members. Partition studs may be layed out at 2 feet on center starting from either end, as convenient.

Normally, 2x3 plates are used with 2x3 studs. A single 2x3 top plate is ample for nonload-bearing partitions. When used in conjunction with a 7-foot 7-inch rough ceiling height, as discussed previously, the net length of a 2x3 partition stud with 2x3 plates will be 7-feet 4-inches (see Figure 7-A).

Actually, 1x3 plates are adequate for nonload-bearing partitions, and may be considered as an alternate. However, special

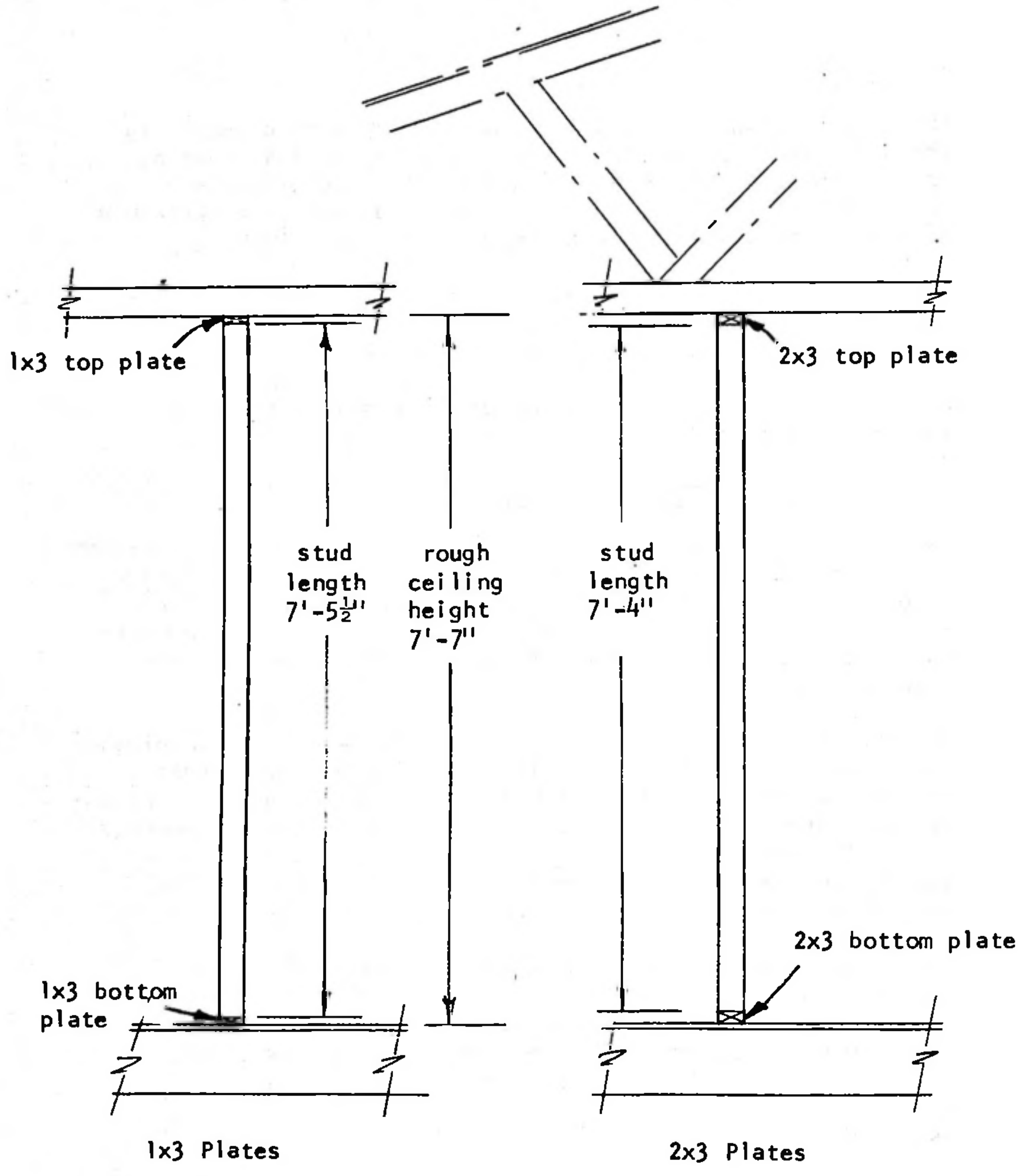


FIGURE 7-A. OVE partition construction using 2x3's spaced at 2' on center with alternate 1x3 or 2x3 plates.

attention is suggested to be sure that the 1x3 lumber is the same width as the 2x3 studs to avoid complications. Used with a 7-foot 7-inch rough ceiling height, the net length of partition studs with 1x3 plates would then be 7-feet 5-1/2-inches, as shown in Figure 7-A.

7.2.1 Framing Interior Door Openings

Openings in nonload-bearing partitions for passage doors, closets etc., have no particular structural requirements. Standard interior passage doors do not impose any undue loads on the framing. Thus, the opening may be single-framed with one 2x3 stud at each side and a 2x3 block across the head; there is no need for cripples (See Figure 7-B). Closet door openings may be framed similarly. No header is required in a nonload-bearing partition.

Walk-in closets are generally fitted with standard hinged passage doors and framed accordingly. The typical 2-foot-deep closet, however, is often fitted with bifold or sliding doors to provide complete access. If the closet width is planned to correspond with standard bifold or sliding closet door widths, no extra framing is required at the front to form the door opening. If the closet width is greater than the door opening, a single "stub" wall is used at one side or the other (rather than shorter stub walls on each side) in order to form the required opening with a minimum of framing (see Figure 7-C).

Framing may be further simplified by using ceiling height closet doors. This will make it possible to eliminate framing over closet door openings, as shown in Figure 7-C. However, 7-foot 6-inch ceiling height doors are not available in all styles, which may limit this choice.

It should be noted that framing details often affect the cost of trim and finish. Either inside or outside corners formed by framing at walls or ceilings add to the cost of finishing. A framing detail which minimizes corners around a closet opening will usually save on framing as well as finishing costs.

7.2.2 Anchoring Partitions to the Structure

Provision for attachment of nonload-bearing partitions to structural framing was discussed previously in the chapter on floor construction. Partitions which run perpendicular to the direction of floor or ceiling framing are simply nailed through the plates to these members at each intersection.

Partitions that run parallel to roof or ceiling framing members may be fastened directly to these members when they are sufficiently close to permit nailing. However, since partitions

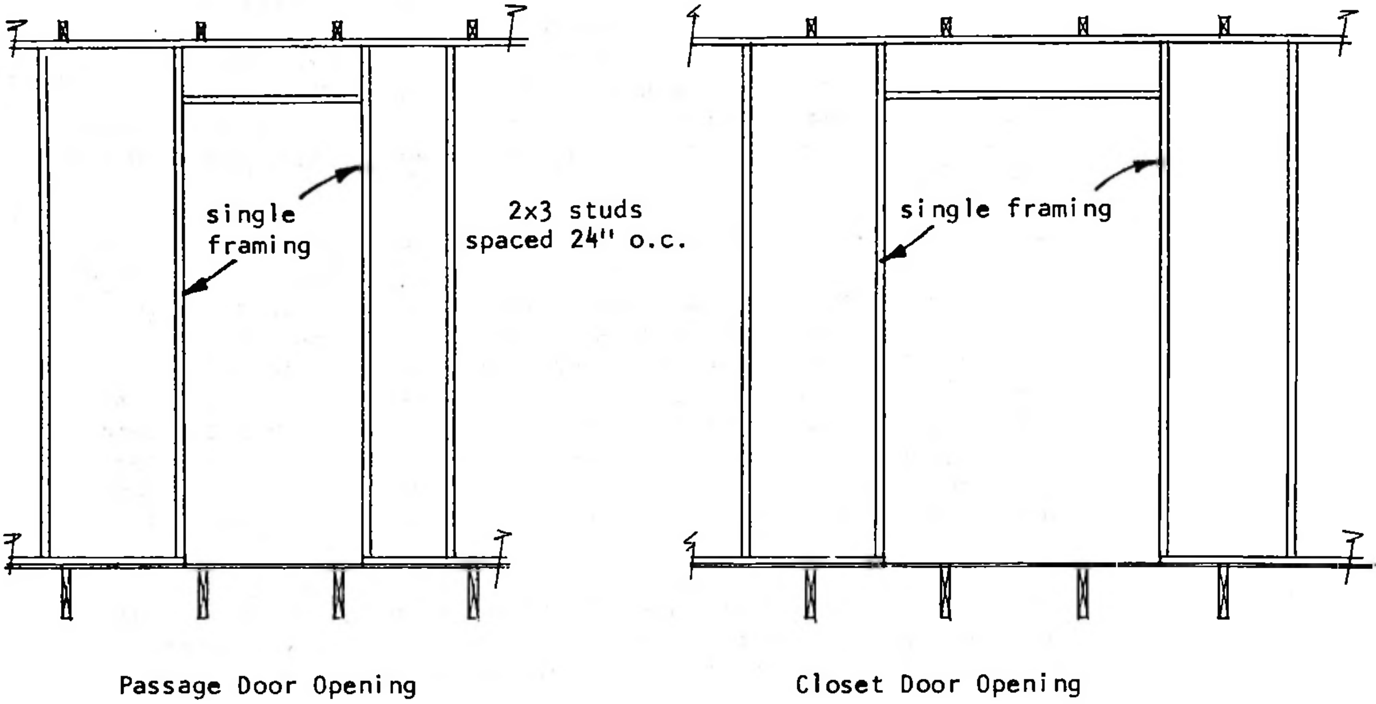
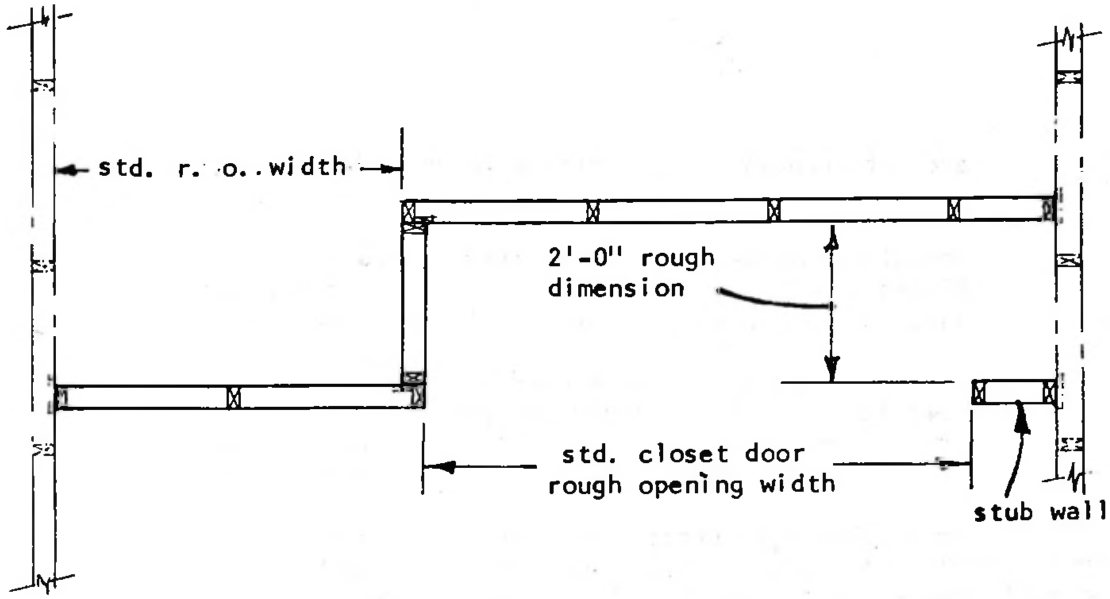


FIGURE 7-B. Single-framed openings in nonload-bearing 2x3 partitions for passage doors and closets



