AFFORDABLE HOUSING

U.S. Department of Housing and Urban Development
Office of Policy Development and Research

Challenge and Response –Volume II

Affordable Residential Construction

A Guide for Home Builders

Joint Venture for Affordable Housing

THE SECRETARY OF HOUSING AND URBAN DEVELOPMENT
WASHINGTON, D.C. 20410

One of my highest priorities when I came to HUD in 1981 was to make housing affordable again. As part of this effort, in January 1982 I announced the formation of the Joint Venture for Affordable Housing as a public-private partnership to find ways to overcome the cost impact of outdated and unnecessary building and land use regulations.

Over the past five years, we at HUD have worked with builders and local government officials in more than 30 communities across the nation in a successful effort to demonstrate that regulatory reform can reduce housing costs both in new subdivisions and for new homes in established neighborhoods. The Affordable Housing Demonstration projects proved that this approach works; the Joint Venture concept of a cooperative effort to reduce housing costs is now an operating program of the Department.

The lessons learned in the demonstration projects, originally reported in a series of individual case studies, have now been combined in two final reports with the general title, Affordable Housing: Challenge and Response.

Volume I, "Affordable Residential Land Development: A Guide for Local Government and Developers," describes the land use, site development, and administrative and procedural changes used in the Affordable Housing Demonstrations. Volume II, "Affordable Residential Construction: A Guide for Home Builders," addresses the changes in building design, materials, construction systems, and marketing methods which proved successful in the demonstration projects.

I believe that the information in these reports will help bring about the changes necessary to reach the goal of affordable housing for everyone.

Very sincerely yours,

Samuel R. Pierce, Jr.

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AFFORDABLE HOUSING

CHALLENGE AND RESPONSE

Volume II

Affordable Residential Construction: A Guide for Home Builders

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U.S. Department of Housing and Urban Development
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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 National Research Center (formerly the NAHB Research Foundation, Inc.) have been searching for solutions to the rising cost of housing.

The Joint Venture for Affordable Housing (JVAH) program has been a significant step toward lowering housing costs. This manual contains a compilation of proven cost-saving construction techniques. All the techniques may not be applicable in every situation, but most builders will likely find many ways to lower housing costs. Volume I, the companion manual, contains proven cost-reduction methods of land planning and development as well as actions local governments can take to encourage more affordable housing.

Acknowledgements

This manual is the result of material obtained from the Joint Venture for Affordable Housing Demonstration builders and from other sources. It was prepared for the Department of Housing and Urban Development by the NAHB National Research Center. The demonstration program was directed by the Office of Policy Development and Research.

The principal author was E. Lee Fisher, with assistance from Carol B. Schaake, Richard A. Morris, and untold others who provided years of residential research effort and documentation. Most importantly, we wish to thank the builders of the JVAH demonstration and the communities who took the risks and put their resources on the line to prove that affordable housing for all Americans can be a reality.

The work that provided the basis of this publication was supported by funding under a contract with the U.S. Department of Housing and Urban Development. The substance and findings of that work are dedicated to the public. The authors 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.

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INTRODUCTION

HUD's Joint Venture for Affordable Housing (JVAH) demonstration was a program designed to help reevaluate building regulations and typical builder practices in an attempt to find solutions for building affordable homes. Many cost saving construction methods had been developed over the years but had not been adopted by local codes or had not been put into practice by builders. The U.S. Department of Housing and Urban Development (HUD), the National Association of Home Builders (NAHB), and the NAHB National Research Center (NAHB/NRC), compiled those ideas and, working with builders, developers and community officials all over the nation, instituted many of them with outstanding results.

The JVAH demonstration program was extremely successful in encouraging understanding and cooperation between different interest groups in finding solutions to high housing costs. This was accomplished by restructuring processing procedures, using land more efficiently, revising outmoded land development practices, and using proven cost-saving construction techniques.

This guide contains methods to reduce costs in most phases of direct construction of the house itself. Cost-saving land use and development techniques and streamlined processing procedures are presented in a companion manual (See Volume I). Most of the methods described herein were demonstrated in at least one of the JVAH sites. Many were repeated in almost all of the sites. The guide is not intended to be the definitive construction manual, but rather a compilation of techniques that were proven effective in the JVAH program and in other areas.

Most homes in the demonstration program were "stick-built" on site. Some were factory-built, i.e., modular, HUD Code, or panelized.

The manual is written for those who are already familiar with construction terminology and "typical" ways of building homes. A reference section at the end of the manual contains titles and sources of other manuals that will provide more complete backup information and data.

It is likely that some of the methods discussed herein are not presently acceptable under some local regulations. Before attempting to adopt any new technique, check the local code or with local building officials. If not acceptable, it will be worthwhile to work with the local authorities for change. Success of an affordable housing program depends upon builders, government officials, and concerned citizens taking necessary steps to encourage innovation.

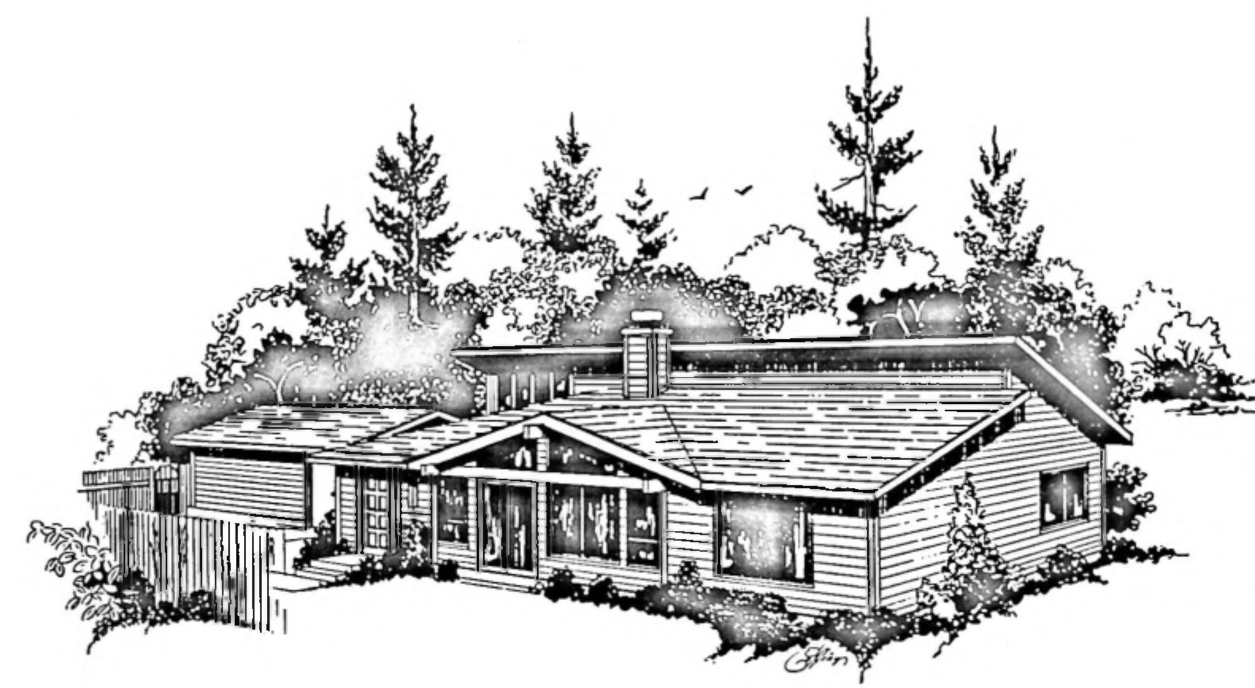
The manual is organized along the lines of how a house is built starting with design, then footings and foundations, floors, walls, etc. Each section contains a general discussion of the topic followed by specific cost-saving innovations, and then JVAH case study experiences. Hopefully each reader will find several ideas that will result in reducing housing costs without sacrificing health, safety, and general welfare features.

HOUSE AND LOT DESIGN

Factors which distinguish good design from poor design are somewhat subjective and vary from buyer to buyer, from builder to builder, and from architect to architect. There are certain qualities of good design that most can agree upon. These include 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. In fact, poor design at any price is difficult to market. The JVAH program proved that well-designed small "affordable" homes actually enhance the neighborhood and add to property values.

Smaller lots present more of a challenge for placement of homes than do larger, more forgiving lots. Space for parking, utility locations, drainage, and driveway lengths are more critical. Privacy, topography, view, and natural growth are important factors in house placement. If natural features are absent, manmade features such as stormwater retention ponds, parks, and landscaping offer opportunities for interesting placement of homes to provide visual variety.



For smaller homes, it becomes more important to orient central living areas to outdoor spaces or views. Single-story homes preserve privacy because they do not look out over fences and more rooms can be placed around patio space.

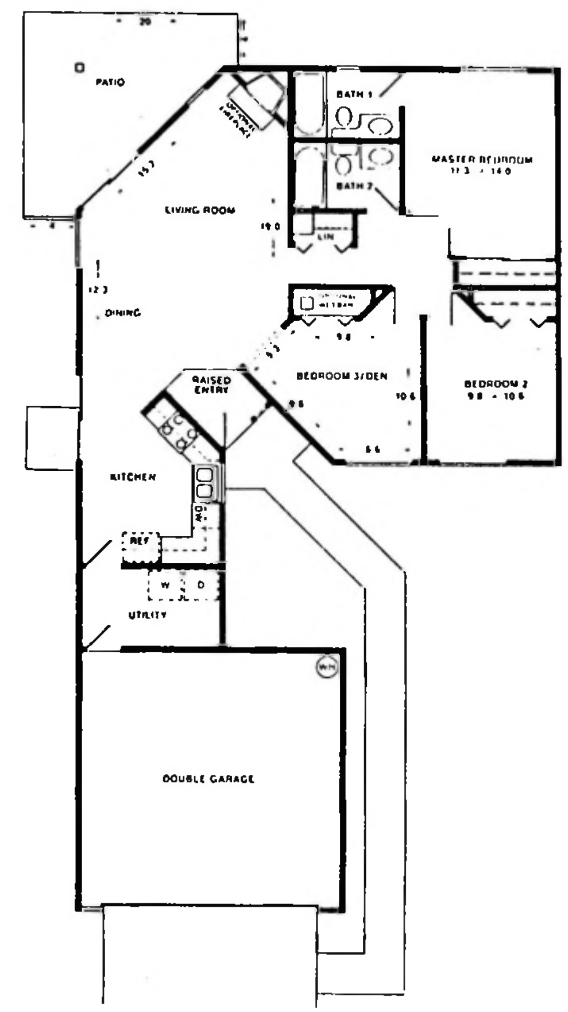
Second story windows should be oriented away from neighbor's yards and toward natural views whenever possible. By promoting outdoor living with decks, patios, porches, and garden seats, small homes become much more attractive and lose the small feeling.

Dwelling Plan Analysis

A well-designed floor plan will consider the functions of different areas of the house; i.e., sleeping, living, working, dining and circulation spaces and their relationships to each other.

By *orienting* major living areas to the south, you can take advantage of the winter sun and provide a measure of *passive solar heating*. Likewise, by placing storage space and seldom used windowless rooms on the north elevation, heat loss to the sunless side of the house will be minimized. These techniques will, of course, be more important in certain climates than others.

Where heating is of little consequence, orientation is not as important. Where heating and cooling are both

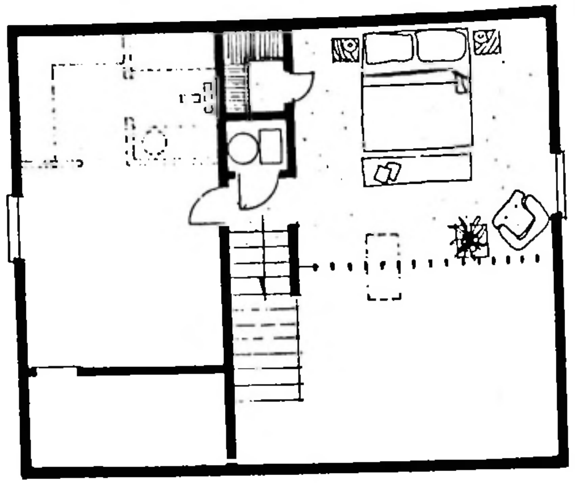


important, shading of south facing windows in the summer becomes very important.

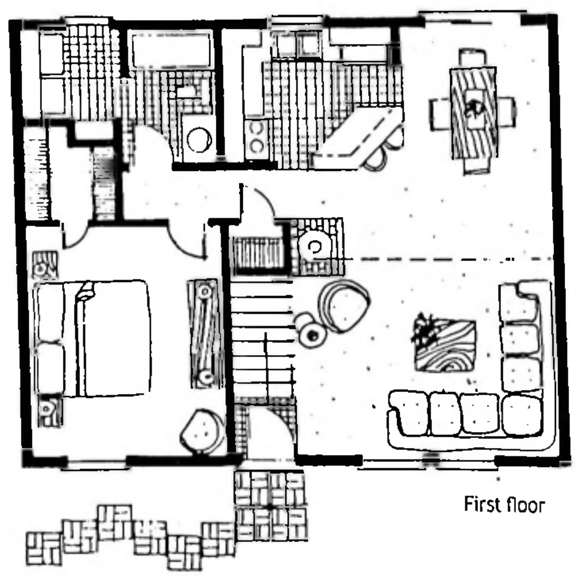
Minimize the distance between ***parking*** and the kitchen. This not only provides relief from carrying heavy shopping bags, but also reduces tracking in dirt across carpeted areas. An entrance from parking through a work zone such as a laundry room provides an area for muddy shoes and heavy outer garments.

Circulation area is, in effect, wasted for most other uses. The exception might be a pass-through work area. Otherwise, small homes cannot afford the luxury of space that is intended solely to travel from one area to another. Good design will hold such space to the absolute minimum without undue traffic through living areas. Placement of entry doors and closets will dictate traffic patterns.

Small homes often seem more spacious by careful use of ***sight distances***. That is, when in a closed-in room, it does not matter whether the house contains 1,000 or 2,000 square feet. Perception of size ends at the walls. Therefore, eliminate interior walls and provide angles where the occupant can look through other spaces, preferably to the outdoors through a large window or sliding glass door. However, looking through a work space is not normally considered desirable.



Second floor



First floor

Several of the small JVAH homes used vaulted ceilings and clerestory windows to provide a feeling of open space. Loft space with a balcony not only provides real space but also the illusion of much more space in small homes. Lofts are also perceived as luxury features even though they are no more costly to build than closed-in space. Open riser stairs to lofts reduce visual blockage and create an "open" feeling.

There are some basic architectural rules that have been proven successful and marketable for small homes. One major rule is do not simply take a large house plan and scale it down. This does nothing but accentuate the smallness.

The number of small families, singles, and empty-nesters is growing rapidly. Most of these are not interested in unusable space. They are more interested in good design and amenities.

Room-By-Room Analysis

Good plans are made up through ***room-by-room analyses.*** How can you tell a good room from a bad one? Before a room can qualify as being well planned, it must pass two tests:

1. Does circulation work inside the room?

2. Is there a place to put furniture and arrange it properly after circulation and stairs are taken care of?

Possibly the most important room is the ***living area***, but it is not necessarily the most difficult room to plan. Kitchens, laundries, bedrooms, bathrooms, family rooms, and storage areas all present planning problems.

The good ***living room*** is free from through traffic and designed for best furniture arrangement. It will be designed for both interior views (T.V., fireplace, feature areas) and exterior views. In a good layout, furniture doesn't have to be moved every time you wish to look at your favorite T.V. program, watch the fire, or look out the window.

A good *kitchen* is not necessarily "glamorous" or "gadgety," although some glamour or gadgets may be marketable. Primarily, a good design is one that works. Is it laid out efficiently? Does it have the right kind of storage in the right places and in the right amounts? Does it make the user feel like a prisoner or does it make the time spent relatively pleasant? Is it located properly in relation to the rest of the plan? Above all, is the kitchen the control area for the rest of the house?

Modern *laundries* are designed to save precious small home space. But this does not mean laundries should be crammed into a left-over corner. The laundry-utility core should be located near the kitchen or a bathroom. Garages or basements are alternative locations although they have draw-backs. Arrange laundry appliances logically with good outside light if possible.

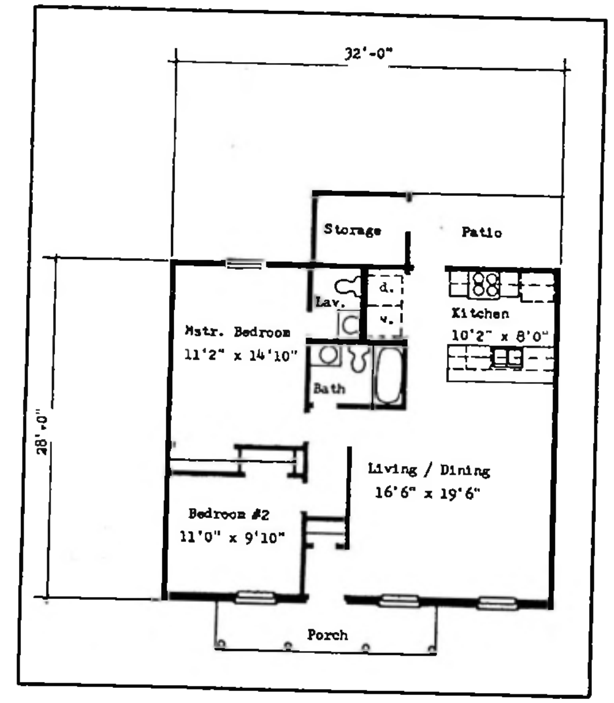
Bedroom space in small homes is often too small. Don't throw away space in excessive hallways. Large windows make the bedroom look bigger and provide plenty of light and ventilation. Master bedrooms should contain adequate space for at least queen-size or twin beds.

The argument for small windows because of privacy considerations is not valid since curtains or drapes are pulled over even the smallest windows. A good bedroom will have unob-structed closet space. Other live storage, where circulation is likely to occur throughout the day, should be placed elsewhere in the house.

Bathrooms, especially in small one-bath and bath-and-a-half homes, should be able to accommodate more than one person at a time with privacy provided for the toilet. They should provide plenty of storage for all the items that functionally belong there. Generous mirror surfaces make the bathroom seem larger. If space is available, a master bath/dressing area off the master bedroom is a desirable feature.

Storage areas often are overlooked in small homes. These areas are even more critical in smaller homes than large ones, where a spare bedroom can double as storage. Small homes on small lots have almost the same storage requirements as large homes. Depending on roof structural design, attic storage with pull-down stairs may be feasible. The most important things to remember about storage are:

1. There is never enough of it.
2. It should be located according to frequency of use.
3. It should be designed, dimen-sioned, and subdivided accurately for articles to be stored, not just vaguely tossed into a plan as a "closet" or "shelf".



Design does not end with a good floor plan. The exterior style and combinations of shape and mass are equally important. Pleasing visual proportions and textures are not limited to larger, luxury homes. Uncluttered, simple appearances can be pleasing in small, less expensive homes too.

In fact, simplicity and restraint in exterior appearance tends to be acceptable to more buyers than expensive scrollwork, bric-a-brac, and gingerbread which often leads to architectural chaos. This is especially true in small homes where one can be deluged with too much "style" in a short visual scan. In other words, it is often better to simplify and spend *less* on exterior appearance for better design.

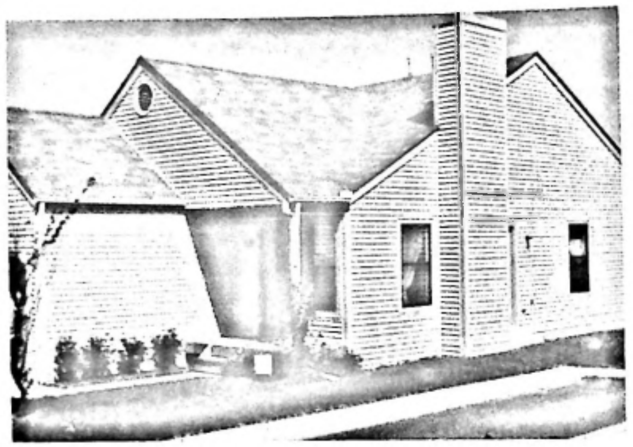
Horizontal and vertical elements of the entry facade need to be balanced and well-proportioned for visual continuity. Selection of exterior surface materials should be made with the market in mind.

Do not ignore what has been successful in the community, but also do not arbitrarily assume that certain sidings and styles will not work. Builders are traditionally much more conservative than the home buying public. This is understandable when one considers the risk involved in doing something different. An award winning design is useless if it does not sell. But pent-up demand for different styles of homes often goes untapped because of too much conservatism.

In the JVAH, Santa Fe builder Mike Chapman risked putting a contemporary, plywood-sided, sloped-roof house on the market in an adobe/stucco, flat-roofed, Spanish architecture community. He was of the opinion that the only reason this style home was not "marketable" was that it had not been built. He conducted a marketing survey that indicated there was, indeed, a pent-up market. The 47-unit first phase sold out in two weeks. The entire 154-unit subdivision sold out one year ahead of schedule. Chapman paid a lot of attention to both interior and exterior design.

Good design rules are not carved in stone for all houses and communities. A California contemporary design might not sell on Cape Cod. A Cape Cod cottage might be out of place in Arizona. But an astute builder will take advantage of a market that all others ignore because of "tradition."

Basically, however, there are some rules that transcend local preferences.

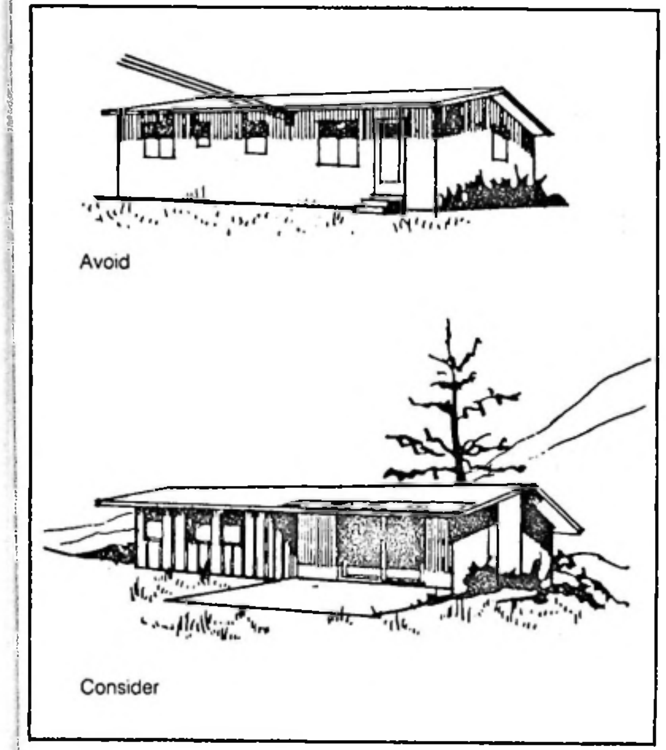


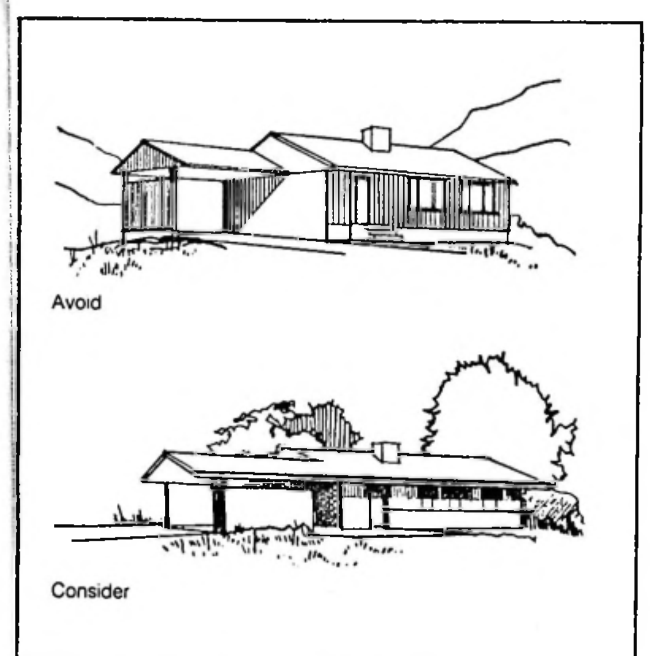
For the *roof*, provide a strong fascia on overhangs. Depth and style of overhangs should complement the overall appearance. A cascade of roofs at the same slope can be visually pleasing if not overdone.

