PANEL ASSEMBLAGE FOR HOUSING:

Some Form and Construction Explorations for Small Buildings

by David Reed Borenstein

Submitted to the Department of Architecture
in partial fulfillment of the requirements
for the degree of Master of Architecture
at the Massachusetts Institute of Technology

February 1984

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2

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ABSTRACT

This thesis examines the consequences of building homes in a factory and explores viable construction alternatives using factory-made panels. The exploration considers panelized systems of dwelling construction and its ability to adapt to a variety of site conditions while providing a wide range of spatial options to the inhabitants.

Thesis Supervisor: Marucie K. Smith
Title: Professor of Architecture

for morris

TABLE OF CONTENTS

INTRODUCTION

During the initial phases of this thesis, I examined the factory houses currently manufactured in the United States. Conceptually, factory houses, like any mass-produced product, are built with a complete, finished home in mind. In the early phases of the production process, a prototype is made. This prototype is then broken up into components of standard dimension, which can be easily manufactured. Finally, these components are assembled to make a finished house. This process, while insuring high construction quality and lessening production costs, can only yield the same prototypic result.

Utilizing this production and assemblage method, manufacturers would have to offer many different completed houses in order to provide a wide range of options for their customers. The options provided should accommodate the different spatial needs of many inhabitants and easily adapt to a wide variety of changes in topography. As the range of different completed houses becomes larger, the process of mass-production becomes proportionately less efficient.

The panelized systems I examined did not easily adapt to sloping sites or provide a wide range of spatial options within the assembly process. This is a direct result of two major factors. First, the panels are not separated into groups that relate to a specific use, e.g., support, closure, infill. Second, the panels are always directly connected to adjacent panels and therefore cannot be used by themselves.

My explorations in panel assembly disclosed the need for allowing a dimension to occur between panel interfaces. This dimension will vary in response to a specific use, while providing three essential functions:

1. It demonstrates a clear separation of panels; each panel will appear and behave differently from other panels according to its use.

2. Panels may be used singularly to establish use territories, or additively to provide further definition of use territories.

3. Lateral displacement of panel surfaces will yield use dimensions; smaller displacements provide spaces for storage, seating, etc., and larger displacements provide room-size spaces.

The proposed panel system provides the user with a structure and weather enclosure. Since the system is adapted from conventional platform framing, it is assumed that electrical wiring, plumbing, insulation, and finishing materials can be installed quickly and easily at the building site.

This system is not offered as a complete solution to the problems of factory houses. One building system can never solve all the problems in every situation.

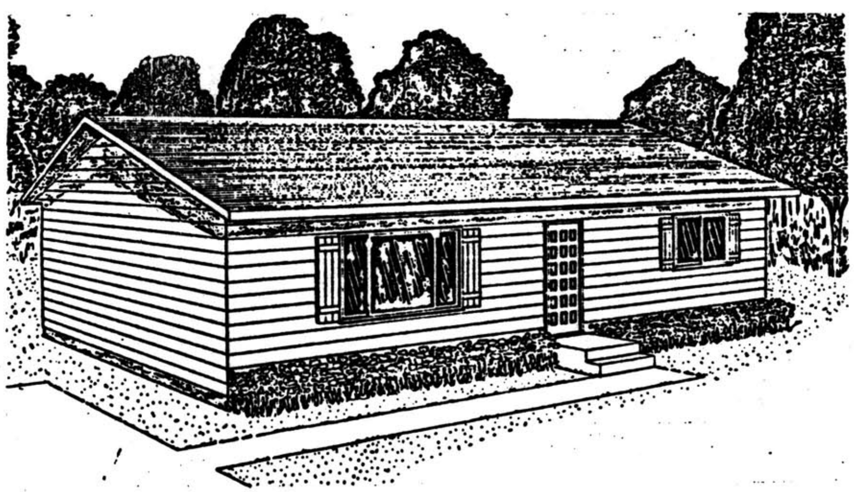
FACTORY HOUSES

"We cannot build without thereby creating a structure, but that structure may be at the heart of the basic concept or only peripheral to it."

Rowland J. Mainstone

FACTORY HOUSES

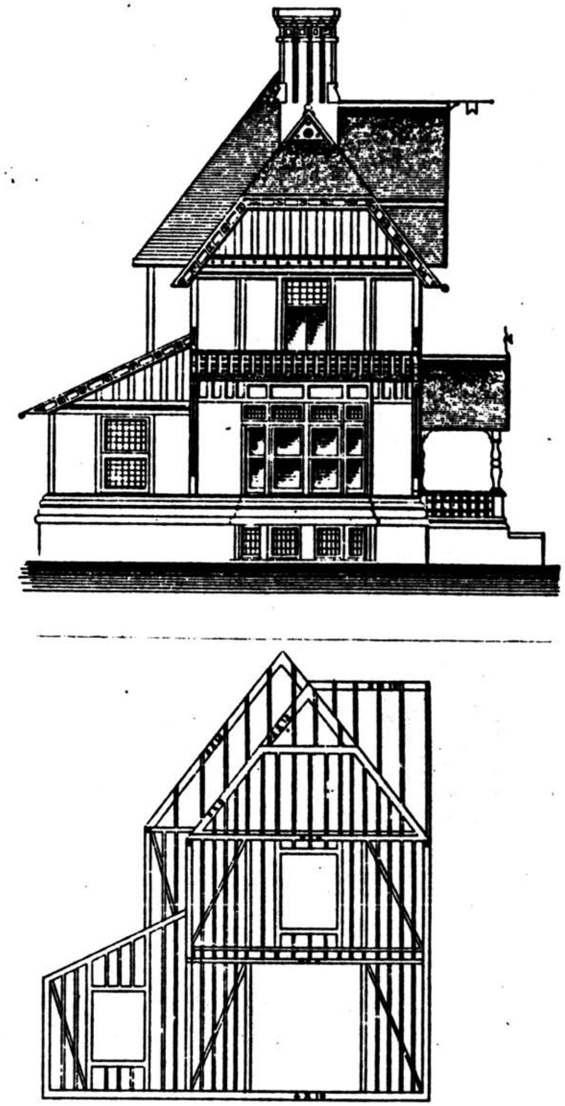
The majority of single family houses sold in the United States are built completely or in large part in factories. In attempting to reduce assembly costs, factory houses are produced utilizing available assembly techniques. These techniques require a standardization of each component in order to insure efficient production.



Tri State Home

Economy and affordability play an important role in the construction of any dwelling. Each year, new methods of dwelling house construction are developed in response to lessening assembly costs. The economies of these methods depend on the industrialized processes of mass production. Mass production and the resulting standardization of components have produced dwellings which can be assembled rapidly and often at reduced costs. Unfortunately, with the standardization of components, a variety of homes are produced which cannot readily adapt to a wide range of difficult site conditions. These homes are known as 'factory houses.'

For the past 250 years, before the onset of factory houses, local builders and contractors have been responsible for nearly all new single-family houses built and sold in the United States. These homes are referred to as 'stick-built,' a process of construction that requires all building parts to be cut and assembled at the site. This process can be relatively slow, but can adapt to a wide variety of difficult site conditions, e.g., varying changes in topography and assembly of the panels in closely confined areas. A building system's ability to adapt to difficult site conditions becomes increasingly important as the population of an area grows. Sites which may have been previously avoided, at the expense of overcoming the difficulty of building on them, may eventually have to be utilized.



A Stickbuilt House

By the 1970s, factory houses accounted for more than half of the new single-family houses built and sold in the United States. In addition, prefabricated parts and components were being used in most all other new houses being built each year by local builders and developers. Donald Spear, publisher of The Redbook of Housing Manufacturers, says "the term 'factory made' [houses] can be used to describe up to 84 percent of all new residential construction."

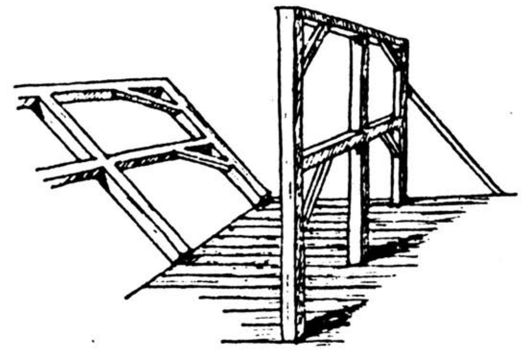
In 1978, 612,000 factory houses of all kinds were made in U.S. factories, according to John R. Kupferer, executive vice president of the National Association of Home Manufacturers. That figure includes mobile, modular, precut, panelized and all other types of factory made houses. Don Carlson, editor of Automation in Housing, a trade magazine of the manufacturered housing industry, feels that Kupferer's figure is low. Carlson, in his bi-monthly studies, has found that in 1978, 731,000 manufactured houses of all kinds, were made in U.S. factories. The chart below gives a breakdown of the specific types of factory houses made in 1978 according to these sources.

	National Association of Home Manufacturers	*Automation in Housing*
Modular houses made in 1978	76,000	141,000
Panelized, precut, all other "prefabricated" houses	261,000	315.000
Mobile homes	275,000	275,000
Totals	612.000	731,000

Total new houses, excluding high-rise apartments: 1,871,000.

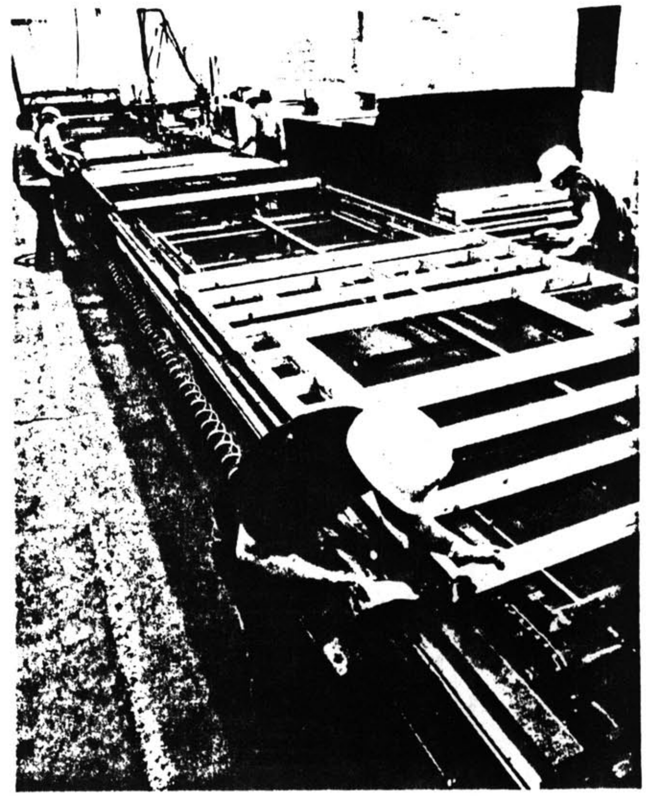
No matter whose figures are correct, manufactured houses of all kinds account for a large number of all new homes built and sold in the United States today.

The idea of making homes in a factory and shipping them to a site for assembly is not a new concept. The first known prefabricated house to be assembled in this country was made in England about 1670 and shipped to Cape Ann, Massachusetts. Many followed, including a few sent to early Cape Cod settlers. More than 500 prefabricated houses were shipped to California from New York during the 1849 Gold Rush. By no means were these processes of prefabrication as mechanized as they are today. By the 1890s, at least two U.S. manufacturers were producing prefabricated houses on a paying basis; one of them, Hodgson Houses, is still in business in New England.



The Hodgson House Model of 1899.

At the present there are more than 1000 different manufacturers of factory built homes. Another 2000 or so companies are mass-producing components for houses such as: floor, wall and roof sections, doors and windows, etc., prefabricated plumbing assemblies and complete mechanical cores (wetcores) with all the main heating, plumbing and electrical parts for the house. These components not only embody the cost and price savings that go hand-in-hand with mass production, but they are usually better made and of higher quality than similar components made at the site, by the time-consuming hand labor of stick-built processes.



High-quality construction is virtually inevitable when structural parts of a house, like these wall panels, are made square on jigs on the assembly line. They are locked into place for virtually flawless joints. Pneumatic hammers shoot nails into each joint with machine-gun speed.

Working indoors in a well-lit, weather-protected environment, worker saws opening in wall sheathing for window. Automatic nailer in background nails down wall sheathing skin to panel, with a score of nails driven each time.

Factory House Vs. Stickbuilt

Home manufacturers claim that lower cost, higher quality, and faster enclosure time are the major advantages of the factory built house as compared to the stickbuilt house. These claims need to be looked at more carefully.

In response to the high cost of dwelling construction, industrialized building methods have attempted to help the home buyer by reducing initial assembly costs. The exact amount a buyer will save in using prefabricated building components is difficult to determine. Primarily it will depend on the building size and type, the distance from the factory to the site, i.e., shipping charges, and the extent to which the buyers can/will build themselves. Generally, however, the reduction of on-site labor will slightly reduce the initial cost of the dwelling.

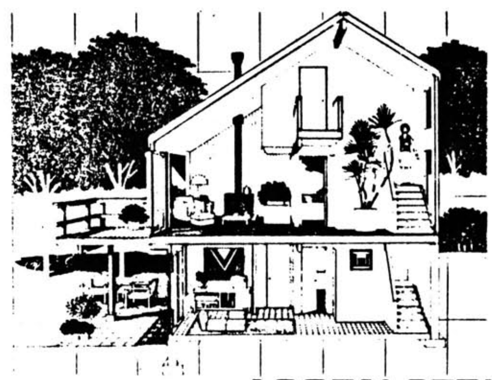
Presently, most factory houses (excluding modular) will only speed up the assembly of the shell/enclosure. This is not, however, the major cost element of the completed dwelling.

The ultimate price of any new home, either manufactured or stickbuilt, is dependent on many factors. The cost of land, insurance, utilities, interior finishing, taxes and mortgage rates, to list a few, will all have an effect on the expense of home building. Lewis Mumford, critic and author of Architecture As a Home for Man, says, "to cut the cost of the shell in half [through rapid on-site assembly] is to lower the cost of the house a bare ten percent." A ten percent capital savings, however, is quite substantial, considering the enormous overall cost of dwelling house construction.

Local builders have often been able to undercut the cost of factory houses through stickbuilt construction. Before a fair cost comparison can be made, it is important to understand the quality of building attained through each process. In general, good quality materials and construction will always cost more than inferior grade materials and poor construction.

All industrialized home manufacturers/ builders claim to produce superior quality dwellings by using top grade materials and sound construction processes. The extent to which these claims are true, depends on the manufacturer/builder and the type of house being produced.

In the better made factory homes, e.g., Acorn Structures and Deck House, top grade materials are used for the sake of the prefabrication process itself. Inferior grade materials tend to slow down the mechanized processes employed at the factory and thereby result in a profit loss to the manufacturer. In addition, the manufacturer's attention to sound building practices are generally a direct result of two major considerations. First, strength, rigidity and durability must be present in the house or components in order to withstand bouncing around during shipment and placement at the site. Also, to increase home distribution, the manufacturer's building practices will generally conform to the toughest local building codes.



ACORN STRUCTURES, INC.

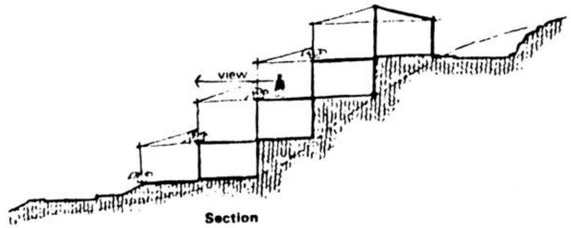
One manufacturer's response to the quality of materials often used in stick-built construction by local builders is as follows:

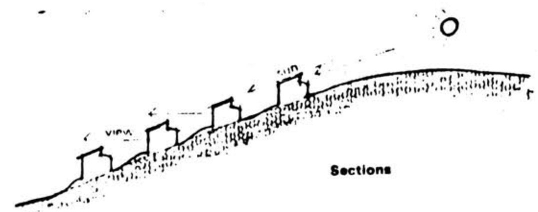
> Take all the 2 x 4 wall studs used In our houses. They're Number One grade, and recently they cost us $1.25 a piece. Local builders in this area, our competition, use utility grade 2 x 4s at a cost as low as .69¢ each. That's a big difference. We pay up to twice as much for good lumber. It really adds up when you consider the hundreds of studs that go into the walls of a house.
>
> Now take into account the extra cost for quality that goes into the other wood and materials throughout the house. It offsets some of the savings made as a result of factory houses being made faster and more efficiently than stickbuilt houses.
>
> (Watkins, p. 15)

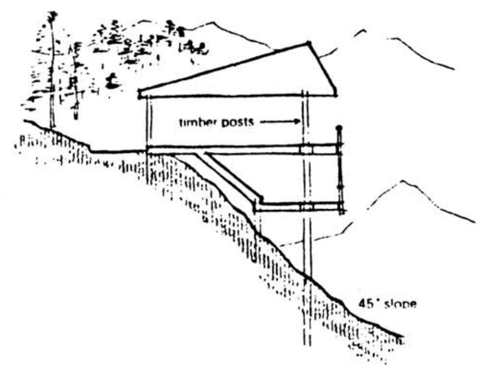
It is also true that some builders use Number One grade lumber and high quality materials in their stickbuilt houses. Their prices, then, will also be higher than the builder who uses lower grade materials. Comparing these better-made stickbuilt houses with factory made houses is now a fair comparison. In this case, the factory house will usually be lower in cost since it is made faster, more efficiently and with less waste.

The above discussion demonstrates some general advantages of industrialized building techniques over stickbuilt construction. There is, however, one major advantage the stickbuilt house has over the factory house; the ability to readily and successfully adapt to difficult site conditions through its initial construction process, while offering a wide variety of spatial options for the inhabitants.

Difficult site conditions may be characterized by local topography, e.g., a steeply sloped grade. Factory houses, presently on the market, are designed for level sites and therefore do not easily adapt to changes of grade. Current solutions practiced by factory home builders include cutting large sections out of the hillside to accommodate the house, filling areas to make a level building surface, and propping up the entire house on stilts. All of these operations, executed with great effort, largely force the site to conform to the standards of the house. There is rarely a reciprocal exchange between the house and the site.







Current solutions practiced by factory home builders include, cutting large sections out of the hillside, filling areas to make a level surface and propping the entire house on stilts.

The problem, then, is to design a method of dwelling house construction which includes the advantages of industrialized processes, without sacrificing the adaptability of stick-built construction to a wide range of site conditions and spacial options.

A dwelling produced through the optimum integration of these construction processes will be referred to here as 'tractable.' The Random House Dictionary defines tractable as:

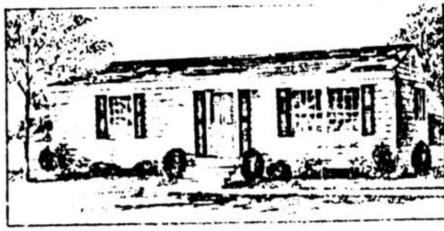
1. easily managed or controlled;
2. easily worked or shaped.

The second definition is more appropriate in describing a type of construction which can easily adapt, or be shaped and worked, to a variety of difficult site conditions and spacial options.

The degree to which a factory house is tractable, depends on its construction type. The present market offers three types of factory houses (excluding mobile homes): modular or sectional, precut, and panelized. In general, the three types differ in their degree of completion upon leaving the factory.

MODULAR

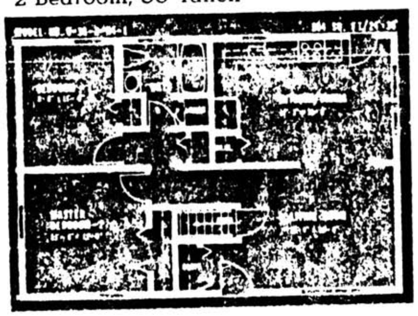
The modular, a three-dimensional package, is ninety-five percent complete as it comes off the assembly lines. Of the three types of homes, the modular is the least tractable, if it is tractable at all. Its major advantage is that it requires very little labor at the site for completion.



WESTVILLE HOMES CORPORATION

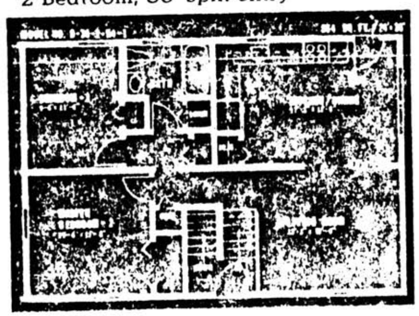
Claremont

2 Bedroom, 36' ranch



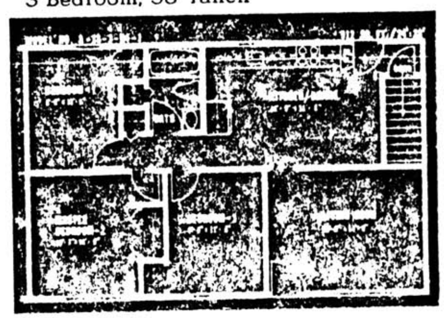
Barre

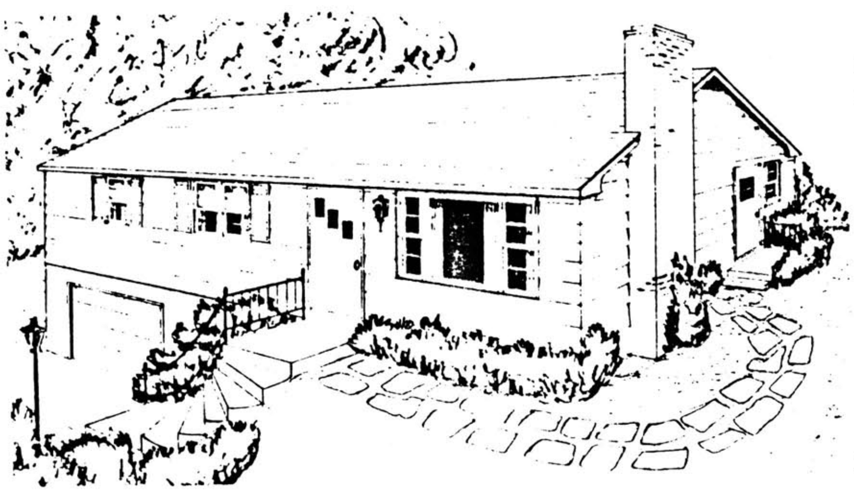
2 Bedroom, 36' split entry

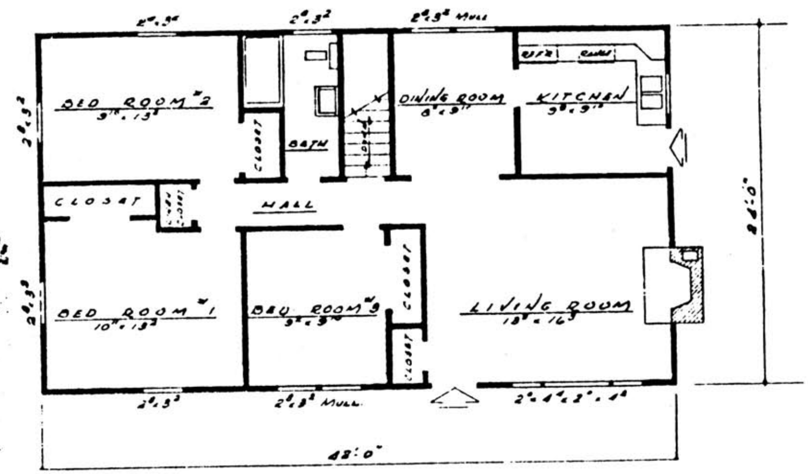


Belfast

3 Bedroom, 38' ranch





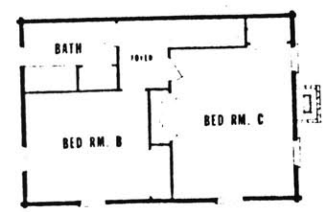


BERKSHIRE HOMES

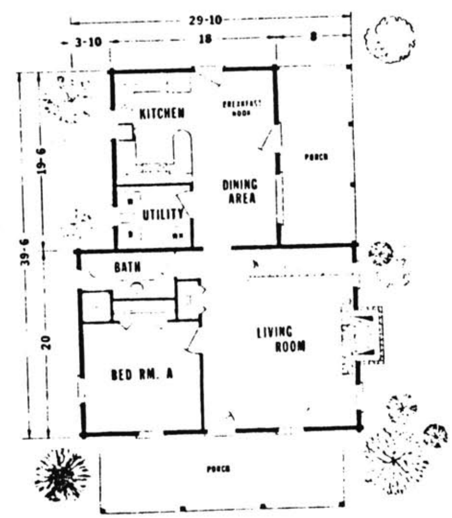
PRECUT

The precut house is the least complete when leaving the factory and therefore requires the maximum on-site assembly time of all three types. Since more on-site labor is involved, factory quality cannot be insured. Yet in spite of its lack of completion at the factory, the precut house is not a tractable method of building. This is due to the fact that all of its parts are predetermined from a standard plan and cut to size at the factory. Its main advantage is that it makes the purchasing of materials easy and eliminates on-site cutting and waste.