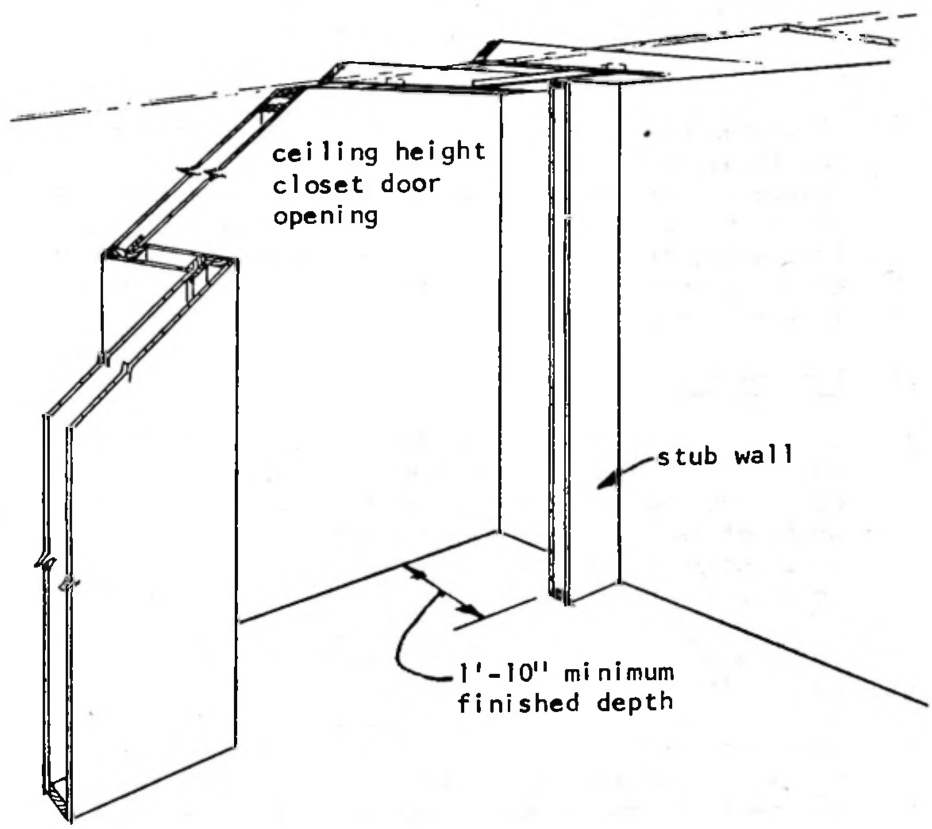


FIGURE 7-C. OVE framing for 2'-deep wardrobe closets with "stub" wall at one side, and alternate ceiling height closet door opening.

are not necessarily positioned on the 2-foot module, parallel partitions will often fall between framing members. When this occurs, the top may be supported with precut 2x3 or 2x4 blocks installed between overhead joists or trusses (see Figure 7-D). Blocks should be spaced no more than 24 inches apart to provide adequate backup for the ceiling finish.

Precut blocks may also be used to form an attic access opening. Properly planned, an attic access opening in a closet, hallway or other suitable location may be provided by simply installing two blocks between trusses to form the opening.

As discussed in Chapter 4, parallel nonload-bearing partitions falling between floor framing members are adequately supported by 5/8" or 3/4" thick plywood flooring, and do not require extra framing or blocking. The bottom plate may be nailed directly to the plywood floor without any special provisions.

As discussed in Chapter 5, a "partition post", as such, is not required for attachment of partitions at the exterior wall. However, a mid-height block is used between exterior wall studs to support the partition stud where it joins the wall. Of course, if the partition should happen to occur sufficiently close to an exterior wall stud, it may be fastened directly to the stud and blocking would be unnecessary.

7.2.3 Partition Intersections

Corners and other intersections of interior partitions are handled in much the same manner as described for exterior walls. Corners may be formed by simply nailing the two end studs of the meeting walls together where they meet. "T"-intersections require only a mid-height block between studs to support the end stud of the intersecting wall.

There are several alternate methods of providing the necessary backup for interior wall finish at partition intersections, as described for exterior walls in Chapter 5. They consist of plywood cleats or metal clips spaced up to 2 feet apart, or 1x3 lumber strips. Standard drywall is not fastened to the metal clips or wood backers. The sheet supported by the backers is installed first so that the adjacent sheet will lock it in place when nailed to provide the recommended "floating joint".

These same methods may be used to provide drywall backup at the ceiling. However, this should only be necessary for

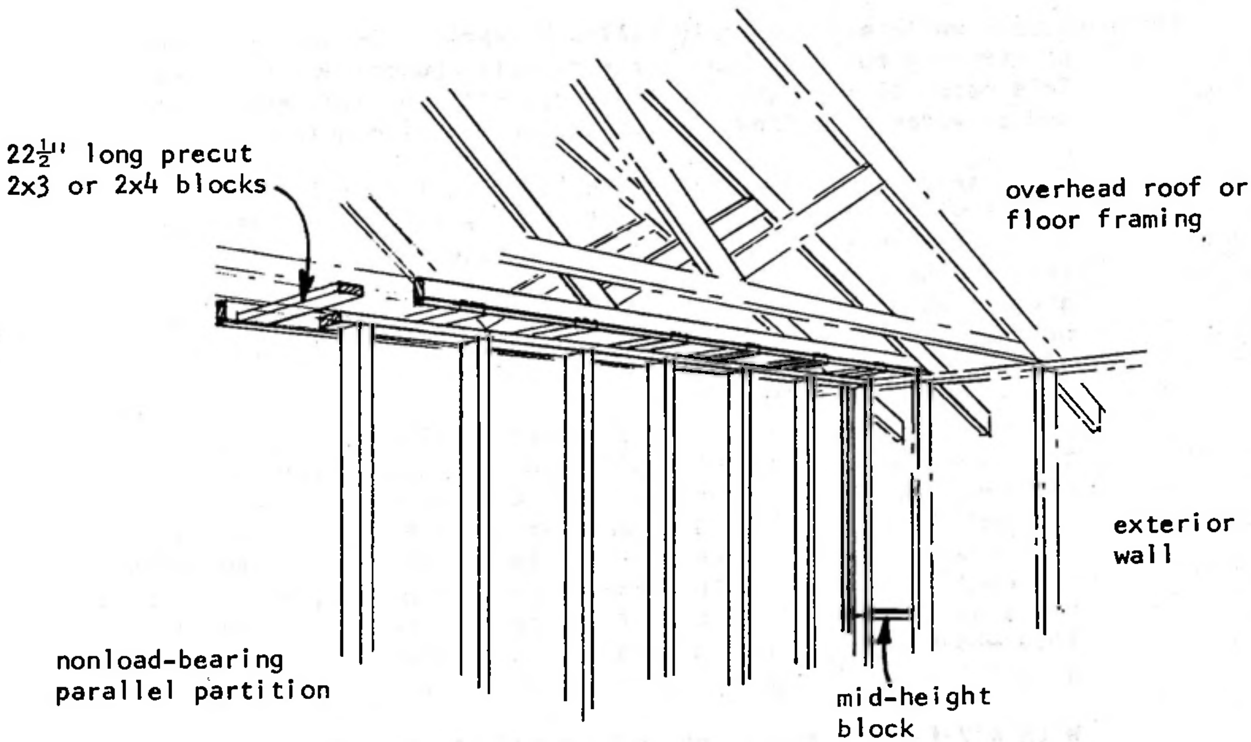


FIGURE 7-D. Precut 2x3 or 2x4 blocks used to support parallel partitions between overhead framing and at the same time, to provide drywall backup.

parallel partitions which occur sufficiently close to overhead joists or trusses to be nailed directly to these members. When parallel partitions fall between overhead members, the 24 inch on center blocking discussed previously will provide the necessary backup.

7.3 Interior Wall and Ceiling Finish

Gypsum wallboard, commonly called "drywall", is now used almost universally for finishing interior wall and ceiling surfaces. This material is cost-effective, tolerant to field conditions and provides a uniform, stable surface for finishing.

The most common gypsum drywall product is 1/2-inch-thick, 4-feet-wide sheets up to 16 feet or more in length. The long edges of panels are tapered to facilitate finishing with reinforcing tape and joint compound. Standard 1/2-inch-thick drywall is almost universally accepted for application to walls or ceilings with framing members spaced up to 24 inches on center.

Typical practice employs 4x12 sheets applied perpendicular to framing members on both walls and ceilings. Blocking is not required behind tapered edges. Ceiling panels are installed first, holding nails back at least 6 inches wherever they abutt a wall. Upper wall panels are then installed against the ceiling to support the edge of ceiling panels, again holding nails back at least 6 inches from the wall-ceiling corner joint. This provides a "floating joint" to discourage corner cracking (see Figure 7-E). No nails are used at the top wall plate.

With a 7-feet 6-inch rough ceiling height, as discussed previously, it is necessary to trim approximately 6 inches off of the bottom edge of lower wall panels. This eliminates the tapered edge at that point and provides a flat surface to permit installation of base trim without the necessity of shimming out the bottom edge. It is unnecessary to nail the drywall at the bottom wall plate since it is fastened when the base trim is applied.

The Gypsum Association recommends use of GWD-54 ring shanked nails that are 1-1/4" long to attach 1/2" thick drywall to wood framing. Double nailing is recommended to minimize defects due to loosely nailed panels. The first nails are driven at the spacing as indicated below, followed by second nails within 2" of the first, then the "first" nail is struck again to make certain that the board is held tight to the framing.

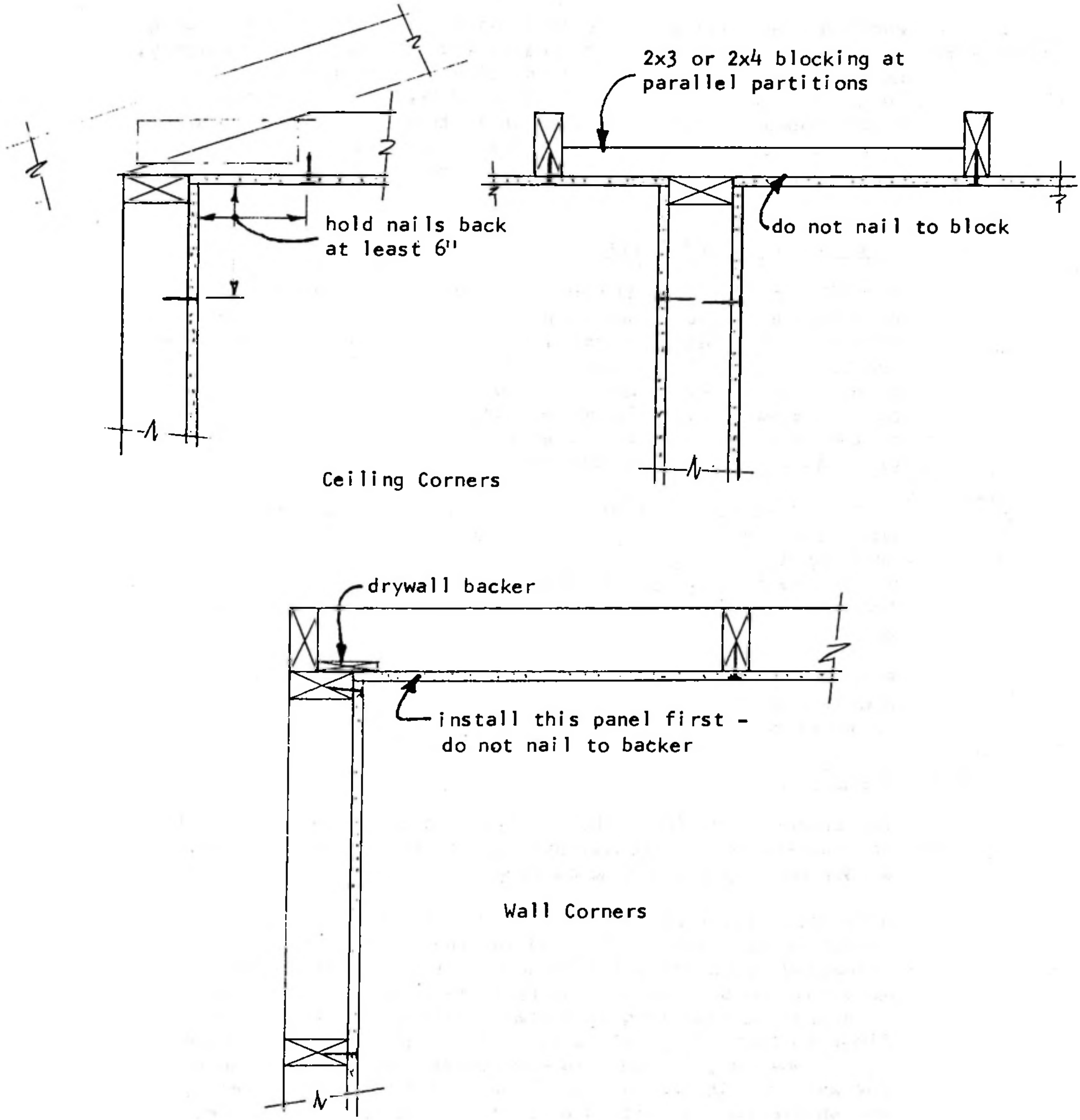


FIGURE 7-E. Recommended drywall installation at wall and ceiling corners provides a "floating" joint to minimize cracking.