Normal transitions, say from the house to the garage, are the best places to change roof lines. Roof overhang changes for a porch or sun shading of windows also create a visual break. Remember, however, each change in roof lines adds to costs.

The *home entry* should be clearly recognizable at first glance. Full-height windows and sliding glass doors on the front of the house need to be easily distinguished from the primary entry. This can be done by creating a transition space to the front entry by using paths, steps, or landscaping.

Once inside, there should be an entrance "space" that clearly defines the area. A separate vestibule or entrance room is not necessary, but the area needs to be defined by a change in floor surface, railings, closets, etc. Ideally, entrance "control" should be maintained from the kitchen. That is, the primary entry should be visible from the primary work area -- the kitchen.





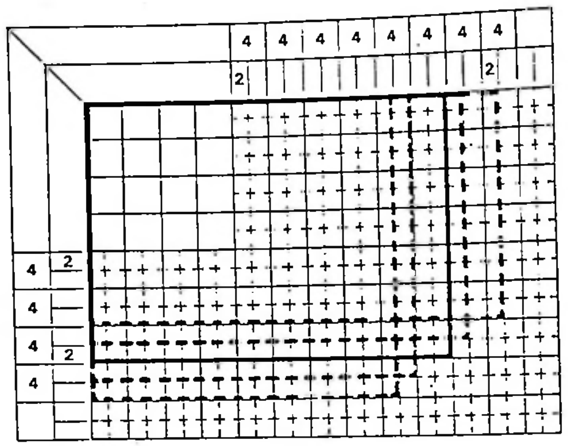
Since the *garage* is often the main entrance for much of the family, it can be designed as a positive entry rather than just a passage door to the garage.

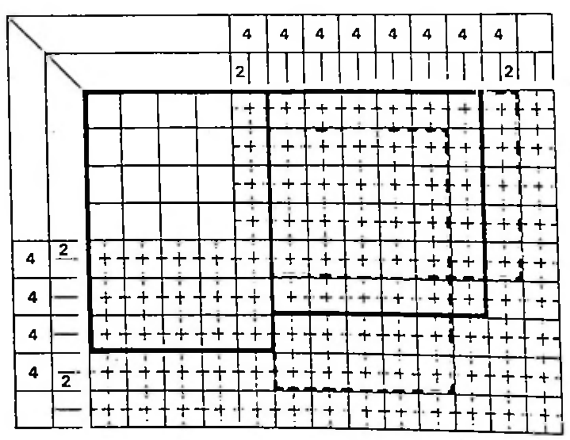
Keep *window and door* heads in line. Wall thickenings add interest (but also add cost), as do front entry setbacks. Carefully select windows to fit overall design and locate them for best natural ventilation and for architectural balance.

The *rear elevation* is often the "forgotten" elevation. Because much time is often spent in the back yard and because the rear elevation is often viewed by the neighbors or from another street, care should be taken to make it attractive also.

For small homes, it is difficult to maintain good width/height *balance*. If the house sits on a high foundation, proportions often are not the best and the house looks "boxy" and even smaller. A *lower profile* elevation tends to make the house appear larger. The building to ground connection can be softened by landscaping, steps, terracing, etc. This tends to reduce the high boxy look.

Designing for Economy





Within the framework of good marketable design, there are methods to ensure that costs are lowered without sacrificing marketability.

First, use ***modular dimensioning***. Most building materials are produced in increments of 2 feet, including trim, lumber, sheathing, and some sidings. The most efficient use of these materials will be obtained if overall house dimensions are laid out on a 2-foot grid. The most efficient plan is a basic rectangle which allows simple floor and roof structures on the 2-foot grid.

For design variation, two offset rectangles provide a break in roof lines as well as an elevation change. An offset garage also can be used to break up the flat front look. Keep in mind, however, that each variation from the basic rectangle adds cost. Depth of the most cost effective rectangle is limited by the allowable span of roof and/or floor framing members.

House shape and configuration effect total cost for the same amount of floor space. For example, an "H" shaped plan has 46 more linear feet of wall, 8 more corners, 4 more roofing areas, 2 more gable ends, and 4 more valleys than a rectangular plan.

The most cost-effective plan is one that encloses the desired floor area

Building Configuration and Design—Cost Considerations

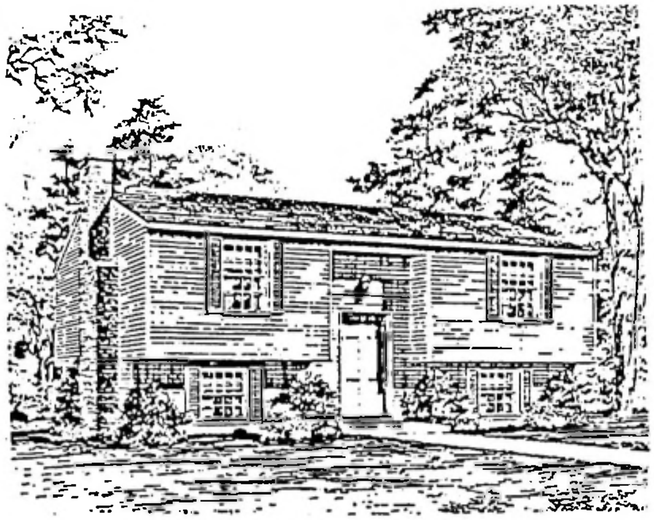
Unit Plan Shape (1,200 sq. ft. average area)	Exterior Walls			Roofing Areas	Roof System			
	Lin. Ft.	Corners			Gable		Hip	
		Out	In		Ends	Valleys	Hips	Valleys
Square Plan	140	4	-	2	2	-	4	-
Rectangular Plan	142	4	-	2	2	-	4	-
Offset Rectangular Plan	156	6	2	4	3-4	-	NA	NA
"L" Plan	152	5	1	4	3	2	5	1
"U" Plan	172	6	2	6	4	4	6	2
"H" Plan	188	8	4	6	4	4	8	4

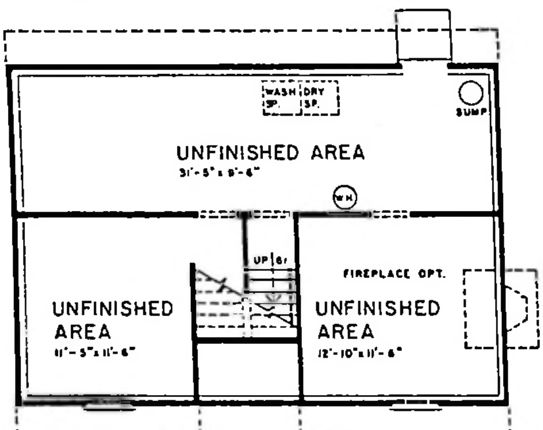
with the least amount of exterior wall. The *ratio of floor to wall* should be as high as possible within design parameters. For example, a 28x40 plan has 1,120 square feet of floor area and 136 linear feet of wall for a floor/wall ratio of 8.24. A 24x46 has 1,104 square feet of floor area and 140 linear feet of wall, a ratio of 7.89. The 28x40 plan is more efficient.

The high floor-to-exterior-wall ratio approach can also apply to the interior partitions. That is, the "open planning" concept of space limits the total length of interior partitions. As mentioned earlier, this is also a technique to make a small house seem bigger inside.

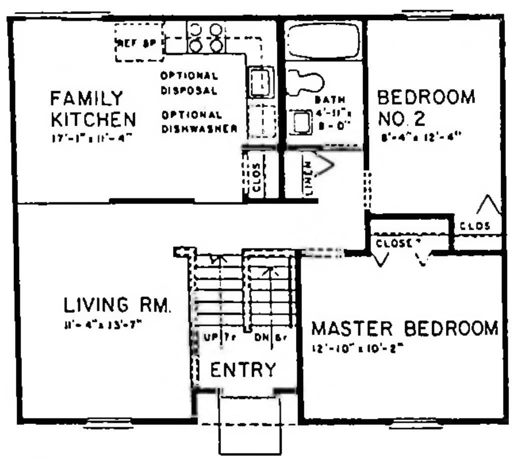
Defining areas by floor textures, railings, ceiling height changes, etc., eliminates the need for some interior partitions. It also results in lower costs for framing, drywall, painting, and, very importantly, for electrical wiring.

Plans that provide for *future expansion* may be desirable in some markets. If done, give special attention to problems of access, circulation, and plumbing and heating extensions. It can be a useful marketing tool, especially to first time home buyers with small families. Future usable space within the exterior shell was provided in the Santa Fe, Lincoln, Tulsa, and Baltimore County JVAH demonstrations.





Lower Level



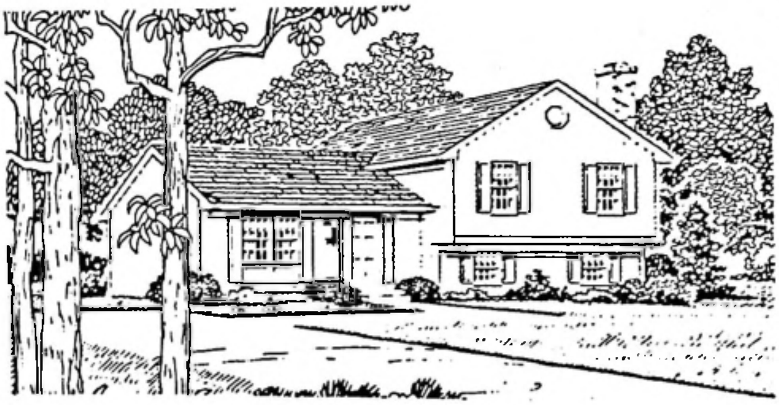
Upper Level

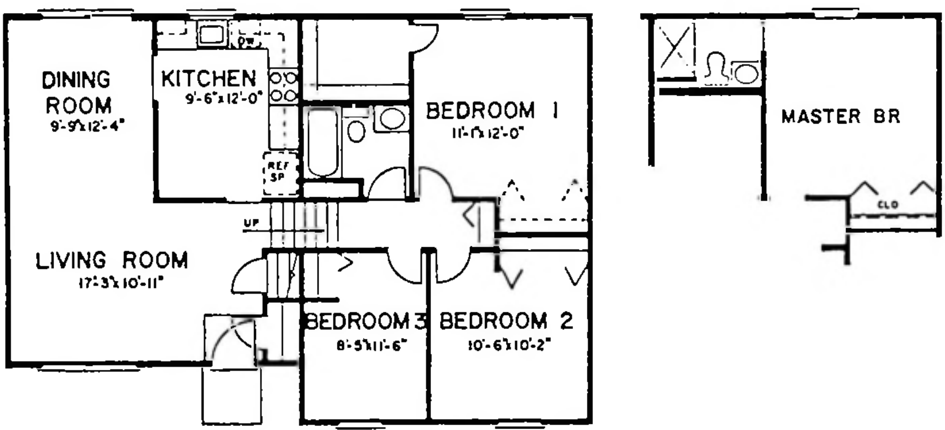
Slab-on-grade designs minimize cost and foundation problems in many areas of the country. If *basements* are perceived necessary because of marketing or site considerations, use multi-level designs which increase habitable space at minimal cost.

If the foundation type is optional, remember that it is almost always less expensive and more desirable to add habitable space above ground than below ground.

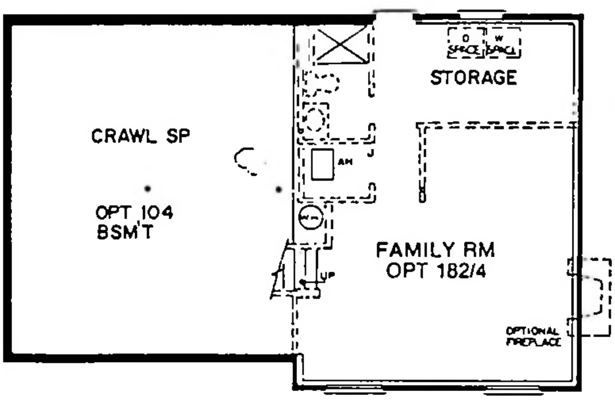
Use *cantilevered floors* over basements, crawl spaces, or first floors on two-story homes to provide design variations or to increase floor area at minimal extra cost. Cantilevers of up to 2 feet are generally permissible and help reduce out-of-square foundation problems. Cantilevered floors must be well insulated to prevent heat loss and frozen pipes.

When laying out *interior partitions,* locate them to intersect with an

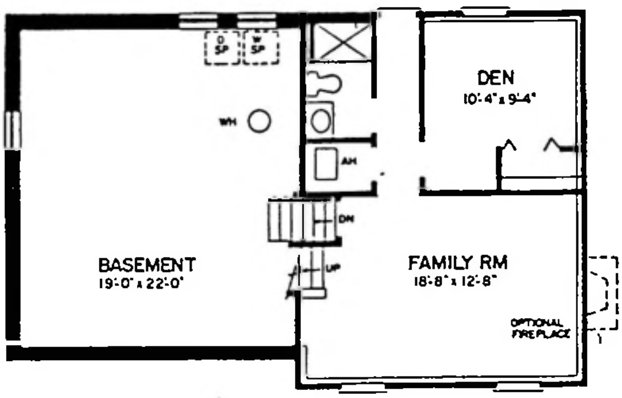




UPPER FLOOR PLAN



LOWER FLOOR PLAN



LOWER FLOOR PLAN

exterior wall stud (on the 2-foot grid). This provides a tie-in without extra framing or blocking and provides one side of drywall backup.

At least one side of *window or door framing* can coincide with normal modular framing in almost every case. It may be necessary to move the rough opening a few inches in one direction or the other to save a stud or two and, in most cases, the architectural balance will not be affected enough for anyone to notice.

If *trusses* are used, *gable end walls* are essentially nonbearing. Because of this, structural headers over openings are not necessary. Therefore, locate large openings in the gable ends if consistent with exterior design and floor plan.

Likewise, interior partitions are usually nonbearing. Openings do not require structural headers. If a load-bearing interior wall is necessary, limit the number of openings in that wall.

Most major model codes allow a 7'6" *ceiling height*. For small homes, this height may provide a better exterior scale. It also reduces siding and may eliminate one step from stairs in a two-story home. However, extra costs can be expected on drywall application. Studs must be trimmed unless they can be purchased precut for 7'6" ceiling heights.

When possible, plan for *straight-run stairs*, parallel to floor framing members, and coordinate the stairs with normal joist positions on one side to reduce floor joist disruptions. As shown in the framing section, stair trimmers and headers can be reduced if properly laid out.

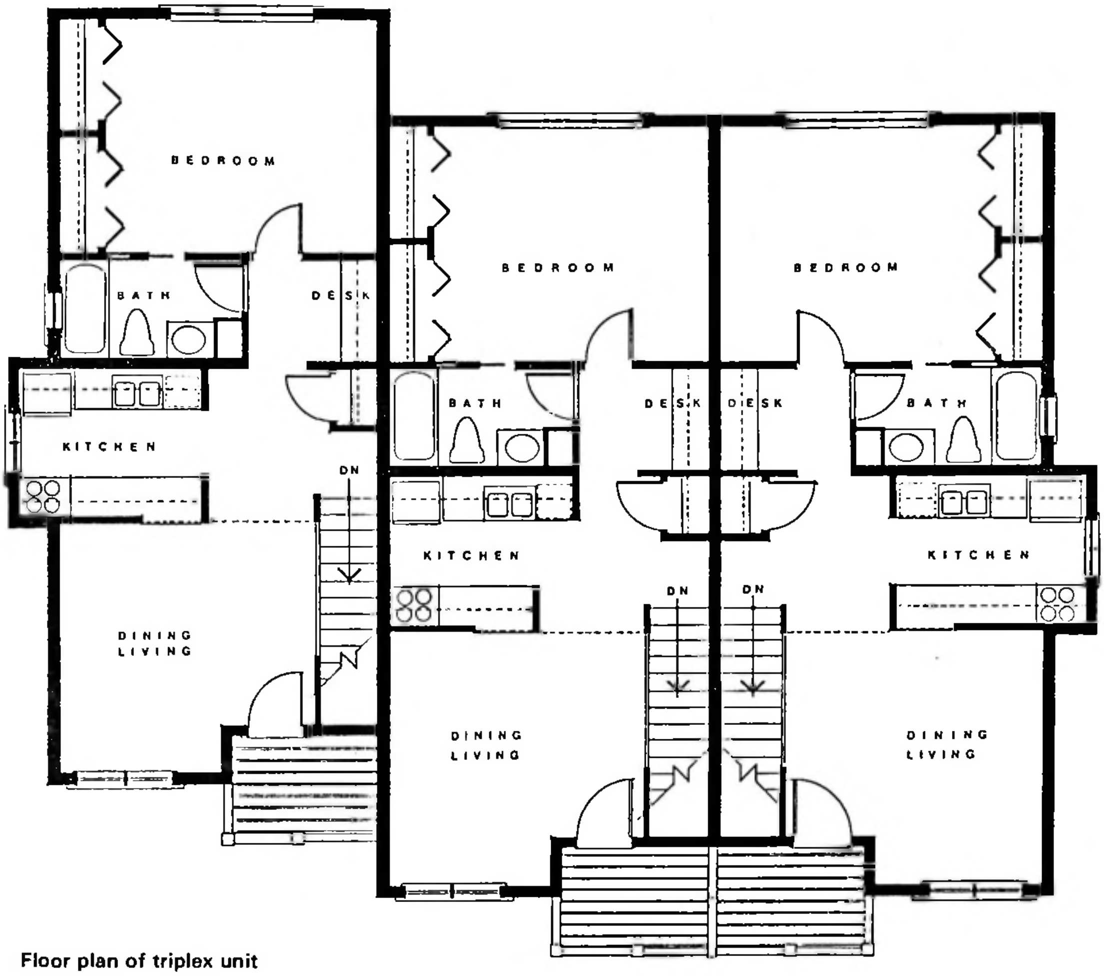
Attic/crawl space access doors should be located between framing members to eliminate structural headers. If framing members are spaced 24 inches on center, ample access space is provided.

Consider *centralized "back-to-back" plumbing* around a common stack to minimize piping requirements. In two-story homes, arrange upper level over lower level plumbing connected to the same stack. It will be necessary, no doubt, to point out these features to the plumbing contractor in order to get a reduced bid from him. Also lay out plumbing to minimize disruptions to structural members. Concentrate as much plumbing as possible in the same wall.

Plan *chases for ducts and flues* to allow ample clearances and to avoid disruption or displacement of structural members. Too often, duct placement is an afterthought which requires expensive solutions.

When practical, locate *heating/cooling equipment* in a central location to reduce duct runs and sizes and to provide good distribution. For small houses, a centralized system often means duct runs of less than 10 feet if high inside wall or ceiling registers are used. However, be sure to follow manufacturers' recommendations concerning placement because some equipment is designed specifically for outside wall locations.

Develop complete *working drawings and specifications* covering all important details for the construction process. Where possible, concentrate details for specific trades on a single drawing. Avoid tight or highly critical dimensions where possible (such as cabinets between walls). If such



Floor plan of triplex unit

critical dimensions are necessary, show in bold lettering, by underlining, or by some other method that leaves no doubt that these dimensions must be accurate.

All design recommendations apply equally to site-built, factory-built (modular and HUD code), and componentized housing. Most JVAH demonstration sites consisted of site-built homes, but modular units were used in Springfield, MA; Orange, NJ; and Elkhart, IN. HUD code-manufactured units were used in Oklahoma City, Stevenville, TX, and Elkhart. Panelized units were erected in Sioux Falls, SD, and White Marsh, MD.

The first step toward cost-effective construction is efficient design. Many costly details can be corrected in the design process. Therefore, the importance of merging good design for marketability and efficient design for construction cannot be overemphasized.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Builders in the affordable housing demonstration were not given specific designs to build. Rather, they were asked to design homes they thought would be marketable in their areas, and to submit these designs to HUD and NAHB/NRC for evaluation and suggested cost-saving revisions.

Since the builders were not subsidized, they could accept or reject suggestions. Most were very successful in offering high-quality, well-designed homes at affordable prices.

Santa Fe, New Mexico

Mike and Walton Chapman were exceptionally daring, building homes that, for Santa Fe, were unconventional for the market. Floor plans were simple and uncluttered. Vaulted ceilings with lofts gave a feeling of spaciousness.

They also offered expandable, do-it-yourself space, but most buyers opted for the builder to finish the space. Living rooms and dining areas were contiguous, which allowed 24-foot unobstructed front-to-rear visual continuity. Sliding glass doors were located to further increase the line-of-sight. Houses were located on the lot in a "pinwheel" configuration. Garages were attached at the lot-line. Solar greenhouses were offered as options.

Lacey, Washington

The JVAH site was a mixture of townhouses, quadplex, zero-lot-line, and pinwheel cluster cottages. Density was eight units per acre.

