U.S. Department of
Housing and Urban Development
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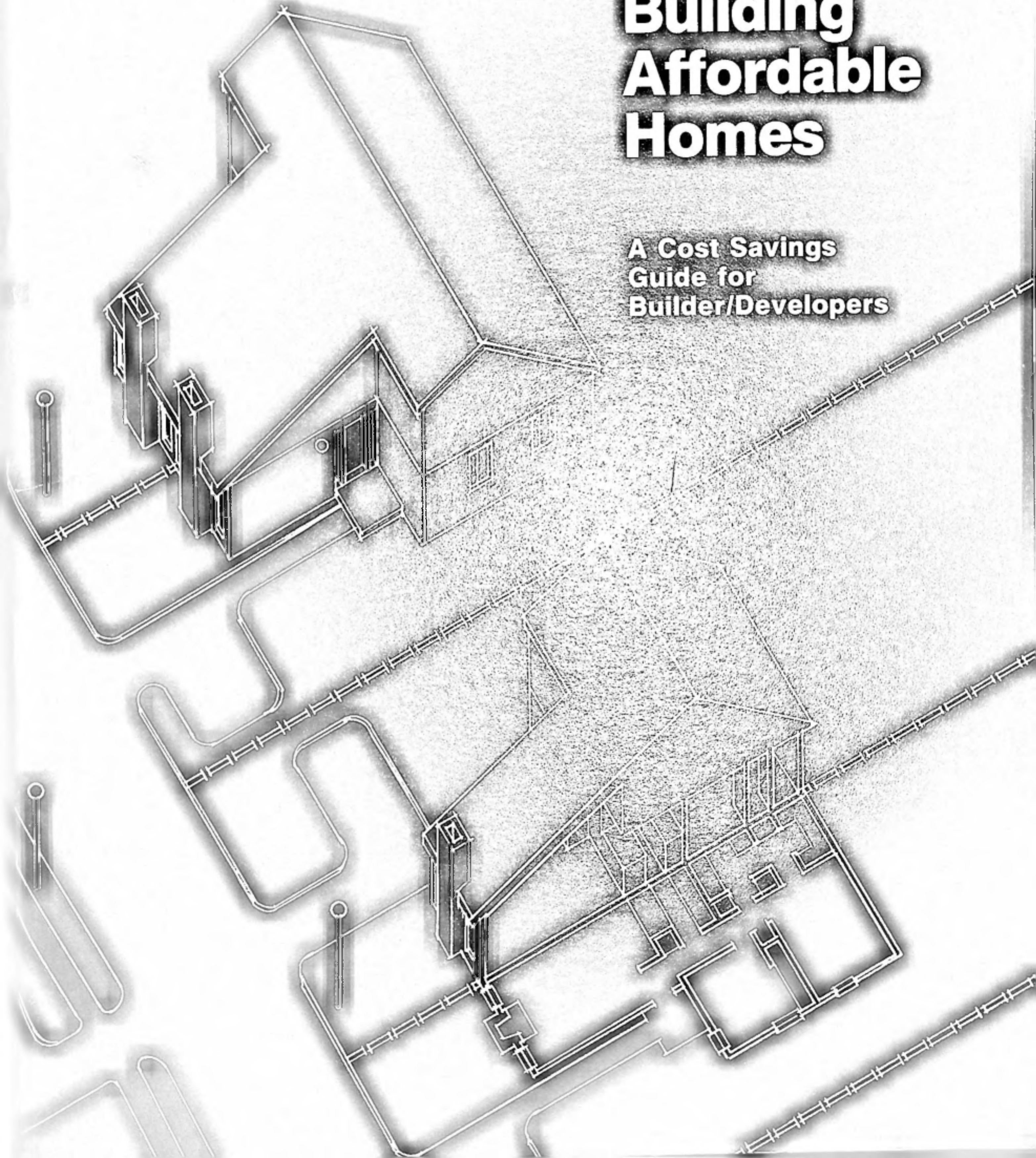
NAHB
Research
Foundation, Inc.

Building Affordable Homes

A Cost Savings Guide for Builder/Developers



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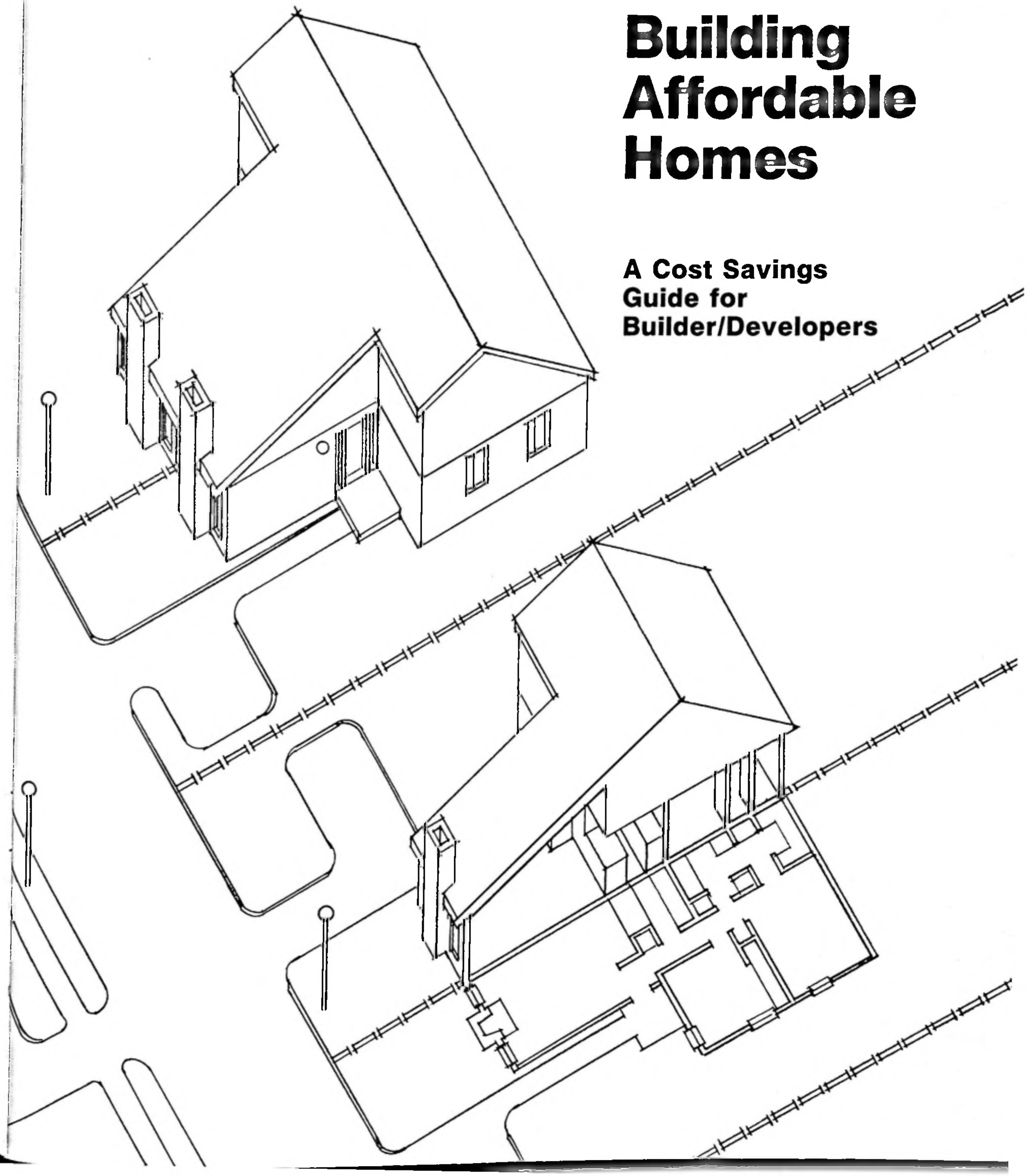


Foreword

For years the U.S. Department of Housing and Urban Development (HUD), the National Association of Home Builders (NAHB), and the NAHB Research Foundation, Inc. have been searching for solutions to the rising cost of housing. One of HUD's more recent efforts, the Joint Venture for Affordable Housing, promises to be a significant step toward lowering the cost of housing for all Americans. This manual is a direct result of the Joint Venture program and contains a compilation of cost saving methods from land development through construction. All the techniques may not be applicable to every situation, but most developers and builders will likely find many ways to lower housing costs.

Acknowledgements

This manual is the result of material obtained from many sources and was prepared by the NAHB Research Foundation, Inc. Especially helpful were Orville G. Lee, Ronald J. Morony, Conrad C. Arnolts and F. Daniel Kluckhuhn of HUD's Office of Policy Development and Research, and Michael F. Shibley, Director of NAHB's Land Use and Development Department. The principal author was E. Lee Fisher. Instrumental in developing the manual were Donald F. Luebs, Ronald K. Yingling, Helen C. English and Carole U. Marks of the Research Foundation.

The work that provided the basis for this publication was supported by funding under a Cooperative Agreement with the U.S. Department of Housing and Urban Development. The substance and findings of that work are dedicated to the public. The author and publisher are solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Government.

Publication management:
The Moberg Group, Inc.
Barbara Jean Gilbert
Publication design: Judith Richland

Contents

Introduction

Today's housing industry faces a crisis of alarming proportions. Too many people cannot afford new homes under current housing delivery methods. Although overly restrictive building codes and land use regulations often prevent use of proven, cost-saving innovations, many communities have begun re-evaluation of their regulations in an attempt to find solutions to affordable housing. HUD's Joint Venture for Affordable Housing is encouraging the kind of understanding and cooperation between different interest groups that will result in looking at the needs of today. In addition to this sense of cooperation between developers, builders and local communities, many are finding that land development and construction methods can be modified to increase value and lower costs.

This guide to cost saving techniques contains methods to reduce costs in land development, design, most phases of direct construction, labor and material. It is not intended to be a complete "how-to" manual, but rather a compilation of brief descriptions of proven techniques that are being used successfully in some parts of the country. Chapter 14 contains a listing of manuals which cover specific subjects in more depth.

It is likely that some of the methods listed herein are not presently acceptable under many local regulations. Before adopting any new technique, be sure to check with local authorities. If unacceptable, it will be worthwhile to work closely with your local jurisdiction to have the regulations changed. The real success of an affordable housing program depends upon builders, government officials and citizens taking necessary steps to encourage innovation in their own communities.

Chapter 1 Land Development

Local Government

Work closely with municipal planners to ensure public need can be safely met without incurring unnecessary expense. Zoning and subdivision regulations are a normal outcome of jurisdictional planning, but they can become more cost-effective when builders and developers work with municipal planners from the time regulations are first discussed. Work with the community to update obsolete subdivision regulations.

Lobby for performance standards to create more cost-effective developments. Performance standards are a technique in which design and development of a site are planned in accordance with the proposed use of the site. They allow for the best possible use of the unique features of the site and allow for innovative ideas and the elimination of time, materials and cost.

Examine local fee, permit and land dedication practices to determine if they cover only the cost of extending service to the new residents rather than subsidizing the existing population. Land dedication or fees-in-lieu should be designed to serve the needs of the new homeowner, not those of the community at large.

Streamline plan processing. Delays caused by hearings and meetings add substantially to costs carried by the builder/developer which are ultimately passed on to the home buyer. Subdivision plans should be evaluated by a knowledgeable review group capable of openly discussing issues and reaching a decision in a short time. Public hearings are seldom necessary and should be eliminated in most cases. One-stop permit processing is becoming accepted in many areas with a reduction in time and costs, not only to the builder/developer, but also to the municipality.

Land use planning is an integral part of the development process. It is important to the success of providing affordable housing. These plans give the builder an indication of the viability of selected areas in which he builds.

Site Design

Design for parking, drainage, walkways, lighting and landscaping as well as for vehicle traffic. Appropriate land planning should be a response to the public good rather than an arbitrary policy.

Eliminate sidewalks. Wherever possible, eliminate public sidewalks, especially on cul-de-sacs or courts. Where sidewalks are deemed essential, 4′ wide on one side only should be adequate. (Figures 1 & 2.)

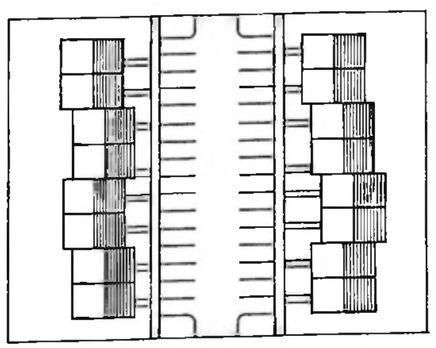


Figure 1. Avoid too much paving in parking spaces and sidewalks on both sides.

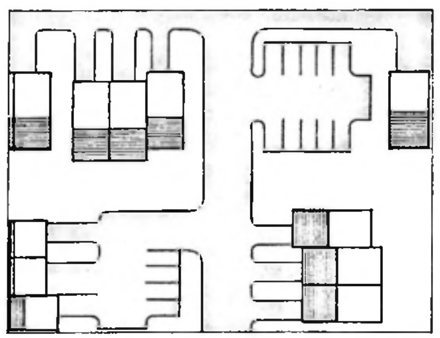


Figure 2. Consider no sidewalk and small parking clusters.

Minimize street lighting. Residential street lighting requirements can often be substantially reduced, especially in rural and outlying areas. See American National Standard Practice for Roadway Lighting, Illuminating Engineering Society, American National Standards Institute, July 11, 1972.

Avoid cul-de-sac with too many light poles and no shrubs or trees. Consider same cul-de-sac with one centrally located light decorative pole and some greenery. Avoid a cul-de-sac with too many light poles and no shrubs and trees. Consider the same cul-de-sac with one centrally located light, decorative pole and some greenery.

Density

Consider higher density to reduce lot costs, provide more open space and a greater possibility of preservation of unique natural features. **Design is a key to successful use of increased density.** A variety of small units with private lots which utilize site design concepts such as zero lot line, duplex, triplex, quadplex or townhouse planning can provide a greater selection of attractive homes at more affordable prices.

The number of dwelling units per acre is the primary development standard that effects the life style, the economics and the environmental considerations of residential development. It is important that the communities, the builder/developers, and the buyers understand the implications of the three examples illustrated. (Figures 3-5.) These plans indicate how twelve dwelling units can be developed at three different net densities, while maintaining an overall gross density of two dwelling units per acre.

The obvious conclusions of these comparisons are:

- As net density increases, lot sizes and roads decrease.
- Greater opportunities exist to preserve natural site features when the lot sizes are decreased and houses are clustered.
- Greater savings to the community, the builder/developer, and the home buyer can be achieved.

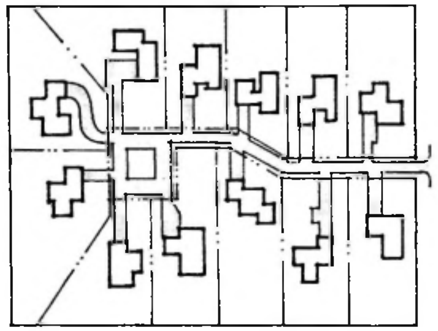


Figure 3.

2 DU/AC Gross
2 DU/AC Net
12 Dwelling Units
6 acres

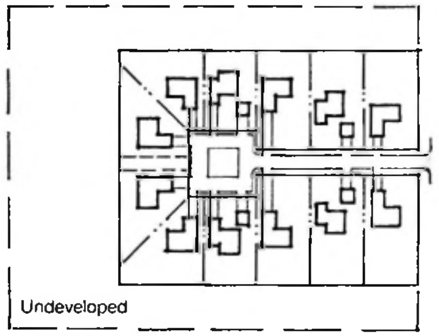


Figure 4.