A precut house comes with bundles of essential parts and lumber sized for quick nailing in place. New England Components/Techbuilt.



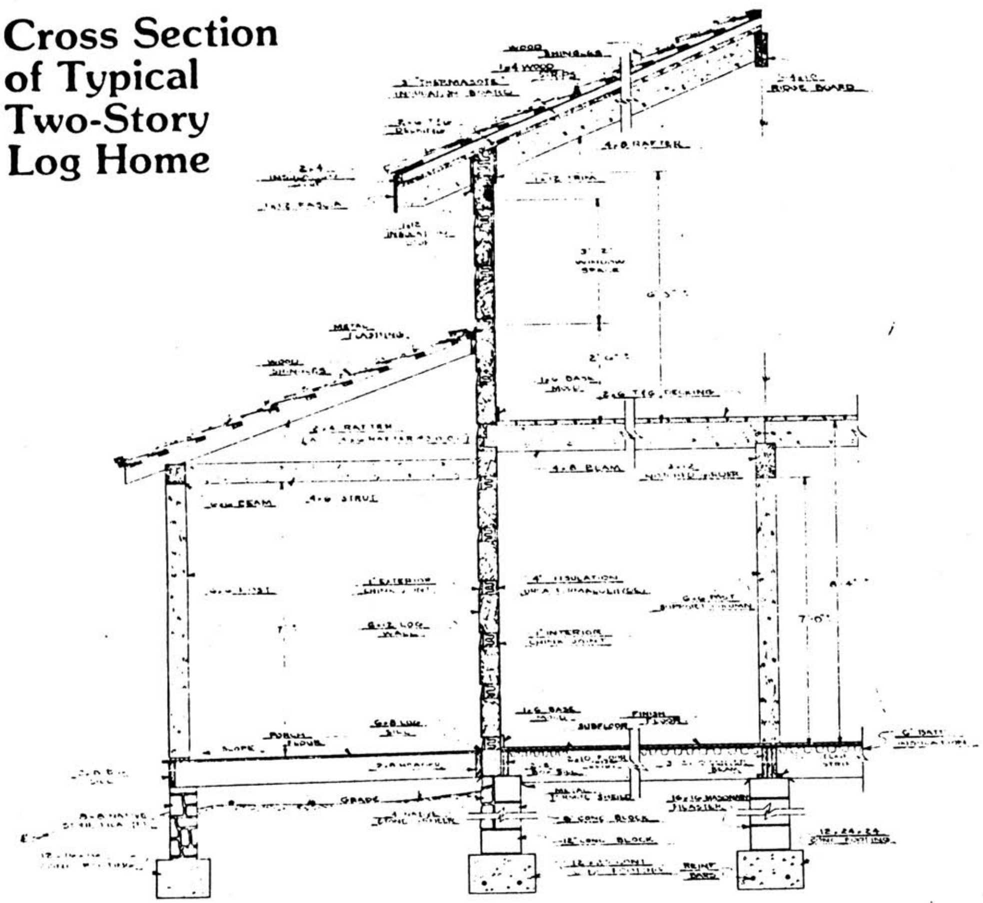
SECOND FLOOR PLAN



FIRST FLOOR PLAN

Log Homes

Cross Section of Typical Two-Story Log Home



Materials List:

20' 0" x 29' 10" • 18' 0" x 19' 6" log building
11 & 6 courses of logs
1 Girder 19' 10" long

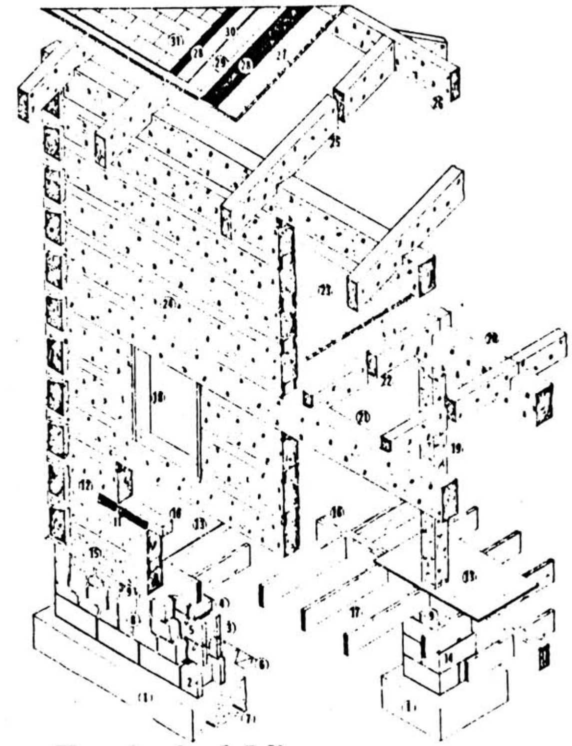
7 - 4x8 19' 6" Ceiling Beams
4 4x8 16' 0" Ceiling Beams
2 - 2x8 19' 6" Nailors
1 - 4x8 4' 0" Header Beam

1 4x10 32' Ridge Beam (lapped)
1 4x10 22' Ridge Beam (lapped)
10 4x8 11' 9¼" Rafters
18 4x8 13' 5½" Rafters
2 4x8 12' Wind Beam

1 4x12 8' Mantle
2 - Mantle Brackets
30 - 1x4 Misc. braces Roughsawn random length
12" spike nails for every dovetail
7" nails for sills and rafters

10 - ½x9" Bolts w/washers & nuts
4 ½x11 Bolts w/washers & nuts

7 6x6 - 7' Porch Posts
4 - 6x6 10' Porch Beams
1 - 6x6 12' Porch Beam
16 4x6 2' Angle Brackets
3 4x6 8' End Struts
22 2x4 10' Porch Rafters



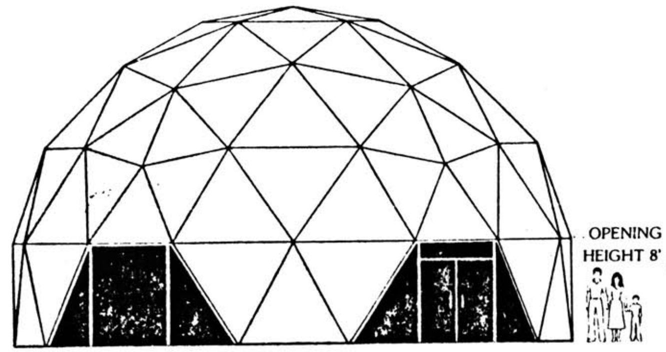
Exploded View

1. Concrete footing
2. 12" starter block
3. 8" concrete block
4. 4" solid cap block
5. Metal wall ties
6. Metal reinforcing
7. Reinforcing bars
8. Native stone veneer
9. Metal termite shield
10. Foam insulation
11. Hardware Screen
12. Cement chink joint
13. Subflooring
14. Masonary pier
15. • 6x8 hewn log sill
16. Center beam
17. Floor joist
18. Window jamb
19. • 6x6 hewn girder post
20. • 6x12 hewn girder
21. • 6x12 hewn beam log
22. • 4x8 hewn beam
23. 2x6 T&G floor decking
24. • 6x12 hewn log wall
25. • 4x8 hewn rafter
26. • 4x10 hewn ridge beam
27. 2x6 T&G roof decking
28. Roofing felt
29. 3" ridgid foam insulation board
30. Nail board
31. Asphalt shingles

• Furnished by Hearthstone Builders, Inc.

PANELIZED

The panelized systems fall somewhere between the modular and precut methods in terms of completion at the factory. The on-site labor is not as intensive as the precut systems, but it does require more assembly time than the modular method. The panelized system is potentially the most tractable of the three types of factory houses manufactured in this country, therefore, it should be examined in greater detail.

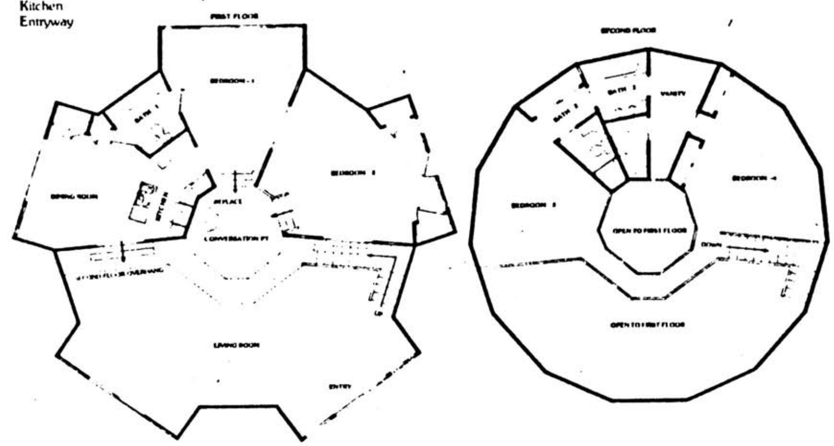


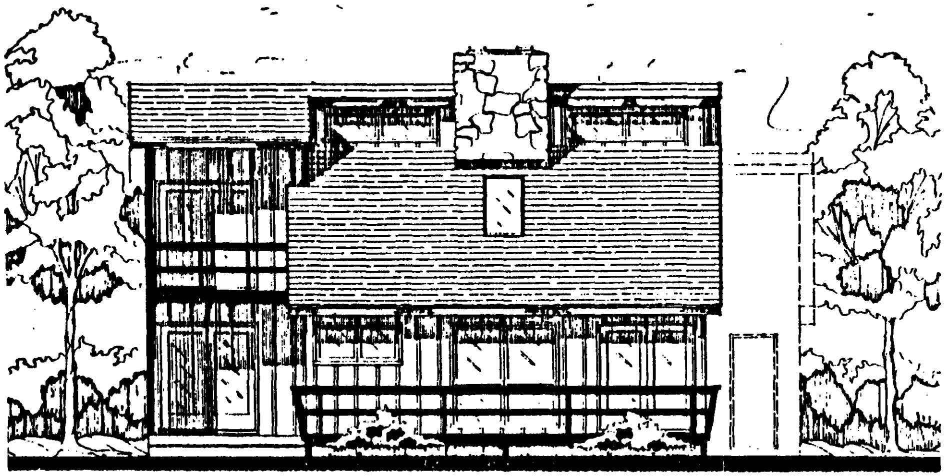
Alpine 45

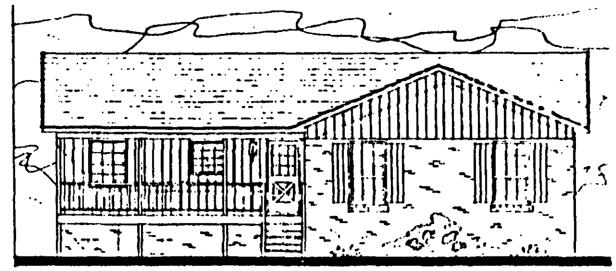
2695 Square Feet
4 Bedrooms
3 Baths
Vanity
Living Room
Conversation Pit
Dining Room
Kitchen
Entryway

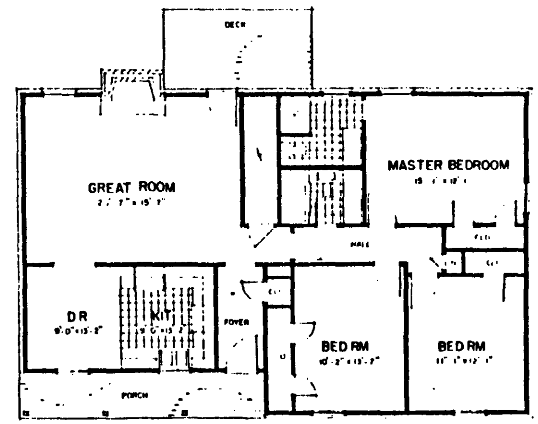
Options as Shown
5 Opening Extensions

Monterey Domes

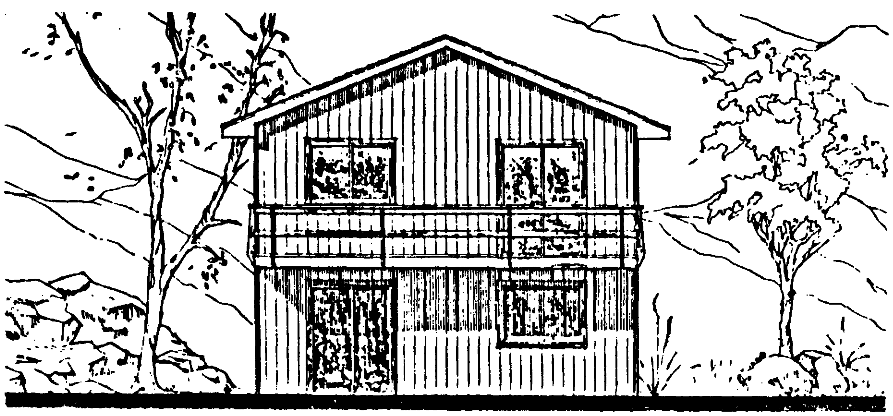








FLOOR PLAN



STANDARD HOMES

The wall framing of the panelized house is completed in sections (panels) at the factory. The degree to which these sections are completed will depend on the specific type of panel system and the manufacturer. In any case, these panels are designed for rapid placement on a suitable foundation. The resulting shell can then be capped with a roof, completing the exterior enclosure. This process generally takes two to three days, but can be accomplished (if all goes well) in one day.

Here is how the shell of a panelized house is erected and closed up within a day or two. The exact shell completion time depends upon the size and type of house. The foundation, with or without a basement, is, of course, prepared in advance. After the house parts arrive, wall panels are erected around the perimeter of the house, roof trusses are installed and covered with panels, and the house is locked up. **Kingsberry Homes, Boise-Cascade Corp.**

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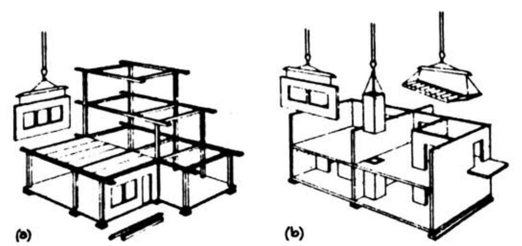
Panels are usually eight feet in height and up to forty feet in length. Panels longer than forty feet require special road permits for transporting and are therefore unusual. Panels sixteen feet and under do not require a crane for assembly and can be handled by a standard work crew of four people.

Panel height and length are generally controlled by the economies available through the use of standard material sizes. They are designed to eliminate as much material waste as possible during the fabrication process. For example, plywood is available in eight foot lengths, so the panels are seldom higher (except at the gable end).

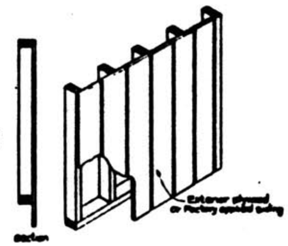
Panel systems may use loadbearing panels or a post and beam structure. Loadbearing panels are the most common and economical, especially when large panels are used. Smaller panels, however, will offer greater tractability. Post and beam systems only make use of the panels as non-bearing partitions and weather enclosure. Since the panels are not being utilized to their full capacity by carrying loads, this system tends to be less economical.



Elements of Manufactured Home Systems. (a) Frame and Infill. Post and Beam Frame Supports Infilling Wall, Floor, and Roof Panels. (b) Panel. Load-Bearing Panels Form a Complete Shell.

Construction of Panels

Most panel construction is adapted from standard platform construction in order to meet differing local building codes. The typical exterior panel consists of studs sixteen or twenty-four inches on center, exterior plywood or hardboard and factory-applied siding with a downlap to cover the exposed floor construction at the edge. Insulation and interior finishing material are generally applied at the site after wiring and plumbing have been installed in the wall. This is referred to as an "open" system, as opposed to a "closed" system in which the interior finish is applied at the factory.

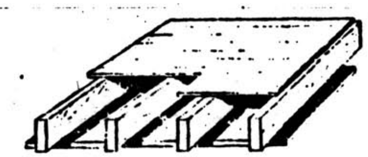


Typical Wall Panel Element Based on Platform Framing: Studs. Sole Plate. and Plywood with Downlap.

Another type of panel frequently used in factory houses is the "stressed-skin" panel, which is the most efficient structural wood system for walls, roofs and floors. Stressed-skin panels are constructed from ribs (studs, joists, etc.) to which plywood is bonded by gluing. When loaded, the plywood and ribs act integrally, and thereby require fewer and smaller ribs. Stressed-skin panels have been used for over thirty-five years and have been thoroughly tested in several laboratories.

NEW "STRESSED-SKIN" (AIRPLANE) SYSTEM

By gluing or otherwise fusing the floor and ceiling material (in this case plywood) to the wood frame we make all the parts work together, with the result that we obtain a saving of about half of the usual structural material.

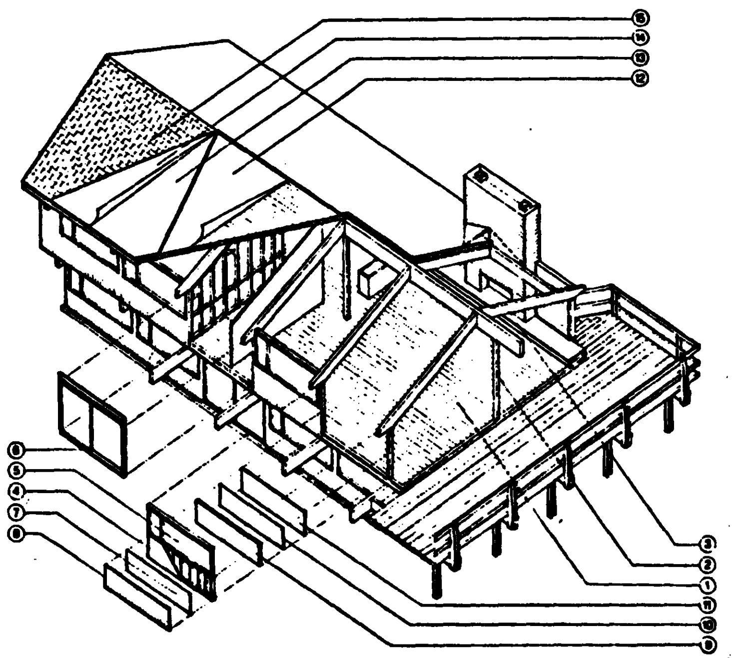


OLD SYSTEM

Beams carried all the load. The flooring and the ceiling material below contributed nothing to the structural properties of the building. They were just "dead weight."

Various Types of Panel Connections. (a) Plain Butt. (b) Butt Covered with Batten. (c) Lapped Joint. (d) Tongue and Groove with Covers Bonded to Ribs for Stressed Skin. Variants with Post, Fillet, and Corner.

One of the commercial panelized systems, 'Deck House,' claims that its design concept, based on post and beam construction, permits almost "unlimited design flexibility in a unique, solid structure." This system, base on a two-dimensional grid, is only tractable within the confines of its standardized framework.



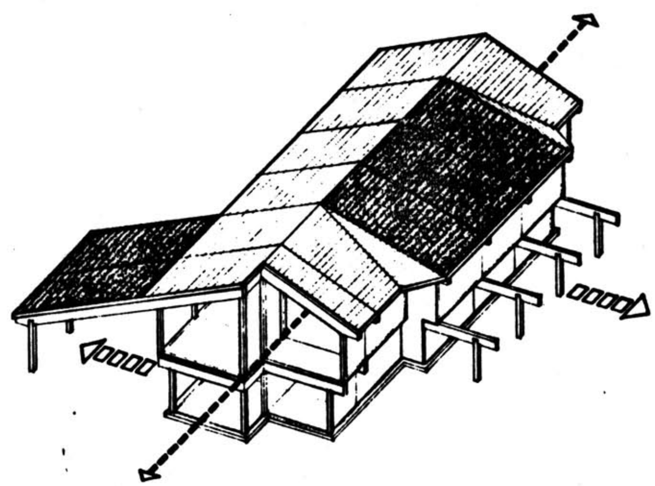
Further claims include: "Roofs can be raised, floors can be lowered--all to create interesting living space and to take advantage of the natural terrain." These changes, however, are not as easily achieved as the manufacturer would have you think. Any change in the fabrication process will result in additional charges from the manufacturer. Large changes are generally cost prohibitive to a point where the buyer may be better off using a stickbuilt process. Even small changes, such as a slight change in floor level can be expensive. Whenever a change is made, it causes an interruption in the production process, and the buyer must absorb the costs. In addition, these changes will also require modified plans and specifications, prepared by the factory's architectural department, increasing the cost still further.