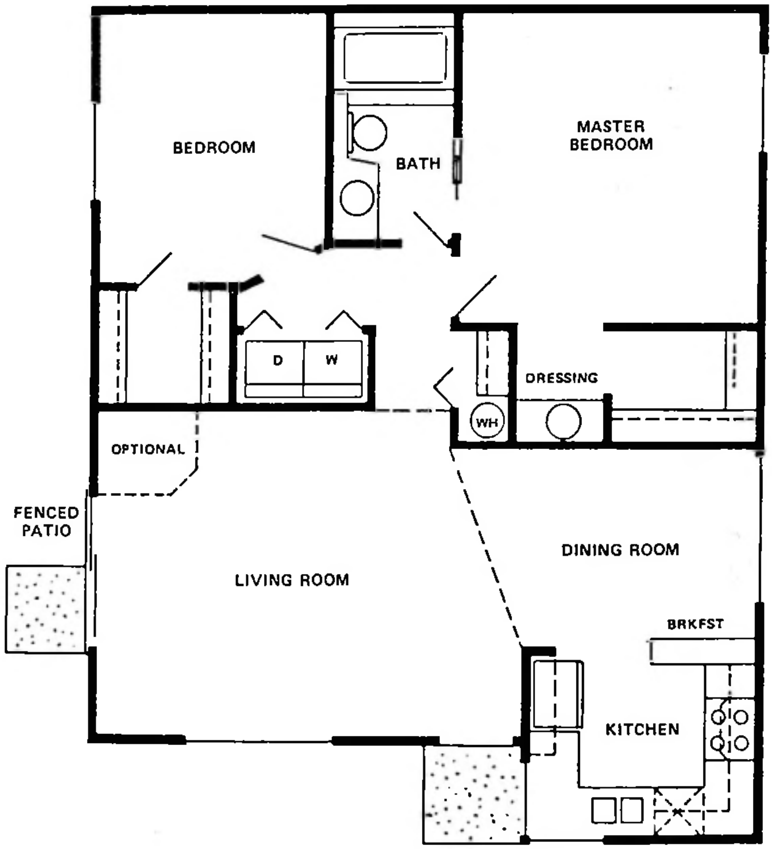
The cottages contained two bedrooms and one bath in 880 square feet. John Phillips, the builder/developer, had previously built another subdivision of these small, inexpensive homes and received national attention in Professional Builder magazine as an award-winning project.

Sixty-four of the 176 units were these cottages. They were basically square in design, giving the best floor area to exterior wall ratio. A small 4-foot offset provided a break in the front elevation and also allowed a break in the roof lines.

The floor plan was very functional with minimal circulation area. The living/dining areas were combined into a "great room" of approximately 360 square feet. A vaulted ceiling over the 14x18 living room area added to the feeling of spaciousness.

A sliding glass door off the living area leading to a small fenced-in yard also helped in making a small home seem very large. A window off the kitchen area facing the front door provided entrance control.

Although it contained only one bath, Phillips provided a second lavatory in a dressing room off the large master bedroom walk-in closet. The bathroom featured a skylight, cultured marble shower surround, and a "step-up" bathtub which added a sense of luxury at minimal extra cost.

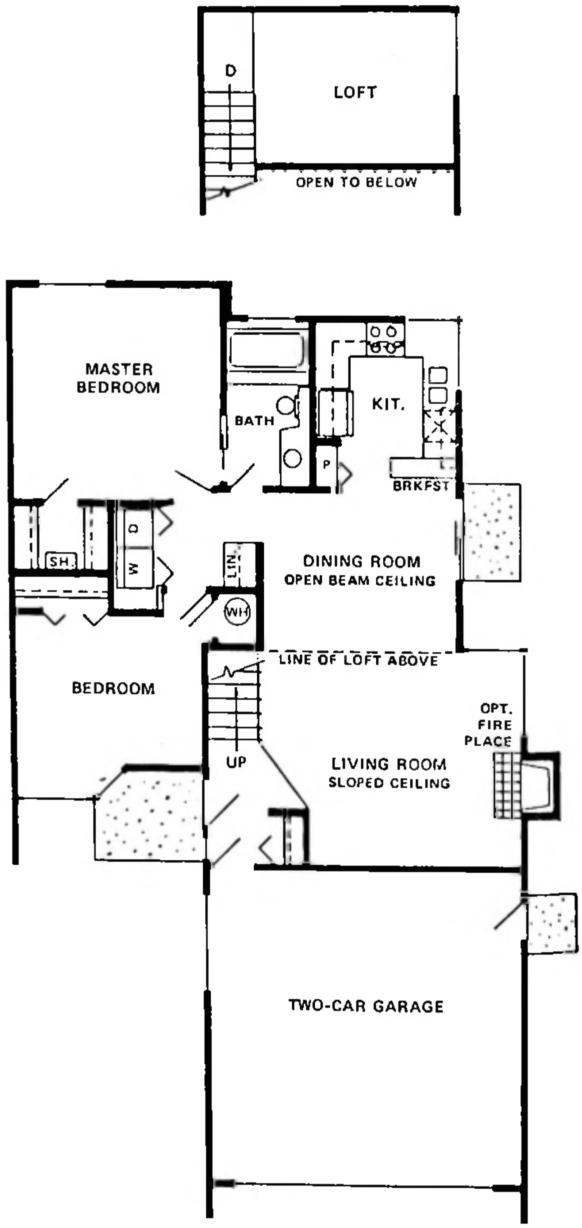


The one-bedroom "loft" home quadplex units were designed for singles, newlyweds, and others who needed minimal space. They were arranged in a back-to-back configuration, each with its own private entrance and small yard.

The smallest loft home contained 648 square feet and the largest, 674 square feet. The main level consisted of a living room with a vaulted ceiling, a dining area with vaulted-open beam ceiling and a kitchen. The upper loft area contained one bedroom and a bath.

The bedroom was open to the living area below, separated by a 4-foot high wall. This provided, in effect, one large open area for all rooms in the unit. The only full height interior partitions were for the bathroom and closets.

The zero-lot-line homes contained two bedrooms and one bath with a small loft overlooking the living area. Each featured a two-car garage. Floor plans were more traditional than other styles within the project, but the loft added interest and the vaulted ceilings created space.



The living room/dining room/ kitchen combination created a large front-to-rear "great room." Interior partitions were minimized by this open approach.

The townhouses were also designed with openness in mind. Living rooms leading into dining areas and vaulted ceilings with lofts made the small two-bedroom units seem much larger.

Phoenix, Arizona

Knoell Homes designed the house plans with the goal of making the small units attractive and saleable while paying attention to production efficiencies.

Innovative use of interior space, such as vaulted ceilings and living areas opening onto outdoor patios, created a sense of openness.

Three models of townhouses and three basic models of zero-lot-line detached homes ranged in size from 770 to 1,295 square feet. The largest detached home had alternative floor plans providing either two or three bedrooms.

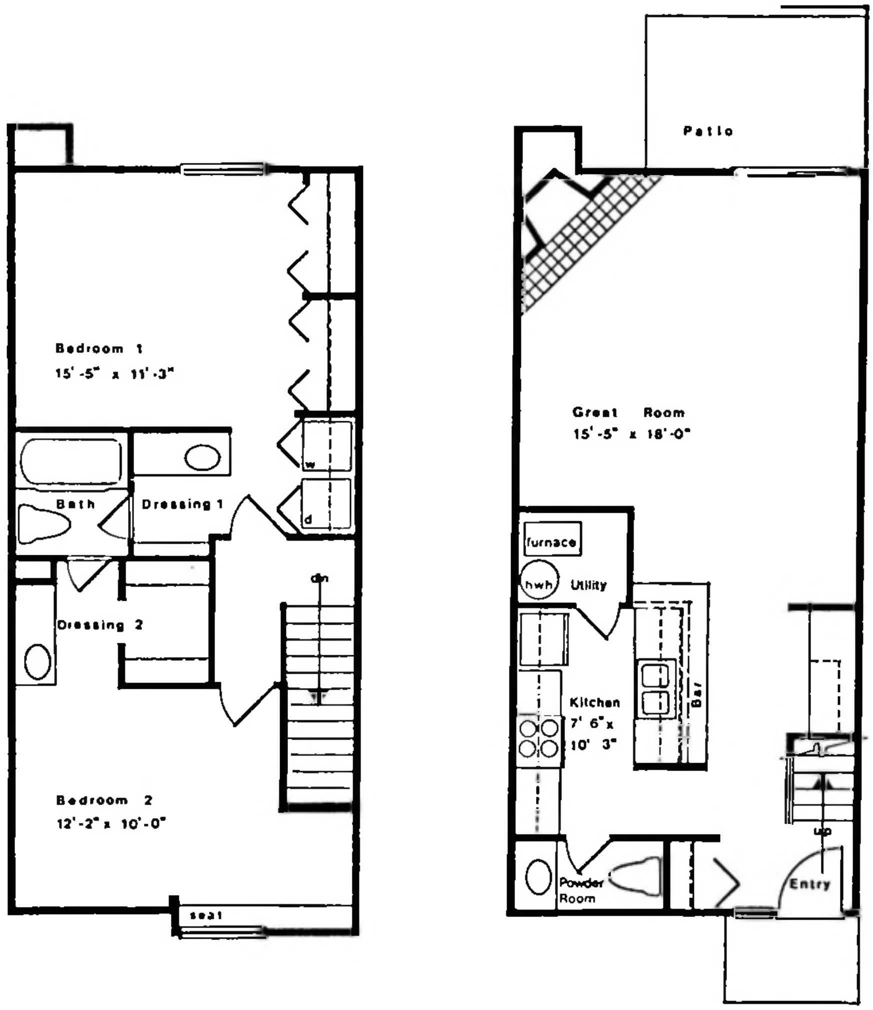
The builder did an outstanding job of combining design with production efficiencies by designing major outside dimensions in multiples of 4 feet and minor dimensions in multiples of 2 feet. Since most construction materials come in increments of 2 feet, there was very little scrap and labor time for cutting, and fitting was reduced.

Mesa County, Colorado

The JVAH project consisted of 50 townhouse units on 2.87 acres, or 17.4 units per acre. Two models, a one bedroom and a two master-bedroom, were built.

The market was determined to be first time buyers, including singles and newly marrieds. The one-bedroom unit contained 896 square feet. The lower level consisted of a large living/dining great room and the kitchen. The upper level contained one large bedroom and a large bathroom/laundry.

The two-bedroom unit contained 1,088 square feet. The lower level contained a 15 1/2x18 great room, kitchen, and powder room. The upper level contained two bedrooms, a single bathroom and separate vanities for each bedroom.



The Coventry

Everett, Washington

The Everett JVAH site, Sunridge, consisted of 81 units on 12.2 buildable acres. Three basic zero-lot-line detached models were built, ranging in size from 1,076 to 1,624 square feet. Sunridge homes were designed to make the units energy efficient, attractive, marketable, and affordable.

The builder, Rich Boyden, was especially attentive to details that appealed to his target market, including interesting angles, privacy, and an abundance of light.

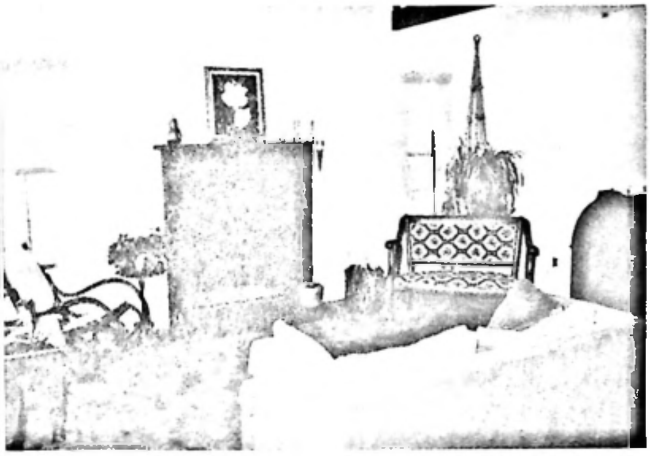
All units were designed with the bulk of the glazing facing south for maximum passive solar gain. Clerestory windows and other large areas of glass made the homes very energy efficient. In addition, Boyden installed small wood burning stoves in all units which proved to be a very desirable feature. Interviews with occupants indicated that, during the winter of 1985-86, total heating costs were between $15 and $50 per month, depending on the use of the wood burning stove. The south-facing windows are shaded in the summer.

Crittenden County, Arkansas

Rex Rogers determined that there was a market for very small (504 square feet to 960 square feet) homes on small lots. Rogers believed basic, no-frills housing would sell in his area.

Four models were offered: a 504-square-foot efficiency unit, a 638-square-foot two-bedroom unit, a 782-square-foot three-bedroom unit, and a 960-square-foot three-bedroom unit. The efficiency unit, which was nothing more than one large room with an accordion wall separating the bedroom area did not sell. However, the other units sold well.

A popular option was a loft which added from 384 to 528 square feet. The homes sold from about $27,000 to about $35,000 without the loft or garages.



Although the units were small and basic in design, they were built with quality materials and workmanship. Exterior walls were built with 2x6 framing, 24 inches on-center, and contained R-19 insulation.

The floor plans have proven to be marketable in other areas of Arkansas. Through the efforts of HUD Area Office Manager, John Suskie, the JVAH program has become extremely successful in the region.

FOOTINGS AND FOUNDATIONS

Because the foundation transfers the weight of the house to the soil, prudent engineering principles and calculations are necessary. However, prescriptive code requirements often codify the worst case situation, adding unnecessarily to costs for all foundations built in an area. The optimum foundation will depend on factors such as climate, soil, topography, and building loads.

Basically, concrete *footing widths* are determined by total design loads in pounds per linear foot of footing and allowable soil bearing capacity in pounds per square foot. *Column footing sizes* are determined by total design load in pounds and allowable soil bearing capacity in psf. See Tables 1 and 2.

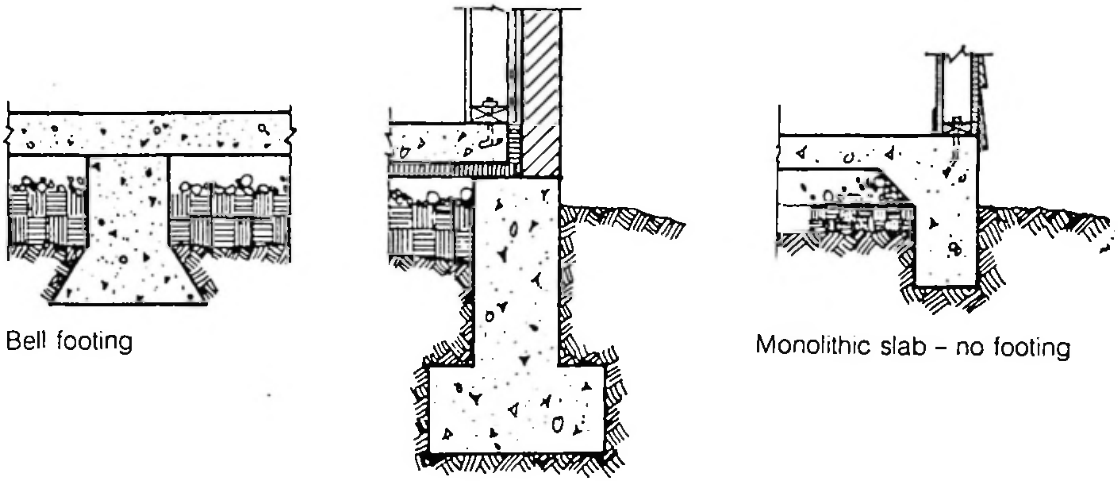
Table 1
Footing Widths, in Inches,
or Typical Single Family Dwelling Loads

Design Load lbs./lf footing	Allowable Soil Bearing Capacity, psf			
	1500	2000	2500	3000
1,000	8	6	5	4
1,500	12	9	8	6
2,000	16	12	10	8
2,500	20	15	12	10

Table 2
Column Footing Size, in Inches,
for Typical Single Family Dwelling Loads

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

As shown in the above tables, if soil bearing tests are made, footing widths may be reduced substantially thereby reducing costs, assuming local codes are performance based.



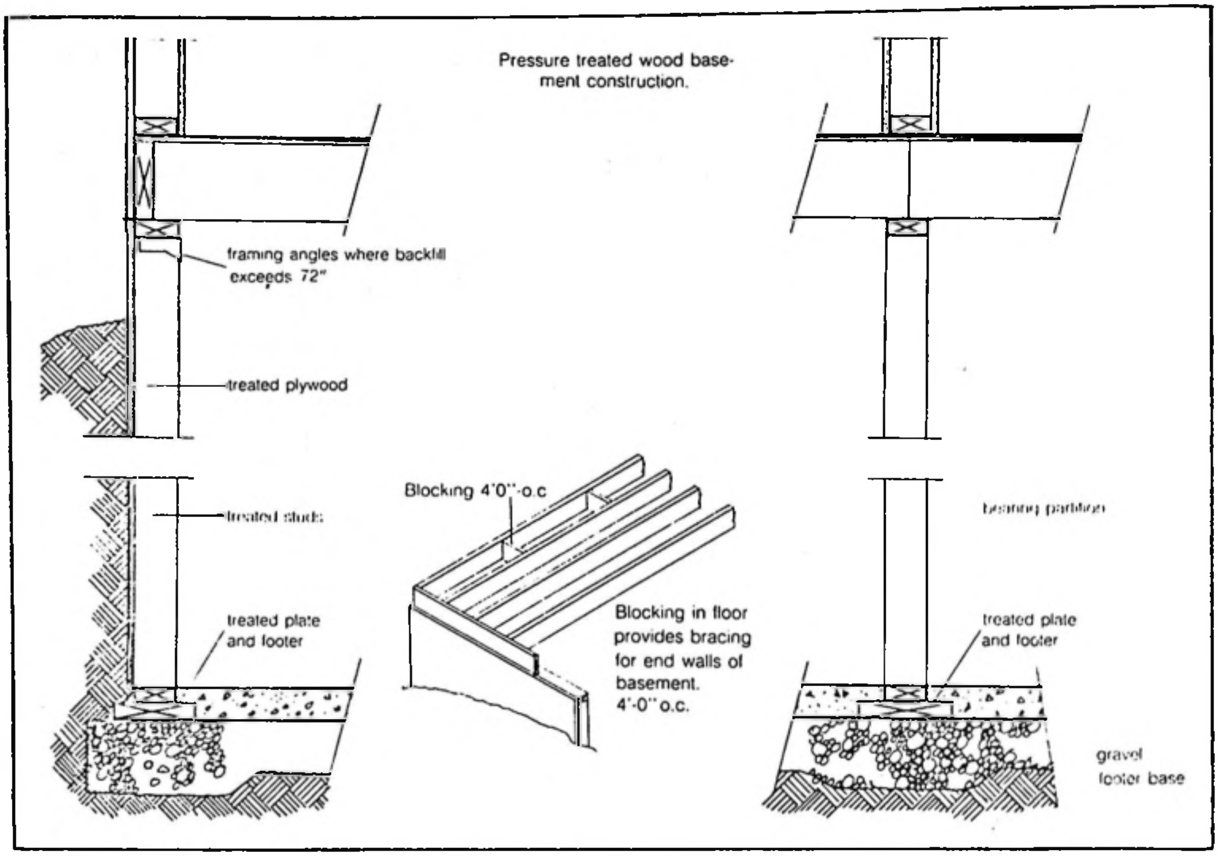
The 1986 CABO One and Two Family Dwelling Code prescribes minimum footing widths and depths, but Section R-108, *Alternate Materials and Systems*, provides a mechanism for innovative design and material usage. All major model codes have similar provisions that should be used whenever soil bearing tests or engineering calculations are appropriate.

Reinforcing of concrete footings is required by some local codes or is routinely installed as "local practice." Footing reinforcement is seldom necessary for footings placed on undisturbed soil. Compacted fill often has sufficient bearing capacity that makes reinforcing unnecessary.

Footings in *expansive soil conditions* should always be designed by qualified engineers and will most likely require reinforcing. Otherwise, elimination of footing reinforcing rods is a legitimate method of reducing costs in many cases.

As with footings, *reinforcement in foundation walls* is seldom necessary in nonexpansive soil and in areas outside of seismic zones 2, 3 or 4. If reinforcement is routinely installed in accordance with local code requirements or local practice, it will be worthwhile to examine soil conditions and work toward change.

Under stable base conditions, concrete slab floors do not require *welded wire mesh*. It is not recognized as structural reinforcement and provides no significant function. 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 mesh is seldom installed correctly, and since properly placed control joints localize cracks, and since carpet or resilient flooring cover cracks, welded wire mesh is of dubious value in most cases. A survey conducted for NAHB in 1984 indicated that about 60 percent of the code jurisdictions do not require mesh in slabs.

Most major model codes require 3 1/2-inch or 4-inch thick *concrete slabs-on-grade*. Because the slab is 100 percent supported on compacted fill and because normal house loadings are relatively light, a 2 1/2-inch thick slab may be more than adequate on soils with high bearing capacity.

The *pressure treated wood foundation* is a proven cost effective alternative to masonry in some areas. As with all foundation systems, the realization of full performance potential requires proper attention to design, fabrication, and installation.

Wood foundations, marketed under the name "Permanent Wood Foundations," have been used successfully in many areas of the country. They are built basically like exterior walls using lumber and plywood treated to American Wood Preservers Bureau FDN standard. Details of the system are available from the National Forest Products Association (NFPA), 1250 Connecticut Avenue, NW, Washington, DC 20036. NFPA is also investigating *pressure treated wood for expansive soil applications*, especially for crawl space foundations.

Waterproofing

Throughout the years, there have been many attempts to develop the definitive basement waterproofing method. Some methods have worked better than others, but basement leakage continues to be one of the most common customer complaints.

Capillary water and condensation on comparatively cool walls and floors create dampness. Most capillary problems diminish or go away when concrete completely cures or when positive drainage steps are taken. A plastic film vapor barrier under the basement slab and on walls reduces capillary action through the concrete. Condensation dampness is a function of internal humidity and temperature difference between air and surfaces. When the dew point is reached, water vapor changes from a gas to a liquid. The most consistent and major problem is the *hydrostatic lateral pressure of groundwater* which seeks out cracks in concrete or mortar joints.

Elastomeric compounds applied to the exterior surface of the foundation wall help reduce the problem. In addition, drain tile set in gravel around the exterior basement perimeter (French drain) helps to some degree. Parging alone is practically ineffectual. Substitution of *plastic films* for parging and many of the so-called "sealants" has, in some cases, been effective.

Good drainage starts by keeping rain and melting snow away from the foundation by proper *surface grading*. A 1-inch rainfall on an 1,800 square-foot roof will generate about 1,125 gallons of water. Add the water that falls within a few feet of the foundation and the drainage from patios, porches, driveways, etc., and the potential for basement leakage is very high unless most of the water has been removed before it has a chance to percolate near the house.

Gutters and downspouts are helpful if the downspouts direct water far away from the foundation. If not, water is concentrated in one area, increasing the probability of leakage at that point. In addition, settling of backfill allows water collection alongside the foundation walls. By paying careful attention to surface grading, foundation waterproofing is simplified.

Many new *drainage boards, panels, fabrics, and plastic mesh* products have been developed recently that are applied to the exterior foundation wall and relieve hydrostatic pressure by draining away water. Some were developed for highway and commercial building construction and have been proven effective. Some even have integral insulation laminated with filter fabrics and water retardant facings.

All these products are based on the fact that lateral water pressure is the culprit in most leaky basements. The major drawback of most systems is that water which has drained down has no place to go once it gets there. *Drain pipe* that simply circles the foundation perimeter can fill up quickly with water and then eventually silt. Water starts backing up the foundation wall, recreating hydrostatic pressure.