2 DU/AC Gross
4 DU/AC Net
12 Dwelling Units
3 acres

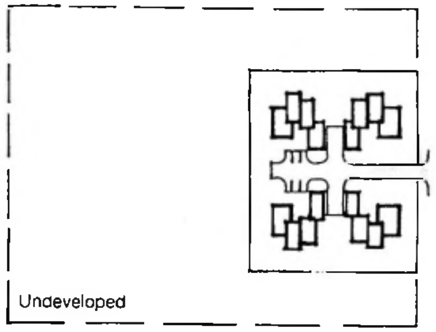


Figure 5.

2 DU/AC Gross
8 DU/AC Net
12 Dwelling Units
1.5 acres

Net Density Comparisons

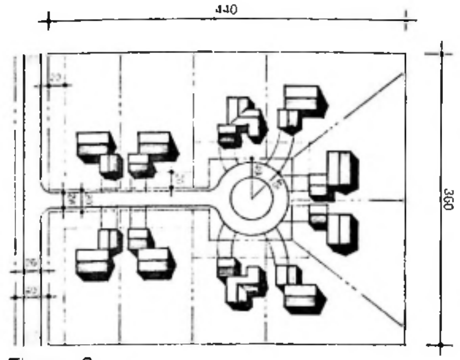


Figure 6.
2.75 Net Density

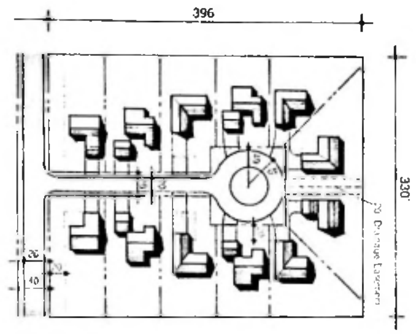


Figure 6a.
4.0 Net Density

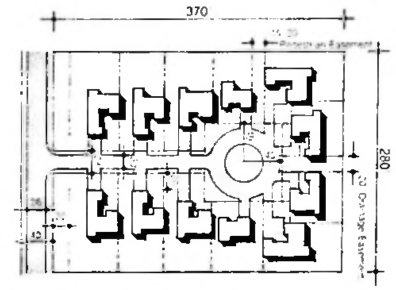


Figure 6b.
Zero Lot Line
5.0 Net Density

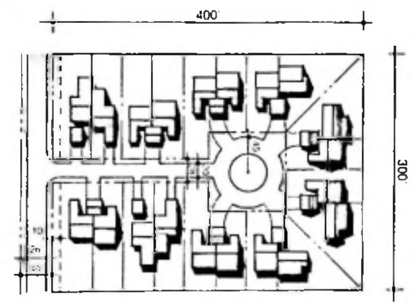


Figure 6c.
Duplex
7.25 Net Density

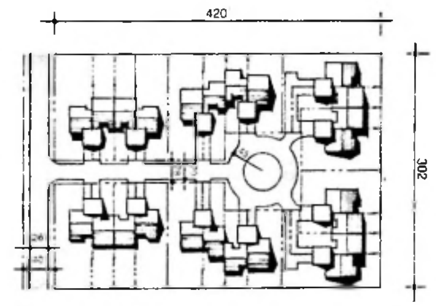


Figure 6d.
Quadplex
8.25 Net Density

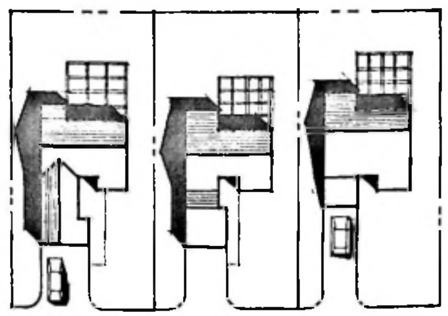


Figure 7. Conventional Siting Practice
8 to 10 feet for side yard

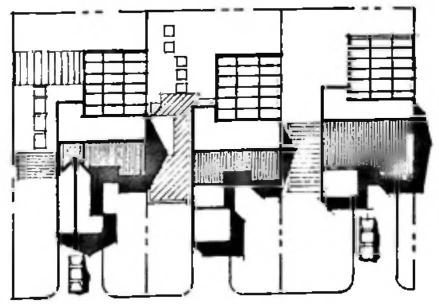


Figure 8. Zero lot line siting
Larger, more useable side yard for outdoor living

Zero Lot Line Developments

Conventional practices for siting houses generally require minimum side yards of 8 to 10 feet on both sides of the house. This often creates side yards which provide little useable outdoor space. (Figure 7.)
Alternative: Site the house with one wall on a side property line and thus combine two small side yards into one larger side yard. (Figure 8.)

Increase Open Space

Another important ingredient in achieving higher density single-family development is a provision for adequate open space. The four diagrams (Figure 9) illustrate the opportunities for providing open space utilizing the small lot principle. In other words, an area might be zoned for four dwelling units per acre, however the site plan could be designed at six or eight dwelling units per net acre. The reduced lot sizes could reduce development costs and provide 25% to 50% of land for open space. Careful consideration should be given to preserving open space areas in as natural a state as possible. This can hold down necessary capital and maintenance costs and may save a potentially sensitive natural area.

Benefits of Increased Density

Reduce Street Construction

net density	total acres	acres developed	average lot size S.F.	S.F. pavement (20')	% develop in R.O.W.	L.F. roads	L.F. per lot
2 DU/AC	6	6	20,863	11,000	4	550	46
4 DU/AC	6	3	10,140	9,000	3.5	450	38
8 DU/AC	6	1.5	5,112	4,000	1.5	200	17

L.F. — lineal feet
S.F. — square feet
DU/AC — dwelling units per acre

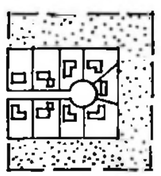


Figure 9a.
In area zoned for 2 DU/AC, ¼ acre lots are used to provide 50% open space and reduce development costs

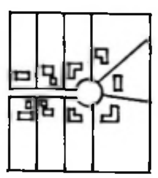


Figure 9b.
In area zoned for 2 DU/AC, ½ acre lots with minimum lot frontage to reduce development costs

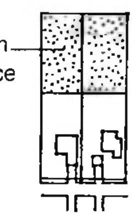


Figure 9c.
Public open space

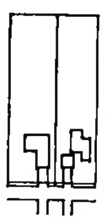
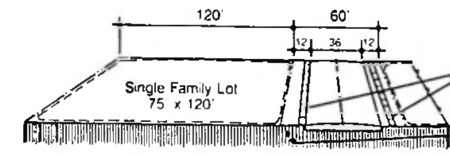
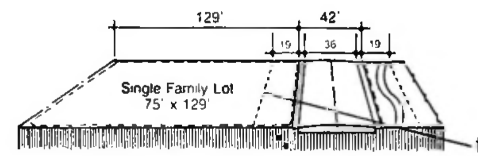


Figure 9d.
Private open space



Typical situation

Figure 10.
Avoid the typical situation.



Alternative

Figure 11. Consider the alternative.

Right-of-Way

Reduce the amount of land in the right-of-way without impairing the function of the traffic and utility systems and thereby create more useable land for housing or common areas.

How to Implement?

- Determine the criteria and reasoning for existing utility and transportation regulations.
- Determine alternate method of meeting all engineering and safety criteria.
- Document advantages and pitfalls.
- Obtain agreements one person at a time through the City staff ranks to serve as support for request before the Planning Commission and City Council.

Everyone Gains Something

City
- more land on tax roll
- less land for public maintenance
- utility line access and serviceability is not hampered

Builder
- more land to sell

Owner
- better "streetscape" due to private landscaping being closer to the street
- potentially safer sidewalk

Street Design

Minimize street widths. There are a broad range of factors and parameters which should be considered in selecting the best street design for subdivisions.

- Width should be based on functional needs.
- Municipal codes should be reviewed against present day objectives.
- Excessive width adds cost, detracts from human scale and neighborhood quality.

A hierarchy of street classifications has been developed which is responsive to the amount and kinds of traffic a street must serve. Table 1 shows street design criteria according to average daily traffic (ADT). Figure 12 shows how narrower streets can lower development costs.

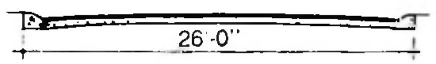
Table 1. Residential Street Design Standards

Street Description

	Place	Lane	Sub-Collector	Collector	Arterial
Service	Very Light	Light	Local Traffic	Local & Thru	Thru Only
Traffic ADT (1)	0-200	201-500	501-1000	1001-3000	3001 +
Pavement Width					
No parking	18′	18′	26′ (2)	28′	(3)
Parking 1 side	18′	18′	28′	36′	(3)
Parking 2 sides	26′	26′	36′	36′	(3)
R.O.W. WIDTH	24′-30′	24′-30′	44′-60′	44′-60′	(3)
Street Slope (4)	0.5% to 15.0%	0.5% to 10.0%	0.5% to 10.0%	0.5% to 8.0%	(3)
Maximum Speed	20 mph	25 mph	30 mph	35 mph	(3)

(1) Average Daily Traffic
(2) Two nine-foot moving lanes plus one eight-foot emergency stopping lane.
(3) Arterial streets shall be designed for specific traffic and roadway conditions as well as other related factors.
(4) Adequate cross slope of at least 2 percent is required to prevent ponding.

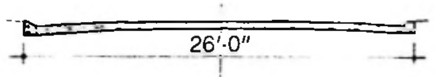
Figure 12. How can changing the development standards lower costs?



Normal Lincoln design standard for street width and cross section

A three step operation
Pour rolled curb and gutter
Pour 5" concrete street base
Place 2" asphalt topping
Cost $80/Lineal Foot (L.F.)

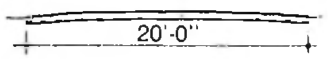
Look at the streets and curbs in Lincoln, NB.



Parkside Village entrance street

A one step operation
Monolithic pour, rolled curb, gutter and street.
6" thick concrete
Cost $55/L.F.

All three alternatives were used depending on use patterns.



Parkside Village interior street

A one step operation
6" monolithic pour of concrete for streets
Remove curb
Reduce width to 20'
Cost $40/L.F.

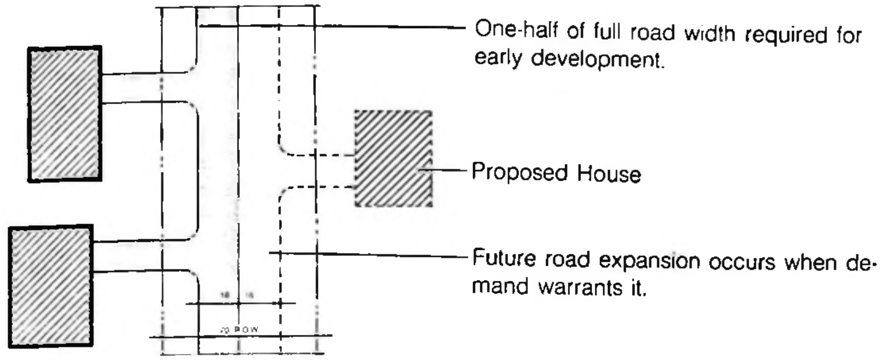


Figure 13.

Use minimum thickness paving. Use minimal paving thickness based on engineering calculations. Usually, 1½" thick asphalt concrete paving is adequate for low ADT residential streets.

Consider "one-half" paving of streets in areas where present and short term land use does not warrant full-width roads during initial development periods.

Traffic Circulation Patterns

Evaluate all component costs that go into the housing package. Streets alone can account for 25%-45% of the land development costs for a subdivision.

Relate width criteria to housing types and traffic requirements. Verify the need for on-street parking—if used at all; or

Remove all on-street parking to permit 20'-24' wide streets.

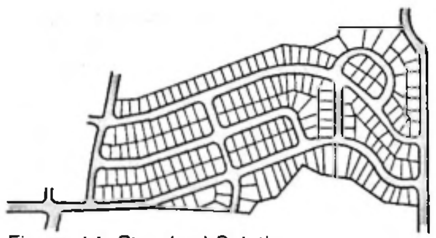


Figure 14. Standard Solution
Uniformly dispersed street pattern conducive to through traffic.

Figure 15.
Suggested Solution
Localized street pattern relating streets directly to the housing they serve, not conducive to through traffic.

Reduce subdivision entrances. ADT can be substantially reduced by minimizing entrance from arterial streets or highways. The reduction in ADT can result in reduced paving widths.

Consider one-way streets. One-way streets may be desirable for loops to reduce ADT or to protect natural features. For ADT of 500 or less, 12' wide paving is adequate if a shoulder is provided for stalled vehicles.

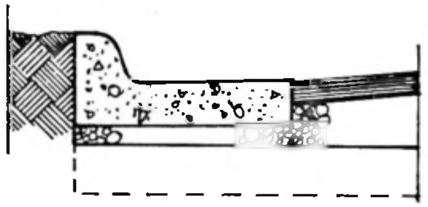


Figure 16a. Vertical Curb

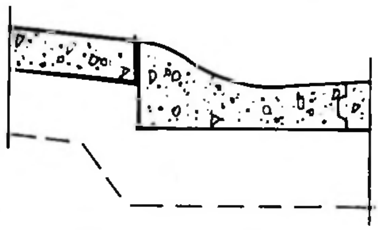


Figure 16b. Rolled curb blending with driveway

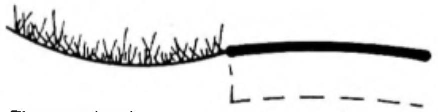


Figure 16c. No curb—grassy swale meets roadside

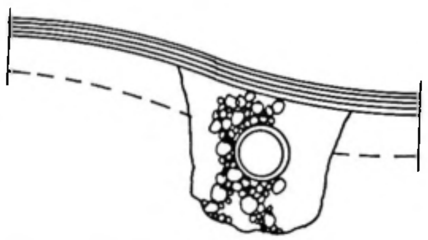


Figure 16d. Culvert carries water under driveway.

Eliminate curbs and gutters. If practical, curbs and gutters should be completely eliminated. Many communities throughout the country have been built without curbs and gutters. If considered necessary, one-piece rolled curbs eliminate driveway cutouts and are usually less expensive than "L" type curbs. (Figures 16a.-16d.)

Drainage

Eliminate combined sanitary and storm sewer.

Use dual drainage concept for storm water management. Two separate design frequencies, one for minor or "convenience" and another for major or "flood", should be considered.

Use streets for storm water control. Traffic and drainage are compatible to a point, beyond which drainage must be subservient to traffic needs.

Use retention and detention to reduce peak run off. Past practices of storm water management have involved the use of lengthy networks of underground piping.

Temporary ponding allows slower release of storm water into municipal sewer systems, which in turn reduces the storm sewer system requirements.

The advantages of ponds or basins are: reducing cost of purchasing and laying pipe; preventing overloaded storm sewer systems. Locating ponds in parks and recreation areas serve a dual purpose. (Figure 17.)