Once your site has been selected, it's time to plan the house.

The Deck House design concept is based on a post and beam construction system, permitting almost unlimited design flexibility in a unique, solid structure.

To understand how this flexibility works, let's examine the logic behind our design system.

Think first of an abstract concept: Imagine a "spine" intersected with "ribs" placed eight feet apart along its length. By extending the spine at either end and adding more ribs, the size of this two-dimensional grid is expanded. Another way of enlarging this grid is to extend individual ribs farther outward from the spine.

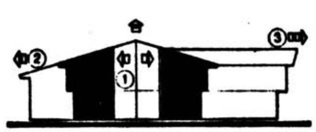


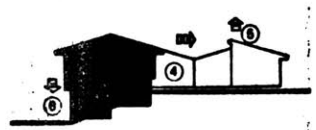
It is a simple transition from this abstract idea to the Deck House design concept. The spine corresponds to the centerline of the house; the ribs correspond to beams. These beams are normally placed at eight-foot intervals along the centerline. In Deck House post and beam construction, the roof and floor beams are supported at the centerline and outside walls by posts, and it is this sturdy, rugged framing which supports the entire structure.

Extend the centerline and add more beams; you expand the house lengthwise. Extend the beams from the centerline; you expand the width of the house. Where design requirements dictate, beams may be added on one or both sides of the centerline at intervals less than eight feet.

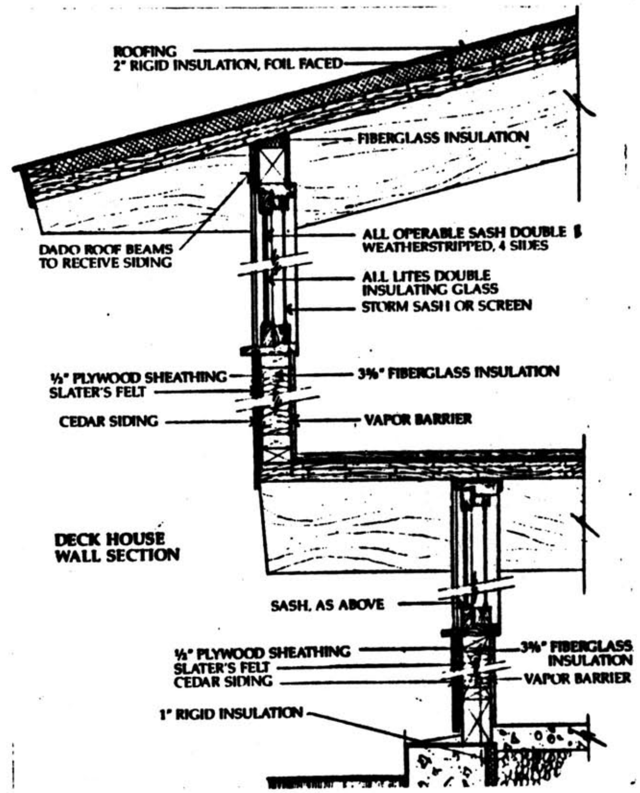
The flexibility of the post and beam structure is not limited to these simple extensions. (1) The width of the house can be increased by adding space at the centerline which, in turn, raises the roof height. (2) Roof beams may be continued outward from the centerline to widen the house. (3) A framework may be placed at right angles to the main structure to create additional variations. (4) Separate structures can be connected with a link, (5) roofs can be raised, (6) floors can be lowered—all to create interesting living space and to take advantage of the natural terrain.

Interior partitions are non-load bearing, thus permitting flexibility in room arrangement. It is also possible to create uninterrupted space by eliminating some of the centerline posts, replacing them with beams.





Deck House claims that any type of change in their system is relatively easy and can be achieved at "reasonable" cost. How reasonable the cost will be is dependent on the type and extent of change from the initial design. It is expected that what is reasonable to the manufacturer will be costly to the buyer.



It is interesting to note that the price sheet discloses construction costs per square foot of all standard models built on a flat site. It does not, however, list construction costs of any models shown in the brochures on sloping sites.

PRICE AND SPECIFICATION GUIDE

DECK HOUSE INC

MODEL	(1) SQUARE FOOT AREA	(2) DECK HOUSE MATERIALS	(3) CONSTRUCTION COST	TOTAL	COST PER SQ. FOOT
7113	1,508	27,000	40,000	67,000	44.00
7123	1,581	27,000	45,000	72,000	46.00
7133	1,680	31,000	44,000	75,000	45.00
7143	1,508	24,000	38,000	62,000	41.00
7163	1,516	34,000	46,000	80,000	53.00
7173	1,683	32,000	57,000	89,000	53.00
7183	1,253	38,000	50,000	88,000	70.00
7193	1,708*	27,000	37,000	64,000	37.00
7114	1,964	31,000	52,000	83,000	42.00
7124	1,938	33,000	53,000	86,000	44.00
7134	1,965	33,000	52,000	85,000	43.00
7144	2,191	36,000	54,000	90,000	41.00
7154	1,833	31,000	54,000	85,000	46.00
7164	1,929	41,000	62,000	103,000	53.00
7184	2,172	38,000	62,000	100,000	46.00
7194	2,681*	35,000	53,000	88,000	33.00
7115	2,401	37,000	56,000	93,000	39.00
7125	2,401	41,000	60,000	101,000	42.00
7135	2,512	40,000	60,000	100,000	40.00
7155	2,694	40,000	61,000	101,000	37.00
7175	3,302*	46,000	68,000	114,000	35.00
7185	2,438*	40,000	66,000	106,000	43.00
7195	2,486*	42,000	68,000	110,000	44.00
7205	2,308	39,000	56,000	95,000	41.00
7215	2,688	45,000	62,000	107,000	40.00
7116	3,777*	54,000	74,000	128,000	34.00
7126	3,000	44,000	65,000	109,000	36.00
7136	2,902*	39,000	63,000	102,000	35.00
7166	2,872	43,000	65,000	108,000	38.00
7176	2,837	43,000	59,000	102,000	36.00
7186	2,703	43,000	56,000	99,000	37.00
7196	2,908	44,000	78,000	122,000	42.00
7206	4,453*	52,000	78,000	130,000	29.00
7216	3,052	47,000	65,000	112,000	37.00
7226	2,963	48,000	75,000	123,000	42.00
7236	3,588	52,000	73,000	125,000	35.00
7246	3,792*	56,000	79,000	135,000	36.00
7117	3,445	55,000	78,000	133,000	39.00
7127	3,445	49,000	72,000	121,000	35.00
7137	3,573	55,000	67,000	122,000	34.00
7147	3,671	52,000	67,000	119,000	32.00
7157	3,900	56,000	99,000	155,000	40.00
7167	3,272	52,000	67,000	119,000	36.00
7177	3,583	50,000	72,000	122,000	34.00
7187	3,923*	53,000	84,000	137,000	35.00
		(4) THE CONSERVATORY COLLECTION			
7314	2,201	40,000	57,000	97,000	44.00
7324	2,901	45,000	65,000	110,000	38.00
7315	3,012*	51,000	75,000	126,000	42.00
7325	3,283*	51,000	73,000	124,000	38.00
7335	3,267*	53,000	77,000	130,000	40.00
7345	3,009*	51,000	74,000	125,000	42.00
7355	3,126	49,000	73,000	122,000	39.00
7316	3,529*	54,000	74,000	128,000	36.00
7337	3,791	59,000	85,000	144,000	38.00

*Garage and/or basement area included.

These prices do not include allowances for the following items:

A. Site work:
   (such as excavating, fill, grading, well, septic system, driveway surface) ______
B. Kitchen and vanity cabinets ______
C. Kitchen appliances ______
D. Lighting fixtures ______
E. Carpeting, oak or ceramic tile flooring ______

Advantages of the Industrialized Panel Systems Currently Available on the Commercial Market

1. High Quality Materials and Construction:

a. Top-grade lumber is used in most panelized building systems, largely because second grade lumber can cause problems with the precision techniques used in the factory, thereby slowing down production.

b. In order for the manufacturers to increase product distribution, panels are built to conform to the toughest local building codes.

c. Special rigidity and durability are built into each panel since they must withstand bouncing around during shipment and erection at the site.

2. Predictable Sale Price:

a. The price of each panel is fixed at the point of departure from the factory. Shipping charges are determined according to the weight over distance and are cost predictable. As in all methods of construction, there are always unknown variables which influence the final cost of the dwelling. Nonetheless, it is still considerably easier to predict the final cost of a panelized system than it is to predict the final cost of stickbuilt methods.

3. Reduction of Building Time:

a. A panelized dwelling can be delivered, assembled and ready to occupy two or three months after it is ordered, a significant difference compared to the usual four to six month completion time required for a stick-built structure.

The time saved in construction can have many advantages. For example, if a construction loan is needed to build the dwelling, the cost of the loan will be lower when the dwelling is completed in a short time. Funds are saved by rapid completion of the dwelling as construction overhead costs are lower when the house is completed faster. These and other construction savings may be beneficial to the builder, but the buyer ultimately pays for everything that goes into the dwelling. The buyer can also save money by moving into the new house earlier, leaving the existing house sooner.

b. Theft and vandalism is also deterred during the construction process since a panelized system can be closed and roofed over quickly, making it lockable. Additionally, work on the interior can begin immediately, no matter what the weather conditions are.

4. Reduced Material Waste:

a. Panelized systems are designed with maximum material economy in mind. Building a house piece by piece will generate a lot of material waste. This addes nothing to the value of the dwelling, but adds to the cost.

5. Simplified Construction Process:

a. The panelized system simplifies the construction process which makes it easier for the buyers to do much of the work themselves and thereby save on labor costs. The construction process is still an enormous endeavor, but it is considerably easier than building with the stickbuilt method. The buyer can decide exactly how much he/she is willing or able to do, and has the option of ordering the house 'kit' in whole or in part.

Disadvantages

1. Visual:

a. Despite the fact that most panelized houses are made from top-grade materials, they all (with the exception of a few models offered by Deck House and Acorn Structures) seem to possess a cold impersonal appearance.

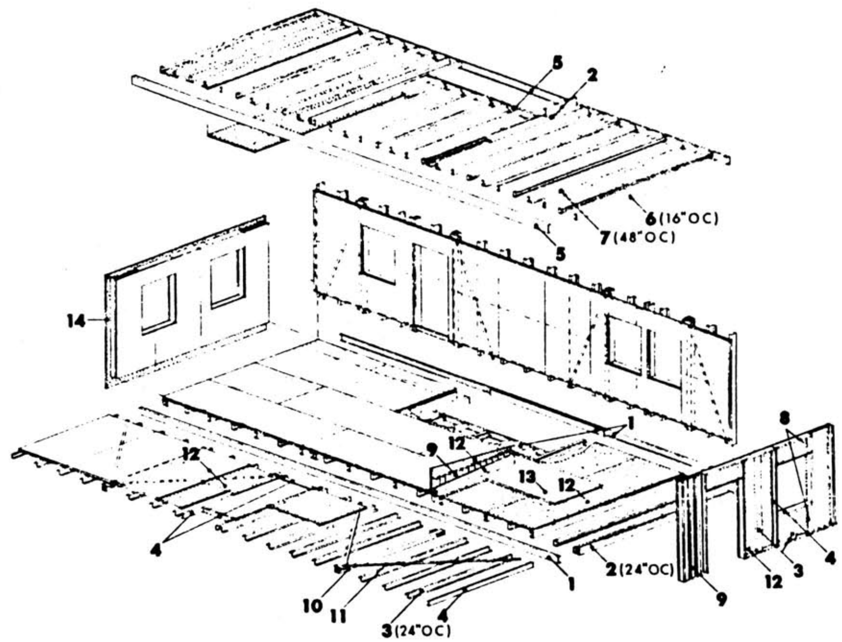
Successful mass production has required a standardization of panels. This has resulted in standard facades, offering very little or no variety in elevation. These homes are at best, mediocre. Taste, of course, is a personal thing. Yet, many people will agree, factory houses, including panelized systems, are generally not pleasant to look at. This is exemplified in the following clipping from a New Jersey newspaper dated March 11, 1983.

NEW JERSEY

Gloucester Township — Developer Daniel Riif's factory-built homes are "ugly," neighbors in the Country Aire development say. They'll try to block the builder from setting up his $54,000 three-bedroom ranch houses near their split-level and colonial homes. Riif owns about 20 Country Aire lots. MARCH 11, 1983 • 7A

2. Lack of Tractability:

a. The major disadvantage, and the main topic of discussion in this thesis, is the inability of present day, commercial, panelized systems to adapt to a wide range of varying site conditions. Further, these systems do not provide the inhabitants with many optional use territories. Albert Dietz, author of Dwelling House Construction said, "The goal of practically complete flexibility of arrangement, utilizing standard panels, but not standardized plans, is yet to be attained." Panels of standard dimension, based on factory production, do not allow for variation within the construction process in intervals less than or greater than the factory set module of four feet. In addition standardized connections only permit panels to be assembled in conjunction with adjacent panels.



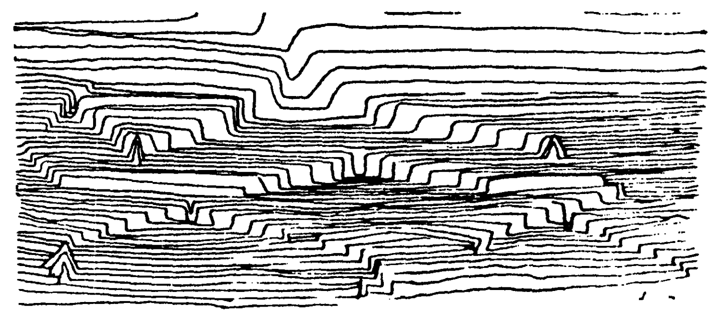
Exploded view and component parts of 36-foot-long first-story module for 2-story prototype town house. Component parts: 1. edge beam, 2. floor joists; 3. wall studs; 4. multi-use channel; 5. ceiling edge beams; 6. ceiling joists; 7. ceiling angles; 8. wall angles; 9. corrugated steel decking; 10. structural steel tube; 11. steel straps; 12. gypsum wallboard; 13. shiplap plywood; 14. woodrock siding. (United States Steel Corporation)

Summary

In the case of panelized systems, problems have arisen as a direct result of product standardization. Panels of standard dimensions, based on factory production, do not allow for variation in the construction process at intervals of less than or greater than the factory set module of four feet (generally eight feet in height and up to forty feet in length). Standardized connections only permit the panels to be assembled in conjunction with adjacent panels. This limits the possibility of having many different spatial arrangements. These problems, depending on the system, tend to prevent the [finished] dwelling from easily adapting to a variety of site conditions. Nor do they offer a wide variety of spatial territories for optional use.

- Partial Definition & Use Territories

Partially defined territories allow for further optional definition and growth. Conversely, territories that are built completely defined become subdivisions of a larger framework. These subdivisions do not encourage optional use and growth.

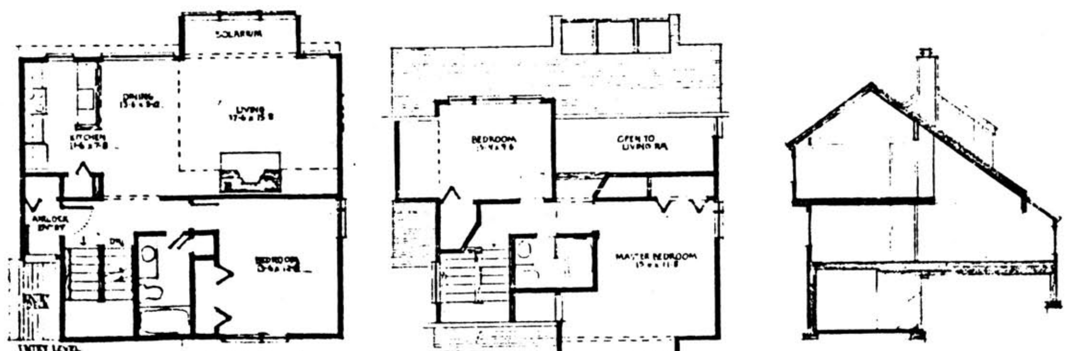


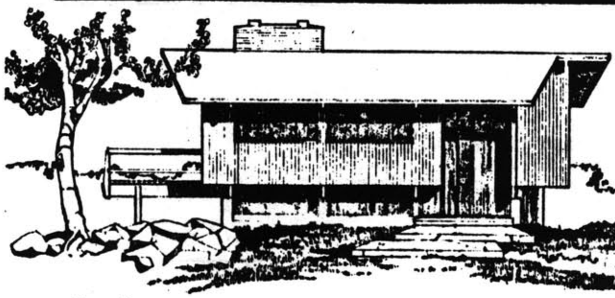
The lateral displacements of surfaces provide partially defined use territories while demonstrating a clear direction of growth.

Drawing - Paul Klee.

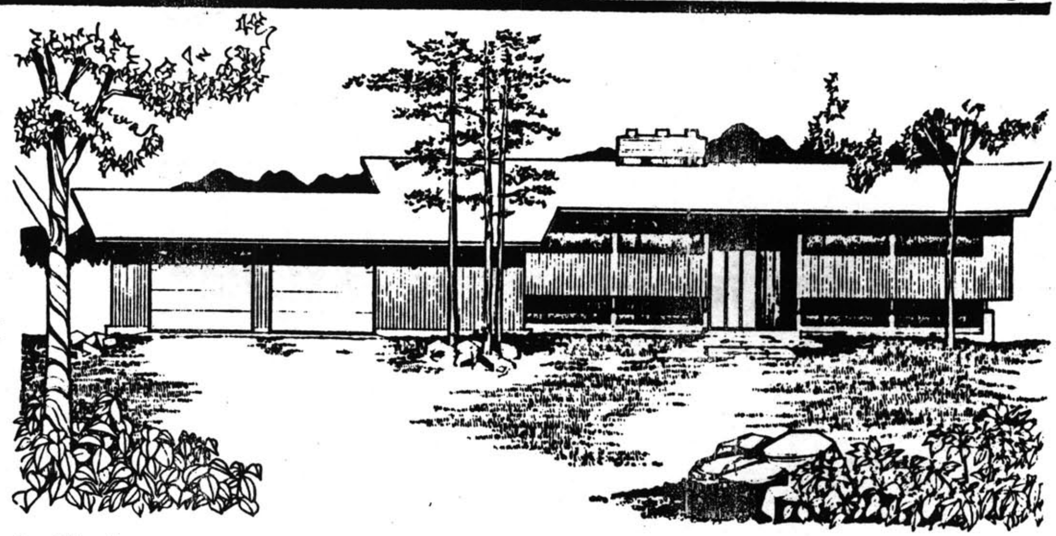
Among the panel systems I examined, Acorn and Deck Houses do not differentiate their panels according to a specific use. Without the option of separating each panel from the other, panels can only be used to make subdivisions of the larger framework. In order to allow a widely varied set of optional uses to occur, each panel should be designed as a separate element. Each of these elements must then be dimensionally coordinated with the larger framework. Where panels of different uses are joined, lateral displacement may optionally occur. This displacement will generate a dimension for optional use.

THE ACORN SS2200

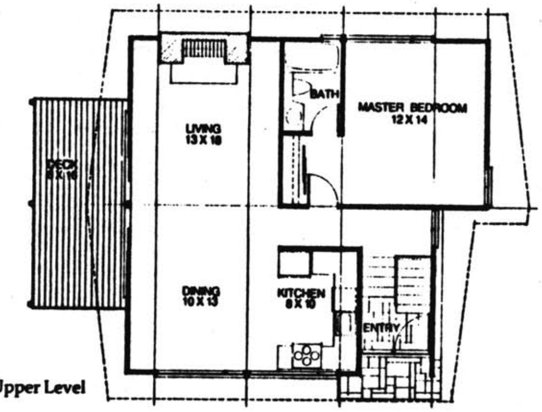




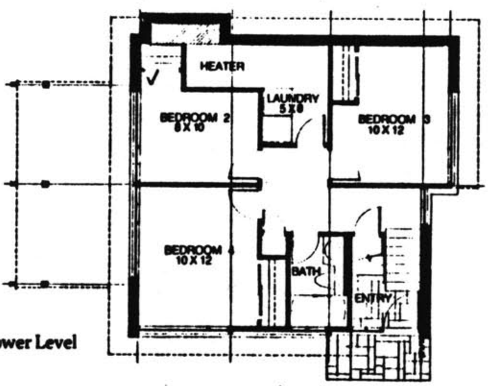
Front Elevation



Front Elevation

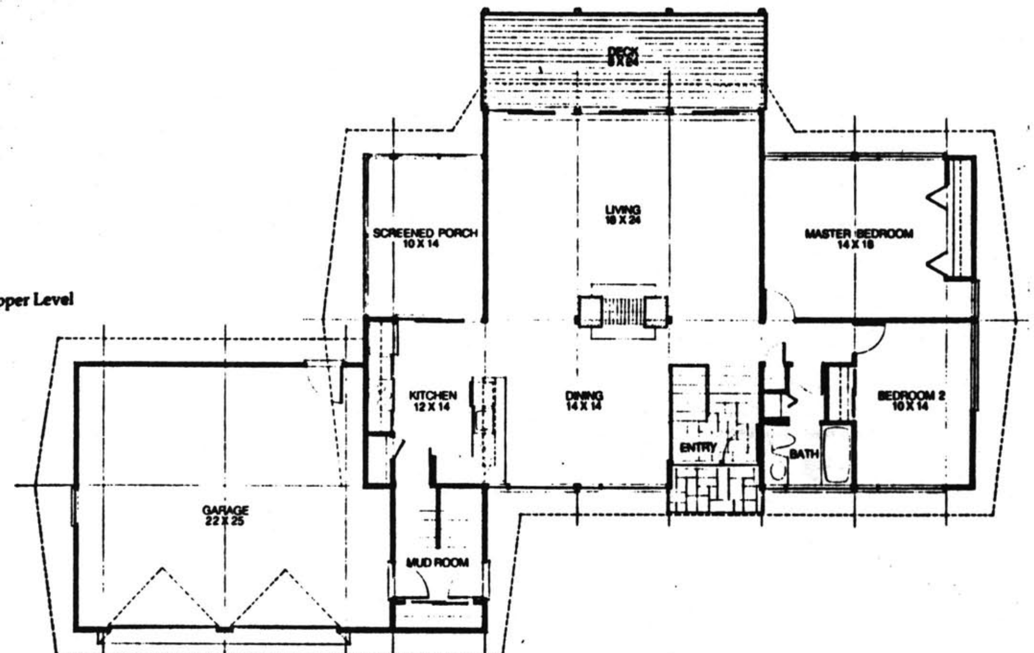


Upper Level



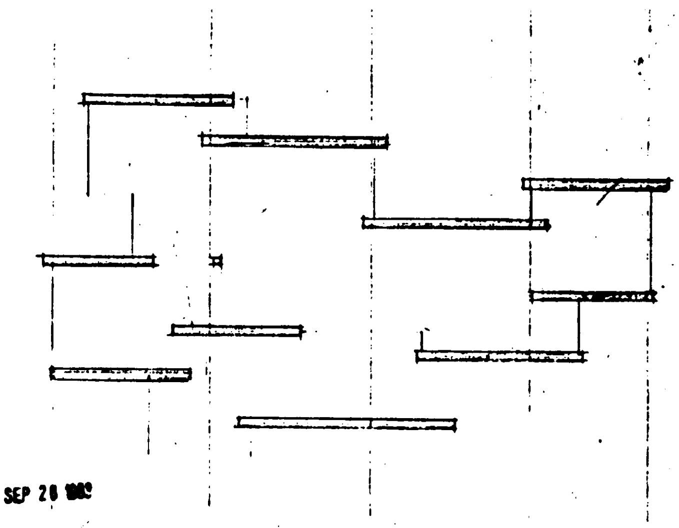
Lower Level

DECK HOUSE

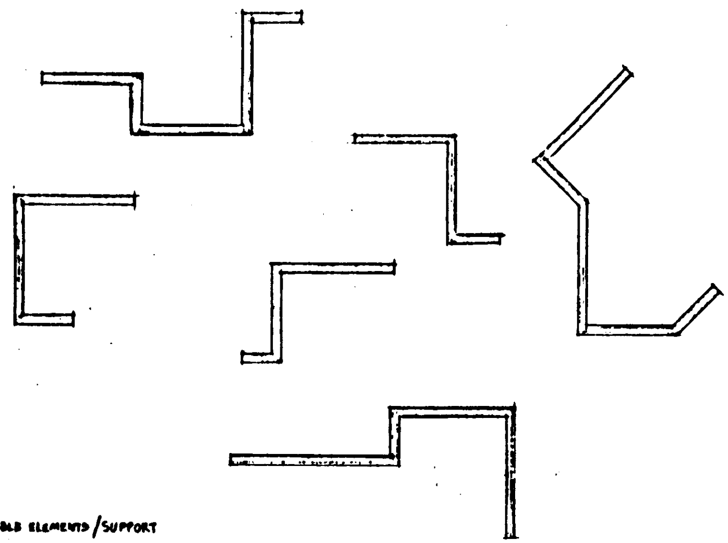


Upper Level

Partial Definition Studies

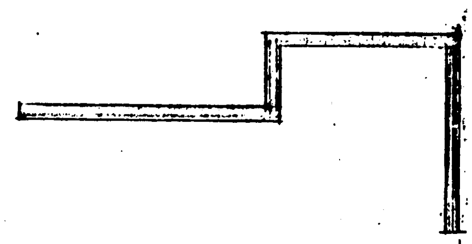


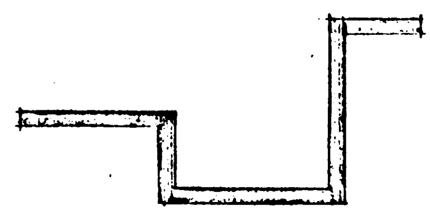
SEP 28 [illegible]