The NAHB/NRC developed a waterproofing method in about 1965 that still works. It relieves the hydrostatic pressure by allowing water to drain in the path of least resistance -- down. The system does not stop at the footing, however. It provides a method which keeps the water away from the foundation wall permanently.

The system is used with the pressure treated wood foundation but was originally developed for use with concrete and concrete block foundations. The system lets water drain under the basement floor in a controlled manner where it can either drain into the soil below the slab or into a dry or wet sump. The system is described in detail in *Basement Water Leakage .. Causes, Prevention, and Correction*, available from NAHB, 15th and M Streets, NW, Washington, DC 20005.

Good supervision and construction practices are very important in waterproofing the foundation. Cleaning the footing prior to placing the foundation wall; using care in placing concrete to prevent entrapped air or aggregate segregation; placing concrete at least 4 feet per pour; vibrating concrete; using low slump concrete; and providing drains for window and door wells all help to reduce leakage problems.

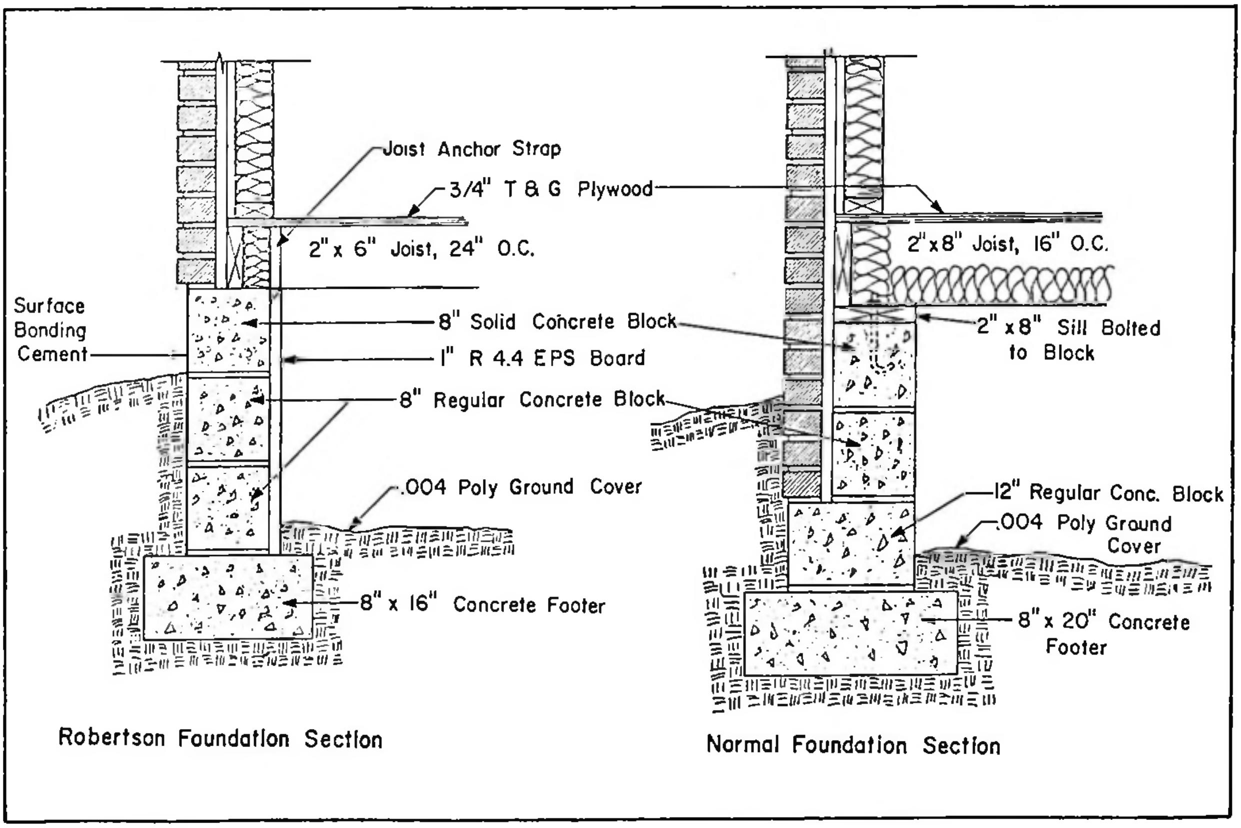
EXAMPLES FROM THE DEMONSTRATION PROJECTS

JVAH Foundations

Several JVAH sites used innovative approaches to foundation construction that reduced costs while maintaining structural integrity. In some cases it was necessary to provide results of soil bearing tests and engineering data to the city building department. In every case, less costly foundations resulted.

Christian County, Kentucky

Crawl space foundations in Christian County typically are built of one course of 12x8x16 block and two courses of 8x8x16 block. The 12-inch block serves as a brick ledger. The builder, Norris "Pup" Robertson, used three courses of 8x8x16 block stacked without mortar and bound together with glass fiber reinforced surface



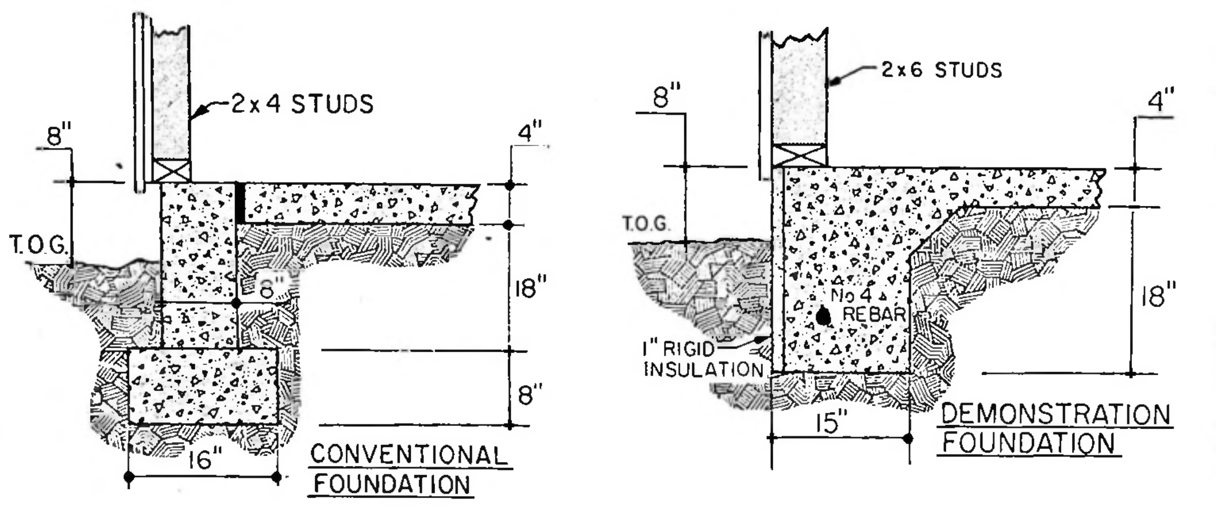
bonding cement. This reduced the concrete footing from 20 to 16 inches wide and eliminated 16 inches of brick veneer.

Cost savings amounted to $203 per unit for the footing and foundation, and $410 per unit in brick for a total savings of $613 per unit.

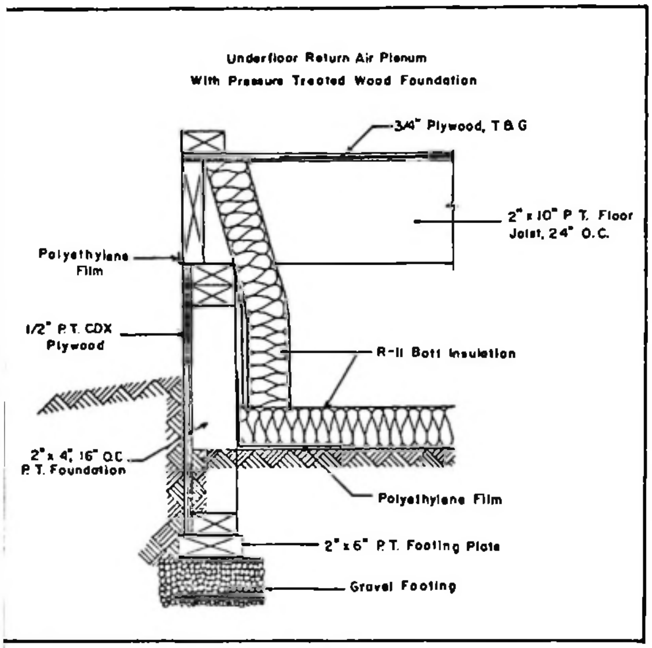
Santa Fe, New Mexico

The typical Santa Fe single family home foundation consists of an 8x16 concrete spread footing and an 8-inch thick, 22-inch high cast-in-place foundation wall.

Mike Chapman, builder, decided to build a thickened-edge, monolithic slab which is common in some areas but not in Santa Fe. This allowed a one-step operation instead of three steps and saved two days of construction time. Cost savings amounted to $106 per unit.



Tulsa, Oklahoma



Typically, Tulsa single family homes are built with concrete slab-on-grade foundation/floors. Crawl space homes with wood floors are rare and usually more expensive. Wayne Hood, builder, decided to build a system unique to Tulsa -- the underfloor plenum system on a pressure treated wood foundation.

Instead of using heating and cooling ducts, the entire underfloor space is used as a sealed plenum chamber. Basically, it consists of wood floor construction with sealed and insulated foundation walls. In the Tulsa JVAH homes, the underfloor area was used as a return air plenum with a conventional up-flow furnace. In most cases, the underfloor area is used as a supply plenum without duct work.

Information on the system can be obtained from the American Plywood Association, the National Forest Products Association, the Southern Forest Products Association, and the Western Wood Products Association. It is being marketed under the name Plenwood.

According to Hood, cost savings amounted to $1,470 per unit versus conventional slab-on-grade foundations with overhead heating/cooling ducts.

Phoenix, Arizona

Knoell Homes conducted soil bearing tests on the site and found the soil had a bearing capacity of over 3,000 psi. Because of this and because of minimal disturbance to the soil, Knoell received a waiver to reduce slab thickness from 3 1/2 to 2 1/2 inches and to eliminate fill under exterior concrete. Savings amounted to $195 per unit.

Valdosta, Georgia

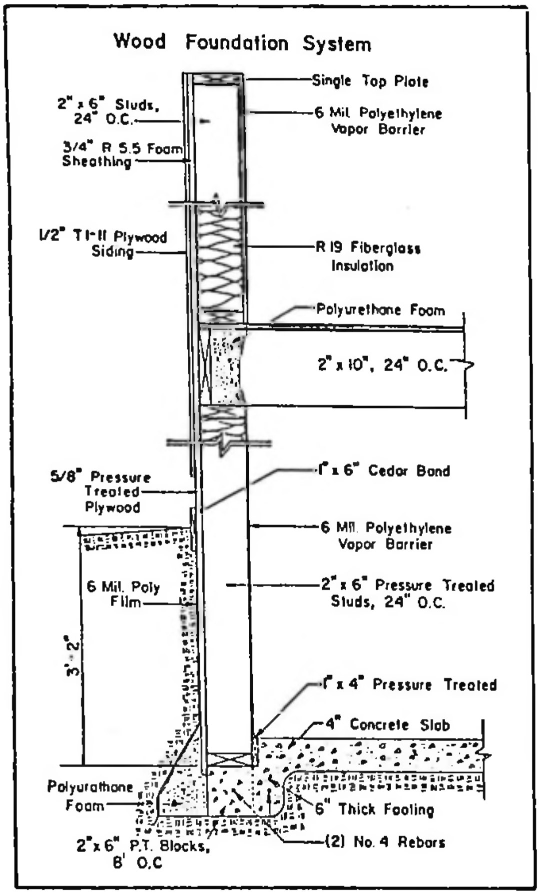
Gary Minchew eliminated reinforcing rods from footings and welded wire mesh from the slab. In addition, he eliminated a metal "key- way" control joint down the center of each slab, saving $132 per unit in labor and materials.

Crittenden County, Arkansas

Rex Rogers reduced concrete slab-on-grade thicknesses from a nominal 4 inches to a nominal 3 inches, and reduced concrete strength from 2,500 psi to 2,000 psi, saving $160 per unit.

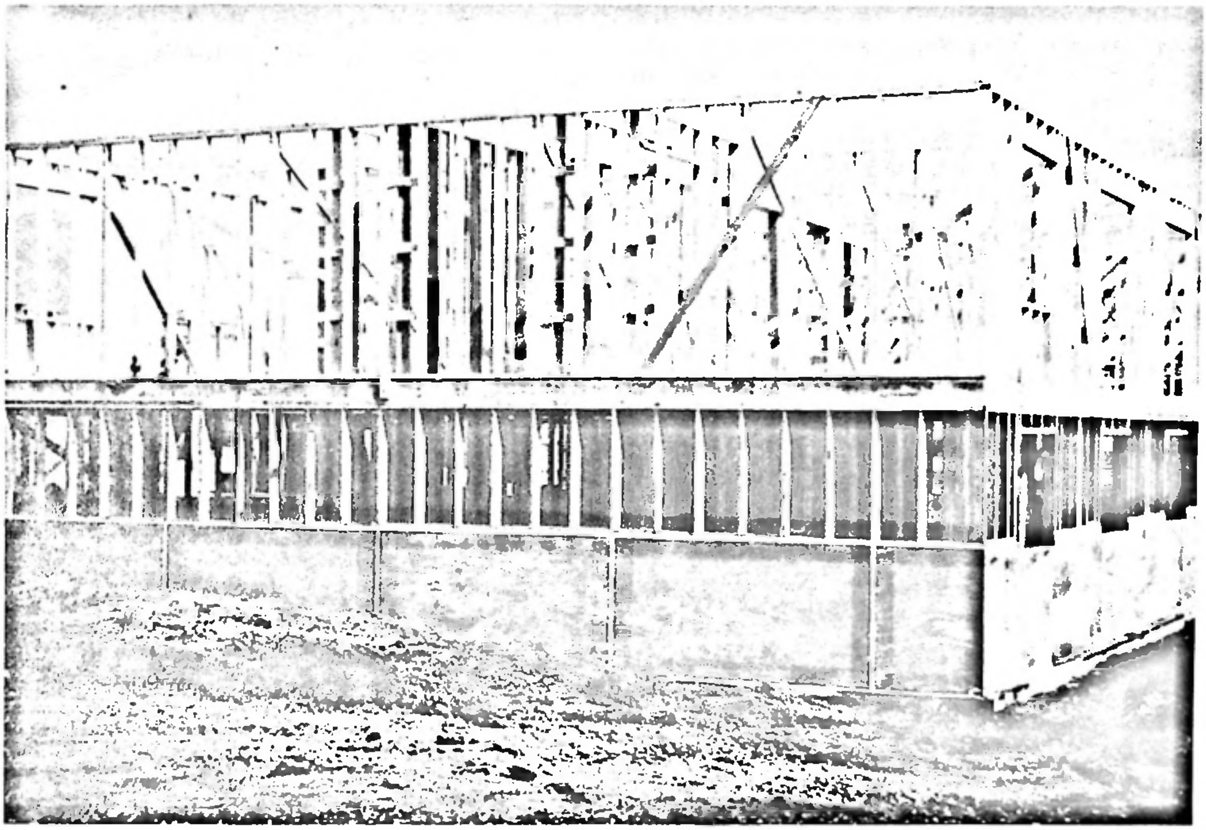
Fairbanks, Alaska

Pressure treated wood basement foundations were used in all Fairbanks JVAH homes. Tom Webb had been building wood foundations for several years and found no sales resistance. Because of the high concrete costs in Fairbanks, the wood foundation was especially attractive. It also allowed Webb to extend the building season which was very important in Fairbanks. Cost savings amounted to $1,035 per unit.



Lincoln, Nebraska

Karl Witt used pressure treated wood foundations in two units but was reluctant to build more because he anticipated negative market reaction. None occurred.



WOOD FRAME FLOORS

Most wood frame floors utilize nominal 2-inch thick joists placed on a center-bearing beam and covered with sheathing. Floor trusses have recently become more popular and post-and-beam crawl space floors have been in use in some areas for years.

Floor design is based on a number of factors, such as:

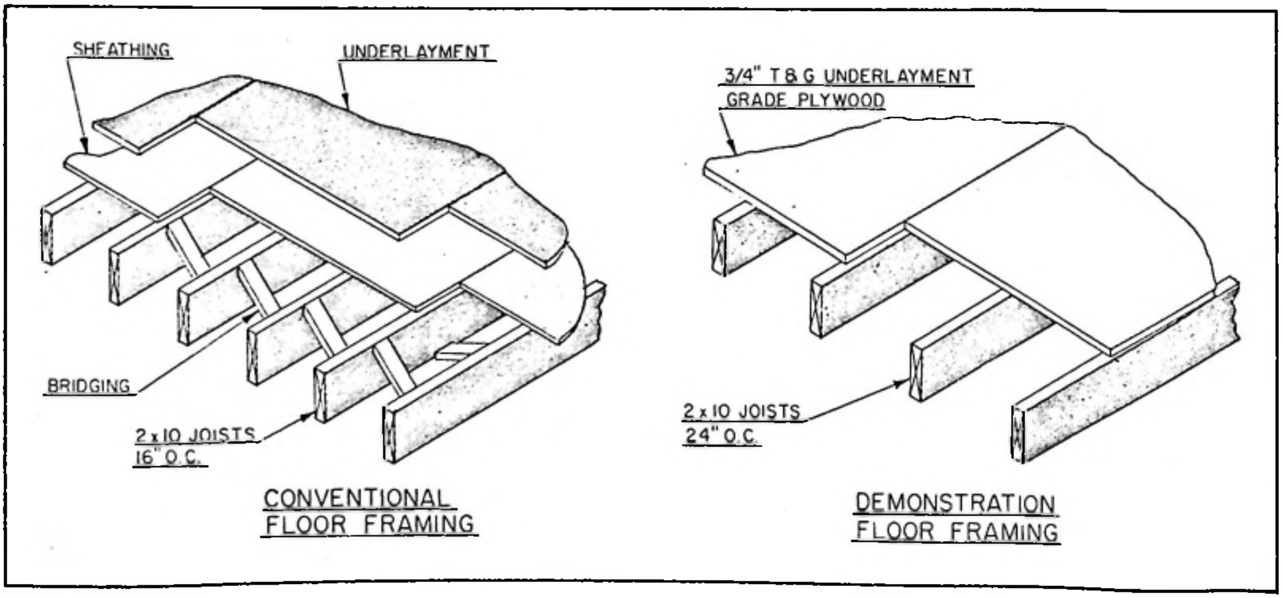
- Design load
- Lumber species, size, and grade
- Clear span between supports
- Floor sheathing materials and thickness
- Fastening techniques

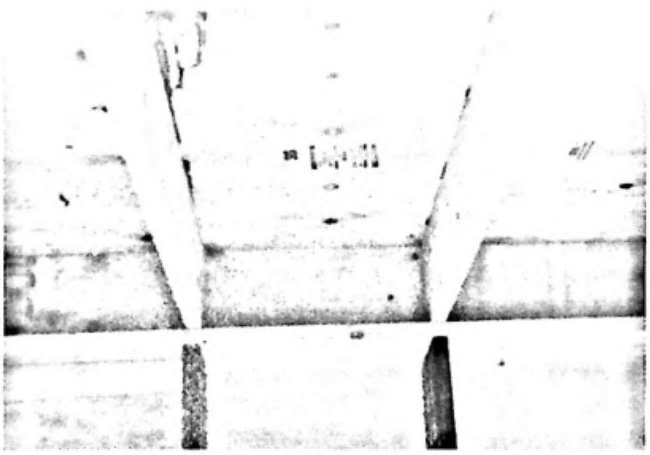
Utilization of *full span capacity of lumber joists* can often save between 6 and 8 percent of joist framing costs. If allowable spans for joists presently used exceed the spans shown on the floor plan by 1 foot or more, important savings may be realized by changing either the joist grade, spacing, or size.

Built-up wood girders are usually more cost effective and easier to work with than steel girders.

Floor sheathing adds stiffness to the floor and, depending on thickness and fastening methods, can result in reducing the size and/or increasing the spacing of framing members. When a plywood subfloor is properly glued and nailed to the joists, the subfloor and joist act together as a composite T-beam and as such will span a greater distance than if the subfloor is fastened with nails only. Glue-nailing is also effective in reducing floor squeaks and stiffens the floor. A single layer tongue-and-groove system is usually less costly than a separate subfloor and underlayment system.

Bridging or blocking between floor joists at mid-span has been proven ineffectual in almost all cases. An extensive series of tests conducted by the NAHB National Research Center in the early 1960's proved that mid-span bridging adds nothing but cost to most floor systems. Major model codes





require bridging only in floors with joists exceeding a depth-to-thickness ratio of 6 to 1 based on nominal dimensions. In other words, joists up to and including 2x12s do not require mid-span bridging.

Another common but unnecessary practice is to ***double floor joists*** under nonbearing interior partitions. In fact, it is not necessary to locate nonbearing partitions over any joist when 5/8-inch or 3/4-inch plywood subfloor is used. The weight of the partition does not warrant extra support. Load-bearing interior walls usually run perpendicular to joists and do not require added support. If load-bearing walls run parallel to floor joists, a supporting girder system is required.

Wood frame floors must be ***anchored to the foundation*** to resist wind forces acting on the structure. In conventional construction practice, 2x6 sill plates are attached to the foundation with anchor bolts, and floor joists are toe-nailed to the sill plate.

Metal anchor straps are available for embedding in the foundation concrete or mortar that do not require holes in the sill plate. Such straps are less exacting and do not interfere with joist or band joist framing as anchor bolts often do.

Sill plates can be eliminated altogether if the top of the foundation is sufficiently level and accurate. Joists, however, must rest on a solid surface and not over the cores of concrete block. Anchorage can be provided by anchor straps attached to the joists and firmly set in foundation concrete or mortar.

Floors built on pressure treated wood foundations do not require separate sill plates or anchoring devices. Joists are toe-nailed directly into the foundation wall top plate.

Stairwell framing costs can be reduced in the design stage by positioning stairwell openings parallel to floor joists. Double joists (trimmers) on each side of the opening are not necessary where the header which they support is located within 4 feet of the end of the joist spans. A single header is generally adequate for openings up to and including 4 feet in width.