Where double nailing is the sole means of attachment, a spacing of 12 inches is specified for walls and ceilings. Increasingly, however, adhesive application is being used to reduce the required nailing as well as associated "nail pop" problems. A continuous bead of adhesive, manufactured for this purpose, is applied to framing members prior to installing drywall panels. Nail spacing may then be increased to 16 inches for ceilings and 24 inches for walls.

7.4 Interior Trim and Millwork

The OVE concept includes minimizing interior trim costs by reducing, eliminating and simplifying trim details wherever possible. Several basic molding shapes will perform the primary function of covering joints. Use of a painted finish on trim permits use of less than "clear" grade wood trim or use of alternate materials. De-emphasizing trim by color matching to the walls helps to create an uncluttered appearance - especially important in smaller rooms.

In the OVE concept, other millwork items, such as interior doors and stairs are simplified, de-emphasized and generally confined to a functional role. Most trim and millwork items may be installed prior to painting the interior, and painted together with walls and ceilings (see section on interior paint).

Prefinished items such as paneling, cabinets, bifold closet doors, flooring, etc., are installed subsequent to painting to minimize masking labor and paint damage.

7.4.1 Base Trim

The primary function of base trim is to cover the joint at the base of the wall. Traditionally, base trim has consisted of a base molding and a shoe molding.

More recently, the increasing popularity of wall-to-wall carpeting has reduced the need for the shoe molding, since carpeting is normally installed directly against the base molding. In some cases, the base itself may be eliminated if drywall or paneling is fitted sufficiently close to the floor so that the joint is covered by carpeting (see Figure 7-F). However, a base mold does offer useful protection to the wall finish from vacuum cleaners and furnishings, etc., and should not be omitted without considering local market preferences.

A base molding need only be of sufficient size to cover the joint and permit adequate attachment. A 1/2 x 1-1/2-inch

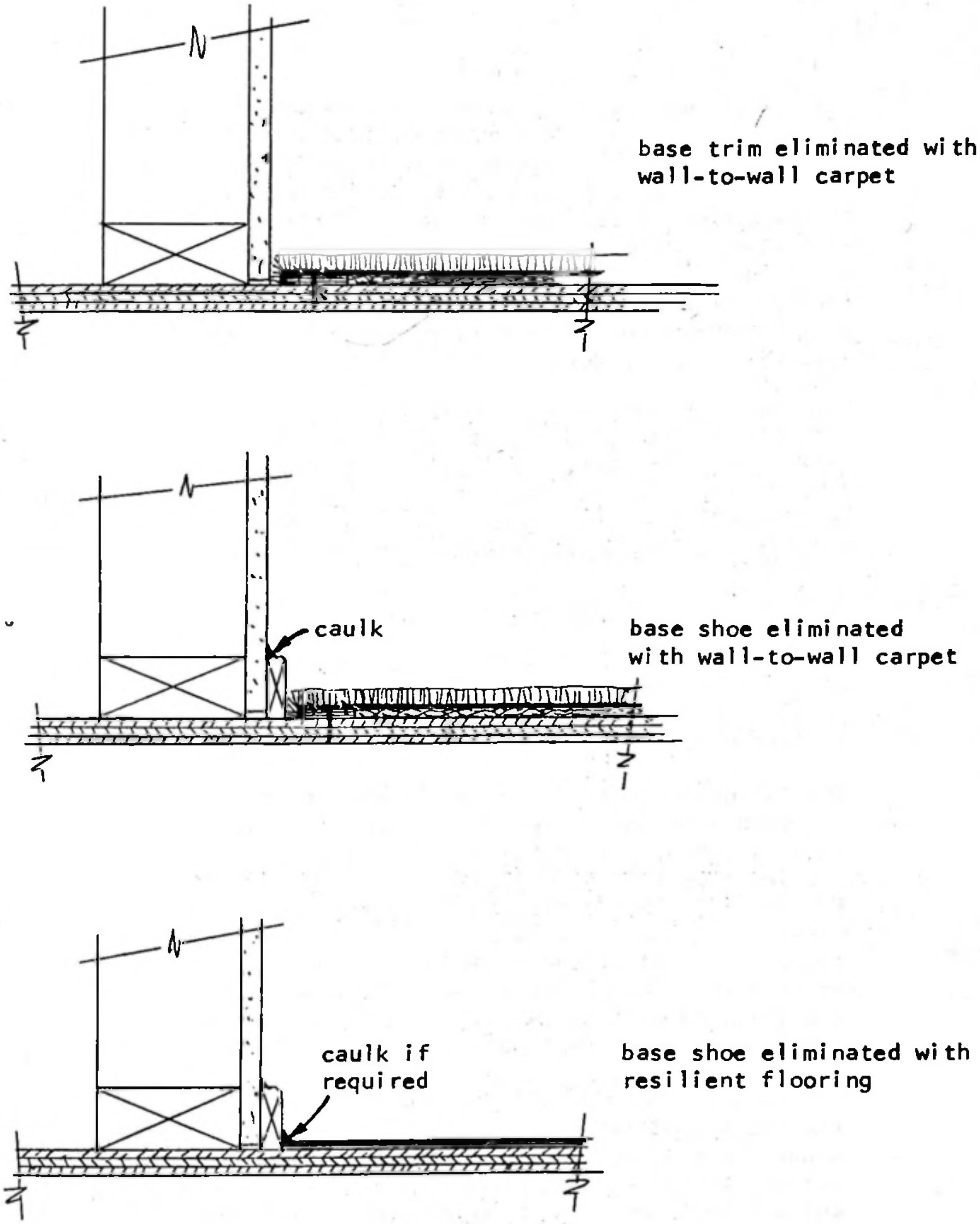


FIGURE 7-F. OVE base details. Other special trim details used with different floor coverings are included in Figure 7-L.

"universal" wood molding is generally adequate for this purpose, and may be used for other purposes as well. A rectangular shaped molding, as shown in Figure 7-F will permit a simple butt joint at inside corners, avoiding the time-consuming coped joint. If the drywall fits close to the floor and presents a square edge at the bottom, as with sheets which are trimmed to fit the 7 feet 6 inch ceiling height, no shimming is required behind the base molding. The use of a suitable painters caulk is recommended to fill any irregularities between the base and the wall.

When resilient flooring is used, it can sometimes be fitted sufficiently close to the base to avoid additional trim. If this is not possible, a prefinished shoe molding or plastic cove base may be installed in conjunction with the flooring. Other specialty flooring materials may require individual solutions as discussed later in the section on floor coverings.

7.4.2 Interior Window Trim

Window trim is usually concealed by curtains or drapes and contributes little to the finished appearance of a home. The purpose of window trim is to cover the joints and corners created by the presence of a window opening.

The increasing use of aluminum window units in recent years has been accompanied by a de-emphasis of traditional wood trim details. Many builders have simply eliminated trim at the head and jambs by returning drywall into the window opening (see Figure 7-G). A separate sill of wood or suitable synthetic material is then used to provide some protection from moisture condensation if it should occur. A small piece of trim, such as suggested for the base, may be used as an "apron" to cover the joint beneath the sill. Caulking may be used to seal the joint where the drywall or sill meets the aluminum window.

A simplified trim detail was used at the aluminum windows in the OVE demonstration house. Wood framing members around the window opening were left exposed as shown in Figure 7-G. An outside corner molding was used to trim around the opening, and all surfaces were painted together with the wall. Where this detail is used, it is suggested that framing members around the window opening be selected for appearance at the time the wall is framed. Special attention is also advisable in framing the opening to fit the window unit accurately.

Where conventional wood window units are used, interior trim may be simplified by "picture framing" the opening with standard window casing. In this detail, casing is installed on all four

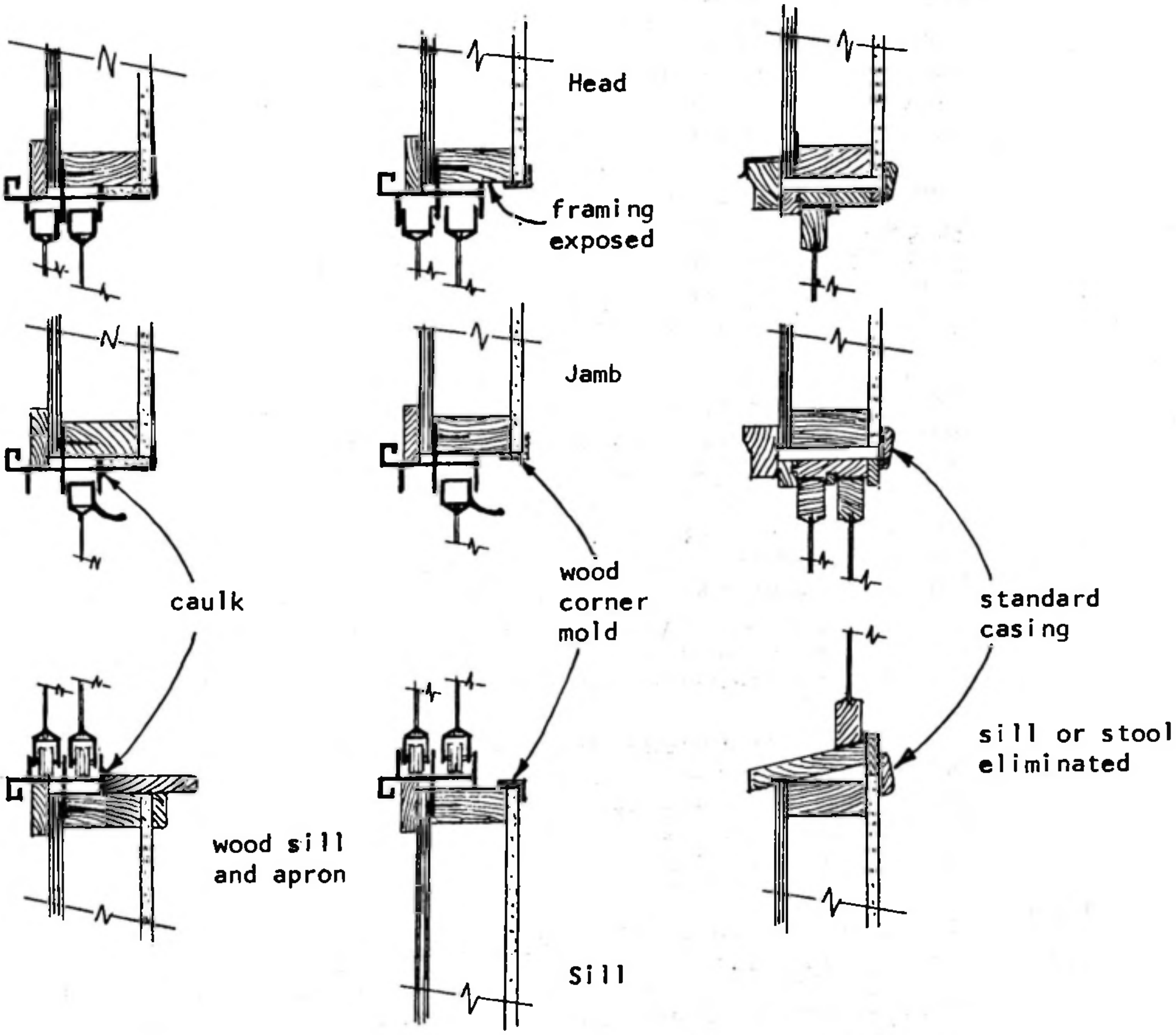


FIGURE 7-G. Alternate interior window trim details for use with aluminum and wood window units.

sides of the opening, eliminating the conventional stool and apron. In many cases a smaller size casing will do the job, such as the "universal" shape described under base trim.