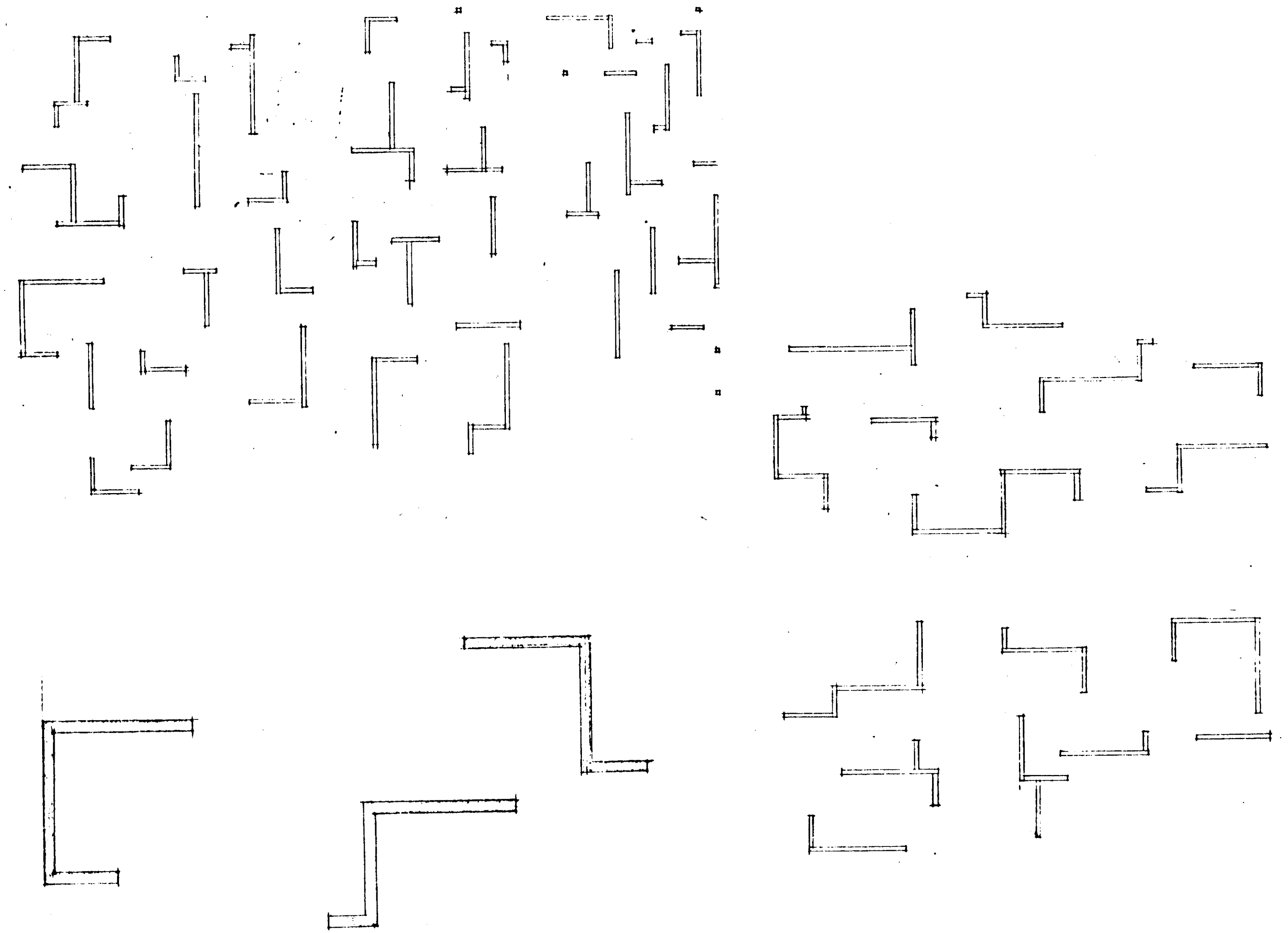


SELF-STABLE ELEMENTS/SUPPORT

SEP 27 [illegible]



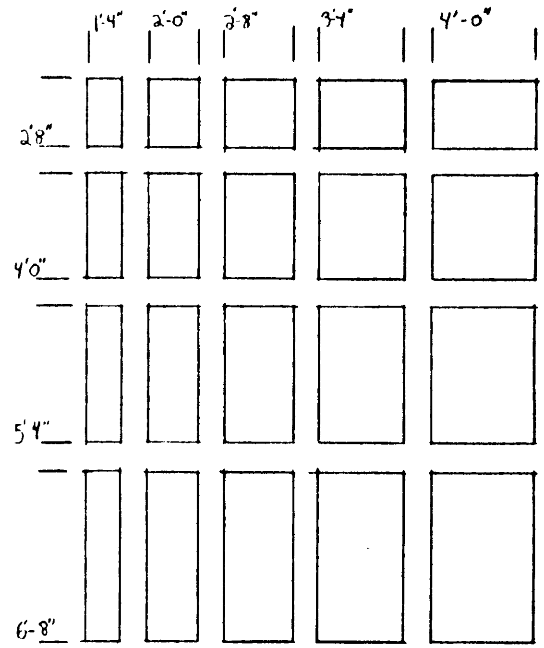


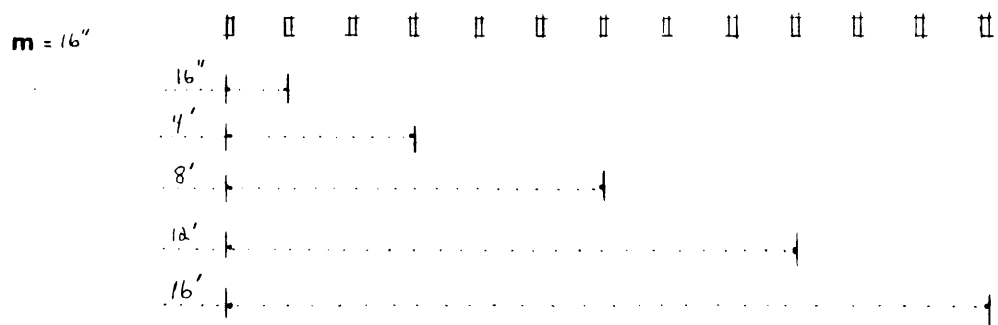


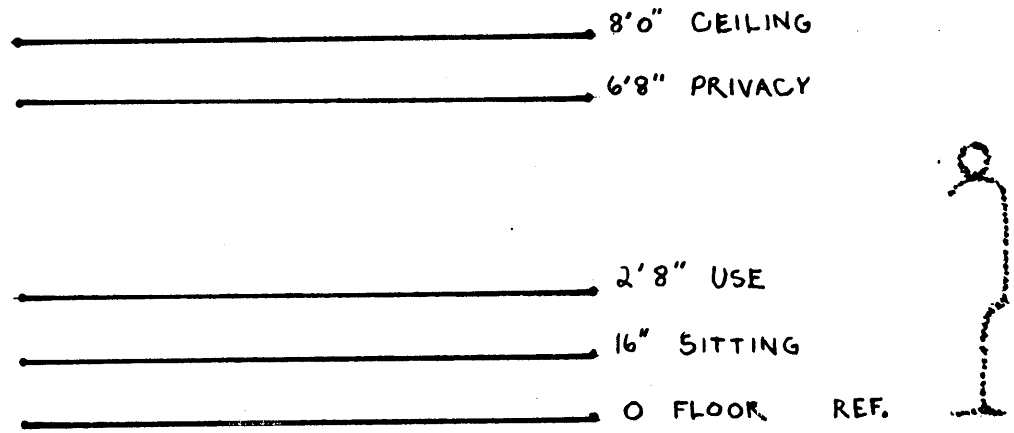
PROPOSAL FOR A PANELIZED BUILDING SYSTEM

MODULE

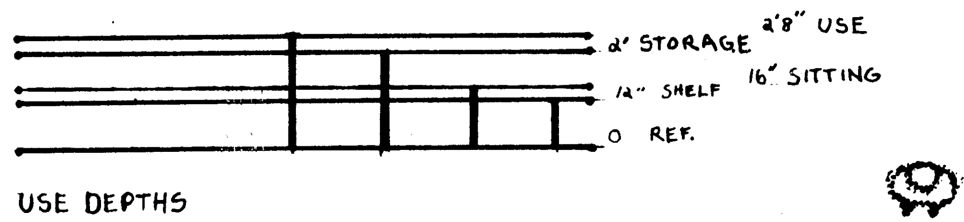
The support, enclosure and infill components are based on an implicit sixteen inch module. This module is the standard for residential materials and construction in this country. Larger modules are generated by adding increments of sixteen inches. Three sixteen-inch modules make a larger four-foot module, which is the dimensional standard for plywood, gypsum board and other sheet materials.







USE HEIGHTS



USE DEPTHS

SYSTEM (GENERAL)

The panelized building system conceptually consists of three basic elements: support, closure, and infill. Each of these elements is comprised of components related to a specific use. The elements can be described as follows:

- Support

Floor panel: Provides a horizontal surface for inhabitation while carrying loads of the closure and infill panels.

Support wall panel: Sets up interior and exterior zones in which closure and infill panels are optionally deployed to partially define use territories. Carries the loads of the floor and roof panels to a masonry foundation.

Prop: Supports floor panels and roof panels in areas where walls are not desired.

- Closure

Weatherscreen: Provides shelter against the elements.

Light regulation: Light is controlled within the dwelling.

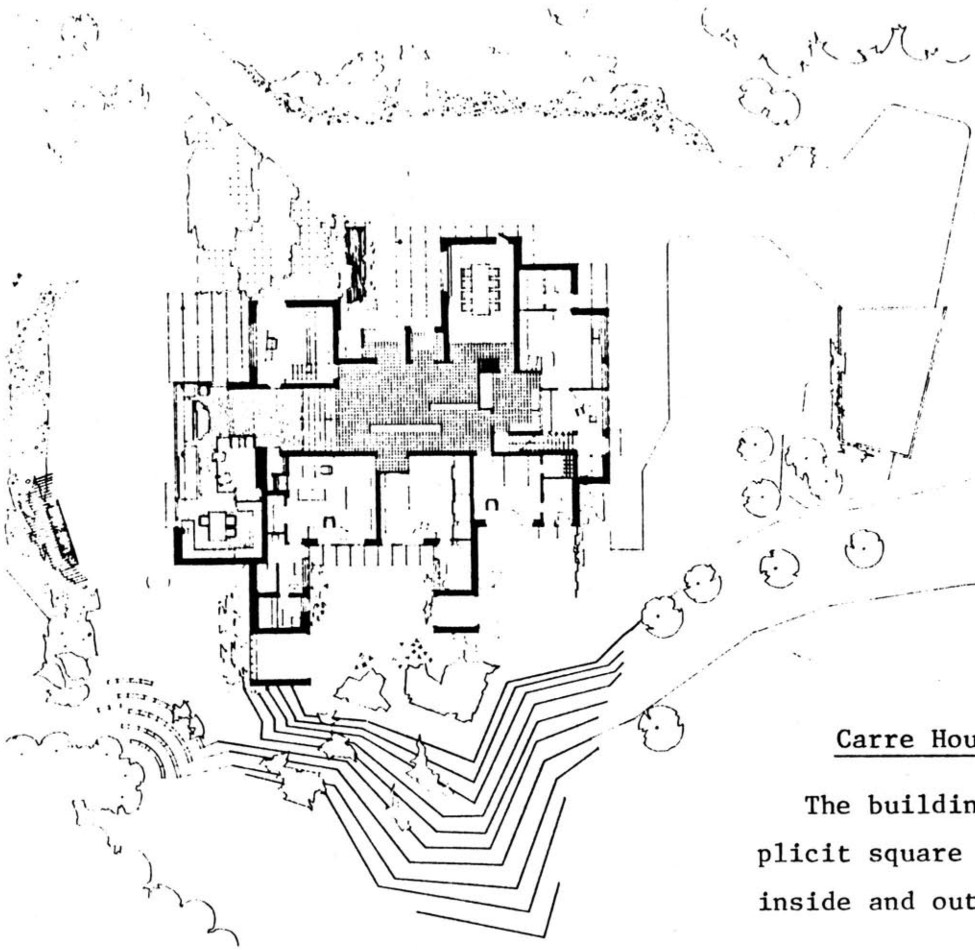
Optional usage: Provides use space where lateral displacements occur between subelements, e.g. sitting, storage, etc.

- Infill

Infill panel: Provides various optional uses while working additively with support wall panels to provide partially defined use territories within the dwelling.

It is assumed that each of the basic elements is responsible for a different job. Therefore they will appear and behave differently from their constituent elements.

REFERENCES For A Panel System

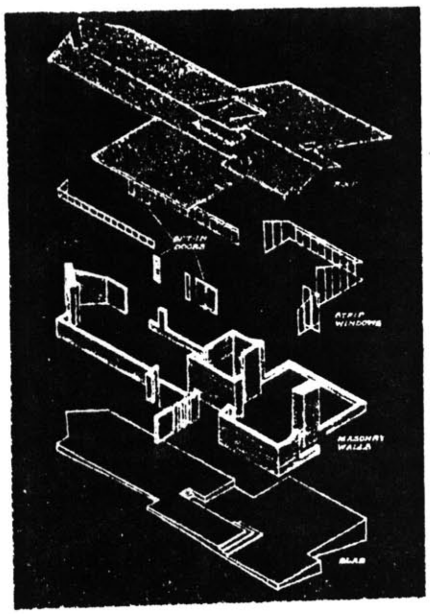


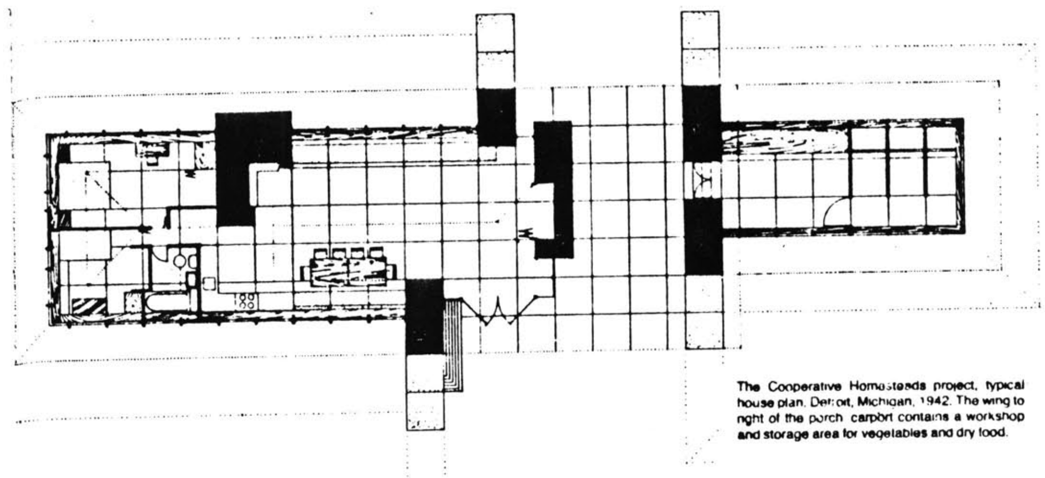
Carre House, Alvar Aalto, 1959

The building form, based on an implicit square module, clearly defines inside and outside use territories.

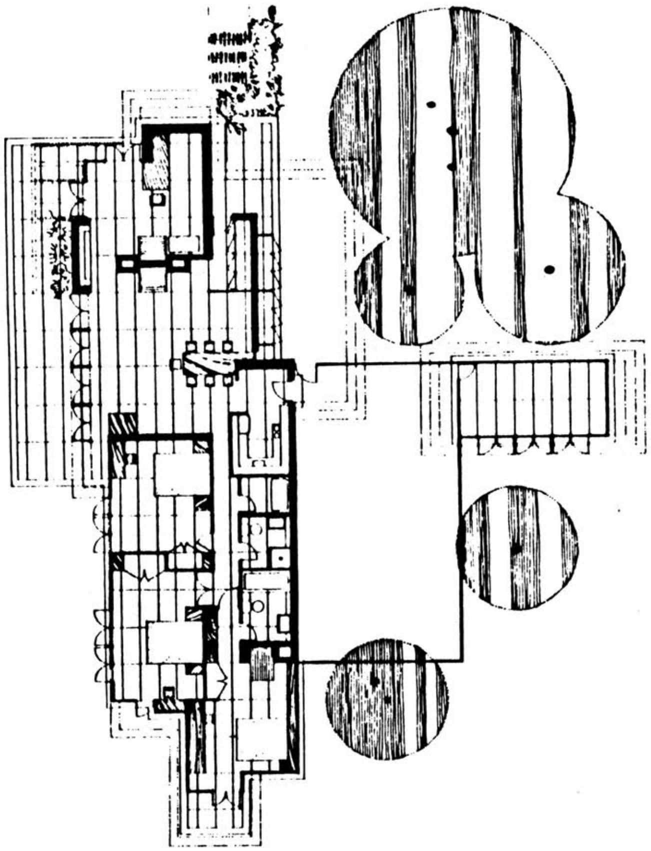
Frank Lloyd Wright saw design as "an abstraction of natural elements in purely geometric terms." His work demonstrates a strict use of dimensioned elements to organize form. In his domestic architecture of wood construction, such as the "Usonian" houses, the use of an implicit two by four foot module is present. Using this module, Wright was able to generate a wide range of spatial variety.

The Evans house, Chicago, Illinois, 1908.



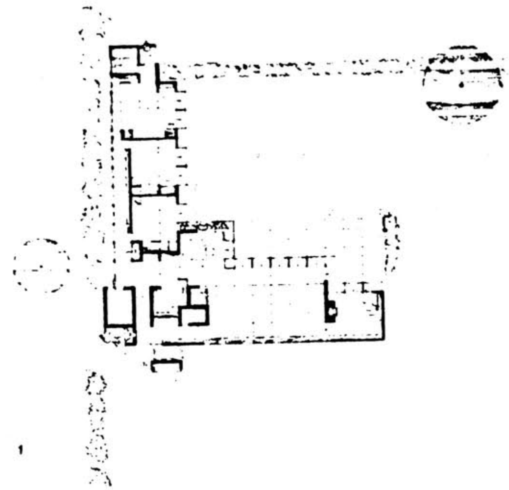


The Cooperative Homesteads project, typical house plan, Detroit, Michigan, 1942. The wing to right of the porch carport contains a workshop and storage area for vegetables and dry food.