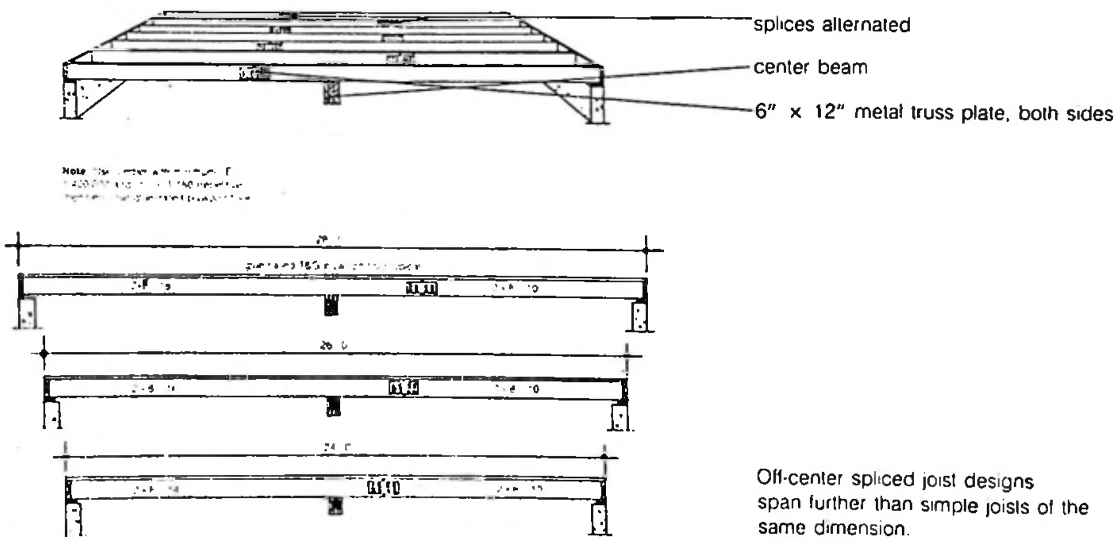
The *band joist* (sometimes called the rim or header joist) typically is the same size as floor joists. The major function of the band joist is to keep the floor joists vertical. Therefore, if wall studs and floor joists are aligned, a nominal 1-inch thick board or plywood band is adequate.

In certain cases, the band may be eliminated altogether. When a structural exterior wall sheathing is used, it can extend over the ends of the floor joists where the band would normally be. Joists must be temporarily braced until the wall sheathing is applied.

The typical wood frame floor has two joists lapping over the center girder, each joist acting independently from the other. This system creates problems with plywood sheathing layout, one side of the floor being 1 1/2 inches out-of-kilter with the other.

The allowable span of floor joists may be increased by maintaining continuity over the center bearing -- that is, if the joist is continuous rather than lapped over the girder.

If two joists of unequal length are spliced together so that the splice occurs at a point off center, an increase in stiffness of up to 40 percent is possible. This *off-center-spliced-joist* technique can result in reduced lumber size, increased spacing, or both. In addition, subfloor layout is greatly simplified.



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

However, the added cost of end trimming and splicing the joists must be considered. A Research report titled Off-Center-Spliced Floor Joists (143-5) is available from NAHB, 15th & M Streets NW, Washington, DC 20005.

Floor trusses are becoming more popular as alternatives to conventional wood frame floors. They are usually more costly but have the advantage of greater spans between supports, thereby creating greater floor plan flexibility. There are several different floor truss designs, some with open webs and some with a continuous plywood web. Open web trusses have the added feature of providing plumbing, wiring, and sometimes HVAC chases without drilling or cutting.

The major disadvantage of single-span floor trusses is the height of the trusses. In order to span greater distances, the truss must be much deeper than conventional 2x framing. This adds extra costs to sheathing, siding, stairs, etc. These, plus the extra cost of the floor itself, should be analyzed versus the value of the clear span.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

JVAH Floors

Innovative floor framing methods were used on several JVAH sites. Some were unique while others were known methods not normally used in the local area.

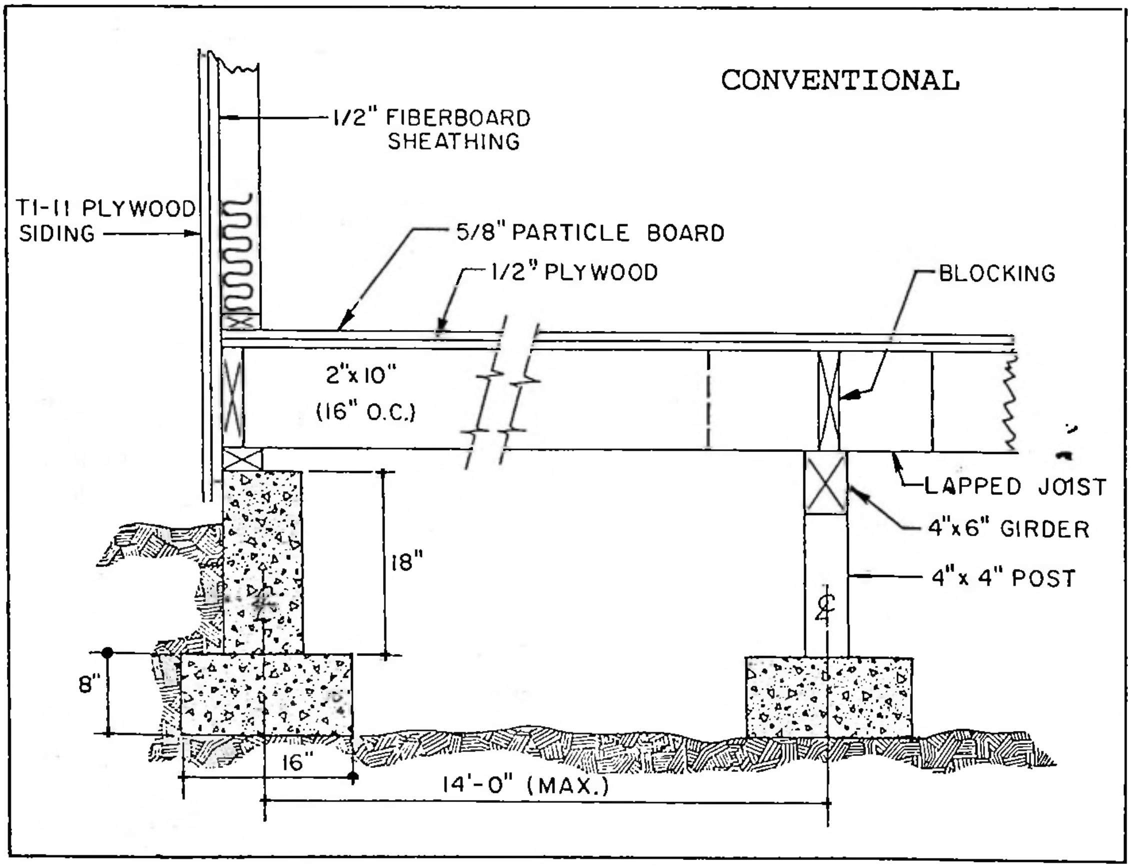
Tulsa, Oklahoma

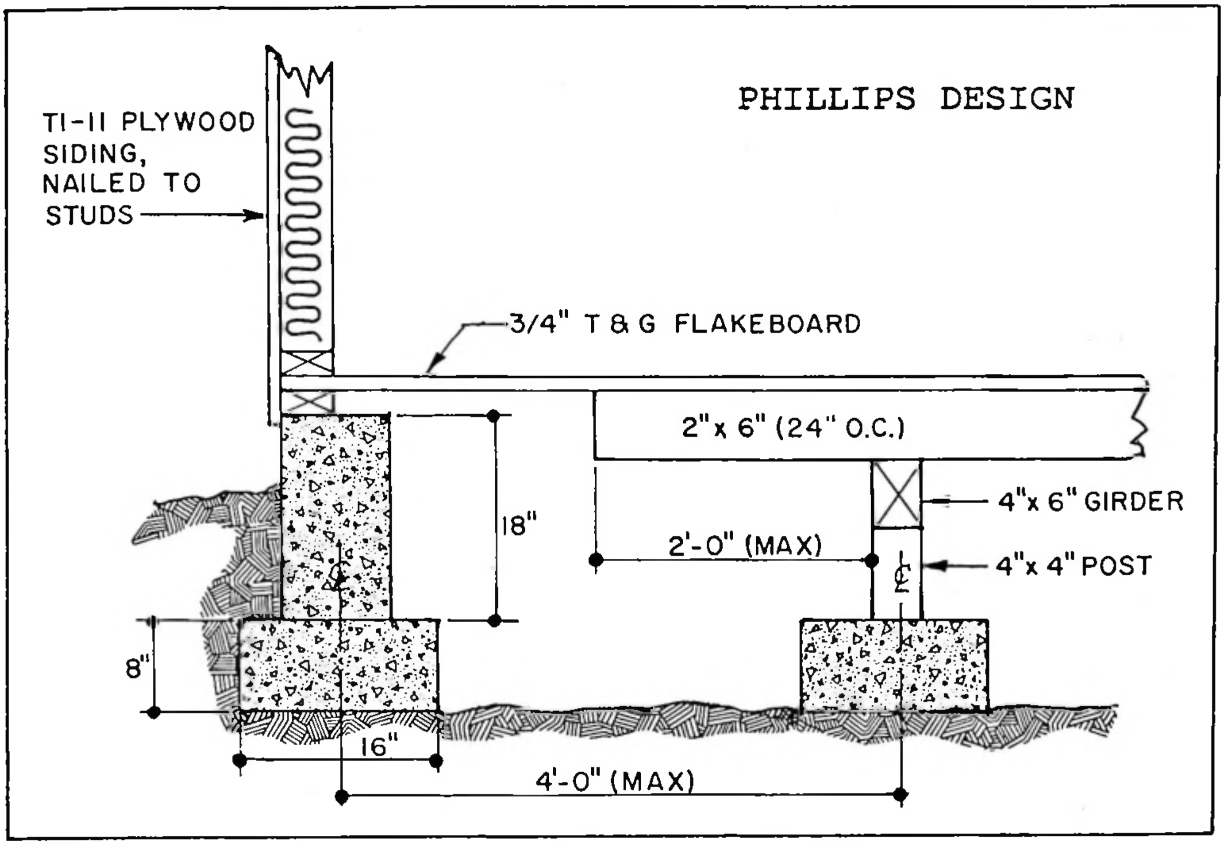
As discussed in the Foundation section, Wayne Hood built the Plenwood system in his demonstration homes. The wood frame floor portion of the system consisted of 2x8 floor joists spaced 24 inches on center with glue-nailed 3/4-inch plywood.

Lacey, Washington

John Phillips constructed one of the most innovative wood frame floors in the demonstration. Typically, in the Lacey area, the foundation/ floor system consists of a conventional spread footing, a cast-in-place concrete foundation wall, a post-and-beam center bearing girder, 2x10 joists spaced 16 inches on center, and a two layer sheathing/underlayment system.

Phillips designed and built a system that used 2x6s, spaced 24 inches on center, spanning about 8 feet between post-and-beam supports. Band joists were eliminated. Floor framing did not come into contact with the perimeter foundation at all. The first interior support girder was placed about 4 feet from the foundation wall and the joists cantilevered about 2 feet toward the foundation.





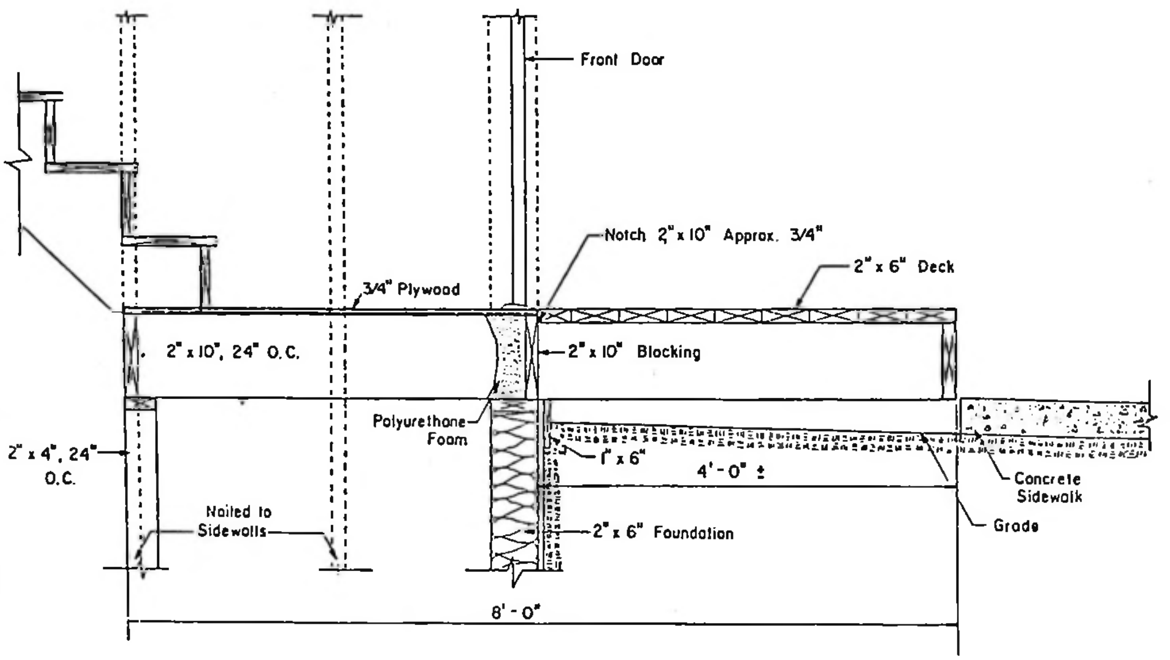
The 2-foot gaps at the ends of the floor joists and the 2-foot spacing where the joists are parallel to the foundation were easily spanned with 3/4-inch tongue-and-groove glue-nailed waferboard. Floor construction costs were reduced by an average of $852 when compared to the conventional floor.

Christian County, Kentucky

Pup Robertson also built an innovative floor system that saved $295 per house. Instead of the conventional 2x8, 16-inch on-center joists over a single center girder, he used two box girders spaced about 8 feet on center and 2x6 joists at 24 inches on center. He used 3/4-inch glue-nailed T&G plywood instead of the more conventional 1/2-inch underlayment.

Fairbanks, Alaska

Tom Webb designed and built a cantilevered front porch deck by continuing the interior stair landing joists through the front door opening. This eliminated deep porch footings and foundations which are very susceptible to frost heave in Fairbanks.



Cantilevered Front Porch
(Continuous 2" x 10")

WALLS AND PARTITIONS

The key to economical wall and partition construction is preplanning to eliminate unnecessary materials and labor. Carpenters usually find extra material is needed here and there to accommodate doors and windows.

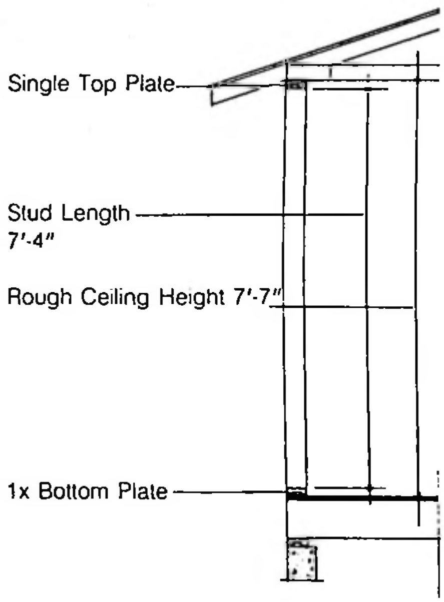
They may also follow traditional training by adding studs where partitions intersect exterior walls, blocking at mid-height of walls, double studs and headers at openings in nonbearing walls, and similar practices. Each of these excessive material uses is avoidable through proper attention in the planning stage. They add significantly to cost without benefit to the home buyer.

Cost savings will be greatest when the overall out-to-out dimensions of the house and the location of wall openings coincide with a module of 2 feet. This provides maximum use of materials that are available in 2-foot increments and reduces scrap and waste.

An important side benefit to preplanning will be education of the carpentry crew. When the crew has built a number of units in accordance with cost saving techniques presented in this section, less detailed instructions and fewer on-site modifications will be required.

Tilt-up wall construction continues to be the preferred method for reducing labor and material costs. Assembling wall sections to the greatest extent possible prior to erection is beneficial since materials do not have to be held up while they are being fastened. This includes framing and sheathing (if used), as well as siding, windows and exterior trim. Fabrication can be done on a shop table or right on the floor deck. Use end nailing, not toenailing, to fasten plates to studs.

OVE Techniques



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

Engineering analysis and testing have resulted in widespread acceptance of many changes in traditional wall framing techniques. Many of these OVE (Optimum Value Engineered) techniques were developed and tested by NAHB National Research Center.

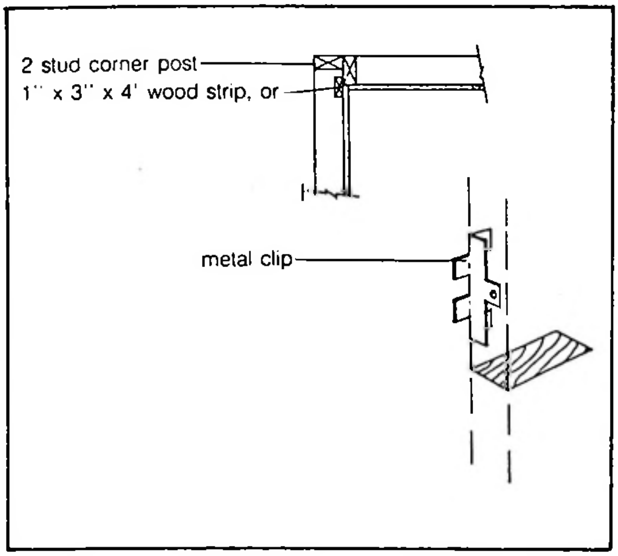
Building ***7'6" high walls*** instead of 8'0" saves approximately one course of siding or two courses of brick, 6 percent of wall insulation, 3 percent of painting labor and material, one tread and riser on a flight of stairs, and 9 to 12 inches of stair landing space.

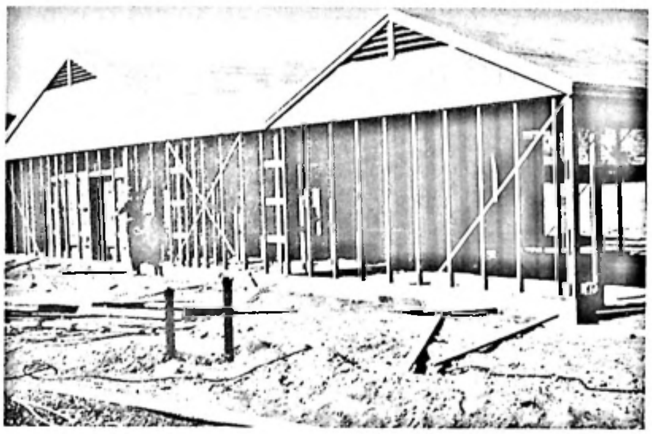
A lower ceiling height also increases the structural capacity of studs acting as a column. The savings in material and labor more than offset the extra labor to cut 6 inches from the top of the gypsum wallboard panels.

Placing ***studs 24 inches on center***, instead of 16 inches, reduces framing labor and material. The 24-inch on-center spacing is permitted in most areas of the country for one story and the second story of two story construction. Use of 24 inch spacing saves nearly a third of the regular studding.

Single top plates can be used when studs and trusses are in line on 24-inch centers so that the weight of the truss bears directly on the stud. Special connectors 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. This technique eliminates one-third of the plate material.

When studs sit directly over floor joists, the ***bottom plate*** is used only to facilitate alignment of the studs, and to provide a nailing base for wallboard, sheathing and baseboard, and not to carry weight from the stud





to the joist. Since the bottom plate doesn't have to be as strong, a 1x4 is sufficient.

Because the maximum load on the corner studs in an exterior wall is one-half or less than the load on a regular stud, ***two-stud corners*** are more than adequate structurally. The third stud in the normal three-stud corner post serves only to back up the interior finish, and can be eliminated. Metal drywall clips or wood blocks can be used to backup the wallboard.

Similarly, ***partition posts*** built into the exterior wall for attachment of interior partitions can be eliminated. The partition can be nailed to a mid-height wall block, and wood blocks or drywall clips can be used to backup the wallboard.

Ceiling nailers can be replaced with drywall clips. Since they secure the ceiling gypsum board to the walls, the clips offer the additional advantage of keeping the ceiling and wall gypsum board from separating. Mid-height "firestop" ***wall blocking*** can be eliminated. Wall plates, floor sheathing, and insulation provide sufficient constriction of air flow within the wall to minimize fire spread, and the blocking is not required for structural bracing.

Headers or lintels, and jack (jamb) studs which support them are required only where loads must be carried to the sides of window and door openings. If the loads don't exist, or if other members, such as roof trusses, joists, joist bands, large areas of structural sheathing, or second story headers carry all or part of the loads across the openings, headers can be eliminated or downsized.

Openings in nonbearing walls can have single 2x4's on each side to which windows and doors are fastened.

Headers and jack studs can also be eliminated in load-bearing walls when windows 22 1/2 inches or less in width are used and placed between the studs.

Other types of headers may be more economical than the single or double 2x8 header. ***Glue-nailed plywood box headers*** normally cost less and also provide extra space for insulation. These headers are formed by glue-nailing a plywood skin to one or both sides of framing members above openings in a load-bearing wall. Water resistant structural adhesives of the casein, urea formaldehyde, urethane or phenolresorcinol type should be used to glue the plywood, and nails spaced 6 inches or less along all frame members.

The face grain of the plywood must be oriented horizontally over the opening, and the top plate must be continuous across the opening. Jack studs are not necessary on openings 4-feet wide or less. Use American Plywood Association exterior grade AC plywood.

If used on the inside surface, butt gypsum board to the plywood, tape and spackle the joint, and apply a thin coat of spackling compound to any plywood rough spots or patches. When painted, there is no apparent difference between the plywood and gypsum board surfaces.

Manufactured ***plywood joists and trussed joists*** can also make cost-effective headers while providing room for extra insulation. Check with the manufacturer for engineered sizes and prices.

Brick veneer costs can be reduced by: starting the brick at floor joist level on 8-inch blocks resting on 16-inch footings, instead of below grade on 12-inch blocks resting on 20-inch footings; using other materials above and below windows and in areas less subject to deterioration, e.g., the gables and the top half of a wall; building the walls 7'6" high instead of 8 feet.

Single-layer panel sidings (plywood and hardboard) are available for application directly to studs, eliminating the need for a separate sheathing.

Returning gypsum wallboard to the windows and using drywall corners instead of using wood stool and casings saves money. Similarly, using drywall returns on bi-fold or bypass closet doors eliminates wood jambs and casings.

Providing a full width opening at the front, dimensioned to receive a standard width bi-fold or sliding door, eliminates jacks and studs beside the opening, and floor-to-ceiling doors eliminate framing and drywall over the opening. Drywall contractors often charge for a full wall even if only partially covered.

Interior nonbearing partitions can be built from 2x3 studs. Also, if floor sheathing is 5/8 inch or thicker, no blocks or joists need to be framed below nonbearing partitions. Where partitions are parallel with ceiling joists or roof framing overhead, use precut 2x4 blocks spaced 24 inches on center to secure the top of the partition and to provide drywall backup.

Cabinet bulkheads can be eliminated. Install ceiling high cabinets, or let the top of standard height cabinets be an extra "shelf".