7.4.3 Prehung Door Units

Prehung interior doors are consistant with the OVE concept. They save a significant amount of on-site labor and contribute greatly to accuracy. They are widely available and extensively used in modern home building.

Prehung door units include door, jamb and trim. Doors are hinged to the jamb and bored for the lockset. Both solid and split jambs are available. Solid jambs are installed in normal fashion by shimming and nailing. The casing is then installed on each side of the opening (see Figure 7-H).

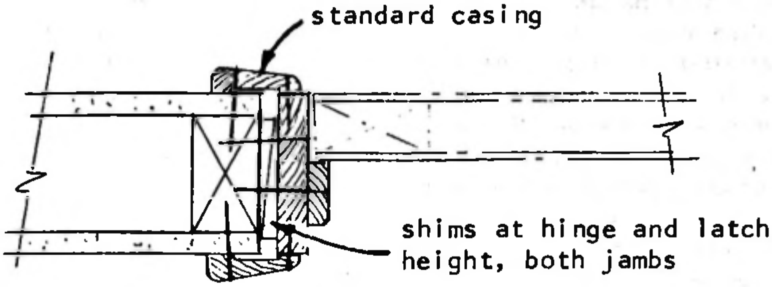
Split jambs have a deep tongue-and-groove joint along the stop which permits the inside half (with the door) to be separated from the outside half, as shown in Figure 7-H. The casing is preattached to both sides. The inside half with the door is installed first by nailing through the casing, then shimming and nailing the jamb at critical points. The outside half is then inserted from the other side and nailed through the casing. The tongue-and-groove joint provides considerable tolerance for variations in wall thickness. Although split jamb units cost slightly more than the solid type, they are often preferred due to lower site labor costs and greater tolerance.

The most cost-effective interior passage door is a flush hardboard hollow-core construction. This type of door takes a paint finish well and may be painted at the same time as walls. An additional coat of semi-gloss paint may be applied for extra service, when desired.

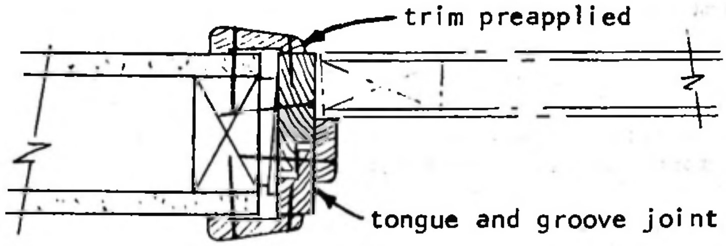
7.4.4 Closet Doors & Trim

Standard interior passage doors are normally used for walk-in closets, whereas conventional 2-foot-deep wardrobe closets are often fitted with bifold or double sliding doors for complete access. Sliding doors provide an inherent tolerance in opening width. They will close satisfactorily even if the opening width is slightly smaller or greater than specified. However, this type of action limits access to half of the closet at a time.

Bifold doors, on the other hand, permit full access to the closet, as desired. Steel bifold doors are stable and provide relatively trouble-free action. Installation is simple and ample adjustments are provided to compensate for minor inaccuracies in the opening size. Steel bifolds are normally prefinished



Solid Jamb



Split Jamb

FIGURE 7-H. Alternate jamb types used with prehung interior door units

in a compatible off-white color and, therefore, should be installed subsequent to interior painting. A variety of styles, including ceiling height models, are generally available. No trim is required around closet openings with most types of bifold or sliding doors.

There are a variety of techniques and products for providing the required shelf and hanger storage in a closet. These include prefinished expandable metal shelves with accompanying brackets, telescoping metal closet bars and related specialty products. While some such products simplify installation, the added cost may well be out of proportion to the benefit. In most instances the most cost-effective solution is a simple wood shelf and closet pole.

Dry 1x12 lumber will provide a very serviceable shelf if knots and other defects are limited. However, 5/8-inch or 3/4-inch-thick, 12-inch-wide particleboard shelves can provide a more finished appearance at the same cost or less. Intermediate supports may be spaced up to 42 inches apart for 1x12 lumber shelves, but no more than 32 inches apart for particleboard shelves due to their tendency to deflect over a period of time when loaded. Ceiling height doors permit installation of an extra shelf to increase closet storage capacity.

The simplest means of supporting shelf ends is with 1x2 or 1x4 lumber cleats nailed to the sidewalls. The cleats should be 2-feet-long to span between sidewall studs for nailing (see Figure 7-1). A 45° bevel at the front edge of the cleat provides additional clearance for door operation and a more finished appearance. A 1x4 cleat is sufficiently wide to provide for attachment of a closet pole; a 1x2 cleat is adequate where it simply supports a shelf, as in a linen closet. The cleats may be precut in advance to simplify construction. A "hook strip" across the back of the closet is not required.

A standard 1-5/16-inch wood closet pole is the most cost-effective means of providing hanger storage. Inexpensive plastic "cups" are attached to 1x4 shelf cleats to support the wood closet pole at each end. Intermediate support, as required for closet shelves, is adequate for the pole as well, and can be provided by shelf brackets with integral rod support hooks.

Intermediate support for longer shelves is best provided with a metal bracket, as shown in Figure 7-1. This type of closet shelf bracket also provides intermediate support for the closet pole. The bracket should be solidly attached through the drywall into wood framing with 2" long screws. However, where

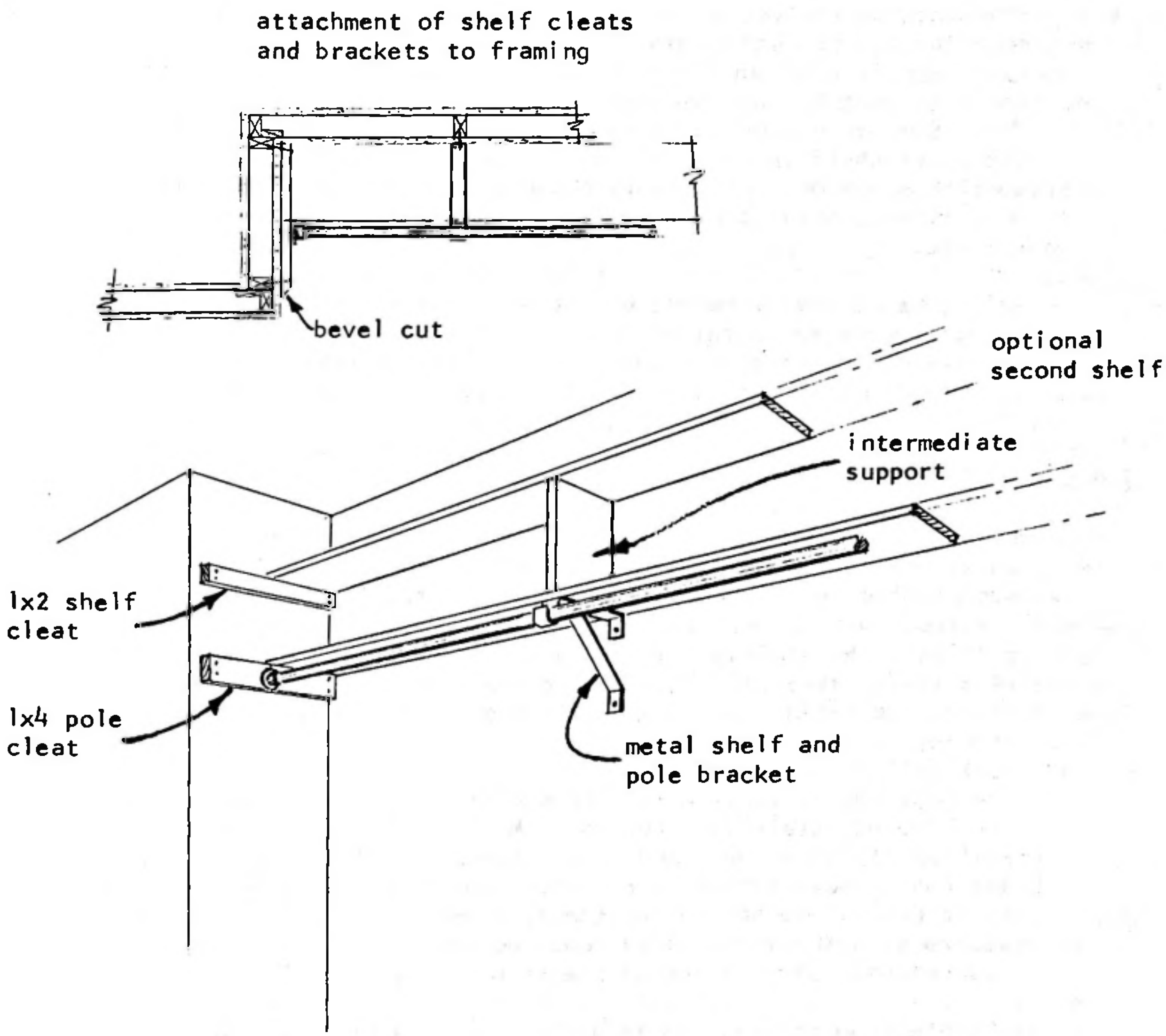


FIGURE 7-1. OVE closet trim details with optional ceiling height opening and extra shelf

framing is not suitably located, it may be necessary to attach the bracket directly to the drywall. A 3/16" x 2" "moly" bolt may be used for this purpose.

Where double shelves are used, a short piece of shelving material may be used to provide intermediate support for the upper shelf. The support "block" is set directly over the lower shelf support bracket and nailed in place, as shown in Figure 7-1. Similar blocks may also be used to support the ends of the upper shelf in place of the 1x2 shown if scrap material is available. Blocks of this type can contribute to the utility of a closet, serving as vertical dividers to form storage cubicles.

All closet shelves, poles, brackets, etc., except prefinished doors, should be installed prior to interior painting. They may then be painted with wall paint at the same time as walls and ceilings. A subsequent coat of semi-gloss paint may be applied to shelf tops for extra serviceability.

7.4.5 Stairways

As discussed in Chapter 2, stairways are oriented parallel to floor joists with proper OVE planning so that the fewest number of structural members are interrupted. This simplifies construction and results in labor and material savings. Where possible, the stairwell should be coordinated with the location of a regularly occurring joist at one side or the other in order to minimize the number of members required to frame the opening.

The most cost-effective type of stairs is a 3-foot-wide, straight run, "boxed" stair construction. More complex stair designs with landings, winders and other special conditions add to cost and labor installation time. With proper OVE planning, the same stair design may be used with most house plans. Prefabricated stairs are used to simplify construction, control quality and reduce cost. Prefabricated stairs are widely available.