Clients: Mr. and Mrs. Theodore Baird
Profession: Shakespeare scholar, college professor
Location: Amherst, Massachusetts
Year of design: 1940
Best source: *Architectural Forum*, January 1948
Builder/supervisor: General contractor, Wesley Peters: supervised by J. C. "Carey" Caraway and Edgar Tafel
Cost: Not known
Floor area: 1,200 sq ft; 111.5 sq m

The Usonian



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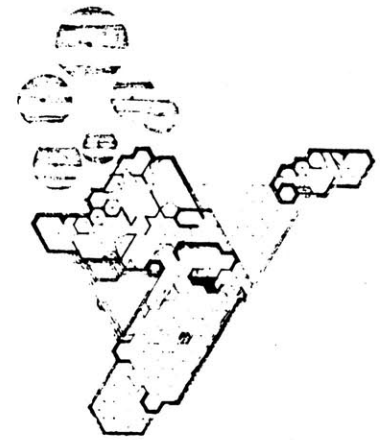

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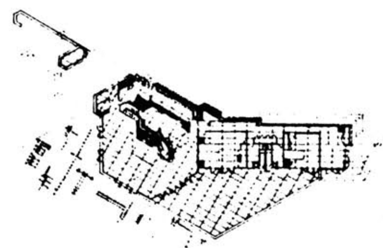

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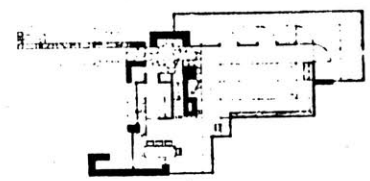

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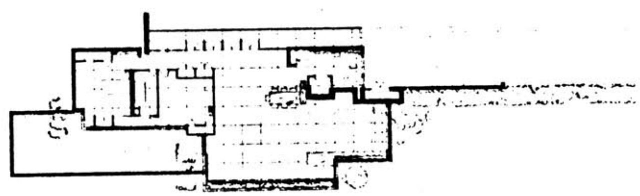


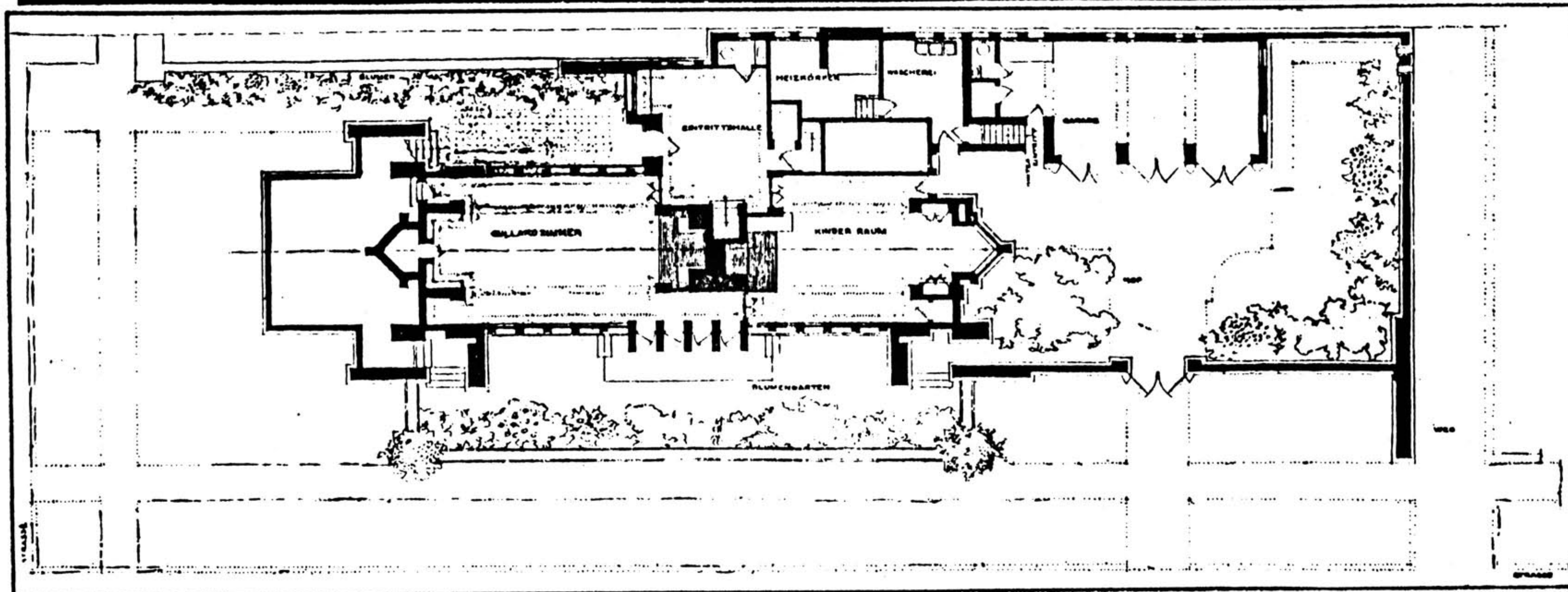
3

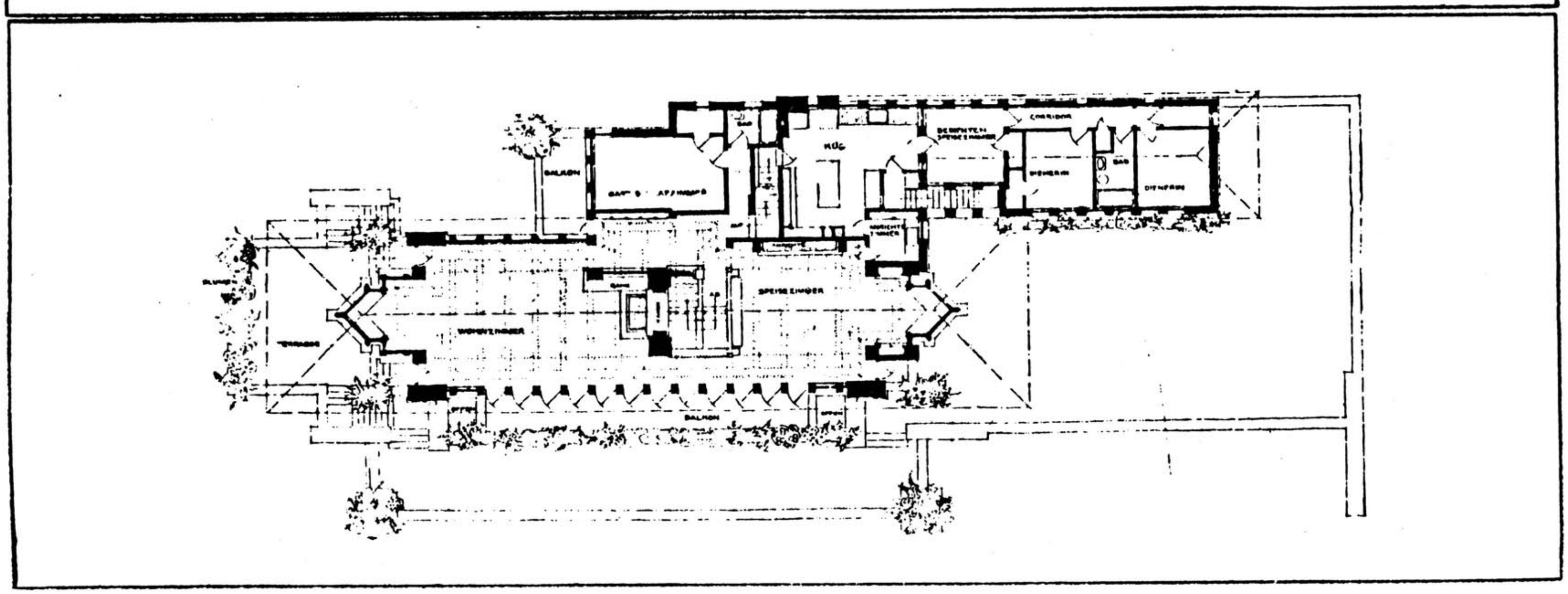
Five Types of Usonian Plans

1 Polliwog, Rosenbaum house.
2 Diagonal, Panshin house project.
3 In-line, Winkler-Goetsch house
4 Hexagonal, Bazett house.
5 Raised, Pew house.

Robie House, Frank Lloyd Wright, 1909

The Robie house demonstrates the destruction of the self-enclosed, box-like room. The main floor is treated as a unified space where the dining room and the living room are partially separated by the fireplace. The plan of the two areas reads as a single flowing space. The openness allows the furniture to create a sense of containment for certain activities, but does not interrupt the spatial continuity.


KINDER RAUM
GARAGE
BLUMENGARTEN


BALKON
CORRIDOR
BAD
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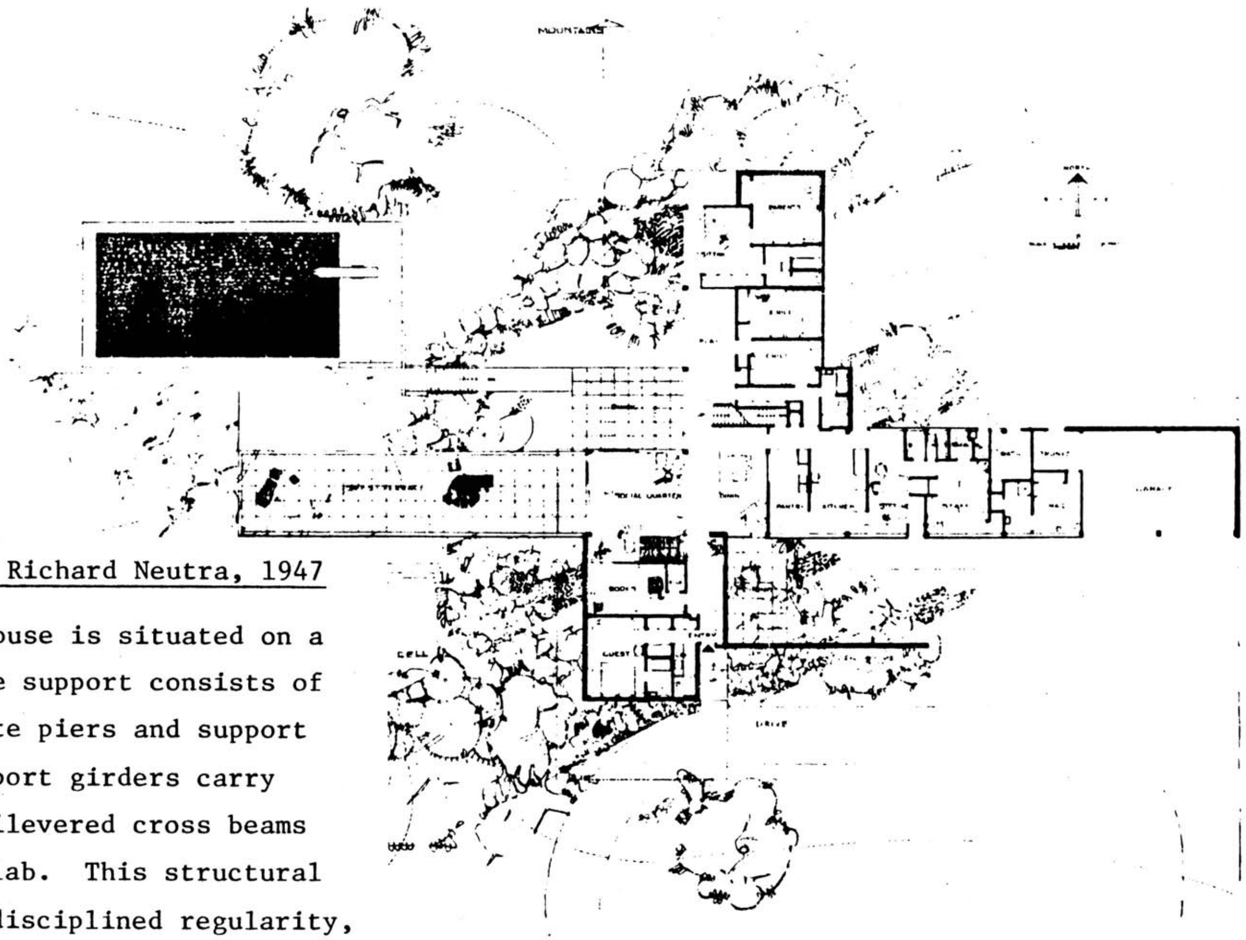
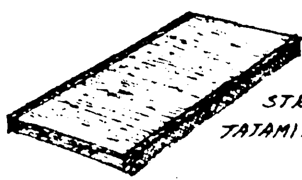
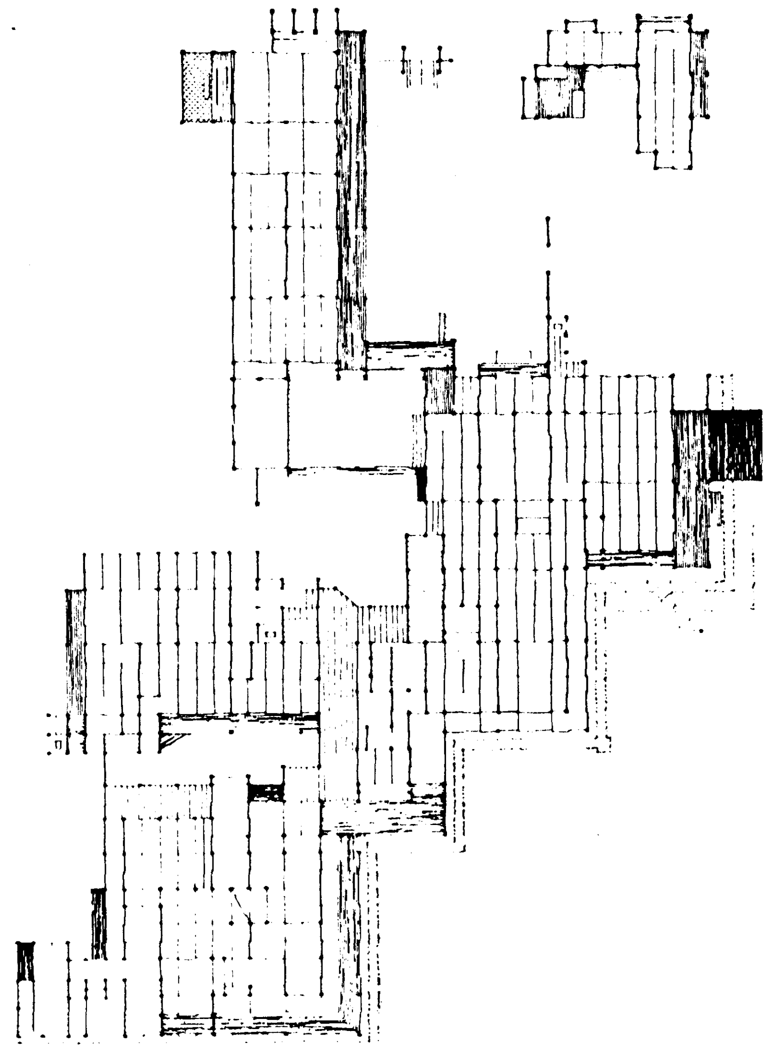


Tremaine House, Richard Neutra, 1947

The Tremaine house is situated on a sloping site. The support consists of reinforced concrete piers and support girders. The support girders carry the loads of cantilevered cross beams and a thin roof slab. This structural system implies a disciplined regularity, but the spacing of the piers varies from 16 to 20 feet. They are freely moved out of alignment when they interfere with the plan; and one, in the living room, is replaced by a six-inch-diameter steel lally column.

A strong conviction for modular coordination can be observed in traditional Japanese architecture. These buildings are organized using a modular unit based on the "tatami." Tatami, straw mats which vary in dimension from one part of the country to another, are roughly three by six feet. These dimensioned elements are used additively to reinforce the relationship of the building to its adjacent landscape.



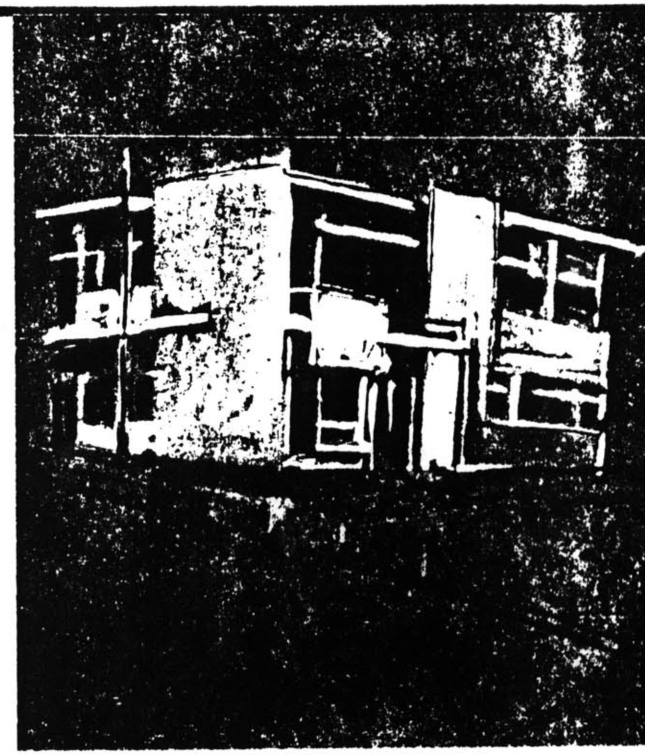


Katsura Detached Palace 1620-25, 1642-47, 1658 Southwest of Kyoto, Kyoto, Japan. Architects and Clients: Prince Toshihito and Prince Toshitado.

Schröder House, Gerrit Rietveld, 1924

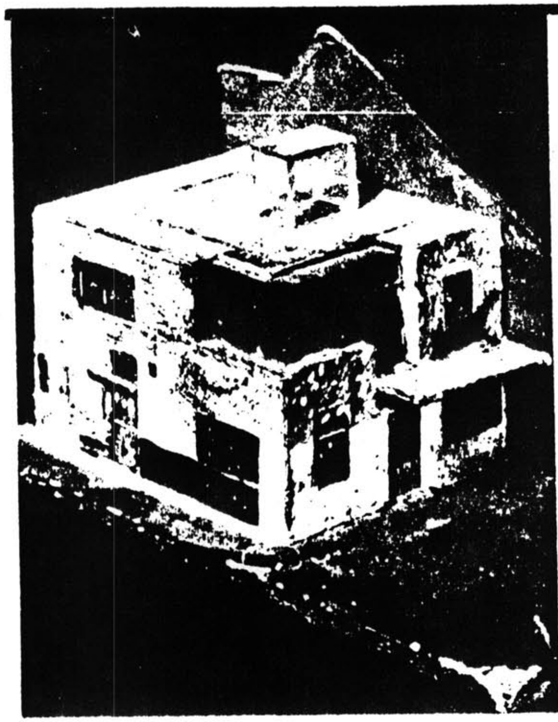
The Schröder house demonstrates a clear visual independence of its component parts. This independence is achieved in various ways: through the use of overlapping components, the use of color to accentuate the form of different elements, and the physical displacement of panels.

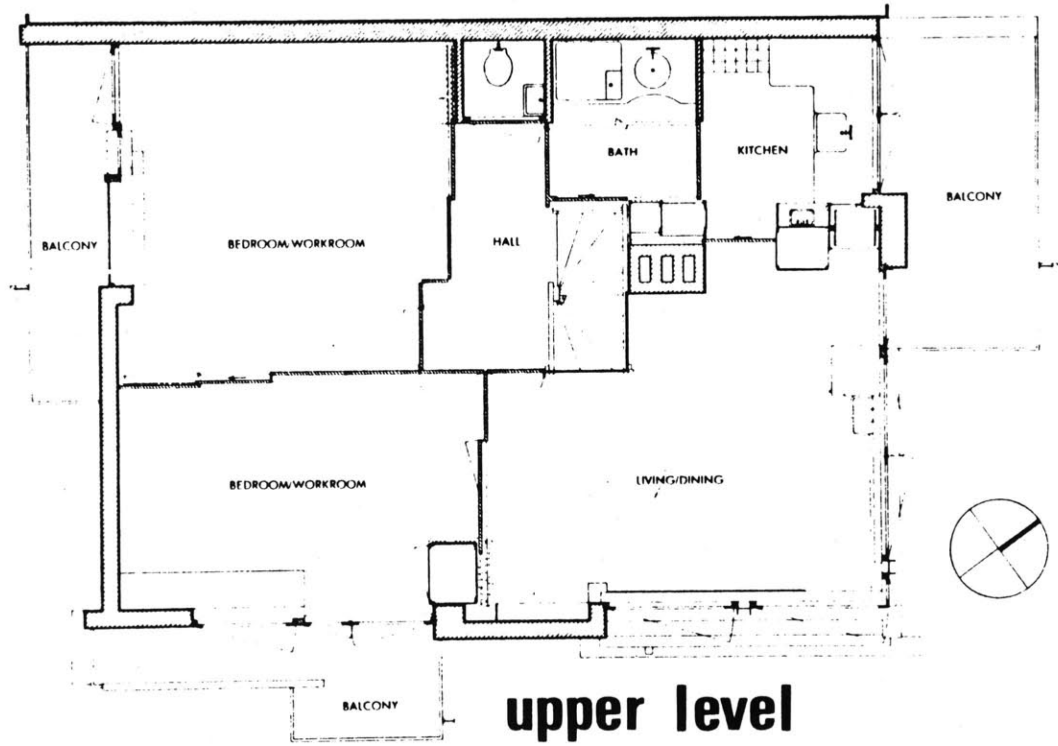
The upper level exhibits design flexibility through the use of sliding panels. The bathroom and stairwell are defined with fixed panels. The rest of the space is one large area which is partially defined by the sliding panels. The territories created when the panels are moved into place are adaptable to a variety of different uses.



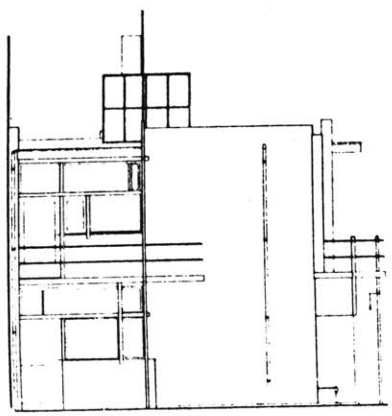
Early Rietveld sketch, circa 1924.