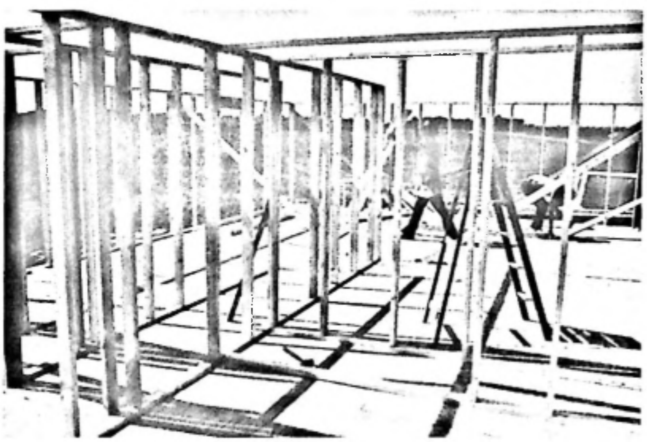
Light gage steel studs have been available for a number of years and are used extensively in commercial and high-rise apartment construction. They are usually installed by the drywall contractor. Steel studs are often cost effective, especially when lumber prices are high, but have not been widely used in single-family or low-rise multi-family construction.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

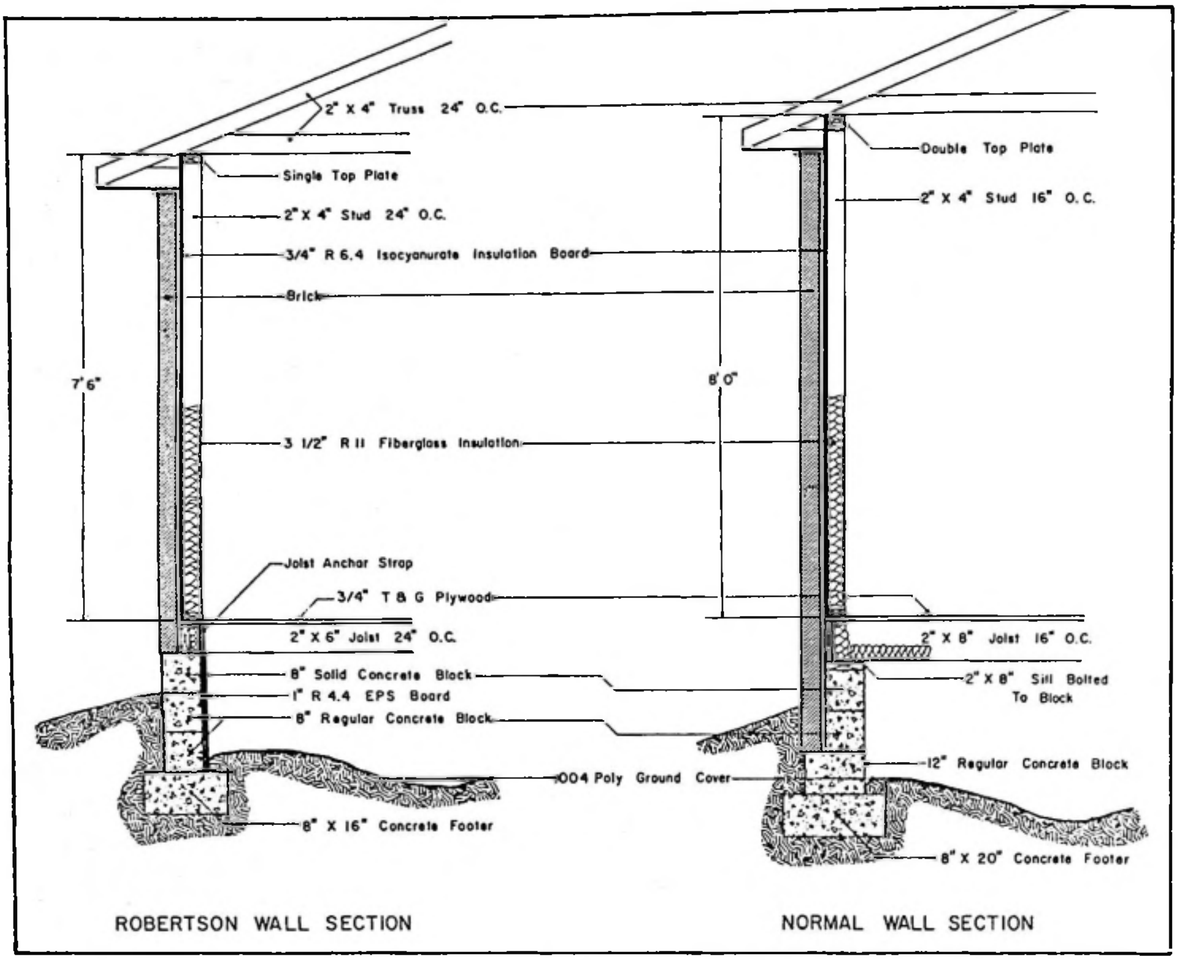
JVAH Walls and Partitions

Most JVAH sites used some aspects of Optimum Value Engineered wall systems to minimize costs. The most commonly used techniques were in-line framing with 24-inch stud spacing, single top-plates, 1x4 bottom plates, two-stud outside corners, metal drywall clips instead of wall and ceiling nailers, and elimination of headers and jack studs in nonbearing walls.

Christian County, Kentucky



Besides using OVE techniques which saved $448 per unit, Pup Robertson saved 3,000 bricks per house by starting the brick at the bottom of the wood floor instead of below grade, eliminating gable brick and reducing the wall height to 7'6"; moreover, since each house required less brick than normal, he was often able to buy odd-lot quantities at substantial savings. These techniques saved $1,685 per unit on brick veneer.



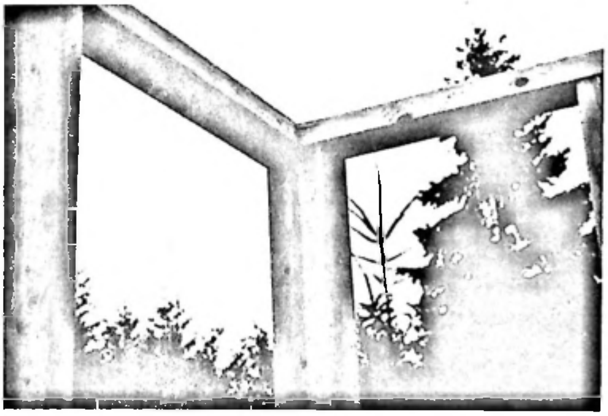
Fairbanks, Alaska	Tom Webb used 2x6 exterior walls and 2x4 interior partitions on 24-inch centers. Costs were reduced by over $1,200 per unit.
White Marsh, Maryland	Ryland Homes has been using efficient construction techniques for years. For the JVAH demonstration, modular housing units were used with 24-inch on-center wall framing, two-stud corners, and no headers in nonbearing walls. Costs were reduced by $850 when compared with more typically used 16-inch on-center framing.

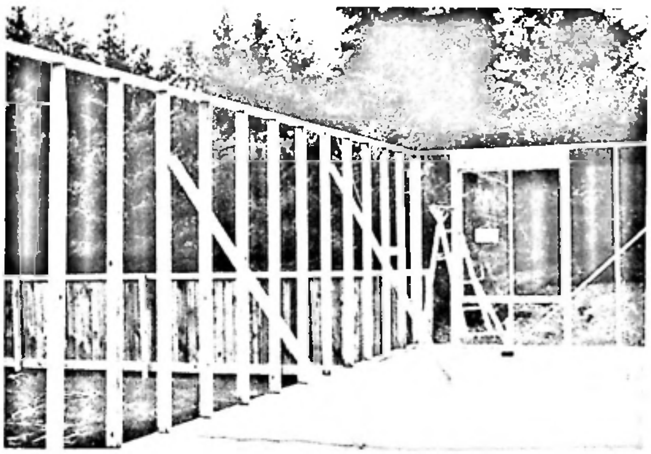
Charlotte, North Carolina

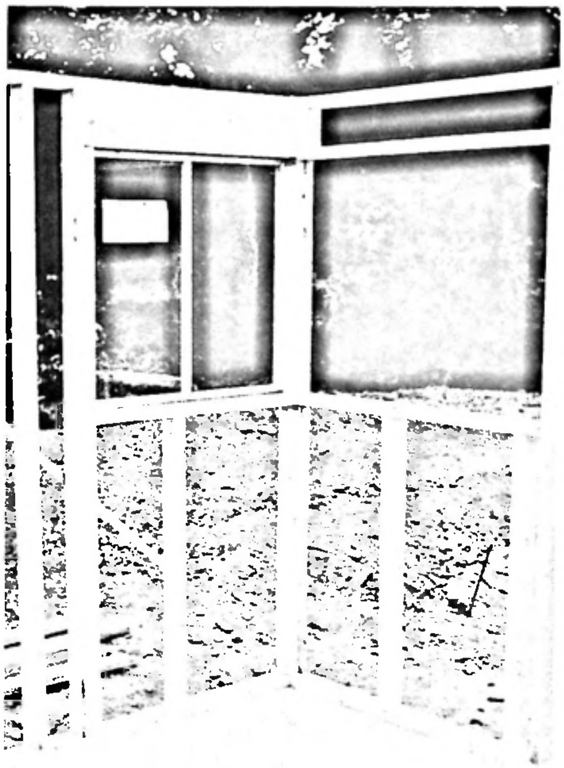
John Crosland had already adopted most of the OVE techniques. In addition to 24-inch on-center wall framing, he also used sections of plywood truss floor joists for window and door headers. This not only was less expensive than typical built-up wood headers, but also provided space for insulation.

Lacey, Washington

John Phillips used almost all of the OVE framing techniques in the demonstration homes. He also had a very innovative floor system (see floor framing section) and used single-layer plywood siding without a separate sheathing. He saved almost $1,200 per unit.







Knox County, Tennessee

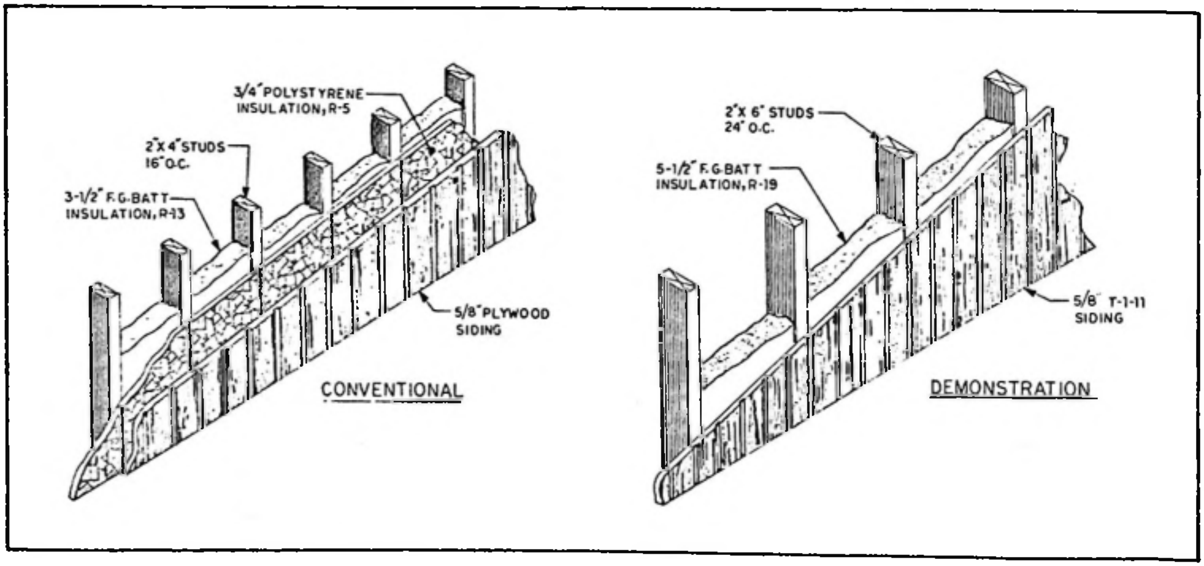
Phil Hamby reduced costs by $425 by using OVE framing techniques and single-layer plywood siding in his JVAH demonstration.

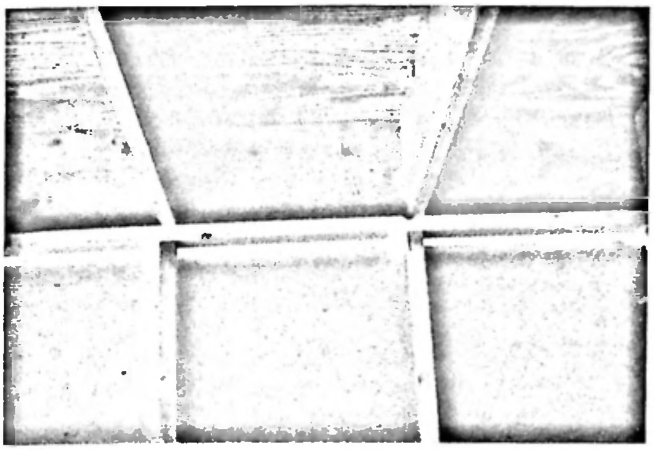
Phoenix, Arizona

Knoell Homes built exterior walls on 16-inch instead of 24-inch centers because the single-layer hardboard siding used required 16-inch stud spacing. However, most other OVE techniques (two-stud corners, elimination of partition posts, no headers over openings in nonbearing walls, elimination of soffits over kitchen cabinets, etc.) were used.

Santa Fe, New Mexico

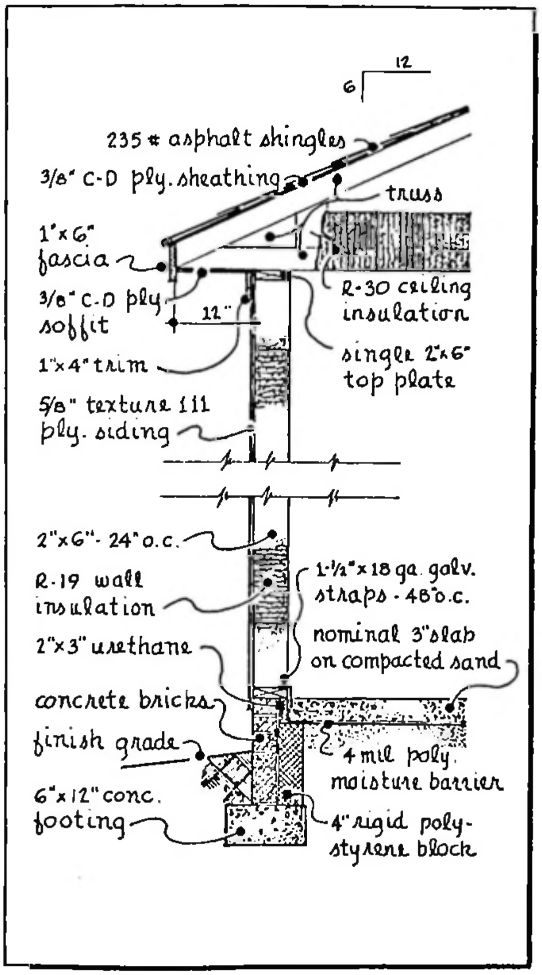
Chapman homes built exterior walls with 2x6 studs, 24 inches on center. He also used most other OVE techniques, including single-layer plywood siding. Exterior wall framing costs





were about the same as conventional 2x4, 16-inch on-center costs. But in order to get the same insulation R-value (R-19) with a 2x4 wall, costs would have been $460 per unit higher. Interior partition costs were reduced by over $200 per unit by use of OVE techniques.

Crittenden County, Arkansas



By using OVE techniques, Rex Rogers saved $495 per unit even though he used 2x6 exterior wall construction instead of the more typical 2x4, 16-inch on-center construction. He had been using OVE for years and has one of the most efficient framing layouts observed in the JVAH program.

Valdosta, Georgia

Gary Minchew has long been a proponent of the OVE framing system. His detailed cost recording system provided a unique breakdown of where costs were saved with OVE. Total reduction amounted to over $1,200 per unit when compared with conventional construction in the area.

Tulsa, Oklahoma

Wayne Hood used 24-inch on-center framing with two-stud corners on all nonbearing walls and partitions, saving $250 per unit.

Burlington, Vermont

Bill Hauke had been using OVE techniques in Vermont for years. He estimated that these methods saved him over $450 per unit in the JVAH In-fill Demonstration Project.

Mesa County, Colorado

Roger Ladd used two-stud corners and single-layer plywood siding on 16-inches on-center exterior walls. Partitions and common walls were framed 24 inches on center.

FIREWALLS

Growing pressures on land availability and housing affordability are resulting in an increase in demand for attached homes. Zero-lot-line configurations are becoming more popular for detached homes because of more innovative use of small lots. The principal added code consideration for attached and zero-lot-line homes is the requirement for fire barriers.

Requirements of the major model codes are not always clear and are often subject to local interpretation and/or amendment. It is important to understand that all major model codes have an "Alternate Materials and Systems" section and that local code officials have the discretion to approve alternate construction. Appropriate documentation is, of course, usually necessary.

To be acceptable, firewall constructions must be rated by a recognized testing laboratory in accordance with ASTM E119, Standard Methods of Fire Tests of Building Constructions and Materials. Many different one- and two-hour wall constructions have been approved and are listed in literature available from the Gypsum Association, 1603 Orrington Avenue, Evanston, IL 60201; the National Concrete Masonry Association, P. O. Box 781, Herndon, VA 22070; and other industry associations and product manufacturers.

For *zero-lot-line homes*, each unit must have an independent one-hour fire-resistive rating. The Standard Code (Southern) Uniform Building Code (ICBO), and the One and Two Family Dwelling Code (CABO), all require one-hour ratings for homes built less than 3 feet from the property line. The Basic/National Code (BOCA) requires a one-hour rating on exterior walls less than 6 feet from the property line. None of the codes permit unprotected openings through a firewall. Normal electrical, plumbing, and ductwork are generally allowed.

The most common one-hour firewall is of wood frame construction with 5/8-inch type X gypsum wallboard or gypsum sheathing attached to each side with 6d coated drywall nails 7 inches on center. Joists are required to be staggered at least 24 inches on center on each side.

For *attached homes*, a two-hour firewall is required, either as two separate one-hour walls or as a common two-hour wall at the property line. Check your local Code. The two-hour common wall typically built is a single wood frame wall with two layers of 5/8-inch type X gypsum wallboard on each side or concrete block. Two-hour walls typically have restrictions on electrical wiring, plumbing, and ductwork within the wall.

In addition to the firewall, some provision is required to block the spread of fire to the roof of an adjoining unit. For zero-lot-line detached homes, codes are somewhat vague because there is no adjoining roof.

In addition to confusing major model code firewall and roof treatments, some local codes require that firewalls be built of masonry construction. This requirement is prohibitive for factory-built construction.

As mentioned, three of the four model codes require a firewall if within 3 feet of the property line. The other code, BOCA, requires a firewall if within 6 feet of the line. If a home is built 37 inches from the property line (73 inches under BOCA), no firewall is needed.

If an easement for use of that narrow strip of land is assigned permanently to the house next door, a zero-lot-line effect is obtained without cost of a firewall or roof parapet. It will be worthwhile to check local interpretation of firewall/roof treatment requirements prior to construction.

Since the major model codes are difficult to interpret and have not seriously addressed detached zero-lot-line homes in many cases, a complete review and rewrite of all codes should be undertaken.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Three JVAH sites, (Lacey, WA; Everett, WA; and Santa Fe, NM), all built under UBC, ran into the problem of firewall and roof treatment requirements.

Santa Fe, New Mexico

In Santa Fe, the normal city requirement is a masonry firewall between attached garages, including a parapet above the wall. The builder obtained the Fire Resistance Design Manual from the Gypsum Association which shows wood frame firewalls.

In addition, he pointed to the 1,000 square foot per floor exception for roof fire treatment in UBC. These convinced the city that a common two-hour wood-framed firewall with no parapet or roof treatment was adequate.

Lacey, Washington

In Lacey, the city required either a parapet extending 30 inches above the roof or that all framing elements (trusses, wall plates, studs, etc.) within 5 feet of the two-hour separation wall be of one-hour fire resistance construction.

The builder, John Phillips, pointed out that none of the other major model codes had this requirement and that fire-resistive sheathing, installed at least 4 feet from the wall, provides adequate fire safety according to building code experts. The city accepted his documentation which resulted in substantial cost savings.

Everett, Washington

In Everett, zero-lot-line homes were built with one-hour fire walls. The city accepted the builder's documentation that type X fire-rated gypsum board under roof sheathing, within 4 feet of firewall was adequate to comply with the intent of the code.

ROOF FRAMING

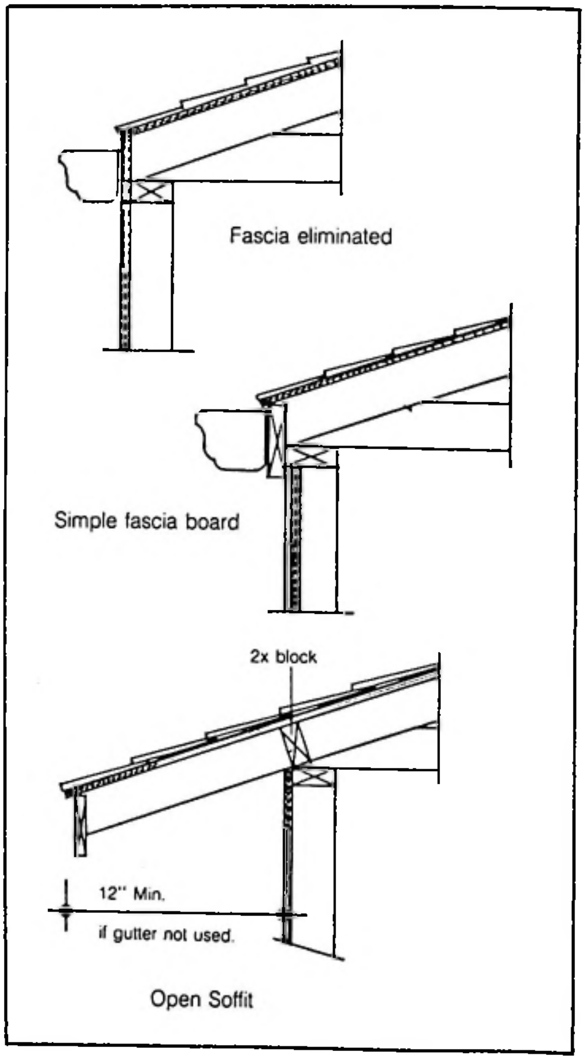
The standard roof truss has become the most common and most cost-effective method of roof framing. Light-weight trusses are the most highly engineered component in new home construction and form the basis of a very efficient roof system. They are easy to install and adapt to many basic designs. Therefore, if cost is the primary consideration, standard roof trusses are recommended.

The "in-line" framing concept discussed in the House and Lot Design section of this manual works very well with roof trusses. That is, the 24-inch on-center roof trusses align with the 24-inch on-center wall studs which in turn align with the 24-inch on-center floor joists. The key to this consistent alignment is to start all layout from the same corner.