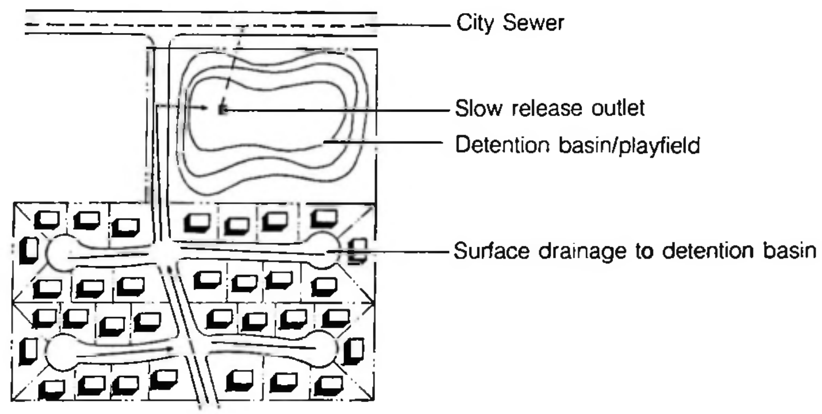


Figure 17.

Use natural drainage and unpaved swales. Open channels, swales and other land grading modifications, fitted to natural contours, increase green space in the community while providing surface drainage. Use natural materials such as grass for channel lining, especially where soil percolation is good.

Use curvilinear storm sewers. Design system to coincide with street patterns inasmuch as possible. Curved storm water sewers have been proven cost-effective.

Maximize spacing between structures (inlets, manholes, etc.). Inspection and cleaning difficulty decreases as pipe diameter increases.

Following are suggested maximum structure spacings by pipe size:

Pipe Size (inches)	Maximum Spacing (feet)
15 feet or less	500
18-36	600
42-60	700
66 or larger	Unlimited

Use prefabricated manholes. Pre-molded fiberglass and precast concrete manholes are usually more cost-effective than site-built manholes.

Utilities

Design water systems for average daily demand (ADD) and peak usage. ADD depends on factors such as lawn sprinkling, average rainfall, metered vs. non-metered systems, and family size. Systems should be designed to provide an adequate supply of safe, potable water under continuous pressure, capable of meeting reasonable fire fighting requirements. Types of dwellings, number of bedrooms, etc., should be analyzed for minimal system designs. Use 2-inch mains to service up to 50 dwellings where fire hydrants are not required.

Use common trench if feasible. Occasionally, utilities refuse to use a joint trench because of scheduling difficulties. If the utility companies are compatible, joint trenching can substantially reduce costs.

Use least expensive material. Conduct periodic analyses of installed material costs to ensure that the least expensive system is used. The least expensive system last year may not be this year.

Optimize location of mains. Avoid locating mains under streets or sidewalks to prevent excessive repair costs. Locate in rights-of-way along sides of streets as much as possible.

Locate hydrants at maximum spacing. Typically, fire hydrants are located on mains no smaller than six inches. However, smaller pipes with short runs to low risk areas in systems with sufficient pressure may provide adequate hydrant flow. For residential areas, fire hydrants should be located so that all dwellings can be reached by 500 feet of hose.

Minimize number of valves. Valves are placed primarily for the purpose of isolating sections of pipe for repair and maintenance without causing excessive numbers of users to be without water service. Therefore, location and spacing of valves should be a matter of engineering judgment based upon the density of housing and lengths of water main.

Use minimal service connections. Size of water service connections from the main to the dwelling depends upon expected dwelling demand, friction losses, street pressure and differences in elevation from water main to height of top fixture outlet. The use of a single service connection to serve two or more dwellings, each with separate meters, is desirable.

Use "blow-offs" at the end of water mains instead of hydrants for flushing mains.

Design sanitary sewers for peak flows. Volume of domestic sewage from residences usually averages less than 100 gallons per capita per day and, depending upon dwelling type, water using facilities and life style, may be as little as 50 gallons per capita per day. A peak of up to three times the average rate of flow occurs in the early morning. Therefore, sewer design should be directly related to peak flow estimates.

Minimize sewer diameter. Use of 4 and 6 inch sanitary sewers provides ample capacity for short streets. A national survey concluded that communities allowing 4- and 6-inch diameter sewers had no unusual maintenance problems. In fact, the problem of solid wastes settling and generating odor is less in smaller diameter sewers because of increased depth of flow for a given quantity of sewage.

Use curvilinear design for sanitary sewers. Curved sewer alignment following street alignment has the following advantages:

- Sewer construction parallel to street center line has fewer conflicts with other utilities.
- Number of manholes can be reduced.
- Amounts of excavation and pipe are reduced.
- Hydraulic efficiency is improved.

Maximize manhole spacing. An 800-foot section of sanitary sewer can be cleaned with equipment that can reach 400 feet. Therefore, manhole spacing can be increased to the maximum capacity of available clean out equipment.

Eliminate drop manholes for sanitary sewers. Unless required to avoid rock excavation or to avoid installed utility lines, it is usually more cost-effective to use a steep hole section or vertical curve rather than a drop manhole to make the transition.

Miscellaneous

Avoid expansive soil. It is understood that expansive soils cannot be avoided in some areas, but expansive soils invariably create costly land development and construction problems so they should be avoided if at all possible.

Use minimum setbacks. By locating homes as near the street as possible, cost of utilities, driveways, sidewalks and landscaping can be reduced.

Minimize site disturbances. By utilizing natural site features, grading and landscaping costs can often be reduced.

Chapter 2 Design

The factors which distinguish good design from poor design are almost indescribable. They vary from buyer to buyer, from builder to builder and from architect to architect. There are, however, certain qualities of good design that most can agree upon. These include, perhaps, a sense of comfort and good taste in the combination of materials, spaces and equipment so that a feeling of inner satisfaction comes to the occupants of the home.

Good design and affordability are not incompatible although some compromises may be required. The ideal affordable dwelling unit will not be "cheap" but rather will consist of high value at low cost. Even though the cost of housing has greatly reduced the potential buyer's housing options, poor design at any price will be difficult to market. In fact, some affordable housing projects have not been successful because of the tendency to be concerned only with cost without proper attention paid to design. A market survey is helpful in determining the number of eligible buyers of certain price range homes but this does not ensure they will want the product offered.

Following are some basic design principles which should be considered when building homes, regardless of price range.

Plan-site relationship

House plans should be developed to take advantage of the site. Whenever possible, major glass areas should face south to take advantage of solar gain. Utility rooms, bathrooms and storage areas should be on the north side of the house. (See passive solar section of manual.)

Large lots are more forgiving in placement and offer more variety than small lots. Therefore, small lots require more care in placement. Privacy, view, topography and natural growth are important factors in house placement.

For open, yet private interiors, orient central living areas to private outdoor spaces or views.

Don't expose living area directly to the front door.

Single story plans preserve privacy because they don't look over fences. They also can place more rooms around a patio space. Second story windows must be oriented away from neighbors' yards and toward their own patio and views.

Landscaping. Keep as many existing trees as possible.

Promote outdoor gardening and living with decks, patios, porches, and garden seats with a view.

Establish landscaping guidelines for the homeowner: Good mix of low, medium, and high shrubbery or trees.

Dwelling plan analysis. A well designed, livable floor plan will consider the functions of the different zones of the house, i.e., sleeping, living, working, and circulation spaces and their relationships to each other. Following are some thoughts that may provide guidance in plan analysis.

- If possible, orient major living areas to the south.
- Protect west elevation from low sun angles.
- Minimize the distance between car parking and kitchen.
- Minimize through traffic in the living room.
- Arrange coat closets near entry doors.
- Provide an entrance through work zone or an area provided for muddy shoes.
- Provide adequate storage for out-of-season clothes and for yard and lawn equipment.
- Minimize circulation area.

Exterior appearance. Regardless of exterior style, there are basic combinations of shape and mass that result in more or less pleasing visual proportions. Roof, overhangs, window shapes and sizes act in unison to provide this pleasant relationship. Continuity of elements is *not* a luxury reserved for expensive housing. Uncluttered, simple appearances can be pleasing in smaller, less expensive homes too. In fact, simplicity and restraint in exterior appearance tends to be acceptable by more buyers than expensive scrollwork, bric-a-brac and "gingerbread" which may lead to architectural chaos. In other words, it is often better to simplify and spend *less* money on exterior appearance for better design.

Visual continuity. Horizontal and vertical elements of the entry facade need to contribute to a balanced, well-proportioned visual continuity. Show restraint in selection of exterior building materials (no more than three) and simplicity in their use. Good proportions throughout the house design also promote marketability.

House Exterior

Roof

- Provide strong fascia line.
- Provide roof overhangs, trellising, facing south for passive solar control.
- "Cascade of roofs" at same roof slope.

Entrance

- Entry should be clearly recognizable at first glance.
- Create a transition space to the entry using paths, steps or landscaping.
- Provide *"Entrance Room"*—vestibule, airlock-entry space, or mudroom.
- Provide *"Entrance Control"* or good view of entry from kitchen.
- *"Car Connection"* to kitchen, entrance closest to car park becomes main entrance. Make it positive, more than just a door through the garage.

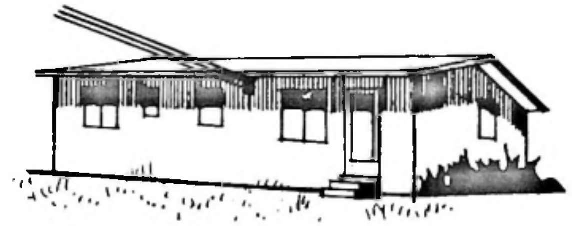
Walls

- Keep window heads in line. Wall thickenings add interest—window seats, bay windows, alcove projections.
- Carefully select windows and locate them for best natural ventilation depending on climate.
- Rear elevation is not the "forgotten elevation." (Figure 18.)

Foundations

- Avoid foundations that are too high.
- Soften building to ground connection . . . use landscaping, steps, terracing, grades, decks, patios, fencing. (Figure 19.)

Figure 18.



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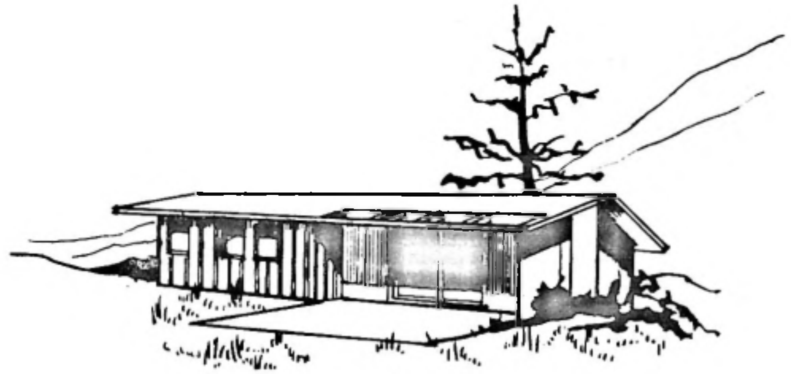
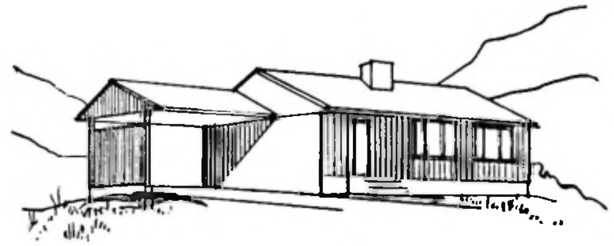


Consider

Figure 19.



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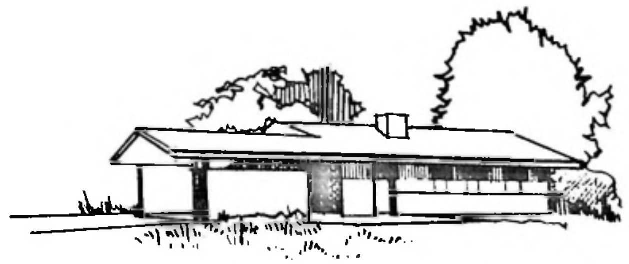


Consider

House Interior

Use modular dimensions. Most building materials are produced in a dimension that is some multiple of two or four feet, including trim and framing lumber, sheathing, and siding. The most efficient use of this material will be obtained if overall building dimensions are layed out on a 2-foot or 4-foot grid.

Consider a rectangular or near rectangular plan. The most efficient plan is a basic rectangle which allows a simple floor and roof structure. For design variation, two offset rectangles provide a break in roof lines as well as an elevation change. Entryways can also be offset to provide a design change. However, the more "zigs and zags" in the exterior wall, the more the cost. In addition, too many elevation breaks on a small house can lead to design confusion.

Depth of the most cost-effective rectangle is limited by reasonable spans of roof and/or floor framing members. Length may be adjusted to provide desired floor area.

Design for minimal exterior wall and interior partitions. The building plan should provide a high ratio of floor area to exterior wall and interior partitioning. The objective is to enclose interior space with the least amount of exterior wall and to use "open planning" inside to limit interior partitions. This is also a technique to make a small home seem bigger inside. Floor area devoted exclusively to circulation should be minimized.

Consider incorporating unfinished areas in the plan that the owner can finish when financially able.

Devise plans that provide for future additions with a minimum of alteration. Give special attention to problems of access, circulation, plumbing and heating extensions to future additions.

Consider slab-on grade designs to minimize cost and foundation problems. If basements are necessary because of marketing or site conditions, consider bi-level designs which increase habitable area at minimal cost. Remember that it is usually less expensive to add habitable space above ground than below ground.

Use a cantilevered floor over basement or crawl space foundations to provide design variations or to increase floor area without complicating the foundation. Cantilevers up to 2 feet are generally permissable and help reduce out-of-square foundation problems.

Locate partitions to intersect exterior wall studs. Where possible, additional framing can be avoided by making an effort to lay out interior partitions to abut a normal exterior wall stud. Insulating is also easier.

Coordinate window and door openings with normal stud locations to minimize framing. Windows and doors can often be moved several inches without upsetting the design balance. Locate openings, particularly larger openings, in gable end walls to eliminate structural headers.

Consider a nominal 7'-6" ceiling height even though it may require trimming of studs and drywall. For small homes, it provides a better interior and exterior scale. It also reduces siding, simplifies framing and trim, and can eliminate one step from stairs in 2-story construction.

Plan for straight run stairs. Orient stairwell openings parallel to floor framing and coordinate with normal joist positions, at least on one side, so as to disrupt as few floor joists as possible.

Locate attic/crawl space access doors between framing members in closet, hallway or other appropriate areas. A 24-inch o.c. spacing of framing members provides ample access.

Use in-line framing. If the same spacing is used on all roof, exterior wall and floor framing, respective framing members may be aligned to provide structural coordination. 24-inch o.c. spacing reduces the number of framing members, coordinates with the 2-foot planning module and simplifies framing layout.

Consider centralized "back-to-back" plumbing. Arrange bathroom fixtures and other plumbing clusters as closely as possible around a common stack to minimize piping requirements. In 2-story units, arrange upper level plumbing over lower level to be connected to the same stack. Concentrate plumbing in the same wall, if possible, to minimize disruptive effects.

Lay out plumbing to avoid structural members in the floor and roof. It is best not to locate plumbing in exterior walls because of structural and insulation considerations and freezing.