The basic boxed stair construction consists of treads and risers inserted into a routed stringer at each side. The details are simple and repetitive, and the strength of the stringers is largely retained. The height of each riser is adjusted to the number of steps and total height (rise) required to reach the upper floor level. The fewest possible number of steps will provide optimum cost-effectiveness. This also minimizes the total length (run) of the stairs and related floor space requirements.

Safety considerations normally limit riser height to a maximum of 8-1/4 inches. Thus, a set of stairs having 12 risers at

8-1/4 inches will have a total rise of 8 feet 3 inches, which corresponds to a 7-feet 7-inch rough ceiling height with a 2x8 floor system at the top (see Figure 7-J). Similarly, safety considerations generally dictate a minimum tread width of 9 inches plus 1-1/8 inch nosing. In the example above, the stairs would then have 11 treads at 9 inches for a total run of 8 feet 3 inches, plus 1-1/8 inches for the first nosing, plus approximately 1 inch material thickness allowance at the top.

The least costly installation typically places a 3-foot-wide set of stairs between two walls for their entire length. A rough framing width of 3 feet 1 inch will allow a 1/2-inch space for drywall at each side. If stairs are installed prior to drywall, the stringers are nailed to wall studs at each side with a 1/2-inch-thick wood or plywood shim between. A small cove molding may be used to cover the joint between the drywall and the stringer or, if the fit is sufficiently close, the joint may simply by filled with painters' caulk. A pre-finished handrail may then be mounted to the wall at one side, subsequent to painting, to complete stair trim.

It is sometimes desirable to open a portion of the stairway to an adjacent foyer, hall or room for purposes of appearance or lighting. A costly detail with "open" treads and risers is not necessary to achieve this effect. Where desired, the same open effect may be created with a basic boxed stair at minimal cost without cutting away the stringer. Wall studs are simply cut flush with the top of the stringer in the open portion and capped at the top with a 1x8 as shown in Figure 7-J. A pre-fabricated, prefinished railing may then be mounted atop the 1x8 trim subsequent to painting.

Many stairways today are ultimately covered with carpeting. This is more easily accomplished at less cost with a boxed stair design. Where carpeting is used, stairs may be constructed from less costly lumber than the traditional hardwoods, since a more durable wearing surface is not required. Also, due to the less critical finish surface, permanent stairs may be installed earlier in construction for convenience and safety, although it is still wise to protect them with a heavy paper runner during construction. A standard boxed stair fabricated from a suitable species of softwood lumber will often provide a cost-effective solution for basement stairs as well.

As with other trim items in OVE construction, the stairs and accompanying trim (except prefinished railings) are installed prior to interior painting so they may be painted along with walls and ceilings. Where carpeting is to be used, it is unnecessary to paint treads. On other exposed portions of the

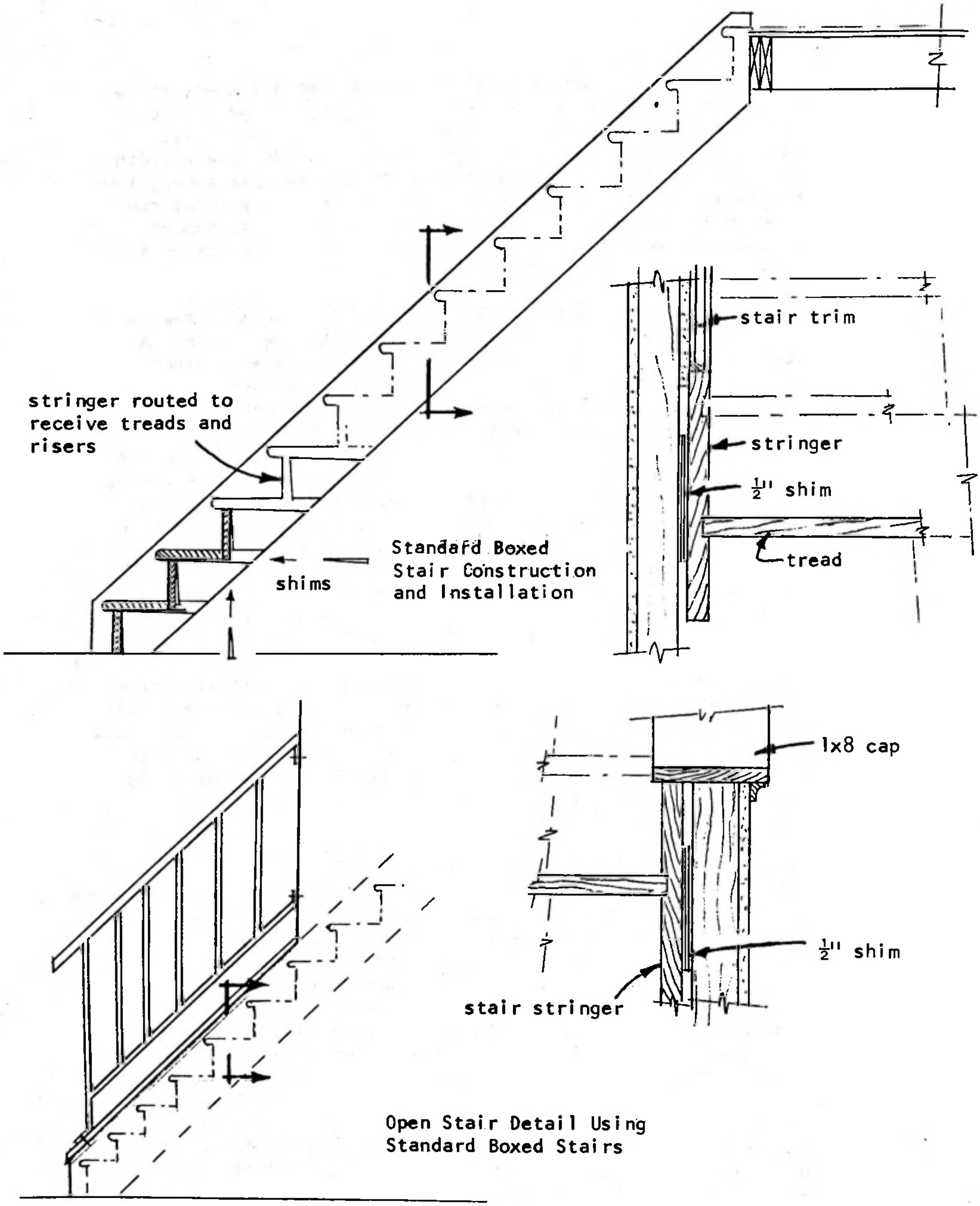


FIGURE 7-J. OVE straight-run boxed stair construction with optional "open" trim detail.

stairs, it may be desirable to apply a subsequent coat of semi-gloss paint for extra serviceability.

7.5 Interior Decorating

The most cost-effective and generally acceptable interior finish is a flat, off-white paint spray applied to all interior surfaces, including walls, ceilings, trim and doors. In order to minimize masking, prefinished or trim items which do not receive a paint finish are installed subsequent to painting.

A variety of other decorative treatments are possible including paneling, wallpaper and textured finishes; however, these are generally costly and should be used with discretion. Bathtub and shower walls require a highly durable treatment to avoid subsequent problems.

7.5.1 Interior Paint

A flat, off-white paint may be used for all interior surfaces, including trim where it is to be painted. A flat paint tends to cover minor irregularities in walls and ceilings. An off-white paint with a high light reflective value increases interior lighting efficiency and the apparent size of rooms, and blends with any decor. The use of multiple interior colors increases cost and complicates interior decorating.

A semi-gloss paint is often used in kitchens and bathrooms to improve durability and cleanability. A single coat of semi-gloss paint may be applied directly over the flat paint, which serves as a "primer". Similarly, a semi-gloss paint may be used on interior trim and doors to increase serviceability. A color that matches the wall paint subdues paint lines where the two types of paint meet, thereby reducing the required painting skill.

Texture paint is sometimes used on ceilings to add interest or to help cover irregularities. These finishes generally cost 2 to 3 times as much as regular paint and are not necessary when the drywall is properly installed and finished.

7.5.2 Decorative Paneling and Wallpaper

Even where cost is a major consideration, it may be desirable to provide some relief from painted walls. However, in the OVE concept additional decorative treatments are limited to areas of high marketing impact and preferably restricted to a single wall.

Wood grained wall paneling is one of the most effective means of providing design interest. A wide variety of such products are available in 4-foot-wide panels. Most of these are very thin, some 1/8-inch or less in thickness, and are not suitable for direct application to studs. When such thin paneling is used, it is applied over standard drywall which need not be finished.

Use of a panel adhesive intended for this purpose is an effective method for application of thin decorative paneling to drywall. A continuous 1/4-inch bead of adhesive applied at each stud location and at the midpoint between studs, resulting in a vertical bead every 12 inches, will help insure that paneling remains flat. This is supplemented with small nails spaced 6 inches along the edge and 12 inches at intermediate studs. Special nails are available in various colors for this purpose. Vertical joints in the paneling should always occur over studs.

In some cases, it may be possible to use less expensive wallpaper rather than paneling for an accent wall. Wallpaper is available in an endless variety of patterns, including wood grains. However, as with paneling, its use can be limited to a single wall surface where there will be a high marketing impact.

7.5.3 Bathtub and Shower Walls

The walls immediately surrounding bathtubs and showers need to be highly serviceable and waterproof to avoid problems in this extremely severe exposure.

Fiberglass reinforced plastic (FRP) tub and shower units with an integral wall surround provide a jointless, leakproof solution. Their use precludes treatment of tub and shower walls as a separate operation, and can eliminate ceramic tile from the construction process.

Where standard bathtubs and shower bases are used, 4-1/4 inch square ceramic tile offer the best solution. Self-spacing tile may be applied directly to 1/2-inch moisture resistant drywall with a waterproof adhesive made for this purpose. Tile are generally installed to a height of about 6 feet. After allowing time for the adhesive to set, all joints are grouted except at the top of the tub or shower base and at corners. These joints should be filled with an elastic caulking compound, such as silicone "tub caulk", to avoid subsequent cracking.

Whether a fiberglass or ceramic tile wall surround is used, special care should be taken to caulk around the hole for the mixing valve to prevent water from gaining access at this critical point.

7.5.4 Cabinets and Countertops

Kitchen cabinets and countertops constitute a major cost item in a typical new home. A certain amount of cabinet storage is essential, and decorative kitchen cabinets are often considered indispensable for sales appeal. However, there are several techniques that may be used to reduce the installed cost of cabinets.

Preassembled, prefinished cabinets are consistent with the OVE concept. The higher quality, better finish and speed of installation are all advantages of prefabricated cabinets. A disadvantage is the relatively high cost, partly due to the large variety of styles and sizes in which they are offered. Standard widths of preassembled base and wall cabinets range from about 12 inches to 36 inches in increments of 3 inches while heights of wall cabinets may range from 12 inches to 30 inches in increments of 3 inches.

Various combinations of standard cabinet sizes are selected to fit each kitchen plan. With careful OVE planning, the number of different cabinet sizes may be reduced to a minimum, thus reducing costs by simplifying ordering, stocking and installation. For example, many kitchen layouts are possible using only 2 or 3 cabinet widths (such as 18, 30 and 36 inches) plus a standard sink base. Wall cabinets can usually be limited to 2 heights - 18 and 30 inches. The choice of style or finish may be limited similarly to one or two variations, regardless of the number of homes being built.

Sometimes the same cabinet arrangements may be used in several different house plans. Where possible, a basic arrangement of cabinets may be obtained as one continuous unit to eliminate duplication of finished end panels and to simplify installation. If special cabinets are obtained they should be planned for the minimum number of doors and drawers, since these are the most costly cabinet components. Backs are unnecessary where cabinets are to be installed over painted drywall.