Simplification of roof overhang and trim details, consistent with design and function, provides opportunities for cost reduction. For example, the *rake overhang* is essentially nonfunctional on a gable end roof. A simple fascia board at the siding/roof junction serves to cover the rough edge of the siding and conceal inaccuracies of fit. Several of the nation's largest builders use this detail on all their production homes.

Roof overhangs are desirable for most designs and provide rain protection for the front and rear of the house. They also can provide summer shading for some windows. When an overhang is used, an inexpensive "open" soffit will eliminate much of the cost of the traditional cornice. All trim details on the underside of the overhang may be eliminated, leaving the truss or rafter tails exposed. Blocking between trusses or rafters and a 1x6 fascia board are the only finish items needed. If soffit venting is needed, screening between trusses or rafters can be used instead of blocking.

Three-eights-inch *plywood roof sheathing* with metal plyclips is an acceptable alternative to 1/2-inch plywood.



EXAMPLES FROM THE DEMONSTRATION PROJECTS

Many of the demonstration projects used trusses and several used the simplified trim details described above. However, several projects also used vaulted ceiling rafter framing to provide more open space in relatively small homes. In some houses the vaulted ceilings provided lofts and expandable space.

Lincoln, Nebraska

Karl Witt used vaulted ceilings with clerestory windows in the living area of his homes. This provided a degree of passive solar heating and natural lighting.

Everett, Washington

Vaulted ceilings with clerestory windows and open soffit overhangs were used in Everett.

Mesa County, Colorado

Instead of the more typical 1/2-inch plywood roof sheathing, Roger Ladd used 3/8-inch plywood with metal plyclips.

PLUMBING

An excellent opportunity exists to reduce construction costs through innovative plumbing. But plumbing is also one of the more difficult areas to get innovations adopted. In spite of the fact that present model plumbing codes are updated periodically, the process is lengthy and uncertain, so none of the model codes reflect current state-of-the-art.

In addition, comprehensive model plumbing codes cover all types of buildings and are overly complex for dealing with relatively simple requirements of single family dwellings.

The four major model plumbing codes are the BOCA Basic Plumbing Code, the SBCC Standard Plumbing Code, the NAPHCC National Standard Plumbing Code, and the IAMPO/ ICBO Uniform Plumbing Code.

Many local jurisdictions use one of the model codes with their own modifications. In almost all cases, local modifications are more restrictive in material and design than the parent model code.

Confronted with these facts, the NAHB National Research Center has compiled a state-of-the-art manual for residential plumbing. This effort, sponsored by NAHB and HUD, resulted in Residential Plumbing Guidelines which contains all requirements to assure a safe, functional, durable, and cost-effective residential plumbing system. NAHB submitted proposed code changes to the Council of American Building Officials (CABO) in 1984, and the proposed changes were adopted in January, 1986.

Substantial changes were made in some areas of the code. Following is a synopsis of the more relevant changes that affect the installed cost of plumbing.

Drains

The load on the drain, waste, and venting (DWV) system is determined by *drainage fixture unit (d.f.u.) values.* This is a measure of the probable discharge into the drainage system by various types of plumbing fixtures and is used to size DWV piping systems.

The newly adopted d.f.u. values are, in every case, less than those in the old CABO code. The old values are basically the same as those used in the other major model codes.

The new CABO code includes d.f.u. values for plumbing fixture groupings. These values are less than the sum of individual fixture units, which recognizes the fact that d.f.u. values are not additive when the probability of simultaneous use is very, very low.

The new CABO code allows 75 foot *spacing of cleanouts* versus 50 foot spacing in the old code. This is consistent with standard available snake lengths.

The new CABO code allows *smaller size traps and trap arms* for some fixtures. Below-grade drain pipe minimums were reduced from 2 to 1 1/2 inches in diameter because of power driven cleanout equipment capabilties.

In practice, large diameter drain pipe is often perceived to be desirable. However, with the lower discharge rates of modern residential fixtures manufactured to water conserving standards, large diameter drains have very low flow rates which promote deposition of solids.

Smaller diameter pipe with higher flow rates actually provides improved transport characteristics. This is a classical case where bigger is not necessarily better and where traditional thought is outdated.

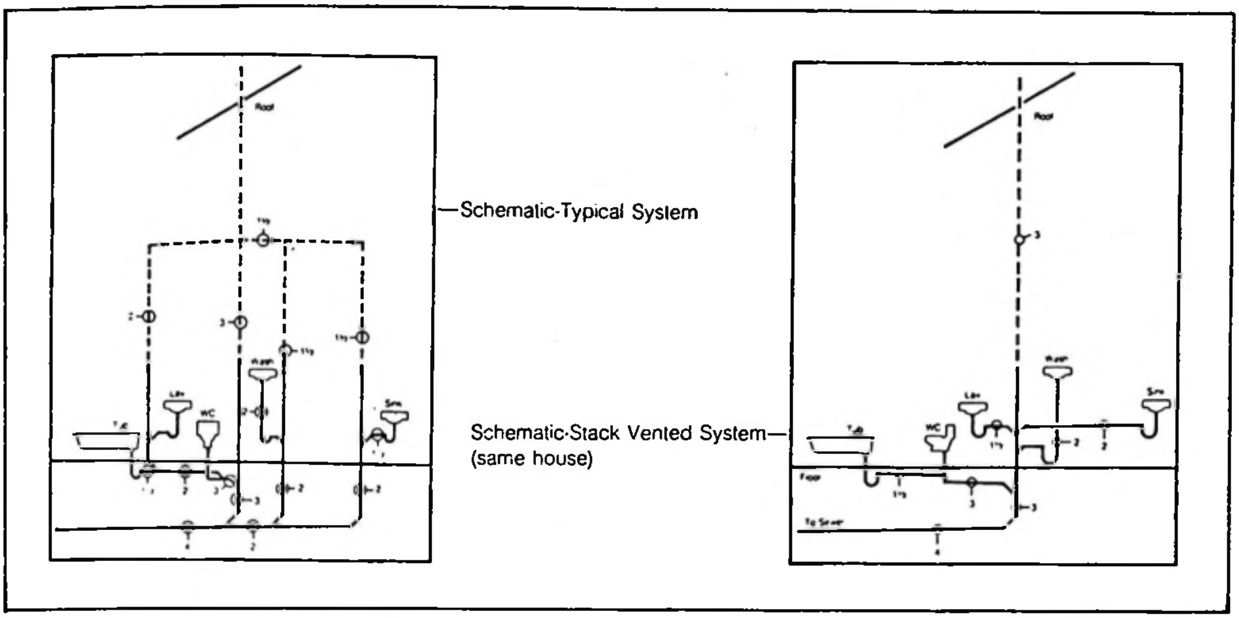
The new CABO code allows an *increase in maximum trap arm lengths.* This provides a degree of architectural flexibility such as the location of kitchen sinks under windows.

Vent Systems

The purpose of the venting system is to maintain atmospheric pressure within the DWV system and to provide venting of gasses by circulating air throughout the system. At low flow rates, characteristic of residential construction, vent pipes need only be of small diameter. In addition, vents need not penetrate the roof. Rather, vents can extend through an exterior wall or roof overhang and terminate downward.

According to the new CABO code, "A *common vent* may be used for two waste fixtures connecting at different levels in the stack but within the same branch interval, provided the vertical drain is one pipe diameter larger than the upper fixture drain, but in no case smaller than the lower fixture drain. The vertical piping between fixture connections serves as a wet vent for the lower fixture." (Section P-2207.7.1, One and Two Family Dwelling Code).

The CABO code also states, "***Stack venting***, with certain preconditions relating to drainage loads and ventings, fitting types and sizes, and placement of connections, shall be permitted as a system that allows fixtures and fixture group to be independently connected to a soil or waste stack without individual fixture venting." (Section P-2207.8, One and Two Family Dwelling Code).



—Schematic-Typical System

Schematic-Stack Vented System—
(same house)

The significance of these paragraphs cannot be overlooked inasmuch as the total cost of plumbing DWV in an average home can be reduced substantially. When combined with other DWV innovative practices, total costs have been reduced by as much as $400, depending on which code was used as the comparison.

Because of this (and the fact that the techniques have been proven for many years to be safe and reliable), it will be well worth while for builders to push for adoption of the plumbing section of the CABO code.

Water Service and Distribution

As with DWV piping, water service requirements in the CABO code have been changed significantly toward cost reduction and efficiency. Health standards have been maintained in all cases.

In all major model codes ***acceptable water service pipe*** materials include copper, galvanized steel, PVC or CPVC plastic, polyethylene plastic, and polybutylene plastic. Some local codes are more restrictive, especially in use of plastic pipe.

The lack of competition in materials often tends to keep the cost of the only acceptable materials high. If for no other reason, a variety of acceptable materials is desirable.

Section P-2405.3 in the new CABO code, ***individual fixture stops*** are considered optional for single-family housing. Experience has shown that individual fixture stops often deteriorate between time of installation and time of their eventual use to the degree that they may require service or replacement. They also create potential sources of leaks. This is a case where possible convenience is offset by more probable inconvenience. In any case, convenience items should not be codified.

Water supply fixture unit (w.s.f.u.) values have been changed in the new CABO code and are consistent with established values in fitting standards. The new w.s.f.u. values for both hot and cold water provides for selection of pipe sizes based on reasonable estimates of peak demands. Measurements made in numerous field and laboratory tests have confirmed these values.

Minimum size of ***fixture water supply pipes*** for all fixtures, except dishwashers and lavatories, is 3/8 inch in the new CABO code. For dishwashers and lavatories, minimum size is 1/4 inch. Fixture group main minimum sizes are either 3/8 inch or 1/2 inch, depending on number and size of fixture branch pipes connected.

The CABO code also recognizes the different *flow rates* of different pipe materials and the w.s.f.u. values vary accordingly. Therefore, supply pipe often can be reduced in size depending on the number and type of fixtures.

The significance of the new CABO One and Two Family Dwelling Code cannot be overemphasized. Studies have shown a total cost reduction in supply piping of as much as 24 percent even when the same piping material is used.

For more information on the innovations discussed herein, write the Council of American Building Officials, 5203 Leesburg Pike, Suite 708, Falls Church, VA 22041.

Other Cost Saving Techniques

There are methods to reduce plumbing costs regardless of code restrictions. Some may require negotiating with the plumbing subcontractor to get full benefit, others may require market evaluation to determine consumer acceptability.

Cluster the plumbing. This cost-saving design principle is to arrange plumbing groupings back-to-back in a common wall and to shorten distances of other plumbing runs as much as possible. In multiple-story buildings, fixtures should be located over each other to minimize DWV and supply piping. Savings can amount to as much as 10 percent. Plumbing subcontractors often bid on a "per fixture" basis so the value of clustered plumbing may not be passed on without negotiation.

White plumbing fixtures are less expensive than colored fixtures. A savings of $40 to $75 per bath can be realized. From a consumer standpoint, any accent or decorating color can be used with white fixtures.

Consider fiberglass bathing modules. They often are less expensive than other bathtub/shower materials.

Wall hung lavatories can reduce costs although vanities have become standard. Wall hung units may be a marketing problem, but they should be considered, especially in powder rooms and/or second bathrooms.

Size water heaters according to intended use. Smaller homes intended for small families do not need large water heaters. Thirty-gallon gas or 30- to 40-gallon electric water heaters are generally adequate. Also, water heaters with a five-year warranty cost about $20 less than units with a ten-year warranty. This reflects an additional five-year insurance policy, not the basic construction of the water heater.

Consider polybutylene supply piping. This material is flexible and, therefore, requires only about 1/3 the number of fittings as rigid pipe materials. It normally costs much less to install and has some advantages in flow characteristics. Field studies have shown cost savings of between 30 and 50 percent.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Portland, Oregon

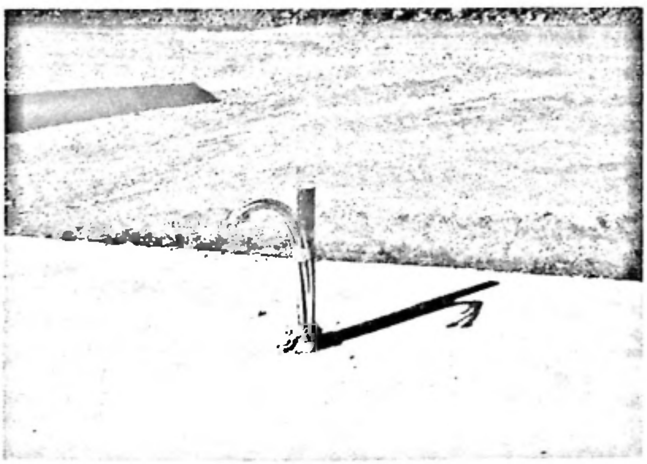
The Portland demonstration subdivision was arranged in clusters of four detached units. The city allowed one 1 1/2-inch PVC water line to run from the main to each cluster and 3/4-inch PVC from there to each unit. This was instead of one 1-inch line from the main to each unit. Cost savings amounted to $32 per unit.

Crittenden County, Arkansas

Rough plumbing was installed in a trough above the slab so the plumber would make only one site visit. All plumbing was clustered to reduce DWV and supply pipe lengths. A standardized DWV plumbing "tree" was used; therefore, much of the DWV system could be prefabricated. The plumbing wall was prefabricated with supply pipe and DWV installed. Polybutylene plastic pipe was used instead of copper. Total plumbing cost savings averaged $182 per unit.

Santa Fe, New Mexico

Polybutylene supply pipe, fiberglass bathtubs, and cultured marble lavatory/vanity tops were used instead of copper pipe, cast iron bathtubs with ceramic tile surrounds, hardboard vanity tops, and ceramic lavatories. Total cost savings amounted to $367 per unit.



Tulsa, Oklahoma	Use of polybutylene supply pipe reduced costs by about $100 per unit.
Phoenix, Arizona	Polybutylene supply pipe was used instead of copper, reducing costs by $65 per unit.
Valdosta, Georgia	Gary Minchew redesigned his homes to cluster plumbing in a central area, thus reducing DWV and supply piping. Because the plumber would not reduce his total bid, Minchew hired his own master plumber and found that his costs were reduced by an average of $400 per house.
Christian County, Kentucky	The builder used CPVC rigid plastic pipe for hot and cold water service versus copper, thereby reducing costs by about $105 per unit.
Burlington, Vermont	Polybutylene water and PVC DWV pipe was used. Reduced size vents and one water main per four units reduced costs.

ELECTRICAL

Electrical codes and their implementation are normally not very flexible. But costs can still be reduced by several methods within the codes.

Floor plans can often be adjusted to reduce electrical costs by ***reducing length of wiring*** or eliminating outlets while staying within the code. For example, since one outlet is needed for each 12 feet of wall, shortening or eliminating walls or moving door locations can reduce wiring, receptacles, switches, etc.

If all points requiring ***heavier appliance circuits are clustered*** and located close to the distribution panel, expensive heavy cable can be minimized.

Check the house during construction to make sure extra outlets are not arbitrarily installed. ***Relocate closet doors*** or other openings to avoid short walls over 24 inches wide which will require an outlet. Remember outlets are not required in hallways.

In some locations, entire homes are traditionally wired with #12 wire and 20-amp devices for general wiring. However, most codes allow the bulk of a house to be wired with ***#14 wire and 15-amp devices.***

Each required lighting point can be switched by a ***single switch.*** Also, bath fans can be switched with the bathroom light. Light fixtures that are not required by code can be pull-chain operated and need not be separately switched.

Smaller homes do not need heavy service load centers. Many can be served by a ***100-amp load center.*** A switched receptacle may be substituted for overhead lights in habitable areas. Only one light fixture is required in a ***basement.*** ***Attic storage*** or equipment service areas require light fixtures. Otherwise, attic lighting is not required.

Extra branch circuits are often routinely installed by electricians to simplify the arrangement of breakers in the panel. Maximize the number of devices on a circuit, and normally one or two circuits per home can be eliminated.

Separate circuits are not required for the refrigerator or garbage disposal. Extra circuits cost about $25 each for additional home run wiring and breakers.

Heavy ***240-volt circuits*** are required for the range, clothes dryer, water heater, electric furnace, and heat pump or air conditioning unit. If house design permits, locating as many of these heavy circuit appliances near the load center will reduce costs. The large feeder cable required for an electric furnace is very expensive. In addition, if the furnace is located near the breaker panel, a separate disconnect is not required at the unit, saving between $75 and $100.

Plastic utility boxes reduce costs by about $1 per wiring point and are allowed by most codes.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Phoenix, Arizona

Homes were designed with duplex outlets located at points of probable use rather than the arbitrary 12 foot minimum. About three outlets per house were saved. Because extra care was taken not to eliminate useful outlets nor to endanger safety of the occupants, the city building department allowed the variance.

In addition, because the units were small and expansion possibilities few, service entrance panels were reduced from 200 to 100 amp. Total electrical costs were reduced by $108 per unit.

Santa Fe, New Mexico

As in Phoenix, the builder was required to comply with all electrical code provisions except the arbitrary spacing of outlets. A well-thought-out layout was submitted based on logical use patterns along with the rationale for outlet locations.

In addition, garage ground-fault interrupters were loop-wired to bathroom outlets, thereby eliminating ground-fault interrupters in bathrooms. Bathroom exhaust fans were eliminated along with overhead light fixtures. Total electrical savings amounted to $320 per unit.

HEATING, VENTILATION, AND AIR CONDITIONING

Because HVAC system design is complex, judgement on system type, size, and location of ducts is often left to the expert -- the HVAC subcontractor. But the builder should understand some basic facts to insure that the most efficient, cost-effective system available is being installed.

Select the most appropriate economical system according to home design, local climate, fuel availability, and market preference. If a ducted system is to be used, a concise guide is available from the National Association of Home Builders, 15th & M Streets, NW, Washington, DC 20005. Titled Residential Duct Systems, this guide describes the most efficient duct methods according to fuel, type of equipment, operating efficiencies, and relative cost.

Design starts with accurate heat loss calculations (and heat gain for cooling). This is the only real basis for selecting equipment and designing the system. Too often equipment is selected based on past experience and judgement.

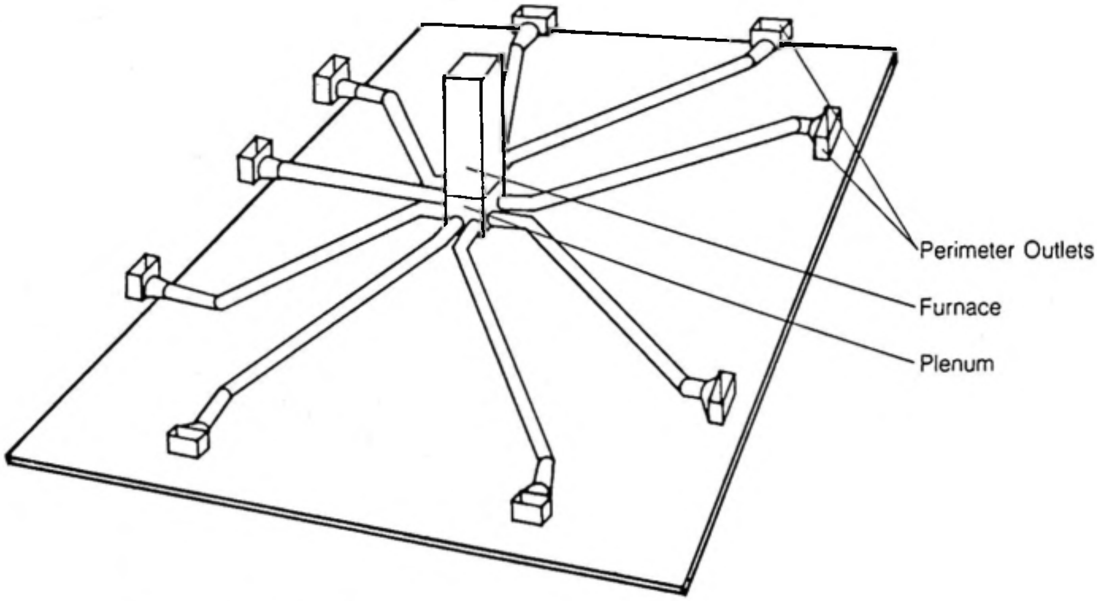
But, since each home design is unique, the HVAC system should be tailor made for that home. Guidelines on how calculations are made are presented in the Residential Duct Systems manual mentioned above as well as in the Insulation Manual for Homes and Apartments, also available from NAHB.

The standard calculation procedure used in the HVAC trade is in Manual J, Load Calculation for Residential Winter and Summer Air Conditioning available from Air Conditioning Contractors of America, 1228 - 17th Street, NW, Washington, DC 20036.

Avoid the tendency to oversize HVAC equipment. Some believe that if a certain size equipment is adequate based on proper calculations, a size larger will be even more desirable. Since the incremental cost of upsizing appears not too excessive, it is tempting to oversize. However, equipment based on sound heat loss-gain calculations is almost always more efficient and uniform in heating and cooling than oversized units. Also, be aware of unit efficiency.

For each 1/2-ton *heat pump or air conditioning reduction*, equipment and duct costs can be reduced by about $275. Wiring costs may also be reduced since a lighter circuit may be possible.

Downsized or redesigned duct systems will be possible in energy-efficient homes where HVAC equipment is smaller. In addition, the system will perform better since proper velocity and air flow will be maintained. Another standard guide for residential duct design is Manual D - Duct Design for Residential Winter and Summer Air Conditioning, from the Air Conditioning Contractors of America, 1228 17th Street, NW, Washington, DC 20036.



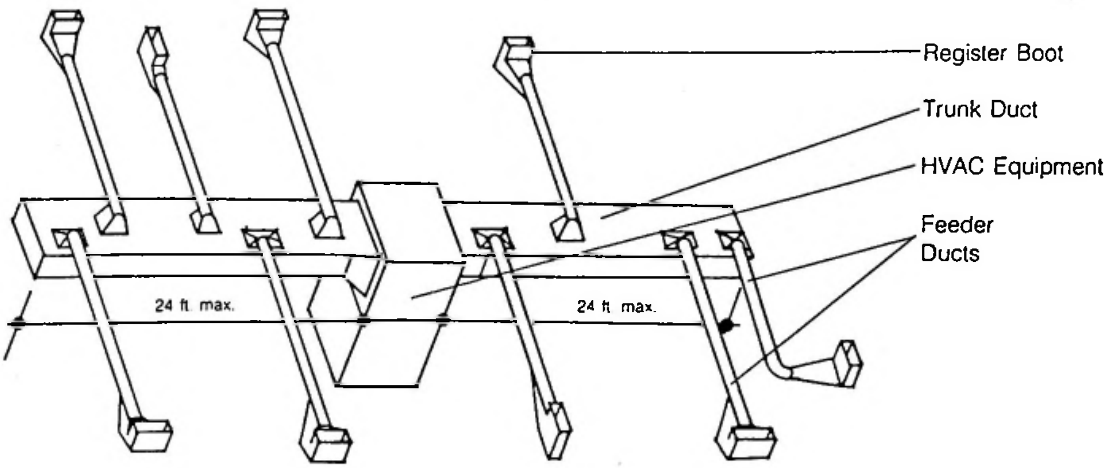
Typical Radial Duct System

In small, single-story homes with a central hall that abuts all living areas, consider using a ***dropped-hall ceiling plenum*** system. In this system, the hall ceiling and walls are drywalled as usual. Then another ceiling, dropped 6 inches to 8 inches below the conventional ceiling, is framed and drywalled, thus providing a plenum for air distribution.