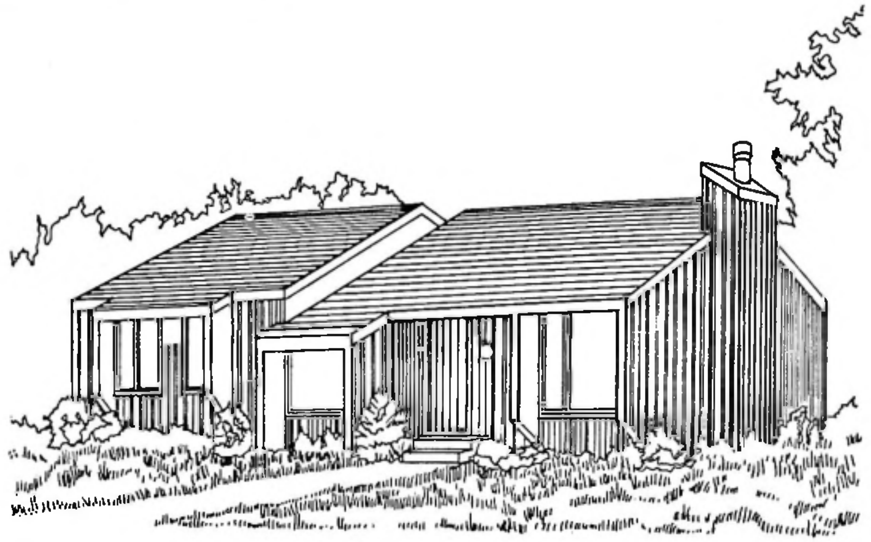
When practical, locate heating/cooling equipment centrally to minimize duct runs and duct sizes and to provide for good distribution. However, be sure to follow manufacturer's recommendations as some equipment is specifically designed for outside wall locations.

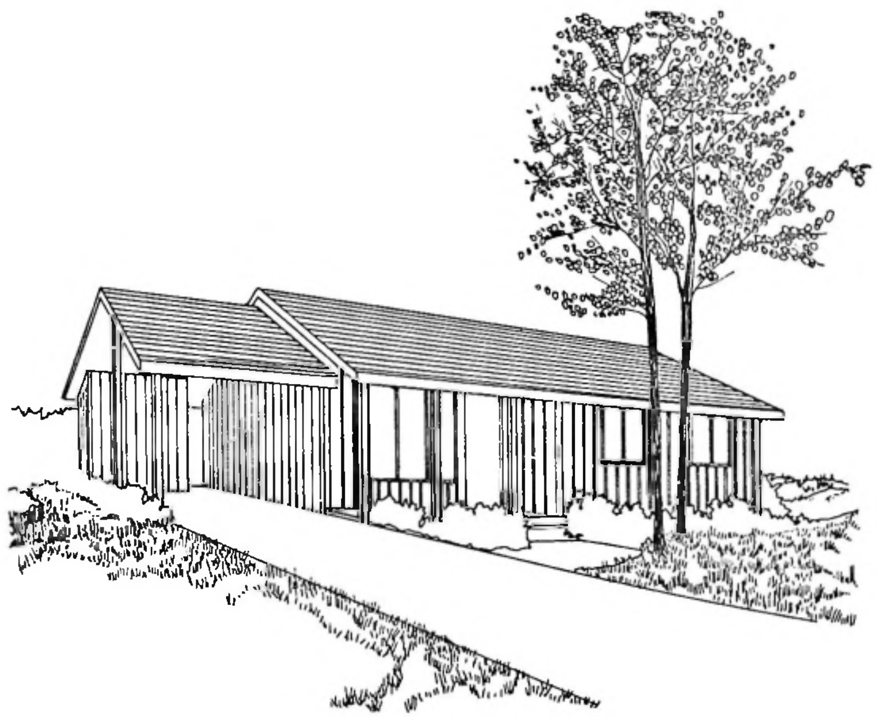
Plan chases for ducts and flues to allow ample clearances and to avoid disruption or displacement of structural members.

Develop complete working drawings and specifications, covering all details for the construction process. Do not, however, clutter drawings with unnecessary information that may confuse the field trades. Where possible, concentrate specific trade details on a single sheet and include materials lists where possible. Avoid tight or highly critical dimensions where possible. When necessary, show critical dimensions clearly and emphasize by circling, bold numerals, or underlining.

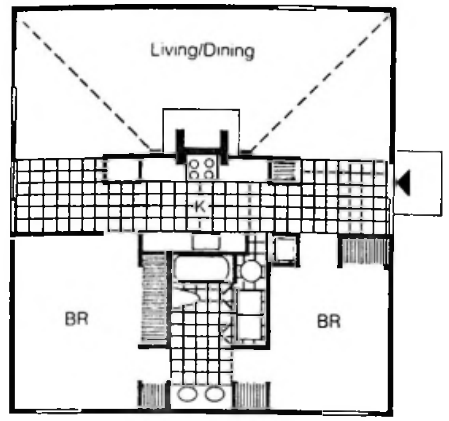
Examples

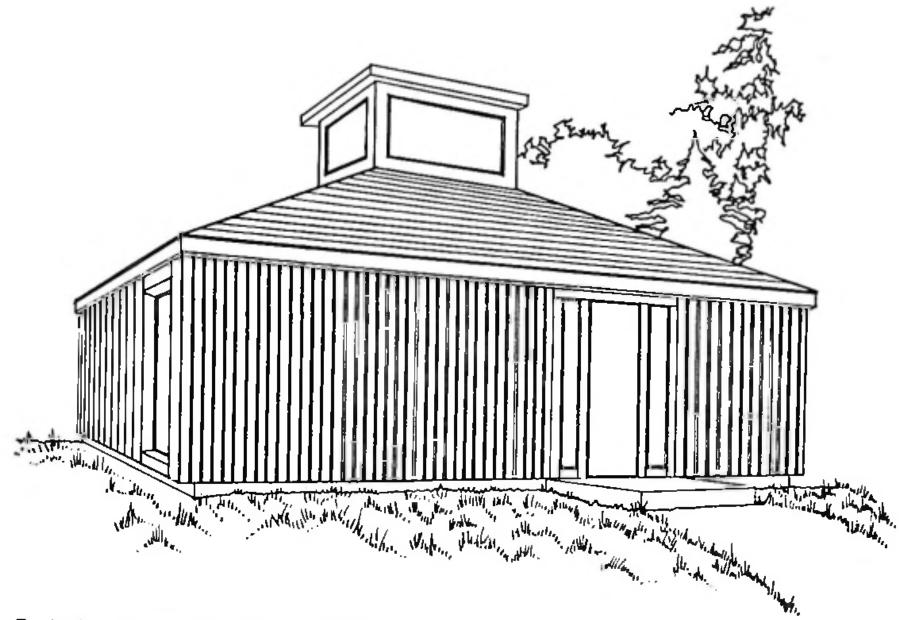
Following are illustrations of what constitutes good design, however keep in mind that all design is subjective and that there are possible flaws or drawbacks in even the best approaches.



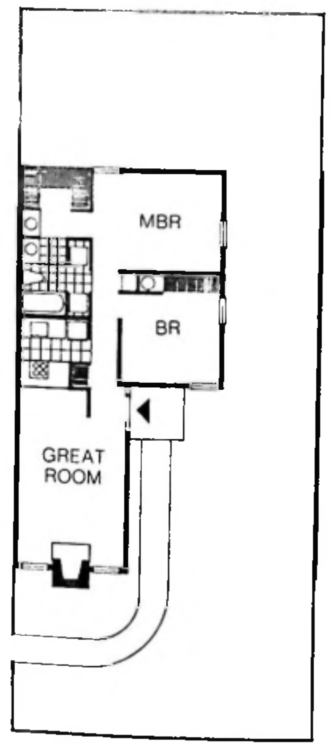


Smaller homes attached or detached, such as shown here, are made attractive by roof lines, set backs, and overhangs.

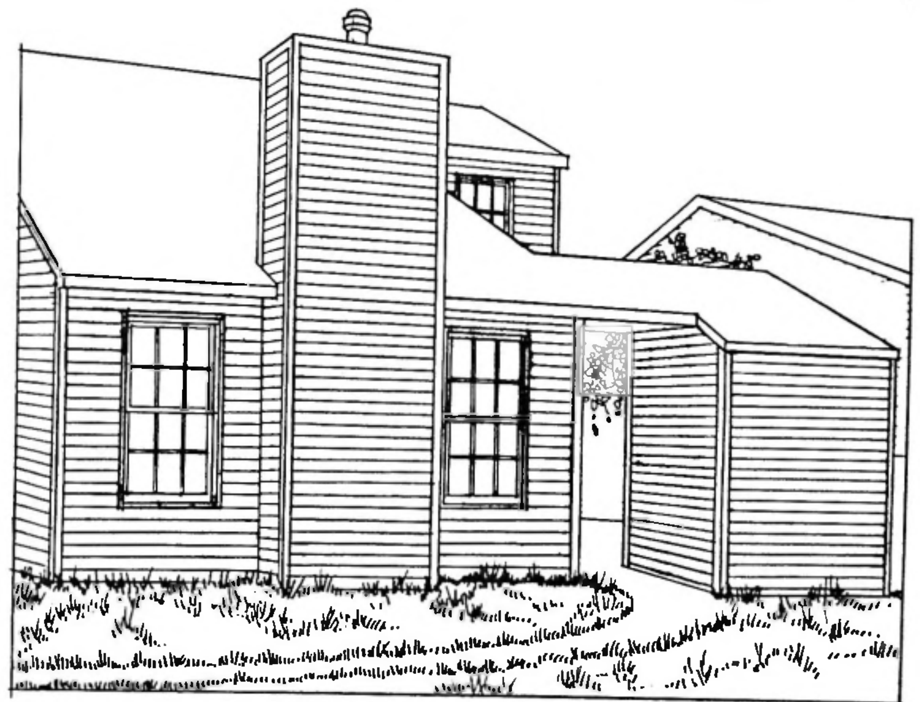




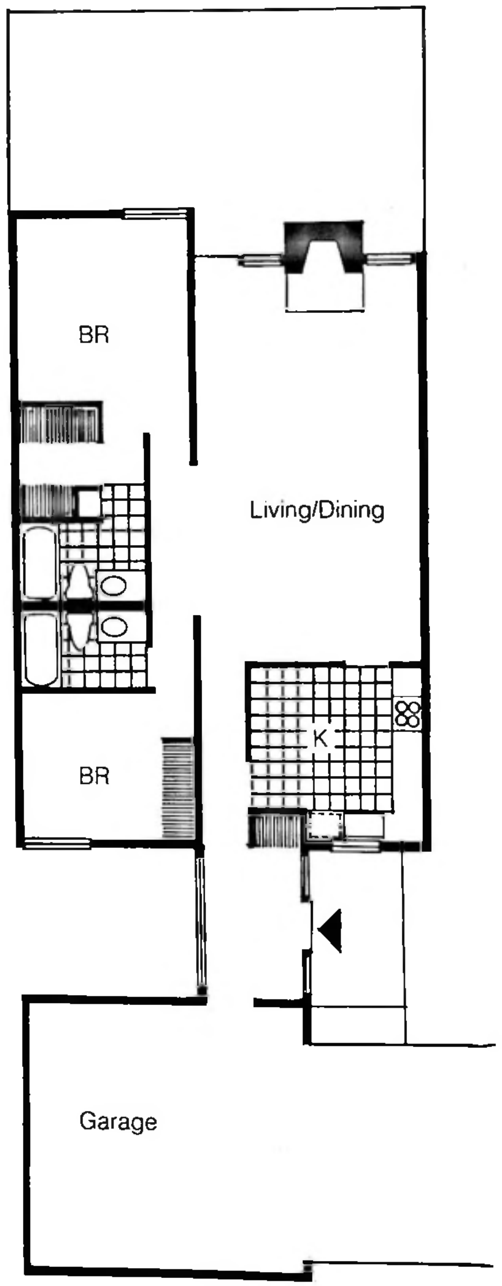
Reducing circulation space provides more living area. Open spaces and vaulted ceilings add to the feeling of spaciousness in small homes.



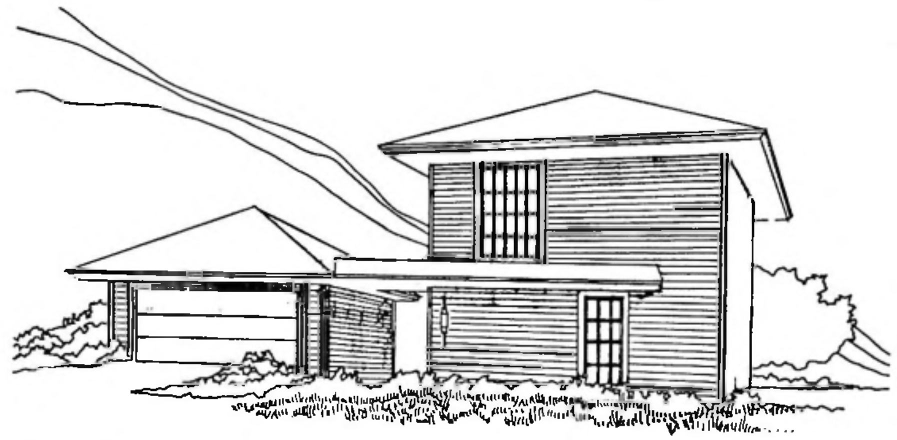
Clustered plumbing reduces costs.



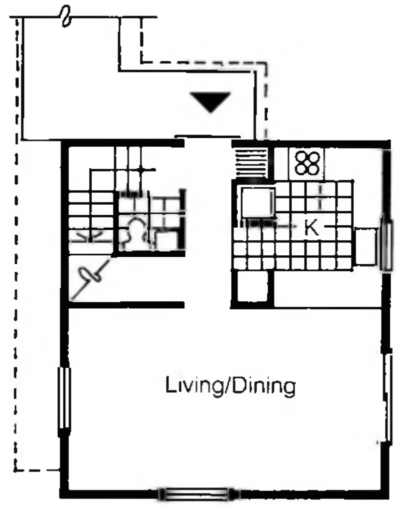
Zero lot-line homes provide ample outdoor space in rear and side yards on small lots.



Some designs are easily adapted to attached or detached construction.
Great rooms provide open multi-use areas.



Small, compact two-story homes can be designed with efficient use of floor space. Exterior treatment can make the home appear larger.



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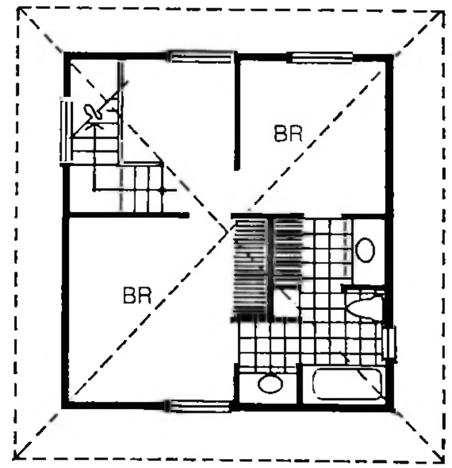


2

Chapter 3 Foundation Construction

Make foundation accurate. 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 increase labor productivity and minimize materials waste during subsequent framing operations.

Use modular dimensions. Overall dimensions of the foundation should conform to the modular planning guidelines discussed in the design section. However, undersizing the exterior dimensions of the foundation by approximately one inch will provide a reasonable tolerance to compensate for minor inaccuracies.

Insulate slabs in colder climates. In colder climates requiring a frost footing, a slab on grade is often the least costly construction on level sites. However, the foundation wall and slab floor should be constructed in separate operations with a suitable insulation between. The insulation should extend at least 24" down on the inside of the foundation wall or inward beneath the slab.