Kitchens may often be planned to avoid corners that require costly corner cabinets and countertops and result in "dead" corner space. Similarly, avoiding kitchen layouts that require cabinets to fit between walls at each end will assure maximum installation tolerance. A "pantry" closet can sometimes be substituted for some of the kitchen cabinets, and can provide more effective storage space at less cost. The use of free-standing appliances will also minimize cabinetry.

Prefabricated cabinets are installed with 3-inch-long wood screws driven through the drywall into wall studs. Base cabinets are set in place and anchored through the top rail at the rear. Wall cabinets are anchored to the wall through a rail at the top and bottom. Wall cabinets do not need to be anchored into a bulkhead at the top, and kitchen layouts which require cabinets to be suspended from a bulkhead are difficult to install properly.

A bulkhead over kitchen cabinets is unnecessary and may be eliminated, leaving an open shelf across the top of wall cabinets. If the open shelf is objectionable, wall cabinets may be extended to the ceiling. With a 7-foot 6-inch ceiling height, a 6-inch extention is all that is required. This may be accomplished by increasing the overall height of the cabinets, which increases storage capacity, or a 6-inch-high filler panel of matching wood may simply be installed at the top (see Figure 7-K).

Countertops are generally available from the same source as cabinets. High pressure plastic laminate counter tops are used almost universally today, and provide a serviceable and decorative surface. They are normally available in either a "post-formed" or "self-edged" construction. The post-formed type has fewer joints and a raised edge to catch spills. Again, minimizing the choice of colors will simplify ordering, stocking and construction. A single neutral color or pattern will often be sufficient, regardless of the number of homes being built.

Bathroom vanitories have come into common usage in recent years due to their sales appeal. They are not essential, however, and the use of a wall-hung lavatory is much less costly. Where used, bathroom vanitories are comparable to kitchen base cabinets. They are available in a wide variety of styles and sizes from the same sources as kitchen cabinets. In OVE planning, these variations are reduced to one or two choices in style or color. A 30-inch width can often be adopted as "standard" for all plans, regardless of the number of homes.

Bathroom vanities can be fitted with the same type of countertop as kitchen cabinets. More recently one-piece molded plastic tops with an integral bowl have come into common usage. This is partly due to sales appeal, but it also has some practical value. Where used, one piece molded lavatories can be specified in a standard neutral color for all installations. This precludes endless possible combinations of countertop and lavatory colors, and helps to simplify the building process.

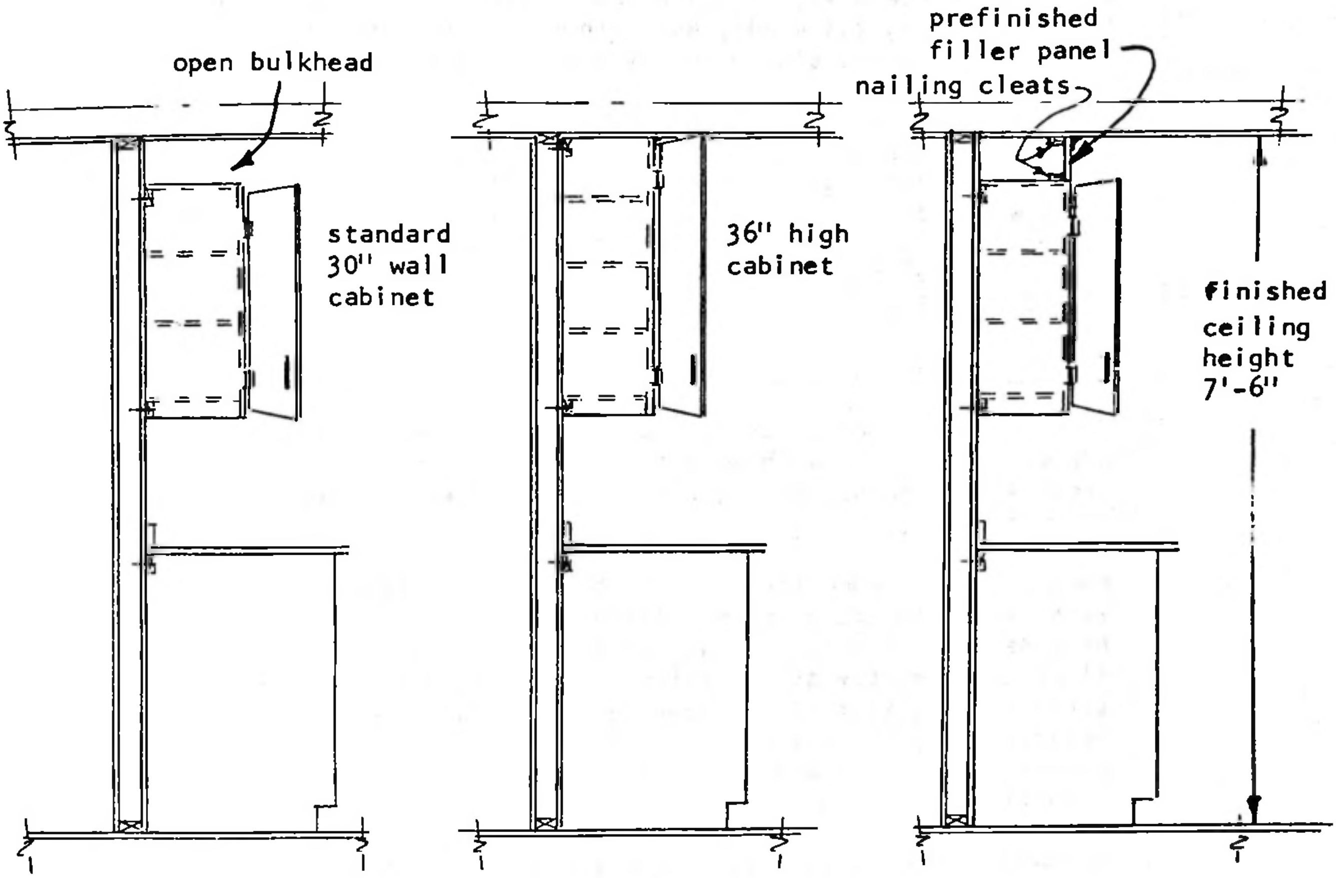


FIGURE 7-K. Alternate methods of installing kitchen cabinets with the traditional "bulkhead" eliminated.

Even with vanitories, medicine cabinets are normally required for storage of day-to-day toiletry items. The least costly installation is a surface mounted cabinet that is simply attached to the wall. Since this type of cabinet does not extend into the wall, it may be used with any wall construction, including 2x3 studs, and without interfering with plumbing or wiring that might be present in the wall.

However, surface mounted cabinets do protrude into the room. For this reason recessed cabinets may be preferred, even at some additional cost. Most recessed cabinets are 4 inches deep, which prevents installation in a 2x3 stud wall. However, since medicine cabinets are typically installed in a 4-inch or 6-inch "plumbing wall", they can often be accomodated with proper planning.

7.6 Finish Floors

In the past, some variety of hardwood flooring was considered standard for homes with wood frame floors. In homes with concrete slab floors, resilient tile flooring was often used throughout.

More recently, wood frame floors have been greatly simplified with the introduction of single-layer plywood floor construction. An underlayment grade tongue-and-groove plywood single-layer floor combines the structural properties of a subfloor with the surface properties of an underlayment. Most floor covering materials may be applied directly to the subfloor if it is properly installed and protected from undue abuse during construction.

Hardwood flooring has been largely replaced with wall-to-wall carpeting in wood floor constructions. Carpeting has also become more-or-less standard over concrete floors. Resilient flooring products are used in kitchens, and increasingly in baths. More costly "specialty" flooring products, including ceramic tile, are used with discretion in OVE construction, with their selection based on a marketing decision.

7.6.1 Wall-To-Wall Carpet

Wall-to-wall carpeting is now widely used as the standard floor covering for bedrooms, living areas, halls and stairways. The appeal of carpeting seems to be universal despite added cost and more limited useful life. Actually, since wall-to-wall carpeting normally replaces some other finish material, at least part of the additional cost is offset.

Wall-to-wall carpet may be installed directly over concrete or single-layer plywood floors. It is very tolerant of minor imperfections in the underlying floor construction, and provides a uniform, appealing floor covering. Together with a suitable cushion or pad, carpeting softens the impact of concrete floors and provides some thermal protection.

There is a wide variety of textures, colors and fabrics available in carpeting. Generally, nylon provides good durability at a reasonable cost. A minimum 20-ounce carpet (weight of pile yarn per square yard) installed over a minimum 50-ounce foam rubber pad is adequate for normal residential use. A heavier pad can be used to provide a more luxurious "feel" at little extra cost. A loop or random sheared pile with a texture or pattern helps to cover minor irregularities in installation and mask subsequent wear paths.

Whether the underlying floor is wood or concrete, carpeting is usually installed with the "tackless" method today. Small strips of 1/4-inch plywood with many barbs protruding upwards are installed around the perimeter. The pad is installed within these strips. The carpet is then stretched over the "tackless" strips and anchored by pressing down over the barbs. Wall-to-wall carpeting is generally installed to the base, although it is possible to eliminate the base as shown previously in Figure 7-F. No shoe molding is necessary.

Techniques for fitting and splicing carpet are well known and widely practiced. Very little scrap or waste is necessary with careful measurement and fitting. Major areas are covered first. Trim pieces may then be utilized in closets and other small areas. Carpet may be installed directly to the floor in closets without using tackless strips or a pad.

Wall-to-wall carpet is one of the last items installed in a new home after all construction trades have moved out. For this reason, carpeting can usually be offered to home buyers in several choices without disrupting the construction schedule. However, if a house has not been sold by the time it is ready for carpeting, it is usually advisable to install a popular carpet rather than show the house with uncovered floors.

7.6.2 Resilient Flooring

Resilient floorings are basically a class of flexible "plastic" flooring products which are installed as a thin veneer over the structural floor, usually with an adhesive, to provide a dense, easy to maintain surface. Resilient flooring is available in either tile or sheet form, manufactured from a variety of ingredients. There are several basic types of resilient flooring of particular interest in OVE construction.

The most widely used sheet products are inlaid linoleum and vinyl. Each has its own advantages. Inlaid linoleum is a time-proven product that can provide satisfactory service over wood floor constructions. The term "inlaid" signifies that the color and pattern extend down through the wearing surface. This product is generally less costly than vinyl. However, the choice of colors and patterns is somewhat limited by the nature of the material. Inlaid linoleum is especially suitable for application in kitchens, utility rooms, etc. But the subdued colors have somewhat less appeal in bathrooms.

Vinyl sheet flooring is produced in a wide variety of colors, patterns and constructions, some of which are quite expensive. The most popular vinyl sheet products consist of a clear vinyl wear surface bonded to a fiber backing, with a printed design between. Some products also have a layer of vinyl foam incorporated to increase resiliency. Vinyl sheet products provide somewhat greater durability and ease of maintenance than inlaid linoleum, but usually at a higher cost. They are particularly suitable for bathroom floors.

The most widely used resilient tile product is a 12-inch-square, 1/16-inch-thick vinyl-asbestos tile. This type of flooring is especially suitable over concrete floors, which provide a stable, uniform base. It is also widely used over wood floor construction. However, the limited thickness of this product can sometimes lead to problems with joints and fastenings showing through. Vinyl-asbestos tile is available in a wide variety of colors and patterns, suitable for kitchens, baths, family rooms, etc. This product provides a serviceable, appealing floor at reasonable cost. Generally, there is less scrap and waste from installation of tile than with sheet flooring since the tiles readily adapt to any room configuration.