High inside wall registers to each adjoining room are connected to the plenum by a short sheet metal boot through the wall. Although the system described has worked well in many installations, some local inspectors insist on sheet metal ducts within the ceiling cavity. If so, the system is still more cost effective than most.

The CABO 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 equipment generally exceed this temperature limit.

Radial duct systems are often the simplest duct systems to install. Branch ducts connect directly to the equipment plenum without trunks. Radial systems are typically installed where it is not necessary to conceal the duct work and where the equipment is centrally located. The basic simplicity of the system provides cost savings through reduced materials and less labor.



Extended Plenum Duct System

In smaller, well-insulated homes where central air conditioning is not required, *electric baseboard heat* with individual room thermostats offers significant construction cost savings, and depending on comparative fuel costs and availability, may offer operating cost savings because of the ability to "zone" heat the house.

One very innovative heating/cooling system that has enjoyed some regional success is the ***underfloor heating/cooling plenum***, being marketed by the wood industry under the name "Plenwood." Instead of using heating and cooling ducts, the entire underfloor space is used as a sealed-plenum chamber to distribute warm or cool air to floor registers in the rooms above.

A downflow forced air heating and/or cooling unit maintains slight air pressure in the plenum, assuring uniform distribution of conditioned air throughout the building with few or no supply ducts. Studies have shown that the initial costs of the Plenwood system are typically about 10 percent less than conventional ducted systems. For more information on the Plenwood System, write the American Plywood Association, P.O. Box 11700, Tacoma, WA 98411.

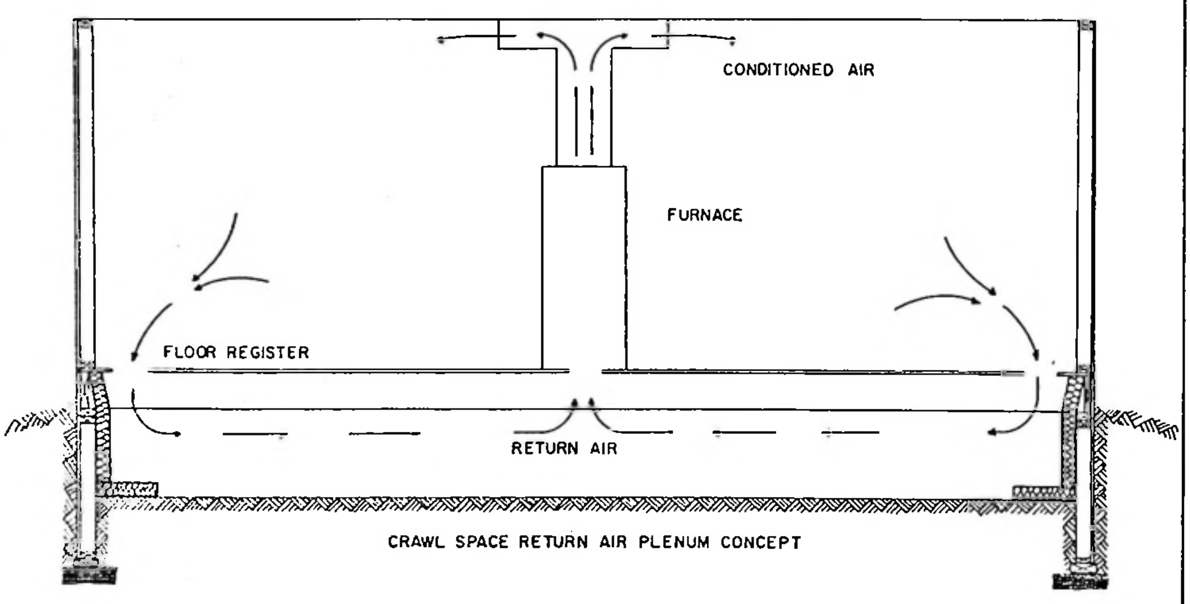
Non-ducted range hoods cost $20 to $40 less, eliminate a scheduling problem, and are more energy-efficient than ducted systems. However, humidity control and indoor air quality should be considered.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Several of the JVAH builders used innovative HVAC systems to reduce costs. In *Santa Fe* and *Phoenix*, bathroom ventilation fans were eliminated, saving about $150 per unit in ventilation and electrical wiring. In *Crittenden County, Arkansas*, the builder used the ductless dropped ceiling approach to air distribution in homes with central air conditioning.

In *Christian County, Kentucky*, a radial duct system was used instead of one large trunk line throughout the center of the crawl space with lateral ducts. This system saved an average of $125 per house.

The most innovative HVAC system built in the JVAH program was in *Tulsa, Oklahoma*, where the Plenwood system described earlier was installed. Wayne Hood used the underfloor area as a ductless return air plenum (See Footings and Foundation Section) with a pressure treated wood foundation. Hood estimated that foundation, floor and heating/cooling costs were reduced by a total of $1,470 per unit.



CRAWL SPACE RETURN AIR PLENUM CONCEPT

BUSINESS/MARKETING

An important means of achieving affordable housing is by running an efficient business. Good business planning, organization, and control are essential to keeping costs as low as possible.

Because affordable housing construction may require regulatory changes and relief from the community, it becomes very important that resultant cost reductions are not offset by business and job site inefficiencies.

Production planning and control combine, in the best possible way, the resources available. This will assure that management, money, manpower, machines, materials, and marketing are integrated in the best way possible to produce affordable housing when the market wants it.

Planning

Hitting the right market at the right time, with the right product, can save thousands of dollars in carrying costs on land, infrastructure, sales centers, model homes, advertising, office overhead, etc. So careful market research is important.

All JVAH builders realized that the primary reason for building affordable homes was that they were priced for the largest unserved market segment in their respective communities. Some found they grossly underestimated the demand. Their buyers included those who could afford more expensive homes but preferred the JVAH units.

But, even if market potential for affordable housing may appear to be obvious, there are still many decisions that must be made and, when possible, contingencies planned for. Therefore, long- and short-range goals should be developed. Questions that may be helpful in formulating company goals include:

- What markets are not being served today?
- What can be done if inflation increases building costs?
- What features will produce significant market advantage?
- What expensive features are unnecessary for the target market?
- What if interest rates increase? ..decrease?
- What related business could be entered successfully?
- If the firm were to redesign its construction methods from scratch, what techniques would be adopted?

In an affordable housing market, faster turnover will reduce land and infrastructure finance carrying costs. Land should be zoned for higher densities than in upper-end housing. Designs will be smaller, simpler, and more production-oriented with fewer options. High-speed production equipment and techniques are appropriate. Less skilled, less knowledgeable employees of all types can perform high-quality work on the simpler tasks required in lower-cost houses. Mass media advertising, open houses, and sales centers may be appropriate to this market.

Organization and Control

Substantial savings can be gained by organization and control of direct costs -- material, land, labor -- and indirect costs -- marketing and sales, finance, equipment depreciation and maintenance, and management.

Labor costs can be controlled by preplanning and scheduling of work, using properly-sized crews, good supervision, and instilling high-quality standards in workers. See the "Production Planning and Control" and "Labor Cost Control and Reduction" sections in Construction Cost Control, available from NAHB, 15th and M Streets, NW, Washington, DC 20005.

Methodical *preplanning of work* reduces lost time. For example, a carpentry crew can frame a wall faster if the crew leader has detailed pull lists, cutting lists, component lists, and wall layout drawings, than if the leader has to do all the thinking on the site while his crew awaits orders.

Efficient scheduling saves time, and "time is money." The longer it takes to build a house, the greater the time-related costs which are incurred -- construction loan interest, insurance, security, overhead per unit, maintenance and rate of capital utilization.

The optimum schedule is one that is reasonably attainable with some effort. The complexity of the scheduling system should not exceed that required for adequate control.

The most *efficient construction crews* usually have three members, although larger crews can be efficient if they form smaller work groups to do the majority of their tasks. One skilled worker on each small crew is usually enough. Having too many skilled people usually means the crew is being overpaid. Specialization improves 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 the task only once every few weeks.

This is why in many cases a subcontractor, although he adds overhead and profit to his labor cost, still costs the builder less for a particular task than the builder's own crew; the subcontractor is faster because he specializes in one task.

Good supervision saves money. A crew leader must be able to provide clear directions and keep his men working when he himself is planning, thinking, or doing his own task. Higher level supervisors should make scheduled inspections from inspection checklists.

At each level, a supervisor should be knowledgeable enough to instruct his workers on how to accomplish any of his assigned tasks. He should consistently demand the highest quality work so that workers learn to "do it right the first time" in order to reduce expensive callbacks and rework, and to enhance the company's reputation. He should praise good work and effort, but make the employees redo all substandard work.

Material costs can be controlled by accurate estimating, source selection, ordering, expediting, receiving, handling, and inventory control. Careful estimating reduces waste and delays due to material shortages. Effective source selection techniques are important, such as requests for bids which evaluate payment terms, lead times, and delivery service, as well as price.

Maintaining histories of supplier performance -- price, quality, service, willingness to expedite late shipments, and response to claims for shortages and damages -- is useful.

Purchase orders should be used to ensure that the price, terms, and conditions are explicit so that suppliers can be held to every condition later. Invoices received from suppliers and subs should be checked against purchase orders.

To *evaluate suppliers* for future purchases, records should be kept of all past purchases, including quantities, prices, delivery time, quality, and any problems encountered. Suppliers should load material in such a way that when unloaded, that which is to be used first is on top. They should place it on the construction site where it will minimize handling labor. They should deliver the right amount of material to the right place at the right time. They should protect the material from weather, and, at the builder's request, band it together for security.

On stocked items, *economic order quantities and reorder points* based on past usage and predicted future demand, should be calculated to minimize inventory carrying cost.

Estimated quantities and prices should be compared with actual quantities used and prices charged with variances calculated for quantities, prices, and total material costs. Positive quantity variances may mean too much material is being sent to the site which frequently results in extra waste, pilferage, and handling costs. Negative quantity variances mean there have been shortages which may have delayed production and required expensive emergency orders.

Land costs should be controlled as carefully as those of labor and material. A "quantity discount" -- low price per lot -- often can be gained by purchasing a large tract of land, and if not used immediately, the land may increase in value. On the other hand, it may depreciate if adjacent land is used for an industrial or commercial purpose. In addition, the longer the land is held, the greater the interest carrying cost, especially if some investment has been made in roads and utilities, etc.

Similarly, if a developer installs the infrastructure for an entire development at one time, he may receive lower prices from his subcontractors. However, he will also have to carry the interest on a large investment during the entire construction period. For this reason, and to reduce the investment required, many developers phase infrastructure installation. Also, if conditions stall sales, the developer is more likely to survive until sales pickup. Because of this risk, many builders stay out of land development entirely and buy developed lots as they need them.

Indirect

Control of indirect expenses can reduce the overhead allocation applied to each housing unit.

Marketing and sales expenses must be carefully budgeted and controlled. Advertising must be aimed at the particular market segment that fits the product, and the proper advertising channels used to reach potential buyers. In some developments, a sales center which later becomes a community building is an effective marketing tool. In other developments, low unit prices are most important, and amenities such as pools, community buildings, parks, etc., raise costs beyond the reach of the target market. Often there are too few units in the development over which to spread the cost.

For some developments, demand is strong enough to justify large newspaper display ads, open houses, and full-time sales personnel. In others, classified ads and the subcontracting of sales to realtors makes sense.

Computers are making an increasing impact on the efficient flow of information used to control sales and production. For more information on computer systems, see Data Processing for Builders, National Association of Home Builders, 15th and M Streets, NW, Washington, DC 20005.

As much *integration* as feasible should be achieved. It should be possible to use quantities developed in the estimating procedure to automatically print requests for bids and purchase orders when accepted prices and terms are entered. Labor, material, and subcontract estimates should feed into the standard job cost system as budgeted costs against which actual costs are compared in variance reports.

For greatest timeliness, posting to the job cost system should be done when purchase orders are placed; any changes can be recorded later with change orders.

When payroll, subcontractor and material invoices are paid, the system should automatically post the general ledger and update other accounting reports.

EXAMPLES FROM THE DEMONSTRATION PROJECTS

Although no systematic effort was made to determine or document cost savings due to business and market efficiency, some examples came to light.

Charlotte, North Carolina

John Crosland Company sought land zoned for low-density development which they thought they could get zoned for higher-density development. They were successful in this strategy at Lynton Place and were able to increase density and reduce their land cost per unit.

Crosland did extensive market research which indicated that a mixed development with condos and medium-priced single-family homes would be successful. They generated early traffic by putting a sales trailer on the site. TV and newspaper display advertising invited people to put on their "muddy boots" and come see the plans and site.

Later, they built a sales center -- future community building with two swimming pools -- and seven model homes. Company personnel performed the sales duties at both the trailer and sales center. Crosland subcontracted all construction and bought wall panels for the condominium portion of the construction; the remainder was "stick-built."

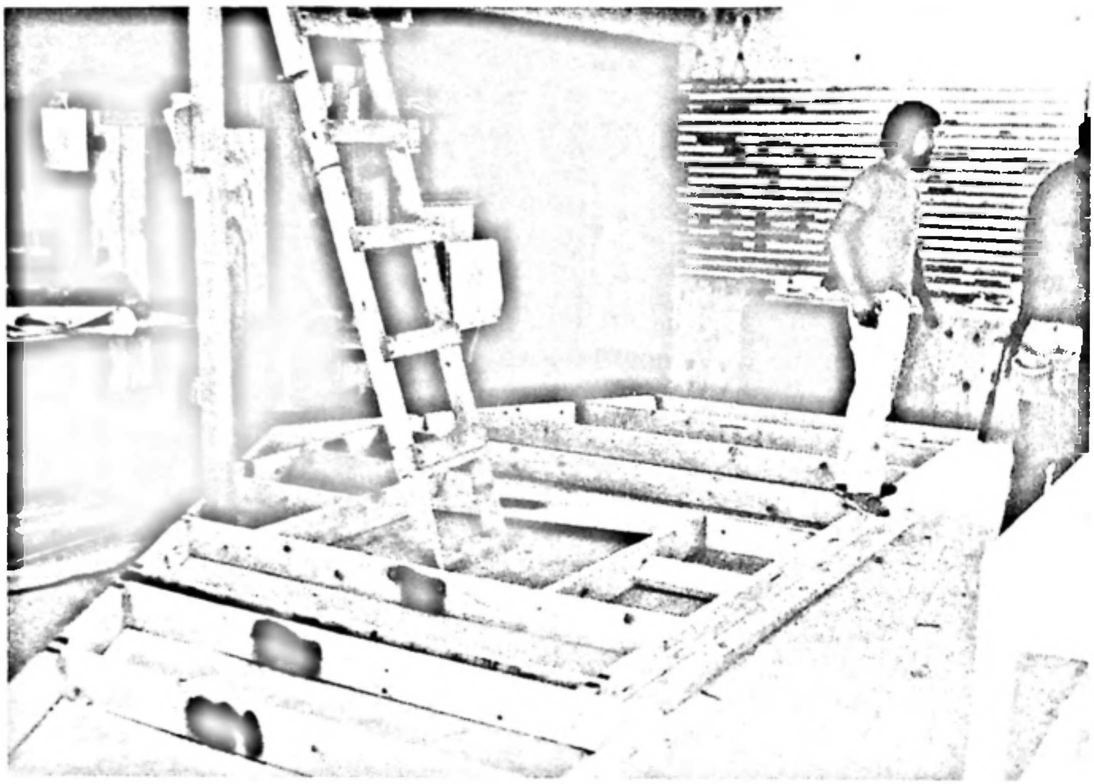
Christian County, Kentucky

In contrast, "Pup" Robertson of Robertson-Tomberlin Homes used a low-budget strategy to market his low-cost high-value brick ramblers. His only advertising was one-column one-inch newspaper classified ads. He built two homes "on spec" and sold them. Thereafter, he and a realtor sold the remaining homes from plans.

Robertson bought all material himself, since in his area, subcontractors were small, and his buying power exceeded theirs. In his rural locale where subs were few and not as highly specialized as in urban areas, he found it cheaper to hire employees by the hour than to pay subcontractor markup and profit.

Santa Fe, New Mexico

Mike Chapman used the exterior shell of the first home built as an on-site shop, which was used for fabricating balcony and stair railings, cutting and finishing trim, and general storage of high-value materials. When the project neared completion, he closed down the shop, installed partitions and fixtures, and sold the home.



REFERENCES

Cost Effective Construction Publications

All-Weather Home Building Manual, Guideline 4, U.S. Department of Housing and Urban Development, Washington, DC

All Weather Pressure Treated Wood Foundation, American Wood Preservers Institute, McClean, VA

Anderson, Hila W., and Gunard E. Hans, Truss Framed Construction, NAHB National Research Center, Upper Marlboro, MD

Anderson, L.O., Wood Frame House Construction, Agriculture Handbook No. 364, U.S. Government Printing Office, Washington, DC (Updated version available in Fall, 1987)

Angleton, Hugh D., NAHB Beam Series, Manual 1., Wood Beams; Manual 2., Plywood I-Beams; Manual 3, Plywood Box Beams; Manual 4, Steel-Wood I-Beams; Manual 5, Flitch Plate and Steel I-Beams; NAHB National Research Center, Upper Marlboro, MD

Basement Water Leakage ... Causes, Prevention, and Correction, National Association of Home Builders, Washington,DC

FHA Pole House Construction, American Wood Preservers Institute, McClean, VA

Fisher, E. Lee, An Approach for the '80s, U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, DC

Fisher, E. Lee, Building Affordable Homes, A Cost Saving Guide for Builder/Developers, NAHB National Research Center, Upper Marlboro, MD

Fisher, E. Lee, Construction Cost Control Manual, National Association of Home Builders, Washington, DC

Fisher, E. Lee, Productivity Improvement Manual, National Association of Home Builders, Washington, DC

Johnson, Ralph J., and Arthur W. Johnson, Insulation Manual, Homes and Apartments, NAHB National Research Center, Upper Marlboro, MD

Luebs, Donald F., EER-2 Energy Efficient Residence, Research Results, NAHB National Research Center, Upper Marlboro, MD

Luebs, Donald F., Reducing Home Building Costs With OVE Design and Construction, NAHB National Research Center, Upper Marlboro, MD

Manual of Plywood and Lumber Savings Techniques, NAHB National Research Center, Upper Marlboro, MD

Permanent Wood Foundation System, American Plywood Association, Tacoma, WA

Permanent Wood Foundation System: Design, Fabrication and Installation Manual, National Forest Products Association, Washington, DC

Six Profit Making Wood Systems, Western Wood Products Association, Portland, OR

Stroh, Robert C., Software Catalog for Home Builders, NAHB National Research Center, Upper Marlboro, MD

Stroh, Robert C., Solar Technology in New Residential Construction, NAHB National Research Center, Upper Marlboro, MD

The Engineered 24" Framing System, Form B420, American Plywood Association, Tacoma, WA

Why are New House Prices So High, How are They Influenced by Government Regulations, and Can Prices be Reduced/, Report to the Congress of the United States by the Comptroller General, May 11, 1978.

Wolfe, Ralph, Low Cost Pole Building Construction, Garden Way Publishing, Charlotte, VT

Yingling, Ronald K. and D.F. Luebs, Residential Plumbing Guidelines, 1986, NAHB National Research Center, Upper Marlboro, MD

APPENDIX I

Joint Venture for Affordable Housing Demonstration Participants

Subdivision Demonstrations

Alaska, Fairbanks
"Woodsmoke"
Webb Construction Inc.
Tom Webb, President

Arkansas, Crittenden County
"Harvard Yard"
Rex Rogers' Homes, Inc.
Rex Rogers, President

Arizona, Phoenix
"Cimarron"
Knoell Homes, Inc.
Thomas E. Knoell, President
Richard Eneim, Vice President
and General Manager

Colorado, Mesa County
"Coventry Club"
Roger Ladd and Company

Florida, Coral Springs, Broward County
"Village Pointe at Coral Springs"
Coral Ridge Properties, Developer
RDK Development, Builder

Georgia, Valdosta
"Forrestwood II"
Minchew Homes Corporation
Gary Minchew, President

Idaho, Boise
"Lakewood Meadow"
HOMCO, Inc.
Bryce L. Peterson, President

Indiana, Elkhart County
Coachman Industries, Inc.
John Letherman, President (Developer)

Kentucky, Christian County
"Hermitage Hill"
Robertson-Tomberlin Homes
Norris Glenn "Pup" Robertson

Maryland, White Marsh (Baltimore County)
"Lawrence Hill"
Nottingham Properties, Developer
The Ryland Group - modular manufacturer

Minnesota, Blaine
"Cloverleaf Farm - 9th Addition"
Good Value Homes
Donald Hardle, President
John Peterson, Land Development Director

Nebraska, Lincoln
"Parkside Village"
Empire Homes
Karl Witt, President

New Mexico, Santa Fe
"Fairway Village"
Walton Chapman Homes, Inc.
Walton and Michael Chapman

North Carolina, Charlotte
"Lynton Place"
John Crosland Company
John Crosland, President

North Carolina, Greensboro
"Covington Place"
Norcon Builders, Inc.
Norwood Stone, President

Oklahoma, Oklahoma City
"Woodland Hills"
Holland Land Company
Jack Holland, President

Oklahoma, Tulsa
"Innovare Park"
Hood Enterprises, Inc.
D. Wayne Hood President

Oregon, Portland
"North Meadow Village"
Black Bull Enterprises
Mike Robinson, President

South Dakota, Sioux Falls
"Ascot Park"
Ronning Enterprises, Inc.

Tennessee, Knox County
"Woodpointe"
Phil Hamby Construction Co., Inc.
Phil Hamby, President

Washington, Everett
"Sunridge"
Boyden Realty, Inc.
Richard Boyden, President

Washington, Lacey
"The Park"
Phillips Homes
John Phillips, President

Infill Demonstrations

Kentucky, Louisville
JRB Development, Inc., Developer
Jim Rey-Barreau President
All-American Housing - modular manufacturer
The Reasor Corporation - modular manufacturer

Massachusetts, Springfield
JDS, Inc., Developer
Robert L. Del Pozzo, President
ASI, modular manufacturer

New Jersey, Orange
"Concord Court"
Neighborhood Resources Passaic, Inc.
Joseph Deming, President
Ryland Group - modular manufacturer

New York, Albany
The Latham Four Partnership, Builder/Developer
Charles Touhey, President

Vermont, Burlington
"Franklin Square"
Hauke Building Supply
William R. Hauke, Jr., President

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