Eliminate welded wire mesh. Under normal conditions with a stable base, concrete slab floors do not require welded wire mesh. Welded wire mesh is not recognized as a structural reinforcement, and it provides no significant function in slab-on-grade floors under these conditions. If installed correctly (in the upper third of the slab) welded wire mesh may be of minor value in limiting the width of cracks. Since, however, mesh is seldom installed correctly; because carpet or resilient flooring cover slab cracks; and because properly placed control joints localize cracks, welded wire mesh is of dubious value.

Consider 2½" thick slabs. Under normal conditions with a stable, well-compacted base, the thickness of concrete slab floors may be reduced to 2½". In addition, a 4-bag concrete mix is structurally adequate for this application and has less shrinkage. Note: Most codes require a 3½" thick slab.

On sloping sites use a crawl space construction to minimize foundation work. Crawl space walls may be constructed of conventional masonry or concrete, or of pressure treated wood, similar to the wood basement construction described later. Crawl space walls may be adjusted in height to compensate for the sloping site at less cost than either slab or basement construction.

For areas with unstable soil conditions consider a crawl space construction using concrete grade beams supported on concrete piers that extend down to a stable base. The concrete grade beams that form the crawl space walls may be poured in place or precast off site. Foundations on unstable soil present one of the more perplexing construction problems. Fool proof solutions have proven to be quite expensive and "quick-fix" solutions have only been marginally effective. Investigate the use of special void forming material (Gates Forming, 90 S. Fox, Denver, CO 80223 or similar) which is intended to create a soil expansion void under the foundation wall. Also investigate pressure treated wood foundations.

Consider underfloor plenum heating/cooling. Where a crawl space construction is used, consider using the crawl space as the plenum for a forced air heating/cooling system in lieu of conventional duct work. *This method requires a tightly sealed and well insulated crawl space.* For further details see Plen-Wood System, American Plywood Association, P.O. Box 2277, Tacoma, Washington 98401.

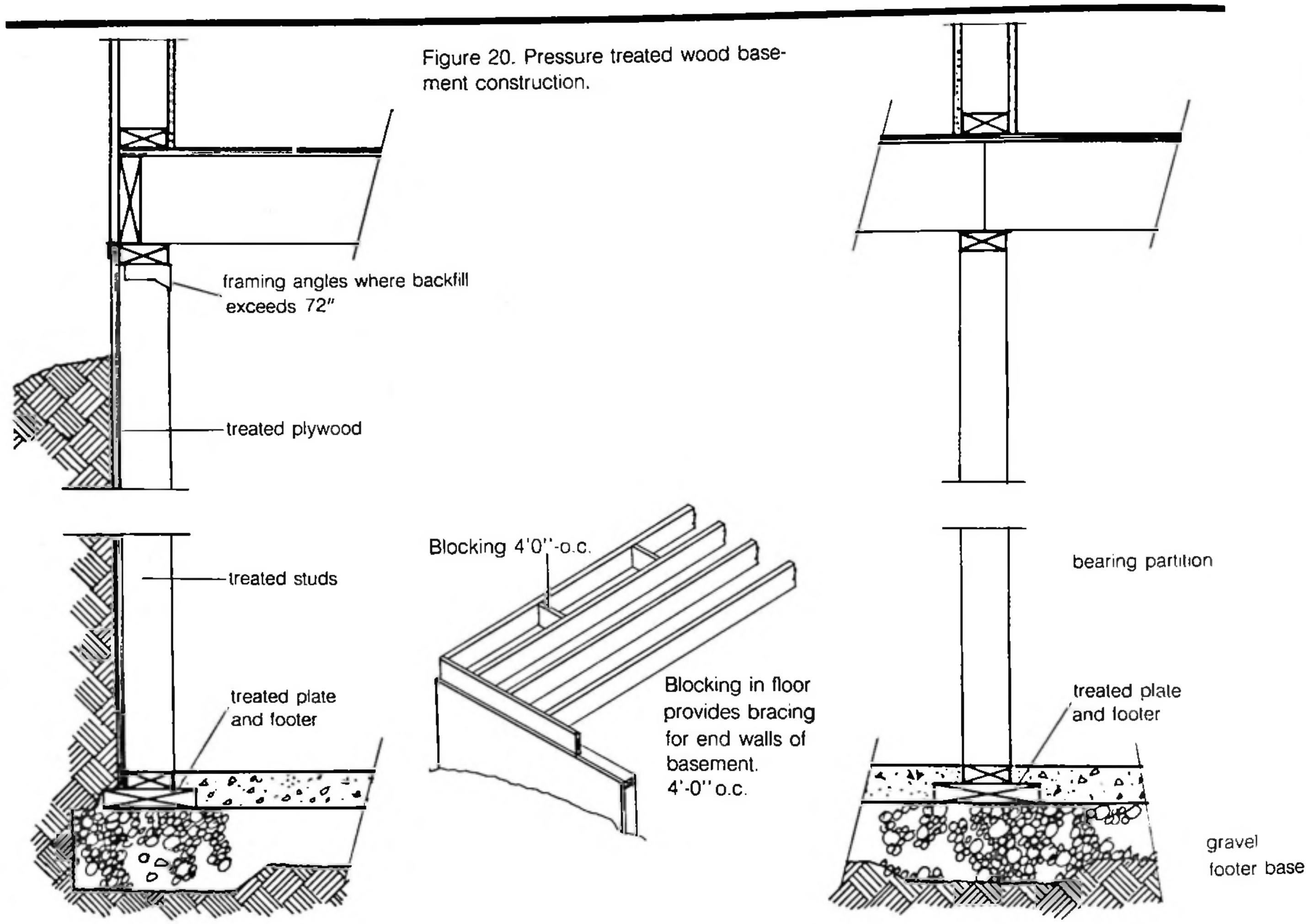


Figure 20. Pressure treated wood basement construction.

Consider pressure treated wood foundations, either basements or crawl spaces. This durable, proven construction readily accommodates insulation, wiring and finishing, as well as reducing construction time, avoiding delays due to weather, and eliminating one trade from the construction process. (Figure 20.) Detailed information is available from the National Forest Products Association, 1619 Massachusetts Avenue, N.W., Washington, D.C. 20036.

Use minimum thickness foundation walls. Where a concrete masonry or solid concrete basement foundation is used, select a wall thickness based on the height of backfill. See Table 2 for minimum recommended basement wall thickness under normal soil conditions. Note that specifications are different for full height basement walls that are laterally supported by the first floor at the top compared to short walls that are unsupported at the top, as in some bi-level construction.

Design footings to soil-bearing capacity. Footings are to distribute the building load to the underlying soil. Most conventional footings are substantially oversized. A significant savings is usually possible by engineering the size of the footing for the local soil-bearing capacity. Soil-bearing tests by a qualified engineer may be required. (Figure 21.)

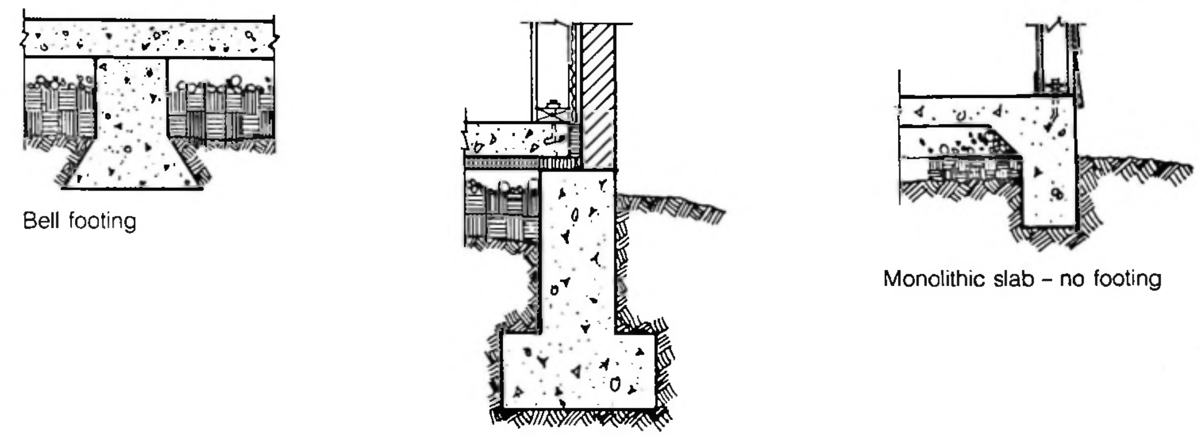


Figure 21.

Table 2 . Minimum foundation wall thickness with normal soil conditions.*

Type of Foundation Wall	Minimum Wall Thickness (inches)	Maximum Height of Finish Grade Above Basement Floor: Foundation Wall Laterally Unsupported At the Top (Feet - Inches)	Maximum Height of Finish Grade Above Basement Floor: Foundation Wall Laterally Supported At the Top (Feet - Inches)
	6	2 - 6	5 - 0
	8	4 - 0	7 - 0
Solid Concrete	10	4 - 6	7 - 6
	12	5 - 0	7 - 6
	6	2 - 0	2 - 0
	8	3 - 0	4 - 0
Concrete Block	10	4 - 0	6 - 0
	12	4 - 6	7 - 0

*Depending on local conditions, reinforcement may be required. Check with a local engineer.

Chapter 4 Floor Construction

Eliminate or reduce size of sill plate. If the top of the foundation is level and accurate, the sill plate may be eliminated in wood floor construction. Floor framing may be erected directly on top of the foundation and anchored by means of perforated metal straps embedded in the foundation and nailed to the side of a joist every 4-8 feet. Where sill plates are used, a 2 x 4 is adequate.

Use built up wood beams. Where a center beam is required in floor construction, use a wood beam built up from standard 2 x lumber rather than a more expensive steel beam. A wood beam is easier to install and fasten with standard carpentry skills, and a wood plate is not required on the beam. It also eliminates a special item and delivery from the schedule. It is sometimes practical to substitute a load-bearing wall for the center beam.

Space floor joists 24″ on center to correspond with the 2′ planning module. This will reduce the number of pieces to be handled and will simplify framing layout, particularly when all other framing is also spaced 24″ o.c. Often, the same size of floor joist as used with a 16″ o.c. spacing may be used at 24″ o.c. if a plywood floor is glue-nailed and/or floor joists are spliced off center.

Use in-line off-center spliced floor joists. The allowable span of floor joists may be increased by maintaining continuity over the center bearing. One way of accomplishing this without full length floor joists is to splice unequal lengths of joist at a less critical point away from the center support. (Figure 22.)

Eliminate double floor joists. Do not use double floor joists under non-bearing interior partitions. In fact, it is not necessary to locate nonload-bearing partitions over any floor joist where a 5/8″ or 3/4″ thick plywood subfloor is used. The weight of the partition does not require extra support.

Reduce stairwell framing members. Where stairwell openings are positioned parallel to floor joists, it is not necessary to use double joists at each side of the opening where the header, which they support, is located within 3 feet of the end of the joists spans. Similarly, a single header is generally adequate for openings up to 4′ in width.

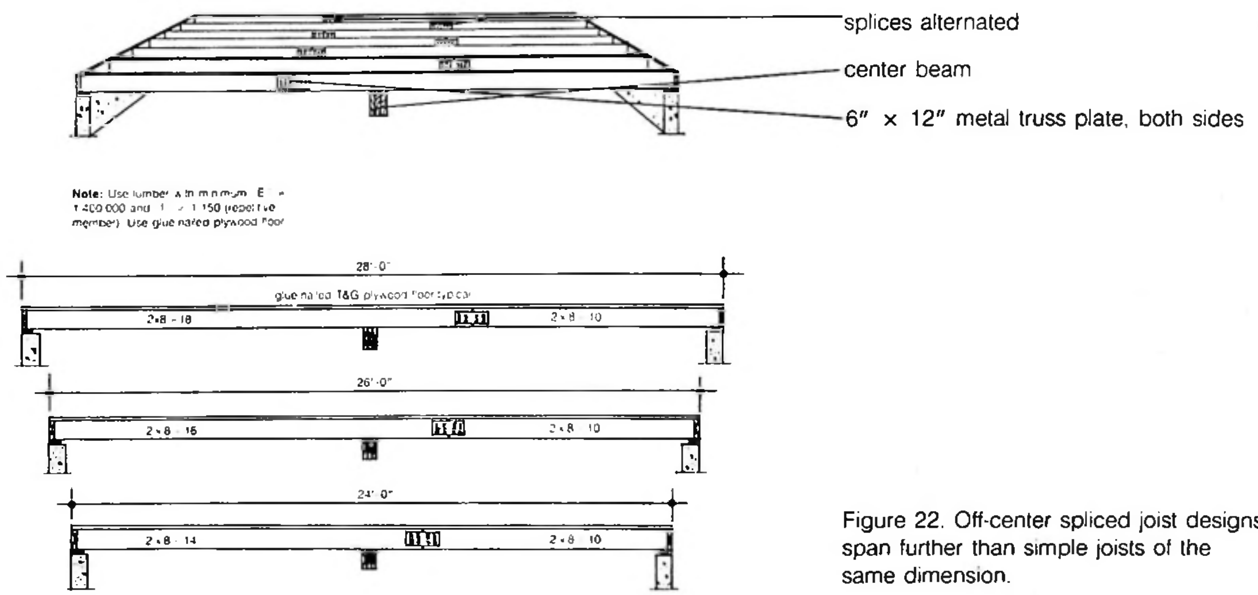


Figure 22. Off-center spliced joist designs span further than simple joists of the same dimension.

Table 3. Allowable spans (ft.-in.) for 24" o.c. joists with 3/4" glue-nailed T&G 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								
2×6	8-1	8-8	9-2	9-7	9-11	10-2	10-6	10-9
	1100	1270	1415	1545	1655	1755	1855	1950
2×8	10-3	11-0	11-7	12-2	12-7	13-0	13-4	13-8
	1025	1180	1310	1430	1535	1630	1725	1810
2×10	12-9	13-8	14-4	15-0	15-7	16-0	16-6	16-11
	970	1110	1230	1345	1445	1535	1625	1710
2×12	15-2	16-2	17-1	17-10	18-6	19-1	19-8	20-2
	925	1060	1175	1280	1380	1470	1560	1640
30 lbs. per Square Foot Live Load								
2×6	8-11	9-7	10-1	10-6	10-11	11-3	11-7	11-10
	1340	1540	1715	1865	2005	2130	2250	2360
2×8	11-4	12-2	12-10	13-4	13-10	14-3	14-8	15-0
	1245	1430	1590	1730	1860	1975	2085	2190
2×10	14-0	15-0	15-10	16-6	17-1	17-9	18-2	18-8
	1170	1345	1495	1625	1745	1860	1970	2070
2×12	16-8	17-10	18-10	19-7	20-4	21-0	21-8	22-2
	1120	1280	1425	1550	1670	1780	1890	1985

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

Reduce or eliminate the band joist. The band joist serves little or no structural function, particularly when wall studs are aligned directly over floor joists. Where a band joist is desired for ease of framing layout or assembly, 1x lumber may be used in place of the conventional 2x band joist. If plywood sheathing or siding is extended down over the floor joist ends, no band joist is required.

Eliminate bridging from floor construction. Bridging does not contribute to the strength of the floor system and is generally no longer required by the major building codes. The exception is that some codes still require bridging for 2×12 or greater joists. The value even for wide joists is questionable.

Preplan floor sheathing layout to minimize scrap and cutting labor. Where full 4'×8' plywood is used, little or no scrap should result when the floor is laid out on a 2' or a 4' module. However, tongue-and-groove plywood is often produced with a face width slightly less than 4' which requires a narrow filler to complete the floor. Square edge plywood filler strips may be used here if the joint is supported by 2x blocking nailed between the joists.