"Without bothering to adapt the house to some extent to the traditional houses on the Prins Hendriklaan, we simply attached it to the adjacent house. It was the best thing we could do—to make it stand out in contrast as much as possible. Understandably, it was very hard to square this with the local building code. That's why, on the ground floor, the house presents a rather traditional layout, i.e., with fixed walls; but the level upstairs we simply dubbed an attic, and there we realized the house we intended to make."
Gerrit Rietveld, 1963

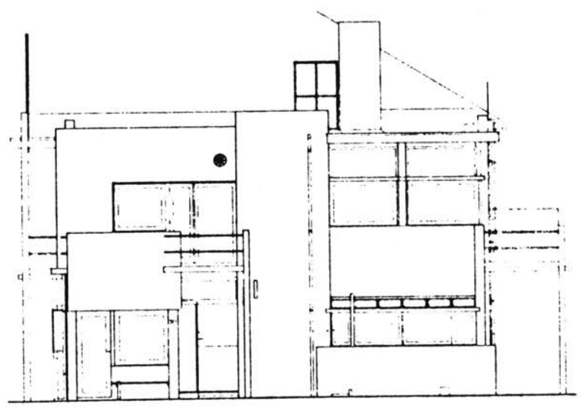




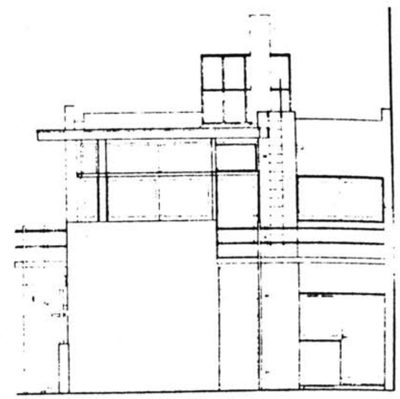
upper level



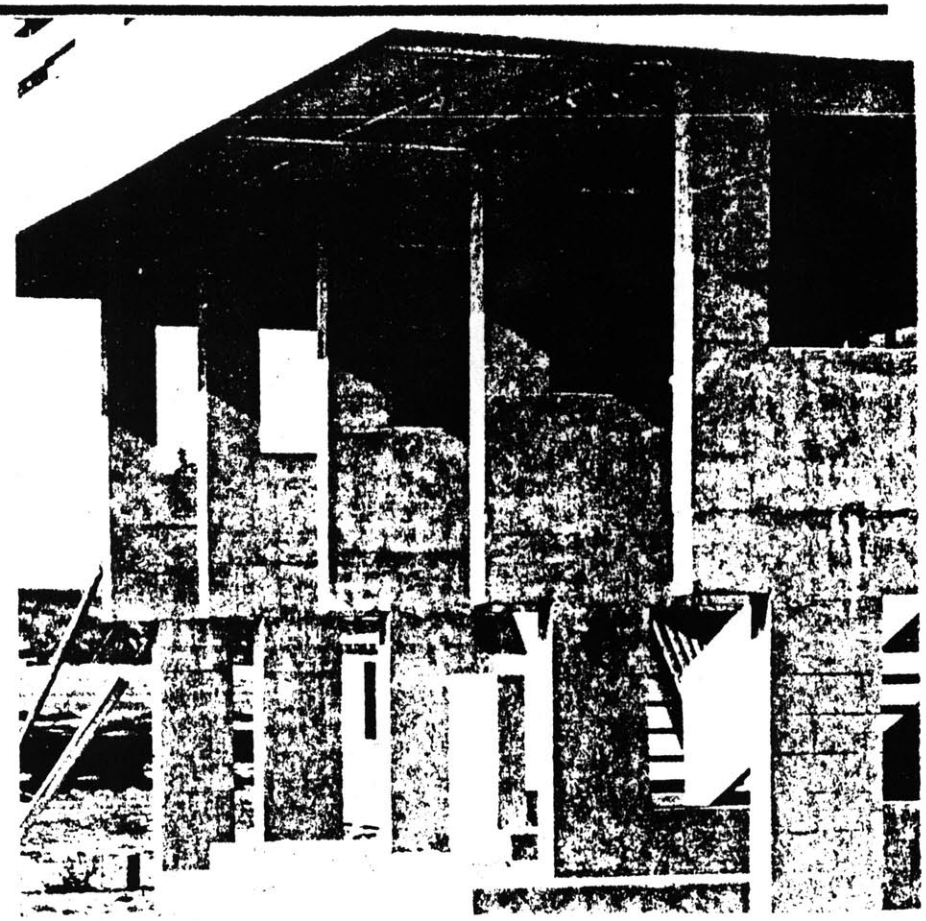
South-west elevation



South-east elevation

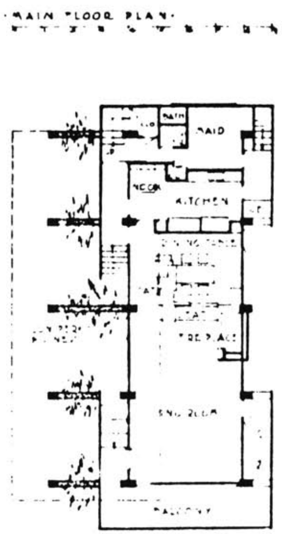


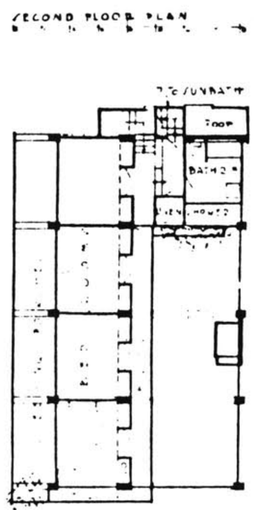
North-east elevation

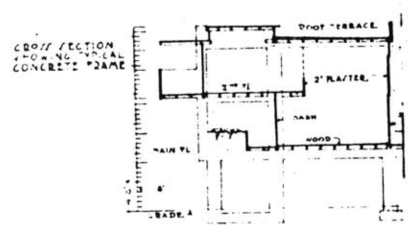


Lovell House, Rudolph M. Schindler, 1926

The support of the Lovell house consists of five similar concrete frames. The structure is placed outside of the enclosing walls, demonstrating a clear separation between support and closure elements. The frames pass upward through the house to support the roof. This provides partial definition to the building's interior, while leaving the periphery open.







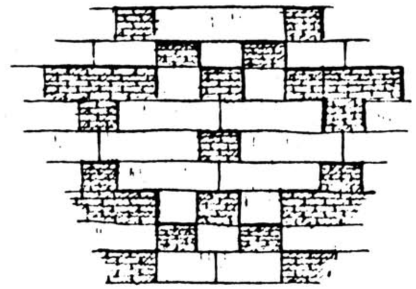
SYSTEM (SPECIFIC)

- <u>Support</u>

The primary function of support elements is to carry loads and set up the first order of partial definition. The support elements consist of four groups: masonry, floor panels, support wall panels, and special props. While providing support, each element operates in a different capacity.

The masonry may consist of stone, brick, concrete, or concrete block. It serves as a foundation or base on which support walls rest. Masonry supports may also support the floor panels directly. In the case of sloping terrain, the masonry also serves as a retaining wall.

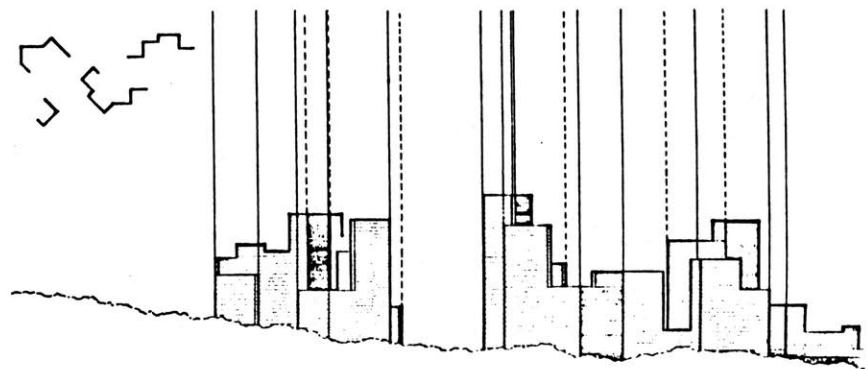
At the ground level, the masonry identifies and defines the ground form. In some places, it reaches past the lower levels, thereby extending pieces of the established ground form to the upper levels.



COMBINING AREAS OF STONE AND BRICK

East Elevation :

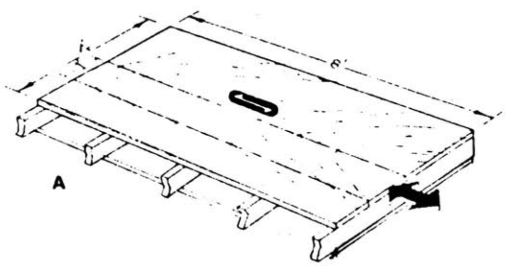
MR F W LITTLE - SUMMER DWELLING - FRANK LLOYD WRIGHT -



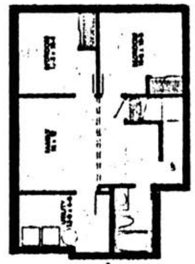
Taylor T. Dueker

The masonry foundation in this system differs from the conventional strip foundations used in most factory houses. It is not treated as a continuous wall, of constant height, operating only at the building's periphery. Rather, it is treated as a discontinuous extension of the ground allowing for further optional definition and growth.

The floor panels and the support wall panels are comprised of 2 x 10 and 2 x 6 construction grade lumber, respectively, sandwiched between two layers of one-half-inch plywood. The resulting panel is referred to as a "stressed-skin" panel.



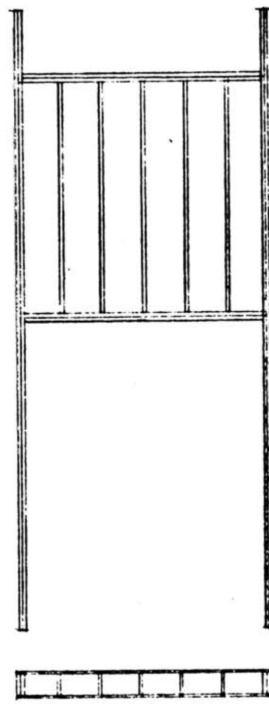
Stressed-Skin Panel


Acorn

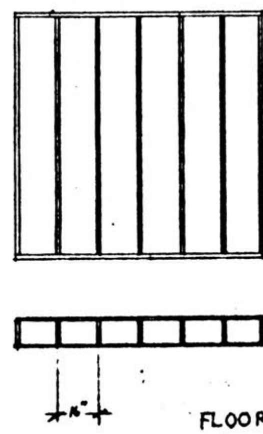
There are two types of floor panels:

- floor panels with extended joists,
- floor panels with flush joists.

The floor panels with extended joists are used to provide vertical continuities within the dwelling, e.g. overlooks to spaces below, provisions for stairs, etc.



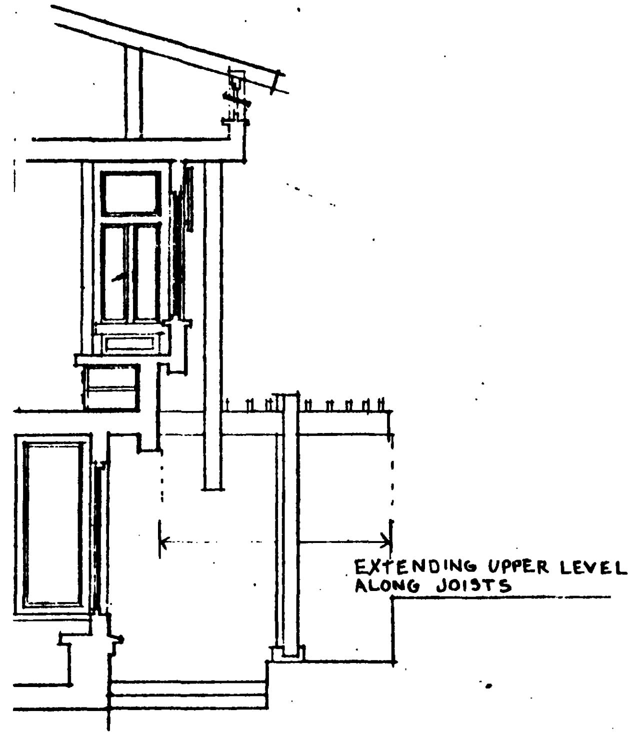
FLOOR PANEL WITH EXTENDED JOISTS



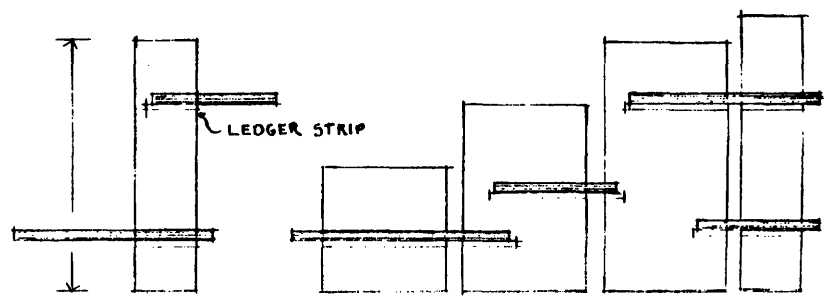
FLOOR PANEL FRAMING

In some cases, the joists may pass to the dwelling's exterior to be supported by props. This condition allows the upper levels to be extended or the joists can be optionally covered with various roofing materials or a trellis.

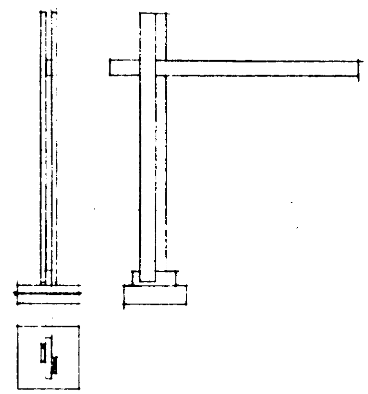
The floor panels with flush joists are used where vertical continuities are not desired.



Wall support panels are used to support floor panels. The floor panels are held in place by a ledger strip which is secured to the side of the wall panel. By varying the height of the ledger, floor panels can be raised or lowered along the side of the support wall panel. This feature makes possible a wide range of optional level changes which may respond to topographical conditions.



Special props may be used to carry the loads of the floor panels and roof panels in places where support wall panels are not desired. When used in conjunction with floor panels with extended joists, props may be optionally placed on either side of the closure panels.



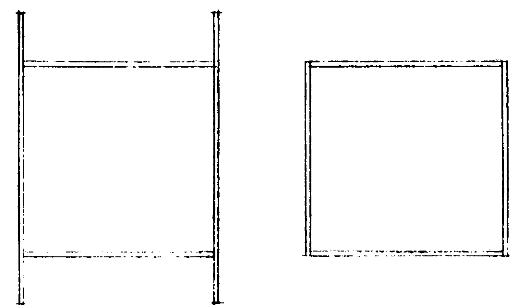
PROP DETAIL
SCALE: 1/4"-1'

- <u>Closure</u>

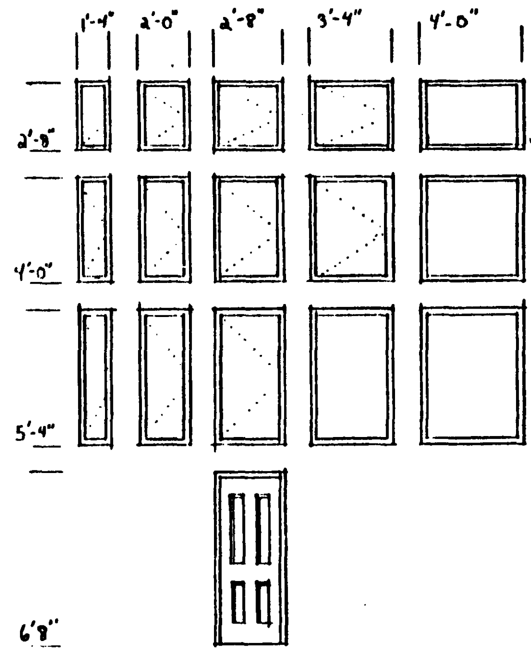
A closure panel consists of a frame which is dimensionally coordinated with the floor panels. The dimensions of four, eight, twelve, and sixteen feet are given.

Two types of closure frames are provided:

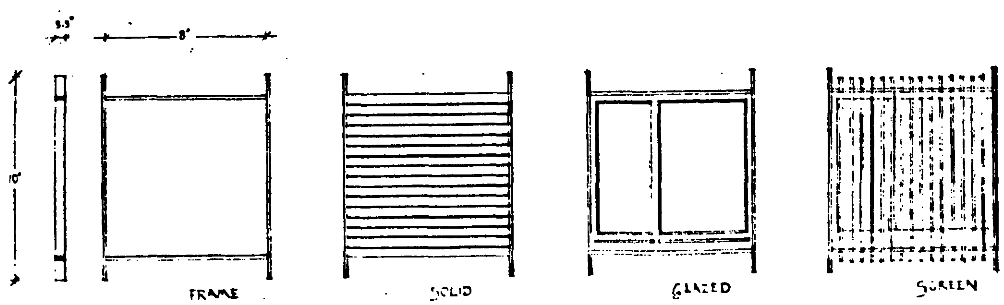
- frames with extended ends which attach to the sides of the floor panels, optionally yielding a use dimension between the closure and the floor panel,
- frames with flush ends which rest directly on the floor panel.



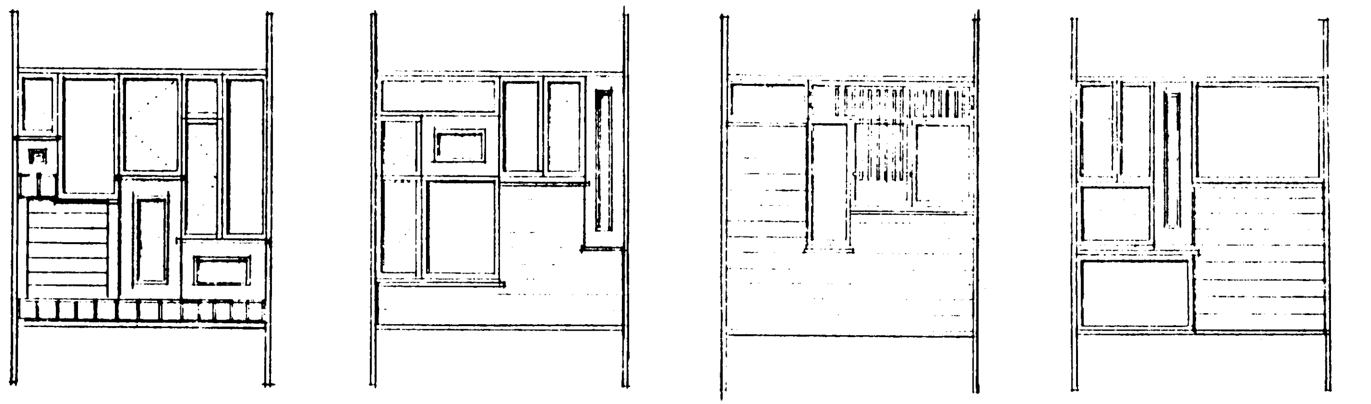
With the sixteen-inch module established, subelements of the closure are conceptualized as a series of plug-in components.



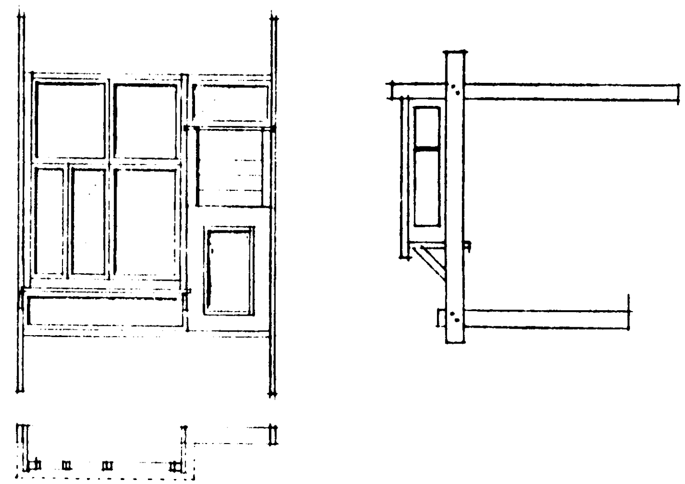
Each subcomponent can be independently manipulated within the closure frame. The dimensioned subcomponents are optionally deployed within the closure framework according to the desired use. Subcomponents may be: a window for light, a wall for opqueness, or a screen for transluscency.



Each of the subcomponents is interchangeable. Windows can become screen or wall, walls can become screen or window, screens can become window or wall.



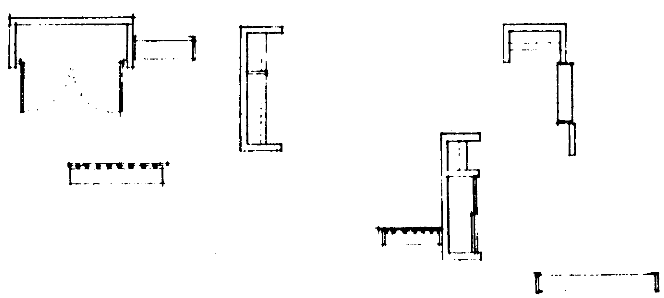
Optional use territory can be generated through the lateral displacement of subcomponents. Depending on where these displacements occur, provisions for seating, storage and other uses can be made.

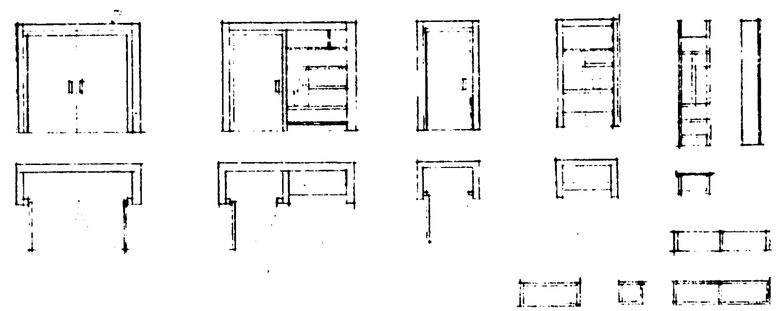


- <u>Infill</u>

Infill panels are essentially movable storage units which are arranged within the dwelling to provide complete or partial definition of use territories. The larger infill panels, such as closets, are structurally self-stable. They can be used singularly or additively with other infill elements.

As demonstrated throughout the proposed system, all infill elements are dimensioned using the sixteen-inch module. The selection and placement of each element corresponds to a specific use.