Any of the above resilient flooring products may be applied directly to an underlayment grade, tongue-and-groove plywood subfloor, providing it has been installed properly and protected from undue abuse during construction. Where the subfloor does not present an acceptable surface for one reason or another, a 1/4-inch-thick plywood or hardboard underlayment, designed for that purpose, should be used over the subfloor. When used, the underlayment should be securely fastened with special nails or staples spaced at 3 inches along edges and 6 inches in both directions across the panel. The use of a construction adhesive will provide additional assurance of secure attachment, especially at joints. Most resilient flooring products are available in embossed patterns. Their use helps to mask any irregularities in the underlying floor, whether the floor is wood or concrete.

As noted previously, resilient flooring can sometimes be fitted sufficiently close to the base to avoid additional trim. If this is not possible, a prefinished shoe molding may be used to cover the joint at the edge of the flooring. In some cases, the base may be eliminated if drywall or paneling is fitted sufficiently close to the floor and a prefinished shoe molding is used to cover the joint. Another alternative is to use a plastic cove base wherever resilient flooring is used (see Figure 7-L). Regardless of the detail used, in OVE construction the flooring subcontractor installs both the flooring and any required trim to avoid a subsequent task by another trade or misunderstandings between subcontractors.

7.6.3 Specialty Floorings

Carpeting and resilient flooring products, as discussed previously, are available in sufficient variety to serve all basic flooring requirements in most homes. Other types of flooring products, such as ceramic tile and hardwood, are generally more costly and are not considered consistent with OVE construction. It is recognized, however, that marketing objectives may sometimes dictate a special floor treatment in certain cases.

A common example of special floor treatment is ceramic tile for bathroom floors. Since the area involved is relatively small, the added cost may be justified from a marketing standpoint. Ceramic tile is available in paper or fabric-backed sheets with tiles properly spaced and arranged in preset patterns. The sheets may be applied directly to single-layer plywood or concrete floor constructions with a suitable adhesive. After the adhesive has had time to set, the joints are filled with tile grout. Ceramic base trim is generally used with a ceramic tile floor as shown in Figure 7-L.

Another special floor treatment which may be desirable from a marketing standpoint is hardwood flooring. Limited use of some form of wood flooring may be justified in certain settings, such as a family room or den, where the sales impact is sufficiently great to offset the added cost. The most practical method of installing wood flooring in a limited area of this type is to use a prefinished product. This permits installation during the final stage of construction, and avoids a separate finishing operation.

Prefinished wood flooring products are available in two basic forms - strip and block. Wood strip or "plank" flooring is offered in various widths, but wider widths are more subject to warping and tend to open up at joints with changes in moisture conditions. Nominal 1/2-inch-thick tongue-and-groove strip

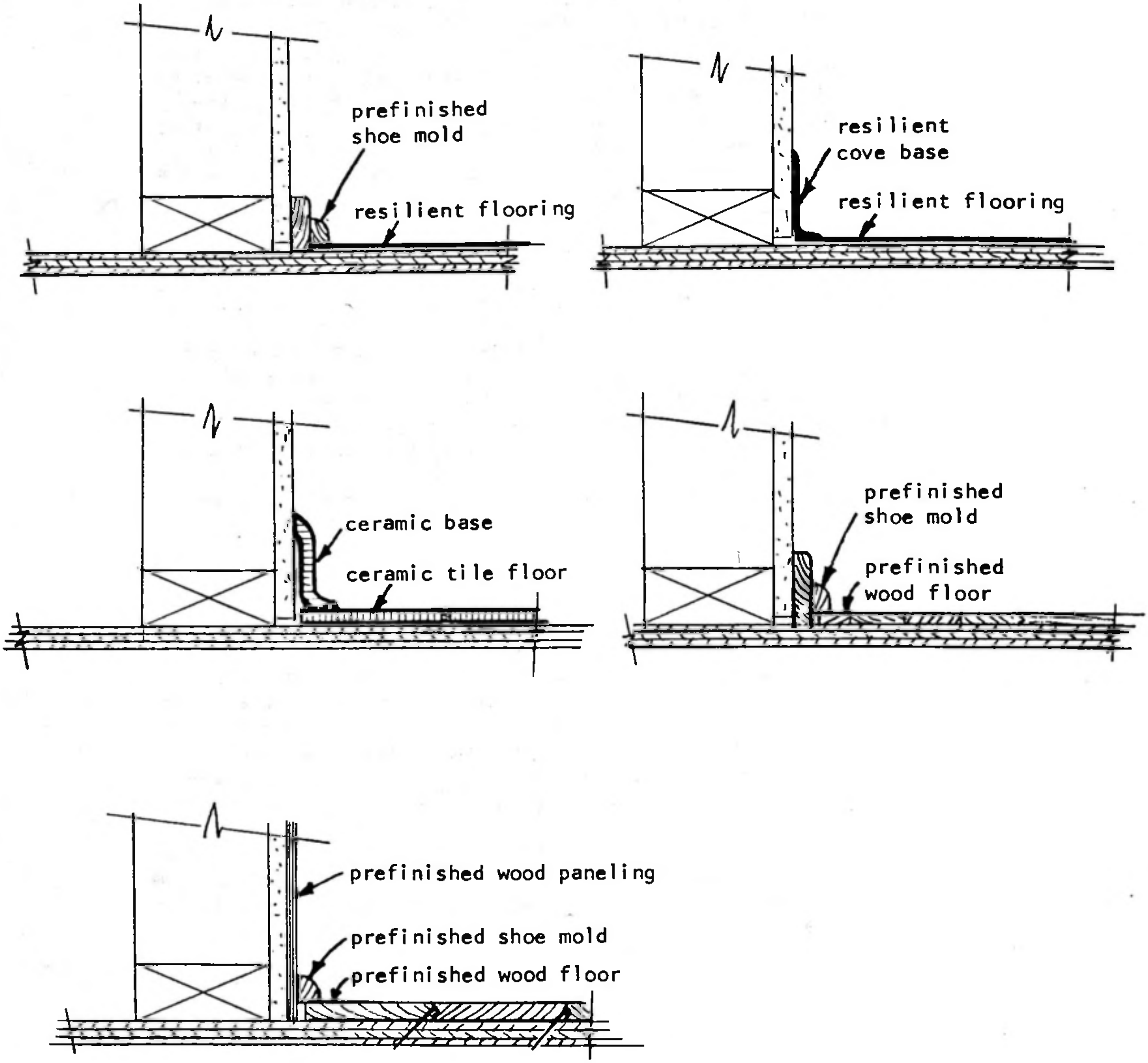


FIGURE 7-L. Alternate base trim details for use with different finish floor treatments.

flooring is suitable for application to a wood floor construction. The strips are blind-nailed by driving special nails down through the tongue at a 45° angle. A manual nailing machine, designed for this purpose, is used to avoid marring the finish. Wood strip flooring may be used over concrete floors, but special higher cost methods of installation are necessary.

Wood block or "parquet" flooring is offered in a number of variations. One of the more common consists of a series of 5/16-inch-thick wood slats attached to each other to form a 7-inch square. Blocks of this type are suitable for use over single-layer plywood or concrete floor constructions. A special adhesive, designed for this purpose, is used for installation.

A standard painted base may be used with prefinished flooring. The joint between flooring and base may then be trimmed with a compatible prefinished wood shoe mold, as shown in Figure 7-L. In some cases, the base may be eliminated if drywall or paneling is fitted sufficiently close to the floor, and a prefinished shoe mold is used to cover the joint.

[illegible]

[illegible]

[illegible]

[illegible]

STRENGTH PROPERTIES

OF COMMON SPECIES AND GRADES OF STRUCTURAL LUMBER

Species and commercial grade	Size classification	Design values in pounds per square inch						
		Extreme fiber in bending "f"		Tension parallel to grain	Horizontal shear "H"	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity "E"
		Single-member uses	Repetitive-member uses *					
BALSAM FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1350	1550	800	60	170	1050	1,200,000
No. 1	2" to 4"	1150	1300	675	60	170	825	1,200,000
No. 2	thick	950	1100	550	60	170	650	1,100,000
No. 3	2" to 4"	525	600	300	60	170	400	900,000
Appearance	wide	1000	1150	650	60	170	1000	1,200,000
Stud	2" to 4" thick 2" to 4" wide	525	600	300	60	170	400	900,000
Construction	2" to 4"	675	800	400	60	170	750	900,000
Standard	thick	375	450	225	60	170	625	900,000
Utility	4" wide	175	200	100	60	170	400	900,000
Select Structural	2" to 4"	1150	1350	775	60	170	925	1,200,000
No. 1	thick	1000	1150	650	60	170	825	1,200,000
No. 2	5" and	825	950	425	60	170	700	1,100,000
No. 3	wider	475	550	250	60	170	450	900,000
Appearance		1000	1150	650	60	170	1000	1,200,000
Stud		475	550	250	60	170	450	900,000
DOUGLAS FIR-LARCH (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Dense Select Structural		2450	2800	1400	95	455	1850	1,900,000
Select Structural		2100	2400	1200	95	385	1600	1,800,000
Dense No. 1		2050	2400	1200	95	455	1450	1,900,000
No. 1	2" to 4"	1750	2050	1050	95	385	1250	1,800,000
Dense No. 2	thick	1700	1950	1000	95	455	1150	1,700,000
No. 2	2" to 4"	1450	1650	850	95	385	1000	1,700,000
No. 3	wide	800	925	475	95	385	600	1,500,000
Appearance		1750	2050	1050	95	385	1500	1,800,000
Stud		800	925	475	95	385	600	1,500,000
Construction	2" to 4"	1050	1200	625	95	385	1150	1,500,000
Standard	thick	600	675	350	95	385	925	1,500,000
Utility	4" wide	275	325	175	95	385	600	1,500,000
Dense Select Structural		2100	2400	1400	95	455	1650	1,900,000
Select Structural		1800	2050	1200	95	385	1400	1,800,000
Dense No. 1	2" to 4"	1800	2050	1200	95	455	1450	1,900,000
No. 1	thick	1500	1750	1000	95	385	1250	1,800,000
Dense No. 2	5" and	1450	1700	775	95	455	1250	1,700,000
No. 2	wider	1250	1450	650	95	385	1050	1,700,000
No. 3		725	850	375	95	385	675	1,500,000
Appearance		1500	1750	1000	95	385	1500	1,800,000
Stud		725	850	375	95	385	675	1,500,000
DOUGLAS FIR SOUTH (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		2000	2300	1150	90	335	1400	1,400,000
No. 1	2" to 4"	1700	1950	975	90	335	1150	1,400,000
No. 2	thick	1400	1600	825	90	335	900	1,300,000
No. 3	2" to 4"	775	875	450	90	335	550	1,100,000
Appearance	wide	1700	1950	975	90	335	1350	1,400,000
Stud		775	875	450	90	335	550	1,100,000
Construction	2" to 4"	1000	1150	600	90	335	1000	1,100,000
Standard	thick	550	650	325	90	335	850	1,100,000
Utility	4" wide	275	300	150	90	335	550	1,100,000
Select Structural	2" to 4"	1700	1950	1150	90	335	1250	1,400,000
No. 1	thick	1450	1650	975	90	335	1150	1,400,000
No. 2	5" and	1200	1350	625	90	335	950	1,300,000
No. 3	wider	700	800	350	90	335	600	1,100,000
Appearance		1450	1650	975	90	335	1350	1,400,000
Stud		700	800	350	90	335	600	1,100,000
EASTERN HEMLOCK – TAMARACK (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1800	2050	1050	85	365	1350	1,300,000
No. 1	2" to 4"	1500	1750	900	85	365	1050	1,300,000
No. 2	thick	1250	1450	725	85	365	850	1,100,000
No. 3	2" to 4"	700	800	400	85	365	525	1,000,000
Appearance	wide	1300	1500	900	85	365	1300	1,300,000
Stud		700	800	400	85	365	525	1,000,000
Construction	2" to 4"	900	1050	525	85	365	975	1,000,000
Standard	thick	500	575	300	85	365	800	1,000,000
Utility	4" wide	250	275	150	85	365	525	1,000,000
Select Structural	2" to 4"	1550	1750	1050	85	365	1200	1,300,000
No. 1	thick	1300	1500	875	85	365	1050	1,300,000
No. 2	5" and	1050	1200	575	85	365	900	1,100,000
No. 3	wider	625	725	325	85	365	575	1,000,000
Appearance		1300	1500	875	85	365	1300	1,300,000
Stud		625	725	325	85	365	575	1,000,000

*Repetitive members include joists, studs, rafters, trusses and built-up beams with at least three members spaced no more than 24" apart.