Use a glue-nailed, tongue-and-groove plywood floor to increase the allowable span of the floor system. (Table 3.) This construction stiffens the floor and eliminates squeaks. It also eliminates the need for a separate underlayment, permitting direct application of finish floor materials such as carpet, tile and sheet goods.

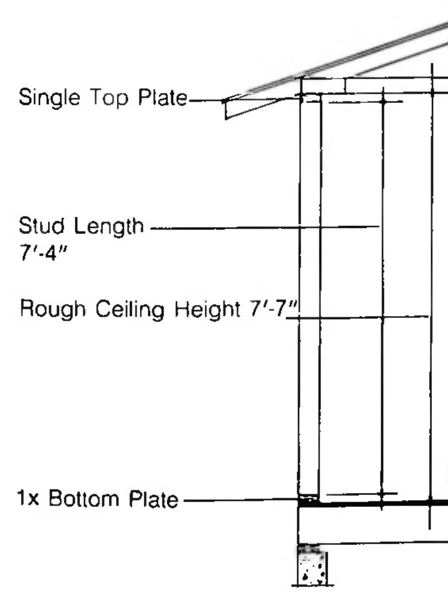


Figure 23. Wall construction for a 7'-6" finished ceiling height with studs vertically aligned over other framing members, permitting single top plate.

Chapter 5 Exterior Wall Construction

Use tilt-up wall construction. Frame an entire wall or wall section on the deck including studs, plates, jacks and headers. Use end nailing, not toe-nailing, to fasten plates to studs. Install sheathing and, where practical, windows and siding before raising the wall.

Consider prefabricated wall panels to speed construction and reduce waste. Where a crane is available, full length walls may be prefabricated. Otherwise, it may be wise to limit wall sections to 12' or 16' lengths to permit handling by a normal carpentry crew.

Consider a 7'-6" nominal ceiling height (7'-7" rough wall height) in order to reduce the required siding, insulation etc., and to eliminate one step for stairs in two story homes. A lower ceiling height also facilitates construction operations such as setting trusses and finishing the ceiling, and increases the structural capacity of studs acting as a column. Work with your lumber supplier to obtain studs that are precut to the proper lengths. (Figure 23.)

Space studs 24" on center to reduce the amount of framing lumber and labor in conjunction with the 2' planning module. A 24" on center stud spacing is acceptable in most areas of the country for one story and the second story of two story construction. While it is structurally adequate for the lower story of two story construction in many cases, it may be necessary to obtain a special approval for this application.

Use single top plate. Where all framing is vertically aligned, i.e. joists and trusses bear directly over a stud, the top plate serves no structural function. Under these conditions a single top plate may be used in all load bearing and non-load bearing walls. Special connections to splice joints in the top plate or to tie corners are not required because the floor or roof system attached to the top plate serves this function.

Consider 1 × bottom plate. Where all framing is in vertical alignment, i.e. studs bear directly over a joist, the bottom plate serves no structural function. Theoretically, the bottom plate could be eliminated. However, the bottom plate serves a practical function in laying out and aligning studs during construction. A 1 × bottom plate is adequate for this function and is easier to install with 8-d nails.

Use 2-stud corners. A 3-stud corner post is not required in wall construction. The third stud serves only to back up the interior finish. By using metal drywall clips or wood cleats to back up interior finish, the third stud can be eliminated, leaving the end stud of each intersecting wall to form a 2-stud corner. (Figure 24.)

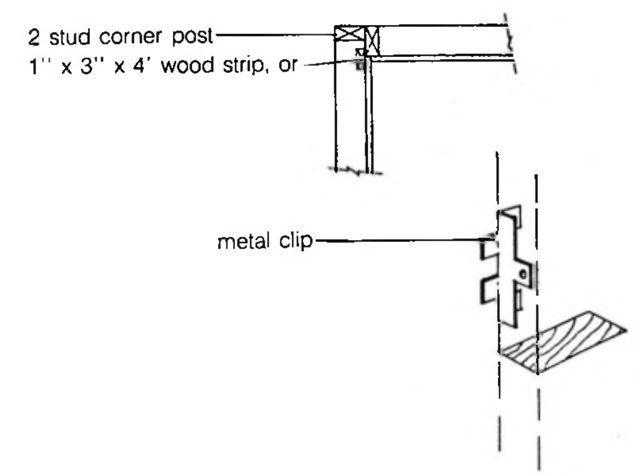


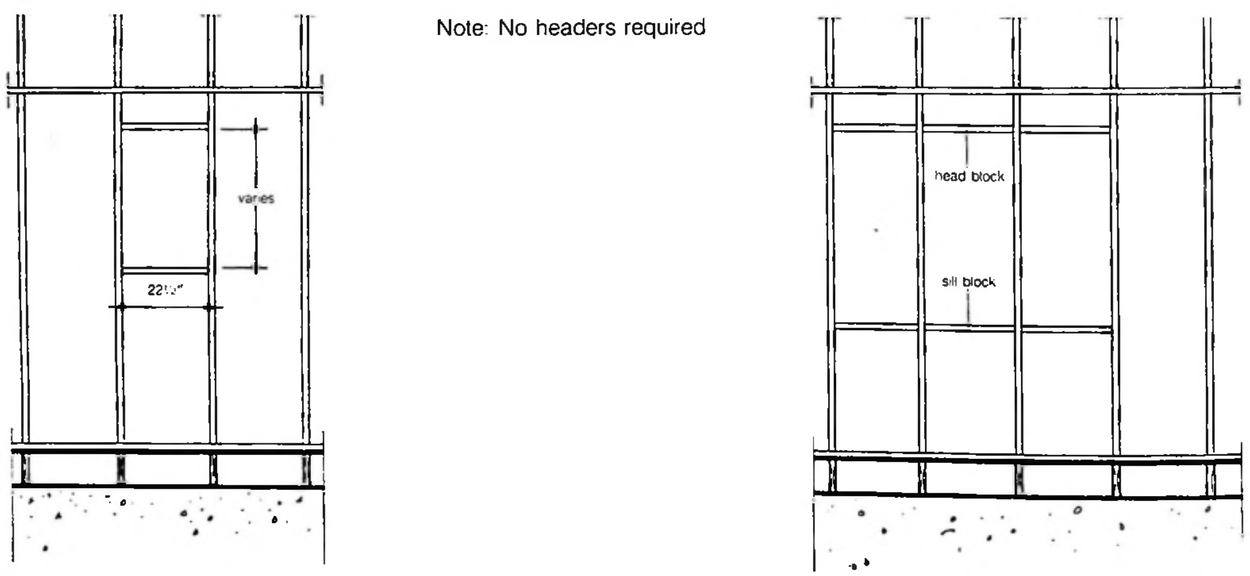
Figure 24.

Eliminate partition posts (channels). A partition post is not required where an interior partition intersects an exterior wall. It serves only to back up the interior wall finish, and interrupts the insulation in the exterior wall. Metal drywall clips or wood cleats may be used for back up, eliminating the need for a partition post in the exterior wall. Ideally, the partition intersects with the exterior wall at a normal stud location and may be attached directly to it. If not, a mid-height block may be installed between exterior studs for attachment of the partition stud at the mid-point to assure that it is secure and straight.

Eliminate mid-height blocking. Mid-height blocking is not required in exterior walls and other load bearing walls as a "fire stop" or structural bracing. Standard platform framing provides all the fire stopping that is necessary and structural bracing is not required. Therefore, mid-height blocking may be eliminated in normal construction.

Eliminate structural headers in non-bearing walls. Structural headers are used to support loads over openings in exterior walls and other load bearing walls. However, in practice they are often used over openings in walls that are not actually load bearing. Typically, only those walls which support the ends of floor or roof framing members require headers over the openings. Non-load bearing partitions and the end walls of a typical house with framing running front to back do not normally require headers over openings. One exception would be the end wall of a house with a hip roof.

Consider the use of 22½" wide windows fitted between studs spaced at 24" on center. If all framing is spaced 24" on center and aligned vertically, a header is not required over this opening. Several windows of this type may be placed side by side to provide the effect of a larger window without disrupting the structural studs. (Figure 25.)



Single Opening

Triple Opening

Figure 25. Window opening between studs eliminates headers, jacks and cripples in a load-bearing wall.

Use glue-nailed plywood headers. Where a structural header is required, use a glue-nailed plywood box header. Such a header may be formed by simply glue-nailing a plywood face over the framing above an opening. It is important to use a suitable structural adhesive for this application. The plywood face of a box header may be used as the finished surface on the interior or exterior, and the void in the box section may be fully insulated. (See Chapter 3, *Lumber and Plywood Saving Techniques*, available from NAHB Research Foundation, Inc., P.O. Box 1627, Rockville, Maryland 20850.)

Use structural paneling for racking resistance. A 4' wide structural panel siding or sheathing provides ample bracing to a wall. Additional measures to provide racking resistance, such as let-in bracing, are not required. Note that non-structural products such as plastic foam sheathing and low density fiberboard do not provide the required resistance to racking.

Consider single layer panel siding. Siding products that do not require the additional support of a sheathing may be applied directly to the studs. However, siding products with open joints or that might otherwise allow wind or rain to gain access to the wall should be installed over a suitable non-vapor barrier building paper, such as 15 lb. felt lapped at least 4" at the edges, if no sheathing is used.

Exterior trim should be minimized for economy. However, exterior trim often serves a valuable function by covering construction joints and providing tolerances at floor, wall and roof intersections, windows, corners, etc. The use of a rustic lumber trim with a stain finish will often provide a functional and appealing effect at minimal cost.

Use accurately engineered headers. If solid or built-up wood headers are used, select the proper size for the loading conditions in each case. Headers may be installed directly under the top plate with a single block across the top of the opening, eliminating the need for short cripples.

Eliminate interior window trim by returning the drywall into the opening at the head and jambs. With aluminum windows the drywall may be simply butted to the window frame and caulked; with wood windows, the drywall may be inserted in the shim space between the window frame and rough framing. A wood stool or sill is usually advisable, and may be fashioned from 1 x lumber with a small molding used beneath.

Chapter 6 Roof Construction

Use engineered roof trusses spaced at 24″ on center in conjunction with the 2′ planning module to optimize materials usage and minimize labor. For maximum cost effectiveness, trusses should be used in conjunction with a straight gable, rectangular roof design. (Figure 26.)

Use prefabricated gable ends resembling a truss, but with vertical web members spaced at 24″ on center. Gable ends may be obtained with a preframed rough opening for attic vents and with sheathing preapplied (if used).

Use gable end vents rather than other types of attic vents, where applicable. Gable end vents are less costly and provide adequate attic ventilation when properly sized. A simple rectangular aluminum or plastic vent is generally the most cost effective.

Use 3/8″ thick Group 1 plywood roof sheathing with ply clips to support the edges at the midpoint between trusses. It is not necessary to stagger plywood end joints over different trusses. Plywood layout and cutting are simplified if each course is installed with the end joints on the same trusses.

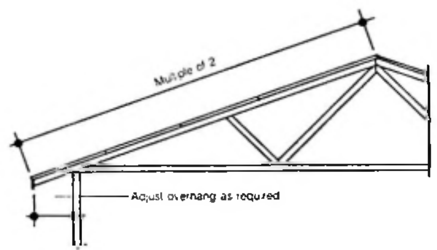


Figure 26. Engineered roof truss

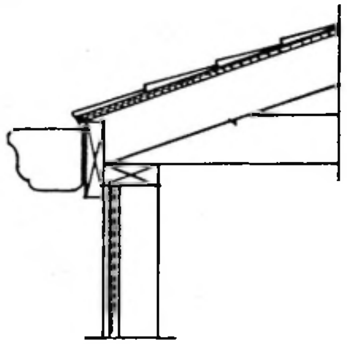


Figure 27a. Simple fascia board

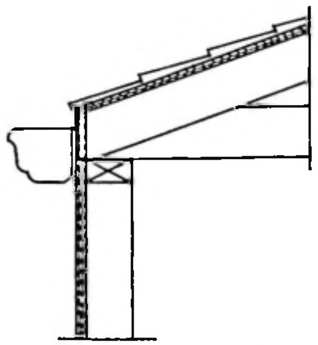


Figure 27b. Fascia eliminated

Consider elimination of the rake overhang on a gable roof. The rake overhang is a costly detail, and serves no real function. A simple 1 x fascia may be used to trim the rake or trim may be entirely eliminated by fitting the siding to the underside of roof shingles.

Consider elimination of roof overhang. Traditional soffit construction is often very costly. For greatest economy the soffit and roof overhang at the eave may be entirely eliminated. However, a gutter is strongly recommended to avoid problems from water running down the wall. (See details, Figure 27.) Elimination of overhang should be considered only if overall design is not harmed.

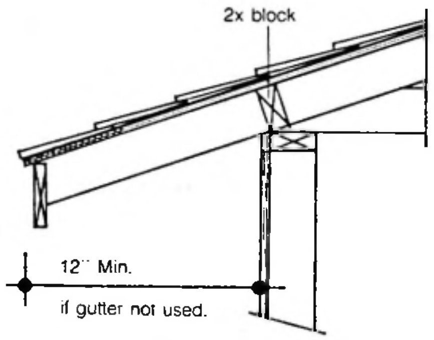


Figure 28. Open Soffit

Consider open soffit overhang. Where a roof overhang is desired at the eave, use an open soffit detail with 2 x blocks to fill the opening between trusses at the wall. A dark stain used in the open soffit area will tend to conceal shingle nails which penetrate the wood sheathing. (Figure 28.)

Standard 240 lb. asphalt shingles are probably the least costly most versatile roofing available. A comparable 210 lb. fiberglass reinforced asphalt shingle is also available. These products are easy to install and durable in virtually any climate. No other roofing product offers such a combination of function and economy.

Chapter 7 Interior Partitions and Finish

Use 2x3 studs spaced at 24" o.c. for non-load bearing partitions. The 2x3 studs offer ample strength for this non-critical application, and the thinner walls add one inch to the dimensions of each room. A single 2x3 plate is generally used with 2x3 partitions, although a 1x3 plate is adequate for both the top and bottom plates. (Figure 29.)

Consider using light gauge steel studs for non-load bearing partitions where they offer a cost advantage. Steel studs install rapidly and provide ample tolerance with their snap-in assembly. Many drywall installers also handle steel studs. However, it should be noted that drywall as well as wood trim must be installed with sheet metal screws, which may present a problem for trim carpenters.

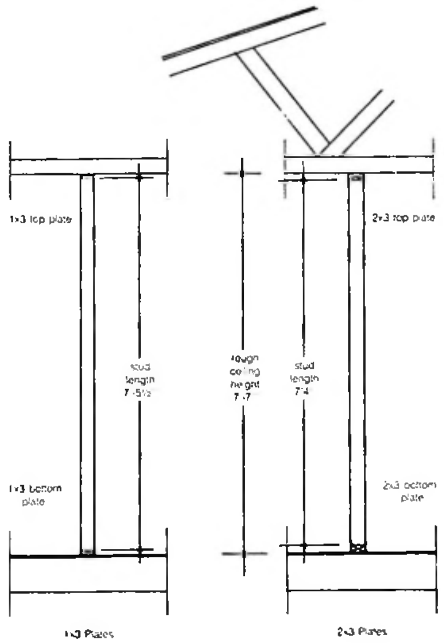


Figure 29. 2 x 3 partition construction with studs spaced 24" o.c. and alternate 1 x 3 plates.