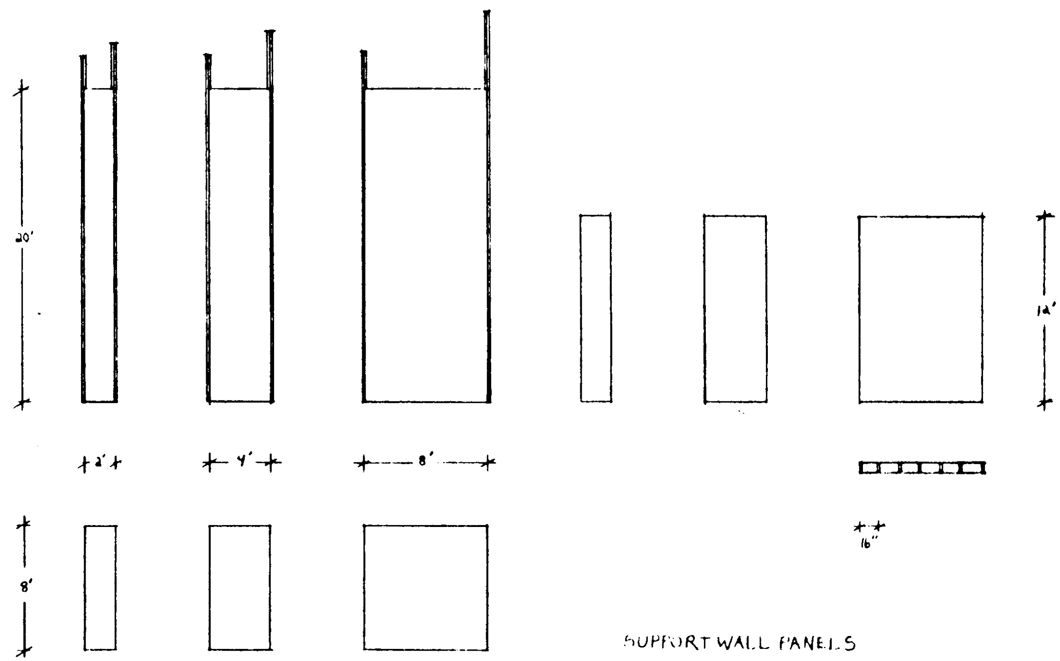
The infill elements are dimensionally coordinated to be used in conjunction with an eight-foot floor to ceiling height. The maximum height of each storage elements is six feet, eight inches. This allows the unit to be easily placed and moved around within the dwelling. The remaining dimension at the top can be left open, or, where acoustical privacy is necessary, can be closed off with glazing or a solid panel.

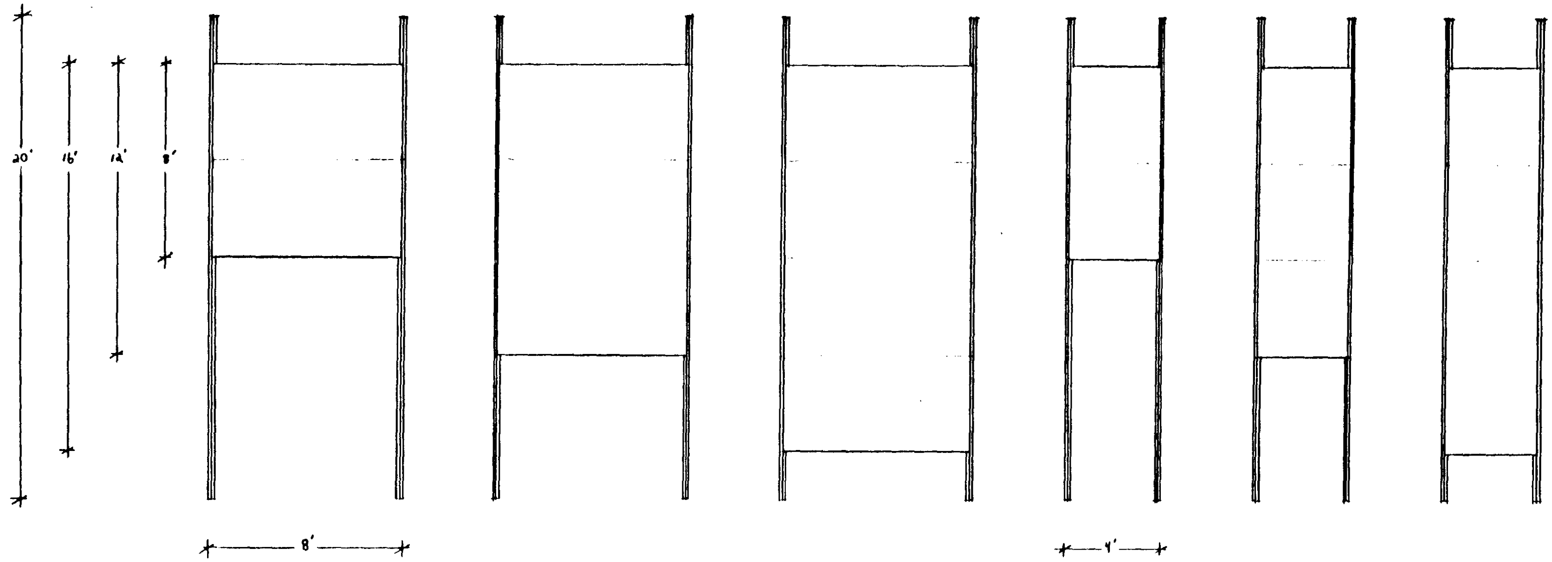
The lateral spacing between infill elements will generally be consistent with the module. This allows territories to become completely defined using only the standard infill elements provided by the system. For example, if the lateral displacement between infill elements is two feet, eight inches, a standard door or another dimensionally equivalent element of the system may be used to provide privacy.

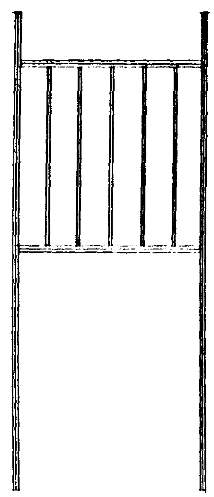
In areas where it is necessary to deviate from the set module, special slack pieces will be required to make up the dimensional difference. These pieces will vary from situation to situation and are therefore difficult to standardize for factory production. In this case, slack pieces may be added at the site using a stickbuilt process.

Catalog Of Elements

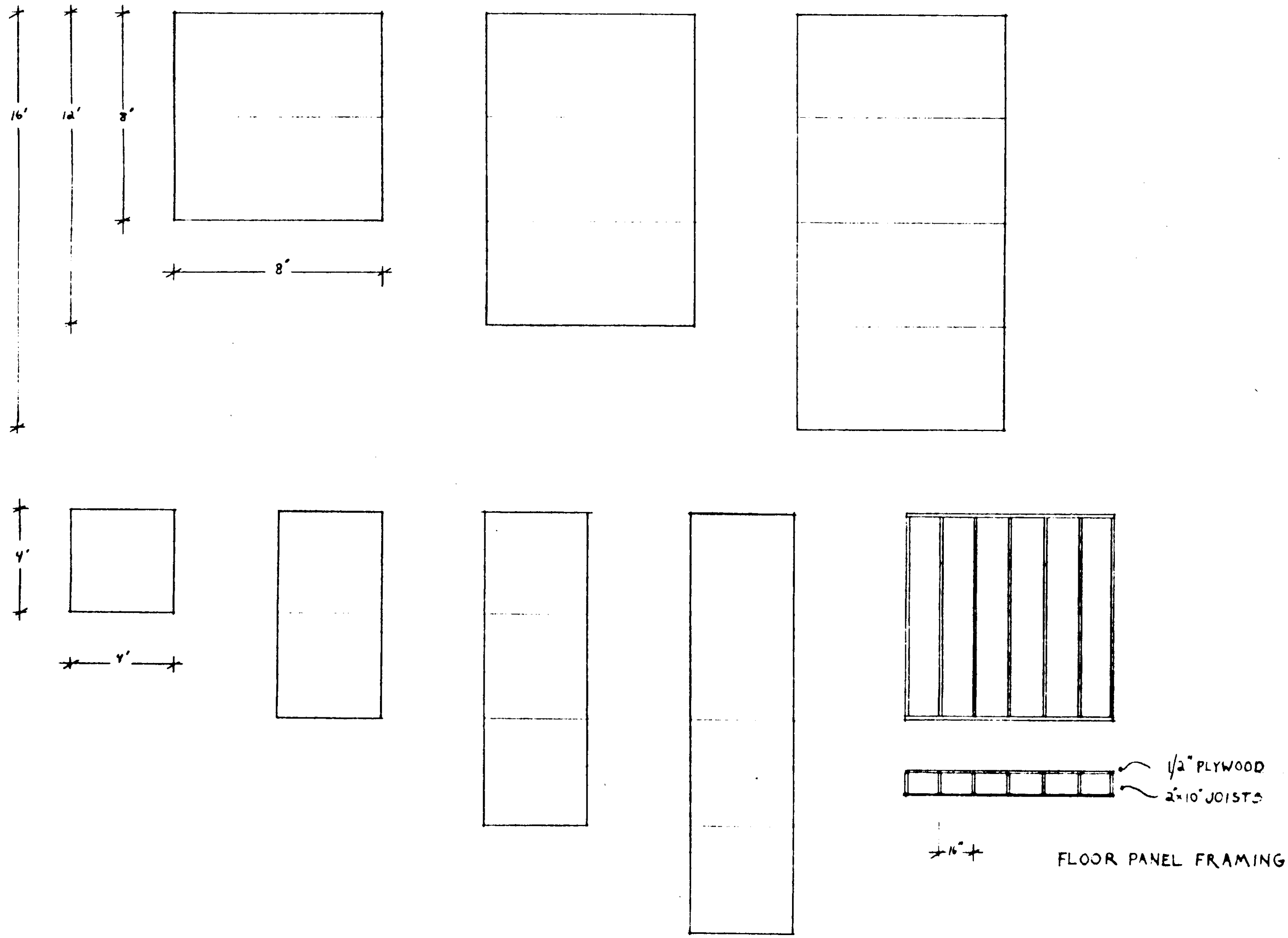
Support

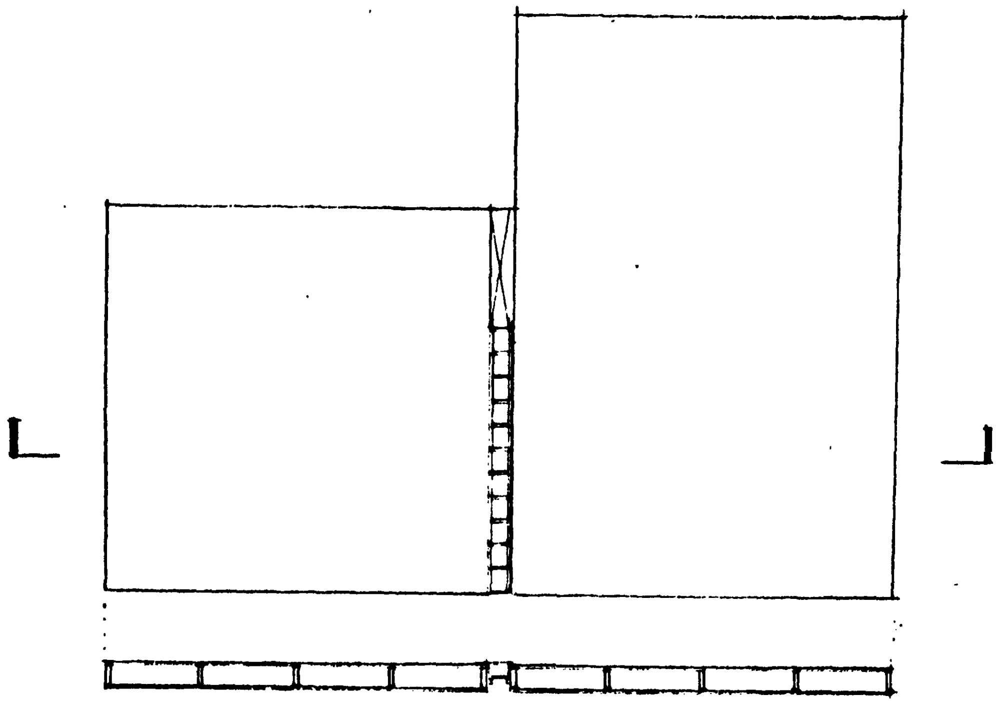




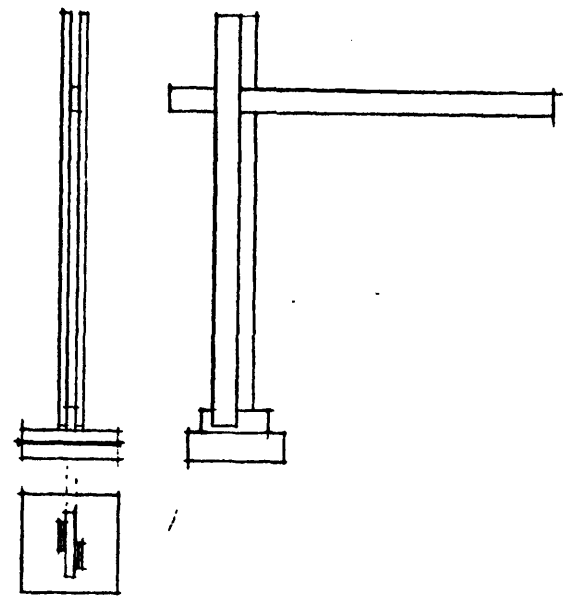


FLOOR PANEL WITH EXTENDED JOISTS FRAMING

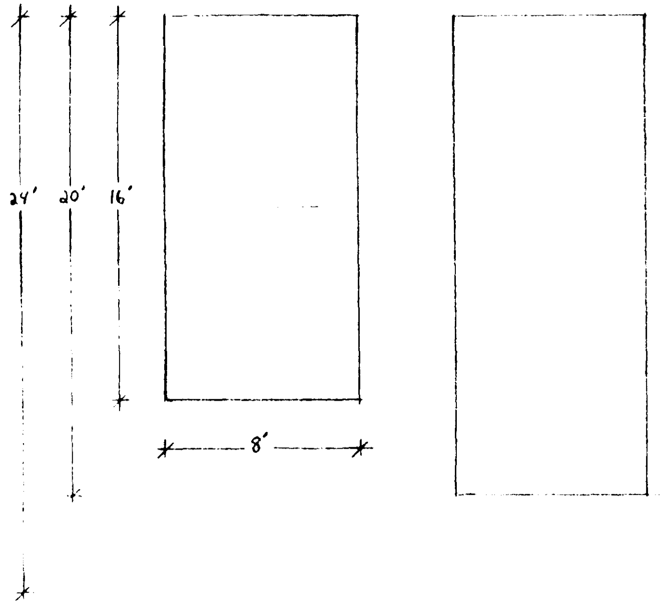

16'
12'
8'
8'
4'
4'
1/2" PLYWOOD
2x10" JOISTS
16"
FLOOR PANEL FRAMING



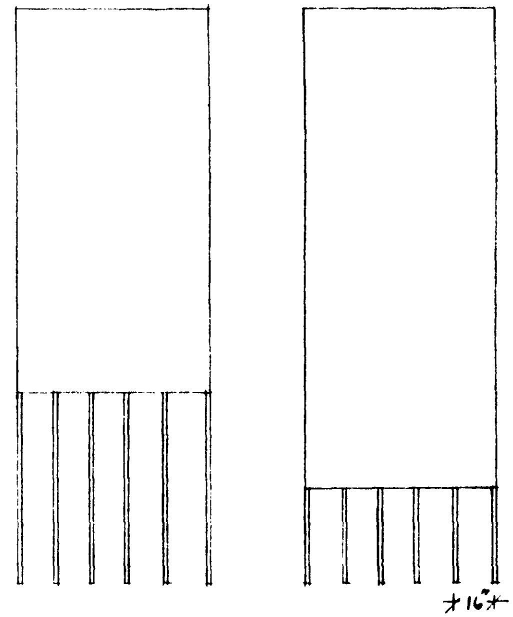
FLOOR PANELS WITH GLASS BLOCK



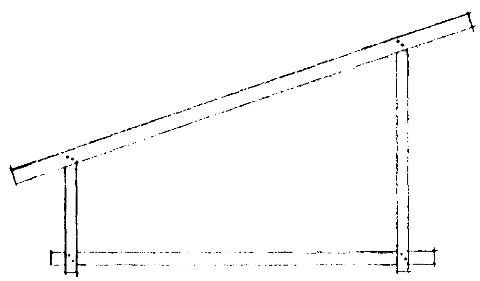
PROP DETAIL
SCALE: 1/4"=1'



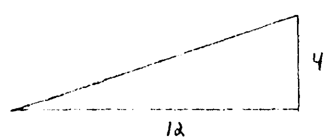
ROOF PANELS WITH FLUSH RAFTERS



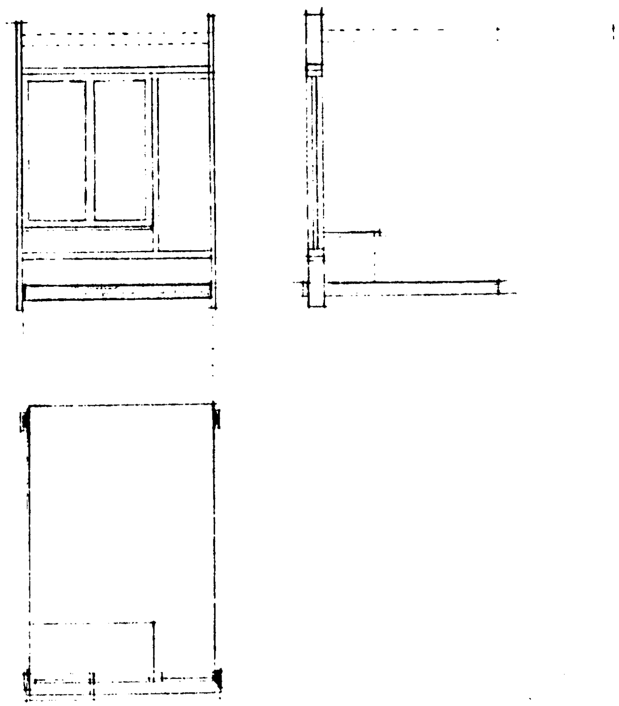
ROOF PANELS WITH EXTENDED RAFTERS



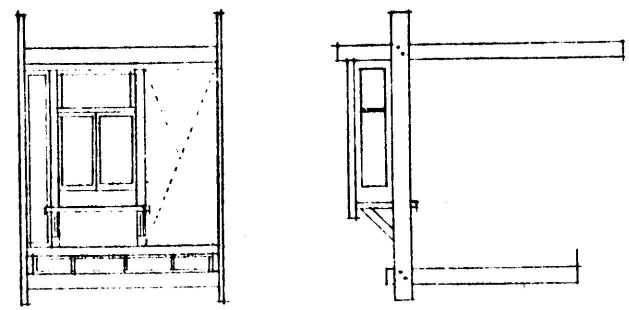
4 in 12 ROOF PITCH

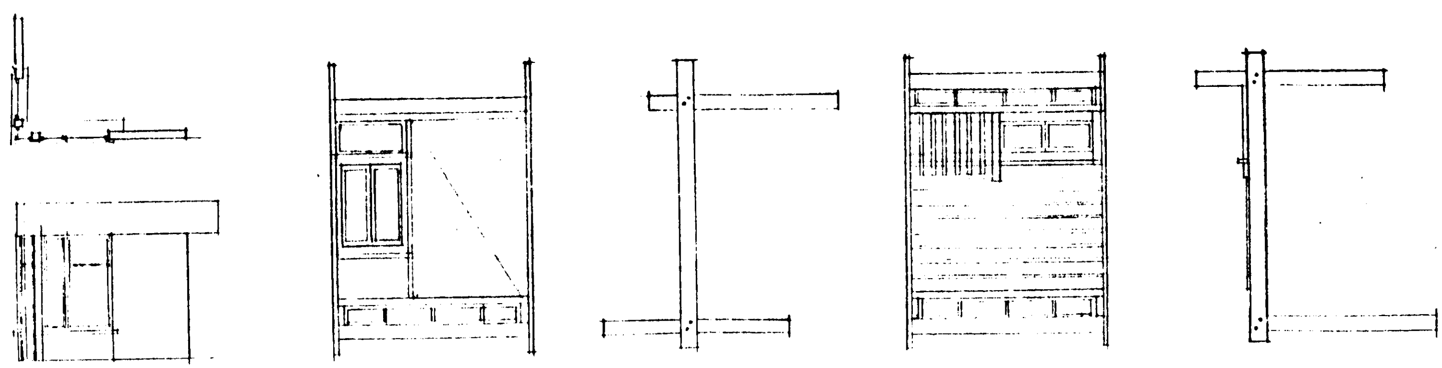


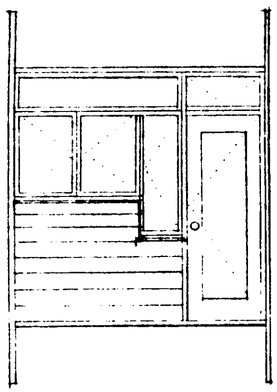
Roof panels are designed to be used with a 4 in 12 pitch (roof rises four inches for every twelve inches of run). This is the minimum required pitch for conventional shingle roofs. Additionally, this is the optimum pitch for allowing the spaces directly below the roof surface to be inhabited.