Species and commercial grade	Size classification	Design values in pounds per square inch: Extreme fiber in bending "Fb": Single-member uses	Extreme fiber in bending "Fb": Repetitive-member uses *	Tension parallel to grain	Horizontal shear "H"	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity "E"
EASTERN SPRUCE (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1500	1750	875	65	255	1150	1,400,000
No. 1	2" to 4"	1300	1500	750	65	255	900	1,400,000
No. 2	thick	1050	1200	625	65	255	700	1,200,000
No. 3	2" to 4"	575	675	325	65	255	425	1,100,000
Appearance	wide	1100	1250	750	65	255	1050	1,400,000
Stud		575	675	325	65	255	425	1,100,000
Construction	2" to 4"	775	875	450	65	255	800	1,100,000
Standard	thick	425	500	250	65	255	675	1,100,000
Utility	4" wide	200	225	100	65	255	425	1,100,000
Select Structural		1300	1500	875	65	255	1000	1,400,000
No. 1	2" to 4"	1100	1250	750	65	255	900	1,400,000
No. 2	thick	900	1000	475	65	255	750	1,200,000
No. 3	5" and	525	600	275	65	255	475	1,100,000
Appearance	wider	1100	1250	750	65	255	1050	1,400,000
Stud		525	600	275	65	255	475	1,100,000
ENGELMANN SPRUCE–ALPINE FIR (ENGELMANN SPRUCE–LODGEPOLE PINE) (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1350	1550	800	70	195	950	1,300,000
No. 1	2" to 4"	1150	1350	675	70	195	750	1,300,000
No. 2	thick	950	1100	550	70	195	600	1,100,000
No. 3	2" to 4"	525	600	300	70	195	375	1,000,000
Appearance	wide	1150	1350	675	70	195	900	1,300,000
Stud		525	600	300	70	195	375	1,000,000
Construction	2" to 4"	700	800	400	70	195	675	1,000,000
Standard	thick	375	450	225	70	195	550	1,000,000
Utility	4" wide	175	200	100	70	195	375	1,000,000
Select Structural		1200	1350	775	70	195	850	1,300,000
No. 1	2" to 4"	1000	1150	675	70	195	750	1,300,000
No. 2	thick	825	950	425	70	195	625	1,100,000
No. 3	5" and	475	550	250	70	195	400	1,000,000
Appearance	wider	1000	1150	675	70	195	900	1,300,000
Stud		475	550	250	70	195	400	1,000,000
HEM-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1650	1900	975	75	245	1300	1,500,000
No. 1	2" to 4"	1400	1600	825	75	245	1050	1,500,000
No. 2	thick	1150	1350	675	75	245	825	1,400,000
No. 3	2" to 4"	650	725	375	75	245	500	1,200,000
Appearance	wide	1400	1600	825	75	245	1250	1,500,000
Stud		650	725	375	75	245	500	1,200,000
Construction	2" to 4"	825	975	500	75	245	925	1,200,000
Standard	thick	475	550	275	75	245	775	1,200,000
Utility	4" wide	225	250	125	75	245	500	1,200,000
Select Structural		1400	1650	950	75	245	1150	1,500,000
No. 1	2" to 4"	1200	1400	800	75	245	1050	1,500,000
No. 2	thick	1000	1150	525	75	245	875	1,400,000
No. 3	5" and	575	675	300	75	245	550	1,200,000
Appearance	wider	1200	1400	800	75	245	1250	1,500,000
Stud		575	675	300	75	245	550	1,200,000
LODGEPOLE PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1500	1750	875	70	250	1150	1,300,000
No. 1	2" to 4"	1300	1500	750	70	250	900	1,300,000
No. 2	thick	1050	1200	625	70	250	700	1,200,000
No. 3	2" to 4"	600	675	350	70	250	425	1,000,000
Appearance	wide	1300	1500	750	70	250	1050	1,300,000
Stud		600	675	350	70	250	425	1,000,000
Construction	2" to 4"	775	875	450	70	250	800	1,000,000
Standard	thick	425	500	250	70	250	675	1,000,000
Utility	4" wide	200	225	125	70	250	425	1,000,000
Select Structural		1300	1500	875	70	250	1000	1,300,000
No. 1	2" to 4"	1100	1300	750	70	250	900	1,300,000
No. 2	thick	925	1050	475	70	250	750	1,200,000
No. 3	5" and	525	625	275	70	250	475	1,000,000
Appearance	wider	1100	1300	750	70	250	1050	1,300,000
Stud		525	625	275	70	250	475	1,000,000
MOUNTAIN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1750	2000	1000	95	370	1250	1,300,000
No. 1	2" to 4"	1450	1700	850	95	370	1000	1,300,000
No. 2	thick	1200	1400	700	95	370	775	1,100,000
No. 3	2" to 4"	675	775	400	95	370	475	1,000,000
Appearance	wide	1450	1700	850	95	370	1200	1,300,000
Stud		675	775	400	95	370	475	1,000,000
Construction	2" to 4"	875	1000	525	95	370	900	1,000,000
Standard	thick	500	575	275	95	370	725	1,000,000
Utility	4" wide	225	275	125	95	370	475	1,000,000
Select Structural		1500	1700	1000	95	370	1100	1,300,000
No. 1	2" to 4"	1250	1450	850	95	370	1000	1,300,000
No. 2	thick	1050	1200	550	95	370	825	1,100,000
No. 3	5" and	625	700	325	95	370	525	1,000,000
Appearance	wider	1250	1450	850	95	370	1200	1,300,000
Stud		625	700	325	95	370	525	1,000,000

Species and commercial grade	Size classification	Design values in pounds per square inch: Extreme fiber in bending "Fb": Single-member uses	Repetitive-member uses *	Tension parallel to grain	Horizontal shear "H"	Compression perpendicular to grain	Compression parallel to grain	Modulus of elasticity "E"
RED PINE (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1400	1600	800	70	280	1050	1,300,000
No. 1	2" to 4"	1200	1350	700	70	280	825	1,300,000
No. 2	thick	975	1100	575	70	280	650	1,200,000
No. 3	2" to 4"	525	625	325	70	280	400	1,000,000
Appearance	wide	1200	1350	675	70	280	925	1,300,000
Stud		525	625	325	70	280	400	1,000,000
Construction	2" to 4"	700	800	400	70	280	750	1,000,000
Standard	thick	400	450	225	70	280	600	1,000,000
Utility	4" wide	175	225	100	70	280	400	1,000,000
Select Structural	2" to 4"	1200	1350	800	70	280	900	1,300,000
No. 1	thick	1000	1150	675	70	280	825	1,300,000
No. 2	5" and	825	950	425	70	280	675	1,200,000
No. 3	wider	500	550	250	70	280	425	1,000,000
Appearance		1000	1150	675	70	280	925	1,300,000
Stud		500	550	250	70	280	425	1,000,000
SOUTHERN PINE (Surfaced dry. Used at 19% max. m.c.)								
Select Structural		2000	2300	1150	100	405	1550	1,700,000
Dense Select Structural		2350	2700	1350	100	475	1800	1,800,000
No. 1		1700	1950	1000	100	405	1250	1,700,000
No. 1 Dense	2" to 4" thick	2000	2300	1150	100	475	1450	1,800,000
No. 2	2" to 4"	1400	1650	825	90	405	975	1,600,000
No. 2 Dense	wide	1650	1900	975	90	475	1150	1,600,000
No. 3		775	900	450	90	405	575	1,400,000
No. 3 Dense		925	1050	525	90	475	675	1,500,000
Stud		775	900	450	90	405	575	1,400,000
Construction	2" to 4"	1000	1150	600	100	405	1100	1,400,000
Standard	thick	575	675	350	90	405	900	1,400,000
Utility	4" wide	275	300	150	90	405	575	1,400,000
Select Structural		1750	2000	1150	90	405	1350	1,700,000
Dense Select Structural		2050	2350	1300	90	475	1600	1,800,000
No. 1		1450	1700	975	90	405	1250	1,700,000
No. 1 Dense	2" to 4" thick	1700	2000	1150	90	475	1450	1,800,000
No. 2	5" and	1200	1400	625	90	405	1000	1,600,000
No. 2 Dense	wider	1400	1650	725	90	475	1200	1,600,000
No. 3		700	800	350	90	405	625	1,400,000
No. 3 Dense		825	925	425	90	475	725	1,500,000
Stud		725	850	350	90	405	625	1,400,000
SPRUCE-PINE-FIR (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1450	1650	850	70	265	1100	1,500,000
No. 1	2" to 4"	1200	1400	725	70	265	875	1,500,000
No. 2	thick	1000	1150	600	70	265	675	1,300,000
No. 3	2" to 4"	550	650	325	70	265	425	1,200,000
Appearance	wide	1200	1400	700	70	265	1050	1,500,000
Stud		550	650	325	70	265	425	1,200,000
Construction	2" to 4"	725	850	425	70	265	775	1,200,000
Standard	thick	400	475	225	70	265	650	1,200,000
Utility	4" wide	175	225	100	70	265	425	1,200,000
Select Structural		1250	1450	825	70	265	975	1,500,000
No. 1	2" to 4"	1050	1200	700	70	265	875	1,500,000
No. 2	thick	875	1000	450	70	265	725	1,300,000
No. 3	5" and	500	575	275	70	265	450	1,200,000
Appearance	wider	1050	1200	700	70	265	1050	1,500,000
Stud		500	575	275	70	265	450	1,200,000
WESTERN HEMLOCK (Surfaced dry or surfaced green. Used at 19% max. m.c.)								
Select Structural		1800	2100	1050	90	280	1450	1,600,000
No. 1	2" to 4"	1550	1800	900	90	280	1150	1,600,000
No. 2	thick	1300	1450	750	90	280	900	1,400,000
No. 3	2" to 4"	700	800	425	90	280	550	1,300,000
Appearance	wide	1550	1800	900	90	280	1350	1,600,000
Stud		700	800	425	90	280	550	1,300,000
Construction	2" to 4"	925	1050	550	90	280	1050	1,300,000
Standard	thick	525	600	300	90	280	850	1,300,000
Utility	4" wide	250	275	150	90	280	550	1,300,000
Select Structural		1550	1800	1050	90	280	1300	1,600,000
No. 1	2" to 4"	1350	1550	900	90	280	1150	1,600,000
No. 2	thick	1100	1250	575	90	280	975	1,400,000
No. 3	5" and	650	750	325	90	280	625	1,300,000
Appearance	wider	1350	1550	900	90	280	1350	1,600,000
Stud		650	750	325	90	280	625	1,300,000

Source: Table 1, National Design Specification for Wood Construction, National Forest Products Association, 1977 Edition.

APPENDIX B - BIBLIOGRAPHY OF COST EFFECTIVE CONSTURCTION PUBLICATIONS

Cost Buster House.
A booklet costing $2.50. Available from local Home Builders Associations. See your local phone directory.

Cost Effective Site Planning: Single Family Development.
$12.50. Available from National Association of Home Builders (NAHB), 15th and M Streets, N.W., Washington, D.C. 20005. When sending orders, please prepay and send street address so order may be sent by U.P.S.

Manual of Lumber and Plywood Saving Techniques for Residential Light - Frame Construction.
$5.00. Available from local Home Builders Associations. See your local phone directory.

Value Engineering in the Construction Industry.

$16.50. Available from Litton Educational Publishing, 7625 Empire Drive, Florence, Kentucky 41042.

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