Single frame openings in non-load bearing partitions. It is not necessary to double the studs at either side of interior door openings nor to install headers or cripples over the opening. This is true regardless of the width of the opening. (Figure 30.)

Reducing blocking. Non-load bearing partitions that are parallel to floor framing do not require blocking or other special support in the floor where 5/8" or thicker plywood flooring is used. Where partitions are parallel with ceiling joists or roof framing overhead, use precut 2 x blocks spaced at 24" o.c. between the framing members to secure the top of the partition and to provide drywall backup.

Interior load bearing walls should be framed the same as exterior load bearing walls with studs aligned over framing members in the floor or roof structures which they bear on, and with structural headers over openings. Note that it is not necessary to align the studs in non-load bearing walls with floor and roof framing members.

Simplify closet framing by providing a full width opening at the front, dimensioned to receive a standard width bi-fold or sliding door. Similarly, a full height opening will eliminate framing at the head. In this case, ceiling height closet doors will permit full access to the closet, and double shelves may be used to increase storage space. Drywall contractors should eliminate these "door/walls" from their estimate.

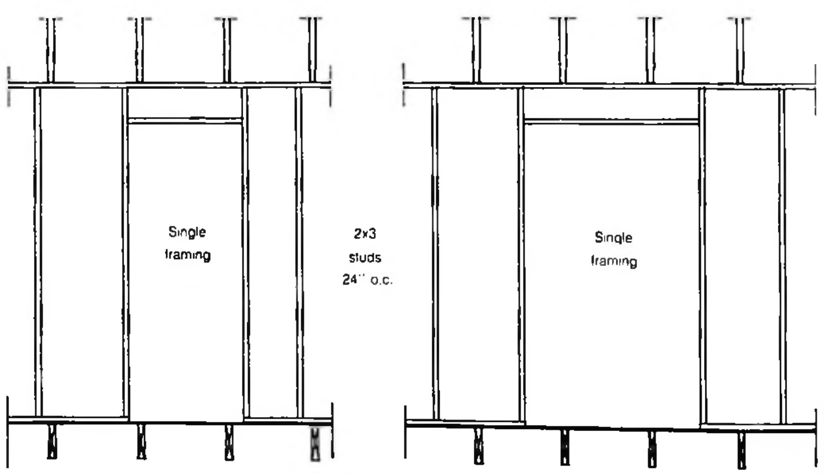


Figure 30. Single-framed openings in 2 x 3 non-load bearing partitions for passage doors and closets.

Use 4x12 foot sheets of drywall installed across the framing on walls and ceilings. 1/2" thick drywall is approved for application over framing 24" o.c. Blocking is not required behind tapered drywall edges.

Eliminate the bulkhead over kitchen cabinets. This is a costly detail, and is difficult to insulate properly. Kitchen cabinets may be hung on the wall at the proper height with an open top, or consider using extra-tall cabinets which extend up to the ceiling. This is particularly appropriate where a 7'-6" finished ceiling height is used.

Minimize and eliminate interior trim wherever possible. Use a small (½" x 1½") base and eliminate the shoe molding; minimize window trim by returning drywall at the opening; use paint grade prehung passage door units; install bi-fold or sliding closet doors that do not require trim. Use less costly finger-jointed trim suitable for a paint finish.

Use straight run, boxed stairs (no open section) where finished stairs are required, to minimize trim. A lower grade lumber may be used for treads and risers where carpet is to be installed. Use prefinished handrail installed subsequent to painting.

One color (flat, off-white) paint may be used for all interior surfaces, including doors, trim, closet shelves, etc. Semi-gloss paint may be used in baths, kitchens and on doors and trim for a more durable finish; it may be applied over flat paint which serves as the primer. Airless spray painting provides a superior finish at minimal cost.

Textured paint may be used to reduce drywall finishing requirements. This is particularly applicable on ceilings where minor imperfections are more apparent over large, unbroken areas. However, textured paints are generally more costly.

Plan kitchens carefully to minimize cabinet and countertop costs. Larger cabinets are less costly per square foot because the number of doors and drawers is reduced. Where possible, use the same cabinet arrangement in different house models, and try to obtain each section of cabinets as one continuous unit to avoid duplication of finished end panels and to simplify installation.

Use metal drywall clips to eliminate studs and blocking for drywall back-up. Metal clips have been proven cost effective.

Chapter 8 Plumbing

Cluster Plumbing. This is a cost saving design concept also referred to as back-to-back plumbing. The basic principle is to arrange typical plumbing groupings such as baths, kitchen, and laundry either back-to-back on a common wall, or in multiple stories vertically on a common plumbing stack. Savings are accomplished by minimizing the amounts of drain, waste and vent (DWV) and water piping labor and materials. All fixtures discharge into a common stack and vent system, and are supplied by a common hot and cold water riser. Additionally, groundwork rough-in is minimized. The water heater should also be located close to this grouping. Savings with such an installation as opposed to locating plumbing in different parts of the house can typically amount to 10% to 15%.

White fixtures. Use white plumbing fixtures (as well as some white to neutral tile color) as opposed to offering color. A direct cost savings of about $40 to $75 per bath is realized plus indeterminate savings in scheduling and coordinating colors. From a consumer standpoint, any accent or decorating color can be used with the white fixtures.

Eliminate fixture supply valves. Typically, codes require individual shut-off valves on the water supply for each plumbing fixture. Their main purpose is convenience when servicing a defective fixture. Individual valves can be eliminated in most cases, with the house service valve closed for occasional repair jobs. Cost savings amount to about $3 per valve or about $50 for a 2½ bath house. It might be pointed out that infrequent use of these valves (once every 10 to 20 years) often results in failure of the valve itself which would also have to be replaced at the time of repair, which in turn requires the "inconvenience" of shutting off the house service valve.

Fiberglass bathing modules. An advantage in using fiberglass tub and shower modules (in conjunction with resilient flooring) is the elimination of ceramic tile. Other advantages include eliminating leaks and callbacks associated with tile grouting, and excellent repairability in the event of damage to the tub. Cost savings relate to the installed cost of alternate materials and costs associated with scheduling an additional trade.

Wall hung lavatories. Vanities have become a standard in many housing markets. In addition to being costly, they can result in considerable scheduling confusion. For example: builder purchases vanity from one supplier; top from another; bowl from plumber; carpenter sets vanity and top (often, out-of-square corner results in poor fit); plumber sets bowl; painter or customer service caulks. The use of a wall hung lavatory can save $50 to $150 per bath.

Reduced venting. Most homes have one or more 3" vent stacks plus several 1½" and 2" fixture vents. Laboratory and field studies have shown that vents as small as ½" can perform satisfactorily in typical installations, their primary function being to equalize atmospheric pressure in a DWV system in order to prevent trap seal loss.

Cost savings with reduced vent systems relate to the quantity of larger size vent piping that can be replaced by smaller vents coupled with the added cost of reducing fittings. The most common material applicable to reduced venting is PVC, available as less costly DWV pipe and fittings in sizes down to 1¼" and as water pipe and fittings in sizes down to ½". Numerous technical and design bulletins on reduced venting are available from the National Bureau of Standards, Center for Building Technology. Results of field studies are available from the NAHB Research Foundation. *The installation of reduced venting systems requires special permission by code authorities.*

Stack venting. Another simplified DWV system is referred to as stack venting, which is recognized by most plumbing codes. In this type of system, each fixture drain is individually connected to the plumbing stack in a prescribed manner, eliminating the need for individual fixture vents. With proper planning of plumbing layouts, economies of stack venting can be maximized. The system is particularly applicable to single bath/laundry/kitchen combinations clustered about a single stack. It might be noted that the vent portion of the stack may be reduced according to reduced vent procedures to provide additional economies. (Figure 31.)

Polybutylene supply piping. Polybutylene water piping is a flexible material with special fittings recently made available to the plumbing trade and accepted by many codes. As a system, polybutylene piping costs less than copper and requires less labor and skill to install. Its flexibility allows it to be installed with fewer elbows and joints. Fittings are an insert type with the joint secured by crimping a metal collar over the pipe where the fitting is inserted. The material is also inert to acid water, which could erode a comparable copper piping system. Cost savings compared to copper range from 30% to 50%.

Plastic DWV. PVC or ABS plastic pipe and fittings are the least costly alternative for above ground DWV piping and are now in common use. Below ground, cast iron is still used extensively due to restrictive codes. However, Schedule 40 plastic DWV is also suitable for use below grade *where it is properly supported for its entire length by granular soil or fill materials such as sand or fine gravel.* The use of plastic pipe can reduce the cost of ground work within the building by approximately 50% compared to cast iron. Used as a sewer lateral outside the building, costs are reduced by about 25% with an added benefit that solvent welded joints cannot be penetrated by tree roots as is the case with some other materials.

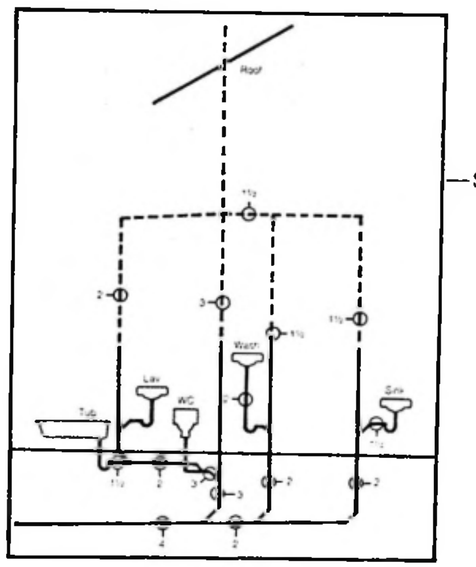
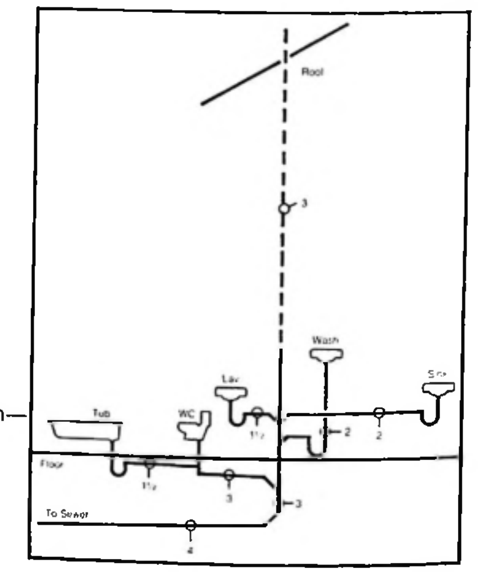


Figure 31.

—Schematic-Typical System



Schematic-Stack Vented System—
(same house)

Chlorinated PVC (CPVC) plastic piping is available for both hot and cold water piping. In general, CPVC pipe costs about 20% to 40% less than copper, however this is partly offset by the higher cost of fittings. Savings in labor range from 25% to 40%. Another advantage is that CPVC is not affected by acid water. Disadvantages are: special provision must be made in hot water lines to allow for expansion; individual fittings or clusters of fittings must be cut out and replaced if minor mistakes are made.

Plastic water laterals. Polyethylene and polybutylene piping is a proven material for providing water service to the house. Its main advantage is reduced material cost. Compared to type K copper, the savings is about $1.50 to $2.00 per L.F. for a 1" lateral.

Smaller water heaters. In many areas, 40 gallon gas or 52 gallon electric water heaters are generally considered to be the minimum size. Guidelines for sizing do not exist. In lower priced homes and homes intended for smaller families, a 30 gallon gas or 30-40 gallon electric water heater is generally adequate. Cost savings can be in the order of $40.00 per down size. Also water heaters with a 5 year warranty cost about $20 less than units with a 10 year warranty. The difference generally reflects an additional 5 year insurance policy and not the basic construction of the water heater.

Automatic vent. Automatic plumbing vents may be used in lieu of a conventional plumbing vent at certain individual fixtures to prevent traps from siphoning. Located on the "downstream" side of a trap, the vent admits room air through a pressure-activated diaphragm each time the fixture is used and the pressure in the drain line falls below atmospheric (room) pressure. At present there are no code standards regulating automatic vents. Each manufacturer's product gains approval through individual product bulletins. (Figure 32.)

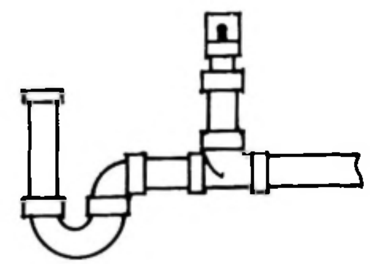


Figure 32. Typical Automatic Vent

Chapter 9 Electrical

Planning. Floor plans can sometimes be adjusted to reduce electrical costs. In general, this involves eliminating outlets or reducing the length of wiring in heavy appliance circuits, while staying within the code. For example, since one outlet is required for each 12 ft. of wall, where a wall can be shortened or a door location moved to adjust the length of wall, each receptacle thus eliminated saves costs. If all points of use requiring heavier appliance circuits are clustered and located close to the load distribution panel, the length of heavy cable will be minimized. Design changes of this type require familiarity with the National Electric Code to maximize effectiveness.

Eliminate receptacles. Several opportunities may exist to reduce the number of required receptacles at a savings of approximately $15 to $20 each.

- Check house during construction to make sure extra outlets are not arbitrarily installed, such as an extra outdoor receptacle or extra room receptacles.

- Relocate closet doors or other openings to avoid short wall sections over 24" wide, which would require one outlet. Make the wall section just under 24", thus avoiding the code required outlet.

- Outlets are not required in hallways.

- An outlet is required over kitchen countertops **greater than** 12" wide. If a short counter is needed, make it just 12" wide and eliminate one outlet.

- If a refrigerator is next to a countertop use the required countertop outlet for the refrigerator as well, saving one outlet.

Use 15 amp circuits. In some areas, entire homes are traditionally wired with #12 wire and 20 amp devices for general wiring. However, codes permit the bulk of a house to be wired with #14 copper wire and 15 amp devices. The savings average about $1-$2 per wiring point.

Eliminate switches. Each required lighting point can be switched by a single switch. Also, bath fans can be switched on with the bathroom light. They are not required to have a separate switch. Light fixtures that are not required by code, such as closet lights, can be pullchain operated and need not be switched.

Eliminate door chimes. Electrical door chimes are not required but are customarily installed in many areas. Eliminating this unit can save approximately $30 to $50 per house.

Use minimum size load center. It is common practice in many areas to install the maximum size 200 amp load center in residences. Many homes, especially small homes, could easily be served by a 100 amp load center.

Eliminate unnecessary light fixtures. The National Electric Code requires one switched light fixture at each exterior door, hallway, bathroom, stairway, attached garage, and in every habitable room. However a switched receptacle may be substituted in habitable rooms, eliminating many fixtures. Vehicle garage doors are not considered exterior doors and do not require a fixture. Attic lighting is only required if intended for storage or equipment service. If such areas have only a small access hatch and are not intended for storage, lighting should not be required. Only one light fixture is required in a basement. Every light fixture that can be eliminated will provide at least $20 to $40 in cost savings.

Eliminate circuits. Extra branch lighting circuits are often routinely installed by electricians to simplify the arrangement of breakers in the panel box. For example, each two rooms might be put on one circuit with only 7 or 8 outlets total. Separate circuits are not required for the refrigerator or garbage disposal. Extra branch circuits cost about $25 each for additional "home runs" and breakers, and in some cases might require a larger load center.

Locate heavy loads close to panel. Heavy 240 volt circuits are required for equipment such as the range, clothes dryer, water heater, electric furnace, and outdoor heat pump or air conditioning unit. If house design permits these items to be clustered together and located close to the load center, as much as $100 to $150 can be saved compared to having these items scattered throughout the house. An electric furnace (or indoor heat pump section) in particular should be located close to the breaker panel considering the large feeder cable required. Also, if an electric furnace is visible from the breaker panel, a separate disconnect is not required at the unit, which could save $75 to $100.

Use plastic instead of metal utility boxes. Plastic boxes come with installation nails preset, require no connectors or grounding, require less labor, and cost less. Approximately $1 per wiring point can be saved by using plastic boxes instead of metal boxes.

Chapter 10 Heating, Ventilating, Air Conditioning Installation

System selection. Select the most economical type of system appropriate to the home and local climate and marketing preference. If a ducted system is to be installed, consider availability and cost of fuels, type of equipment, type of duct system, relative cost of system and operating efficiencies. A concise guide on this subject, prepared by the NAHB Research Foundation, Inc. titled *Residential Duct Systems*, Copyright 1981, is available from the National Association of Home Builders, Fifteenth and M Streets, N.W., Washington, D.C. 20005.

Heat loss calculations. Perform or obtain an accurate room-by-room heat loss calculation (and heat gain calculation for cooling). This is the only real basis for selecting equipment or designing the system. Do not rely simply on someone's judgement. Guidelines on this subject are also provided in the above referenced manual as well as the *Insulation Manual for Homes and Apartments* available from the same source. The standard calculation procedure used in the trade is presented in *Manual J-Load Calculation for Residential Winter and Summer Air Conditioning* available from Air Conditioning Contractors of America, 1228 - 17th Street, N.W., Washington, D.C. 20036.

Equipment sizing. Select equipment based on the above calculations. It will probably be smaller than you are accustomed to, cost less, and operate more efficiently. In general, heat pump and air conditioning equipment is available down to 1-1/2 tons or about 18,000 Btuh output. Several gas furnaces as small as 32,000 Btuh output are also available. Properly sized smaller equipment also permits the duct system to be reduced. For each 1/2 ton that a heat pump or furnace with air conditioning system can be reduced, equipment cost is reduced by about $200. Savings in the duct system amount to about $75 per 1/2 ton. With electric heating, wiring costs are also reduced since a lighter circuit can be run to the electric furnace or indoor heat pump unit as well as the outdoor unit. These savings could be in the order of $10 to $50 per ton.

Downsize duct systems. In energy efficient homes where heating loads and HVAC equipment are smaller, ductwork may be engineered to provide a savings in material and labor. For example, in a typical 3 bedroom home which might have traditionally required an extended plenum system (see Figure 33) with a 16"x8" trunk duct, 6" round feeder ducts and 4"x12" perimeter registers, an engineered system with a 12"x6" trunk

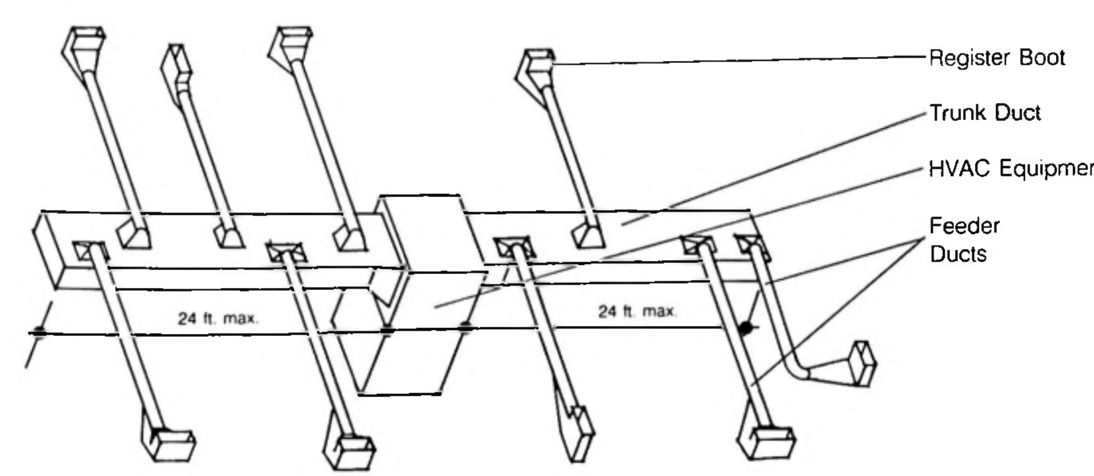


Figure 33. Extended Plenum Duct System

duct, 3" and 4" round feeder ducts and 2¼ x 10" perimeter registers could be adequate at a savings of $100 to $250. In addition, the system would perform better with the smaller equipment, since the proper velocity and air throw would be maintained with the smaller ducts. A standard reference for residential duct design is *Manual D - Duct Design for Residential Winter and Summer Air Conditioning*. Copyright 1979, available from Air Conditioning Contractors of America, 1228 - 17th Street, N.W., Washington, D.C. 20036.

Dropped hall ceiling plenum. In single story homes with a central hall, consider using a dropped hall ceiling plenum system *(Residential Duct Systems* referenced previously). In this type of system the hall ceiling is drywalled as usual, then the hall ceiling is dropped 6" to 8" with another layer of drywall being installed to form an air distribution plenum. High sidewall registers that serve each adjoining room are connected to the plenum by a short boot through the wall.

This type of system can eliminate most of the ductwork in many installations at a savings of about $600. The *One and Two Family Dwelling Code* permits such "gypsum ducts" up to 125 degrees F., which would accommodate low output temperature equipment such as most heat pumps or electric furnaces. Fossil fueled furnaces, which generally exceed this termperature limit, are not recommended. In this case use as a return plenum.

Radial systems. Radial duct systems are often used in single-family homes and are probably the simplest duct system to install. With radial duct systems there is no trunk duct. Branch ducts which deliver conditioned air to individual outlets connect directly to the equipment plenum. Radial systems typically are used where it is not necessary to conceal ductwork, and where the equipment may be centrally located. This is the lowest cost system for many single-story structures. The basic simplicity of the system provides cost savings through reduced materials inventory and the use of less specialized labor. (Figure 34.)

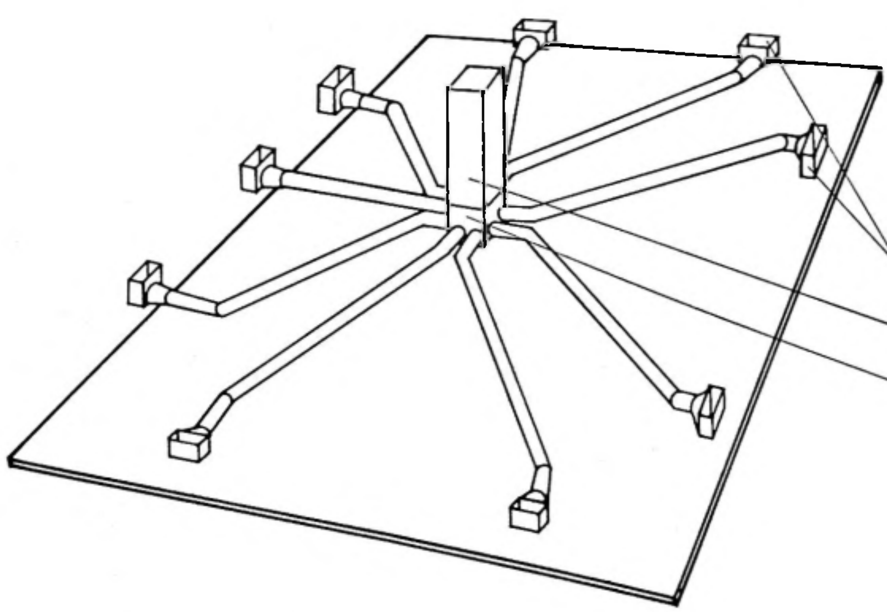


Figure 34. Typical Radial Duct System

Electric furnace with high energy efficiency rating (EER) air conditioning. In climates with a mild heating season but with significant air conditioning requirements, an electric furnace with a high EER air conditioner is often more efficient than an air-to-air heat pump. High efficiency air conditioners can operate up to 50% more efficiently than heat pumps on the cooling cycle. Since the heating season is short, the savings from operating a high efficiency air conditioner can more than offset the relatively inefficient electric resistance heat, and the installed cost of such a system will be about $300 to $400 less than an equivalent heat pump system.

Electric baseboard. In smaller, well insulated homes where air conditioning is not required, electric baseboard heat with individual room thermostats (or other room-by-room resistance heat system) offers significant construction cost savings.

Exhaust ducts. Generally, bath fans can be exhausted directly into well ventilated attics. The savings in labor, duct and vent terminals can range from $10 to $30 per fan and can be marketed on the basis of energy savings. In addition, the possibility of water damage caused by condensation in metal exhaust ducts is reduced. In kitchens, a non-ducted range hood may be installed, eliminating a scheduling problem as well as $20 to $40 for exhaust duct installation. These methods are more energy efficient and can be so marketed.

Chapter 11 Labor

Use minimum crew size. Large crews tend to have a higher percentage of non-productive time. Also, inefficient workers can easily "hide" in a large crew. Studies have indicated smaller crews are much more efficient.

Use efficient crew composition. Studies indicate that a majority of construction work in most trades requires only semi-skilled or low skilled workers. Accordingly, a crew composed entirely of highly skilled workers is overly qualified and overpaid for most construction tasks.

Consider specialists for higher productivity. Workers who are assigned a specific task to do over and over become much more efficient at that task than a general "all-around" worker who might do that task only once every few weeks.

Consider component prefabrication. Off-site or on-site prefabrication of components often reduces total labor costs and creates better material control. Candidates for prefabrication include wall panels, plumbing trees, "wet" walls, stairs, etc.

Examine trade structure if possible. If at all feasible, look at ways of reallocating certain tasks to different trades such as carpenters drilling holes for plumbers and electricians and installing insulation in some areas while framing (behind bathtubs, in corners, or other areas which will be difficult to insulate later). Concrete crews can easily place water supply pipe and DWV plumbing trees prior to pouring slab.

Examine every construction task for:

- Purpose – what is achieved?
- Place – where is it done?
- Sequence – when is it done?
- Person – who does it?
- Means – how is it done?
- Tools – what tools are used?
- Product – what product is used?
- Material – what material is used?
- Design – how is it designed?

For each of the above, ask the following:

- Is it necessary?
- What are the alternatives?
- Who, what, when, why, where and how could or should it be done?

Examine labor saving tools and equipment. Conduct an economic anaylsis of labor saving devices to determine true cost savings, if any, of these devices. Equipment to consider might include power nailers and staplers, wall panel jigs, fork lifts, etc.

Chapter 12 Materials - General

Reduce scrap and waste by:
- Accurate take-off of materials
- Purchasing proper size to do job
- Instructing workers on importance of materials
- Ordering bundled or otherwise unitized materials
- Using cut-offs for blocking when possible
- Eliminating on-site clutter
- Do not let lumber yard take-off job. They will over estimate.

Improve material handling:
- Have materials delivered near point of use.
- Use techniques that minimize damage, i.e., pallets and fork lifts.
- Have lot numbers clearly marked on material.

Reduce theft and vandalism by:
- Temporary compound with fence
- Roofing stored on roof
- Doors/windows locked in garage or other closed area
- Temporary security guard in some locations
- Barricades if feasible
- Spray paint colored stripe on lumber stack to help identify your material.

Note: Scattered, cluttered material looks inviting to otherwise "honest" neighbors. (If it is needed, it would be better cared for.)

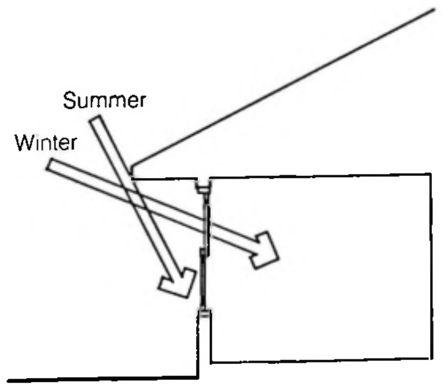
Specify building materials and products that are locally available.

Chapter 13 Passive Solar Design

The passive approach to solar heating is not a special trade or industry per se; rather, it is an approach to building that takes advantage of the fact that the sun is lower in the southern sky in winter than it is in summer. South-facing windows not only let in light and allow a view, but collect heat as well. Therefore, homes can usually be designed to provide a high percentage of their total heating requirements from this solar heat gain.

There are varying degrees of passive solar design. Homes that take maximum advantage of direct gain passive solar have methods to collect, store and distribute heat comfortably. Most homes so designed in the past have not been in the "affordable" category. Even the most modest dwelling, however, can derive some measure of benefit from the passive solar approach because of its simplicity of construction.

One variation of passive solar heating is called "sun-tempering" and simply consists of maximizing south-facing glass while minimizing north and west-facing glass. This approach can easily contribute 25 percent of the home's heating requirements if the glass area is shielded at night with insulating drapes or insulating shutters. If thermal storage mass and circulation system is added, passive solar may contribute as much as 75 percent of the heating requirements. The added first cost of a complete system, however, might be prohibitive for an affordable home.



The objective of this discussion is to provide an overview of passive solar concepts. Several excellent manuals have been written on passive solar design which provide in-depth information on the methods that are used across the nation. Some of these manuals are listed in Chapter 14. Following are some basic hints for providing affordable housing with a degree of passive solar heating.

Orient glass area toward the south. Most home designs already have a high percentage of glass area on one side, usually the front elevation. Very often, a simple reorientation on the lot can take advantage of the present design.

Provide summer shading of south facing glass. Because the sun is "higher" in the southern sky in summer, its rays can effectively be blocked from windows by shading techniques. Roof overhangs, second story balconies, awnings and deciduous (leaf-shedding) trees are methods of providing summer shading. In very hot climates, even shaded glass can make cooling loads excessively large.

Solar heat the major living spaces. Design the dwelling so that major living spaces - living room, dining room, family room - are to the south. This provides maximum solar gain in those areas where people are most likely to be during daylight hours. Radiant heat is most effective when the occupant can sit, work, eat, or sleep near the heat source.

Limit north and west glazing. Glass areas on the north elevation are always net energy losers. On the west elevation, gains in the winter months are light compared with the long, hot afternoon sun in the summer. Consider triple-glazing of north and west facing windows, even in moderate climates.

Consider energy efficient construction prior to adding passive solar. To take maximum advantage of passive solar design, the home should be properly insulated and weatherstripped first. If so, heat loss through walls, roofs and door/window cracks won't offset gains through passive solar design.

Consider adding thermal storage mass. As mentioned, when special collection and distribution methods are added, first cost can quickly become prohibitive. However, a value analysis might prove that some storage mass is actually cost-effective to the homebuyer on a month-to-month basis. This is an analysis that each builder must make, taking into account:

- Cost of additional thermal mass
- Climate
- Local fuel costs
- Expected solar heating fraction
- Lending institution's attitude on qualifying buyers, i.e.; monthly pay out versus income.

In conclusion, passive solar systems are adaptable to almost every climate, site and building style and can be incorporated in many cases with very little, if any, extra cost in its most basic form. Care should be taken in extremely cold and extremely hot climates because of excesive window heat loss in the former and excessive summer gain in the latter.

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