Closure







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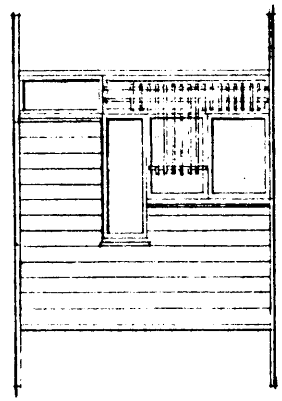

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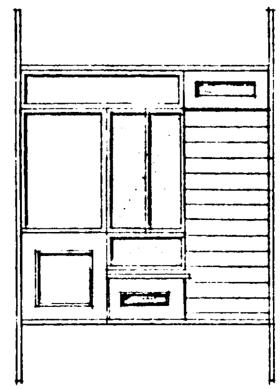

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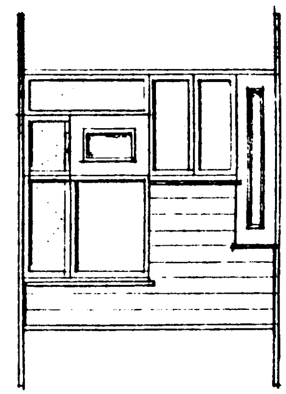

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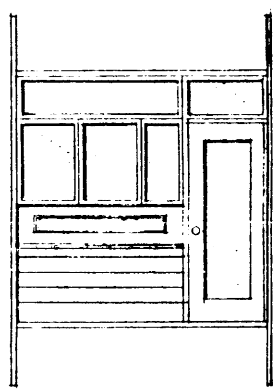

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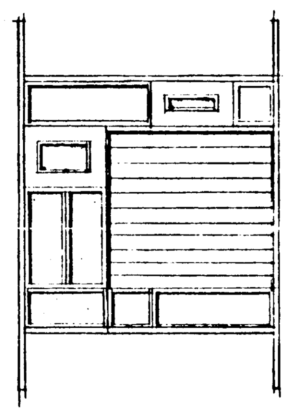

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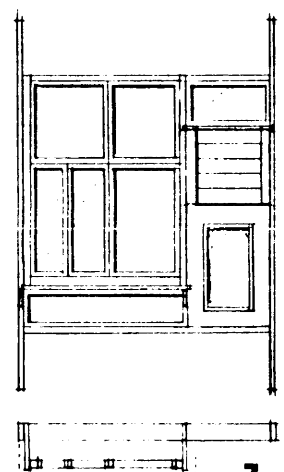

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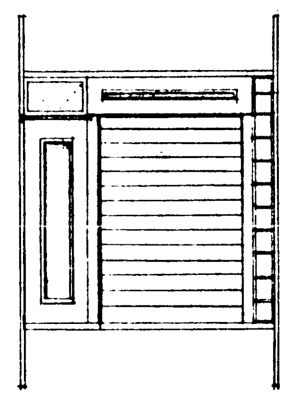

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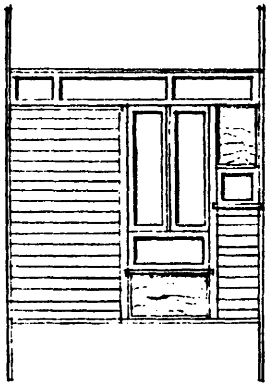

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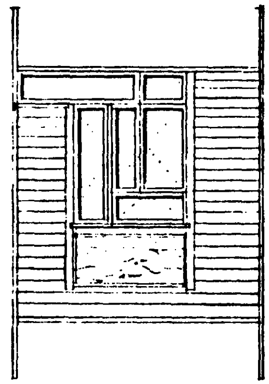

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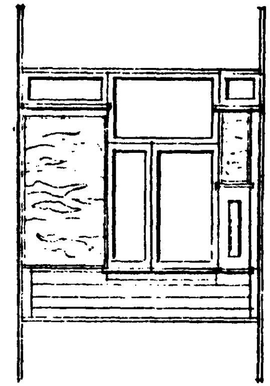

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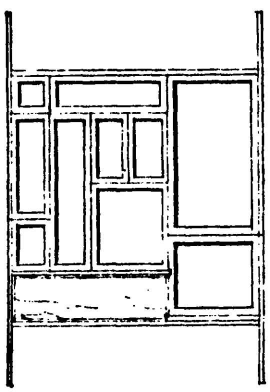

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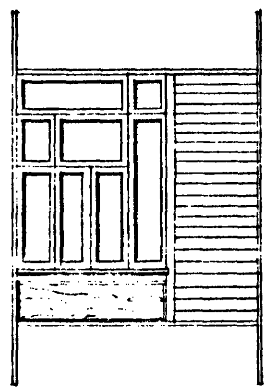

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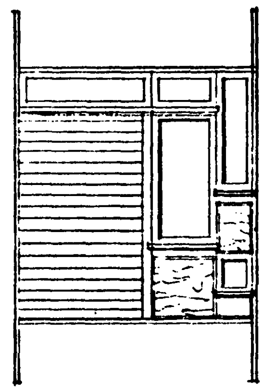

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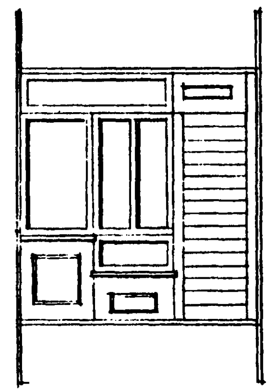

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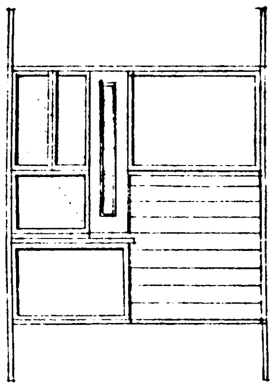

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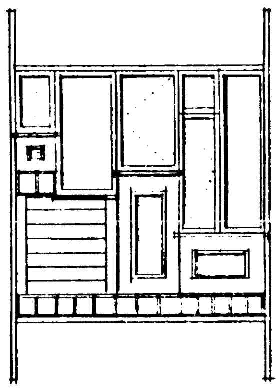

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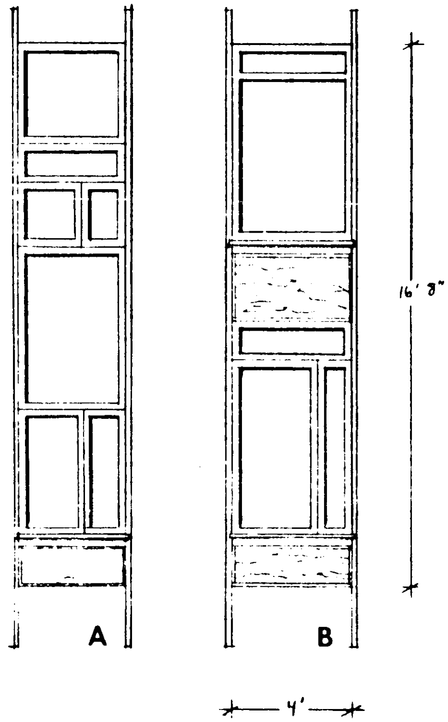
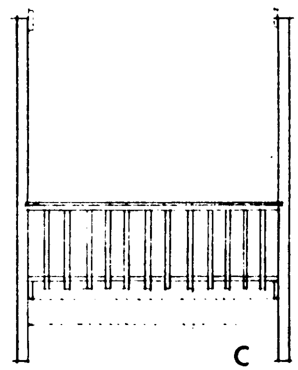
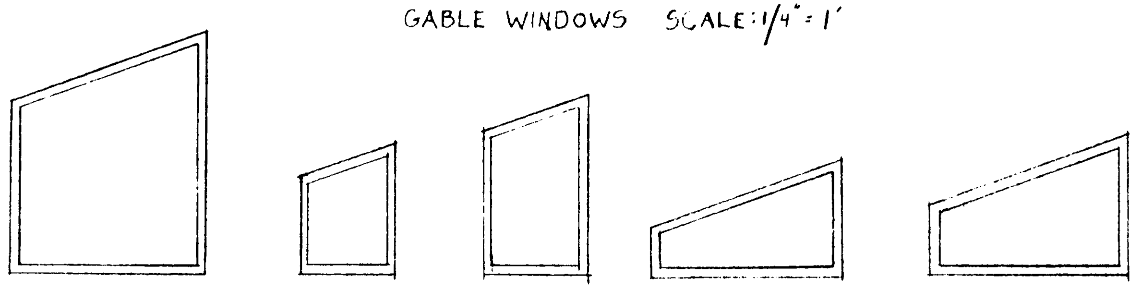


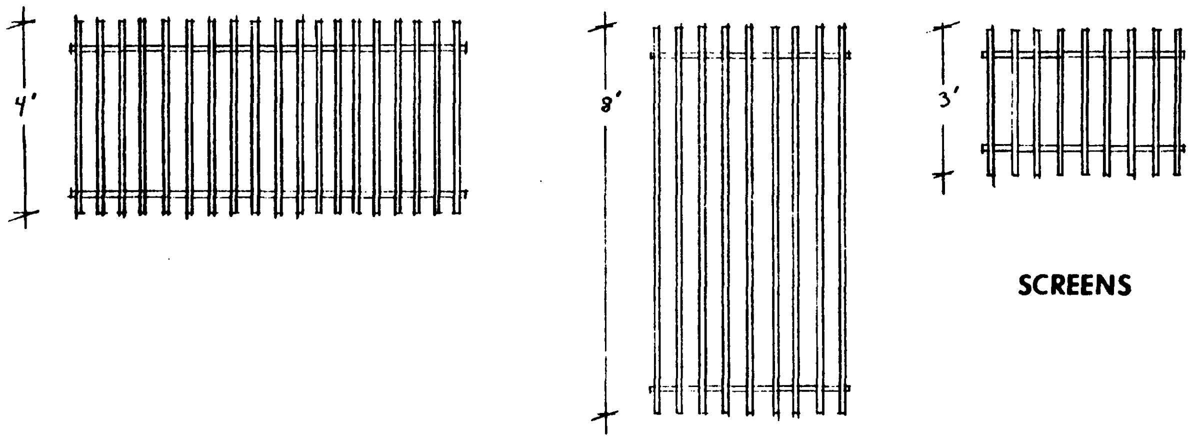


PORCH RAIL / ROOF SUPPORT PANEL

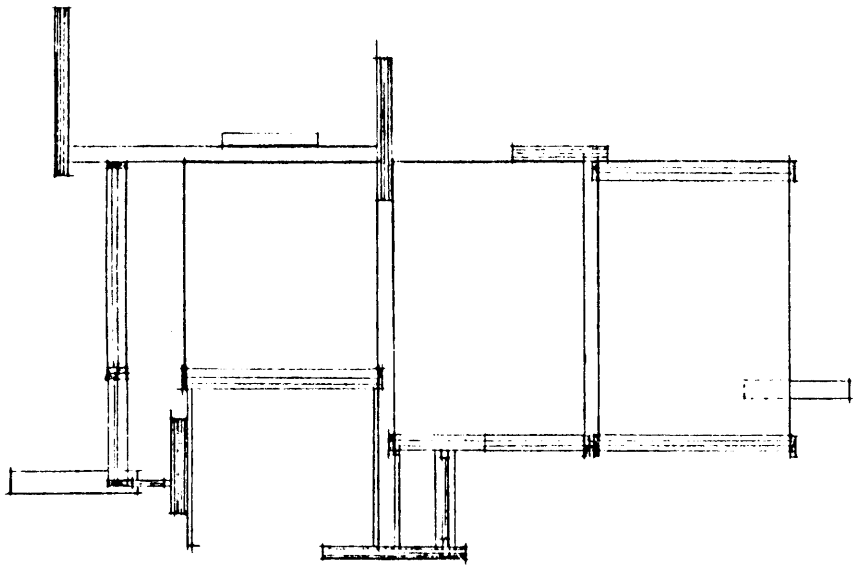
TWO STORY CLOSURE PANELS

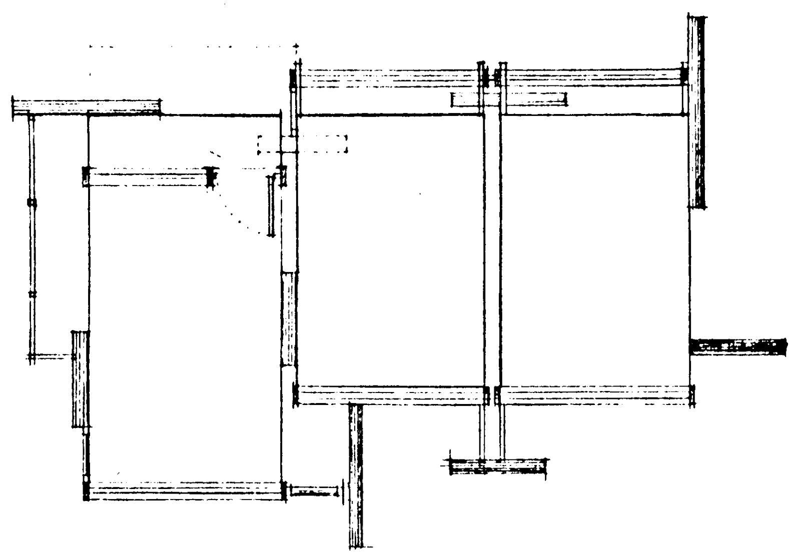
GABLE WINDOWS SCALE: 1/4" = 1'



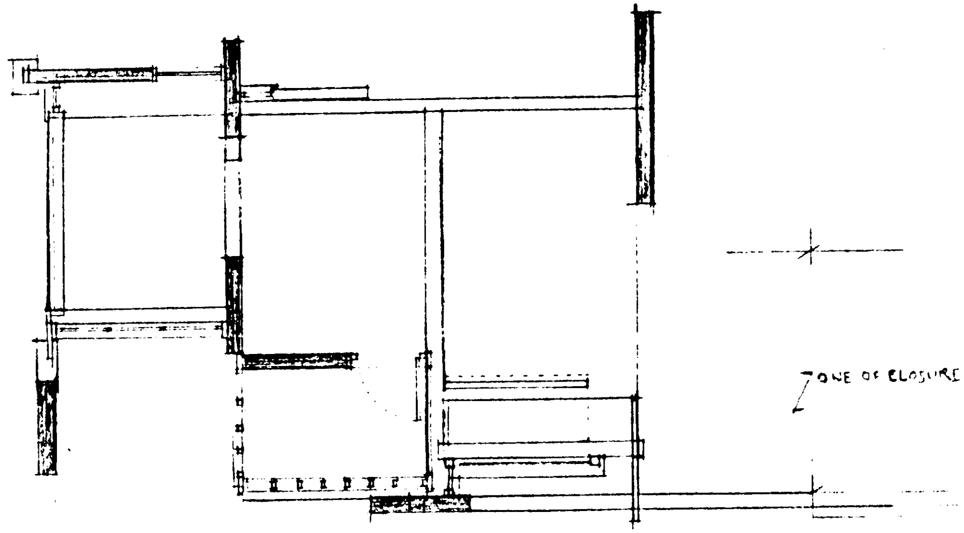


SCREENS

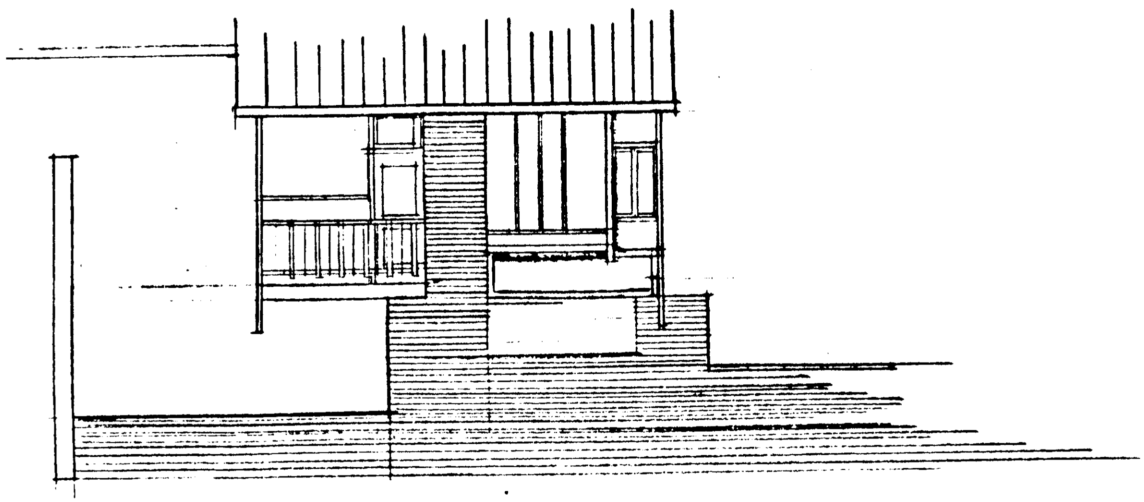




Closure Placement



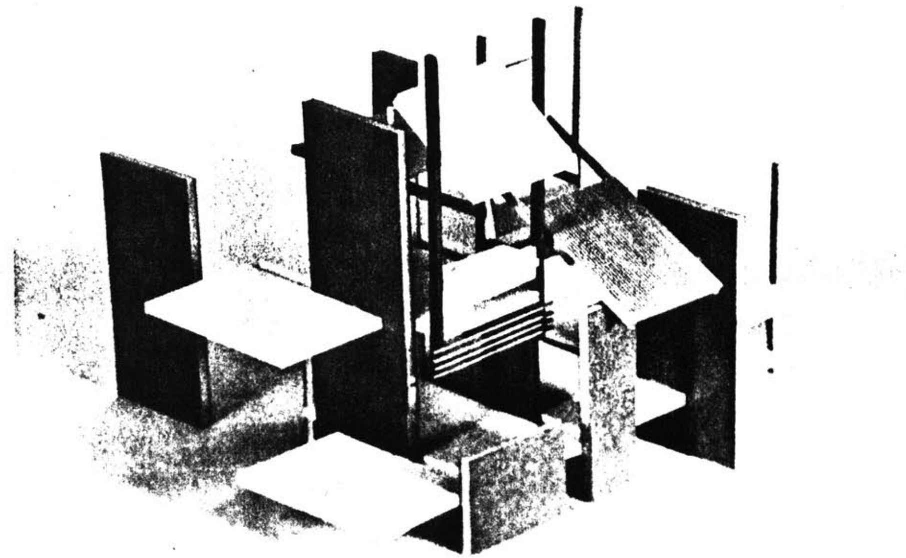
PLAN

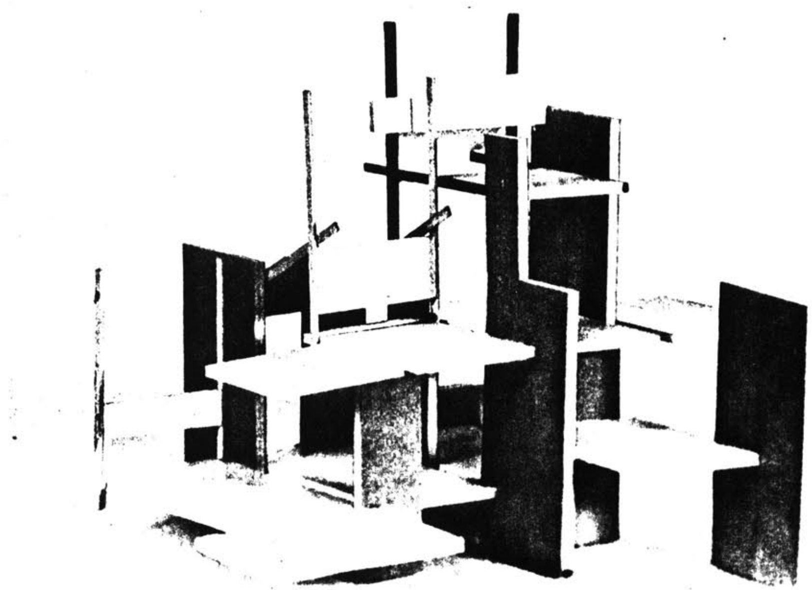


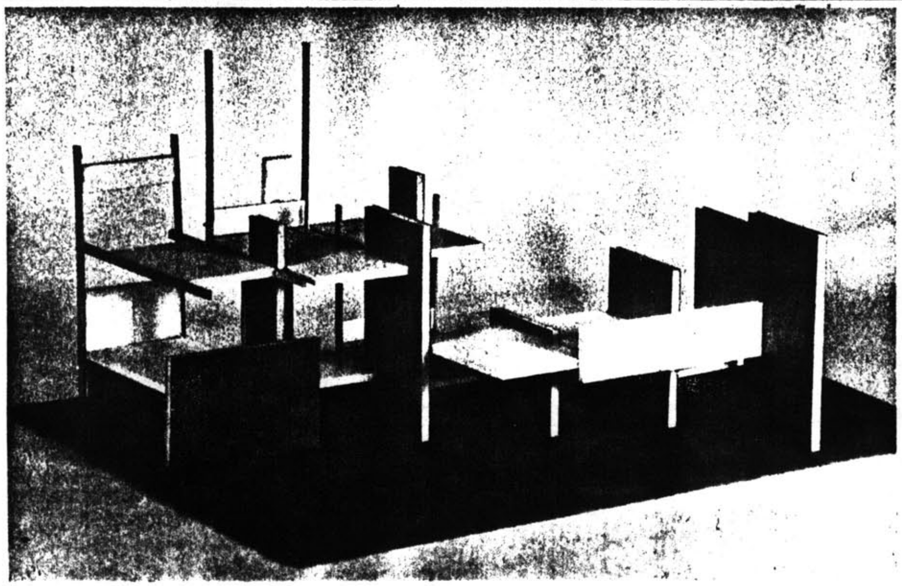
ELEVATION

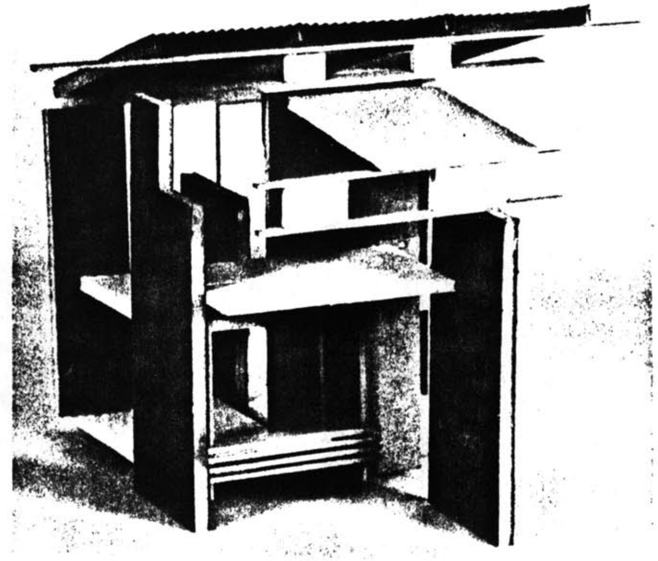
Models:

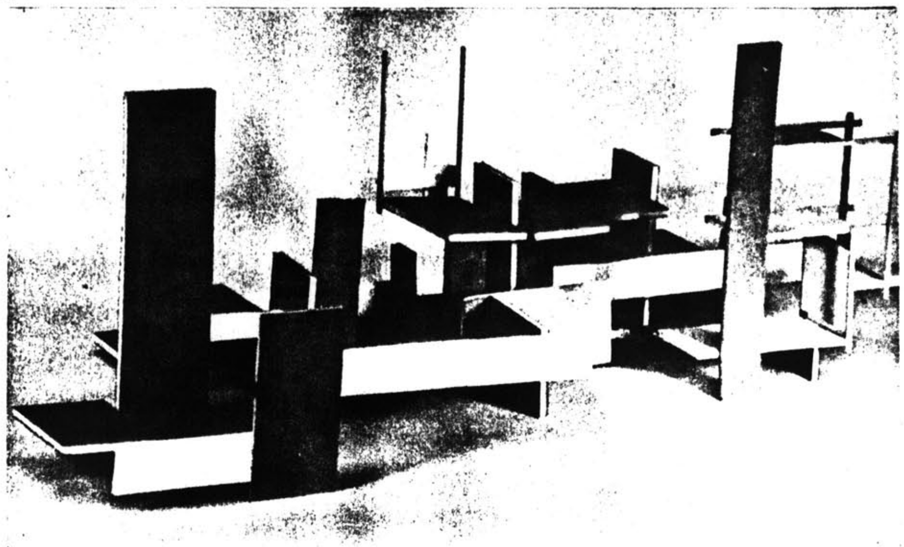
Closure / Support Studies











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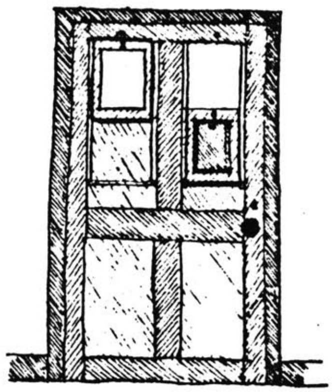
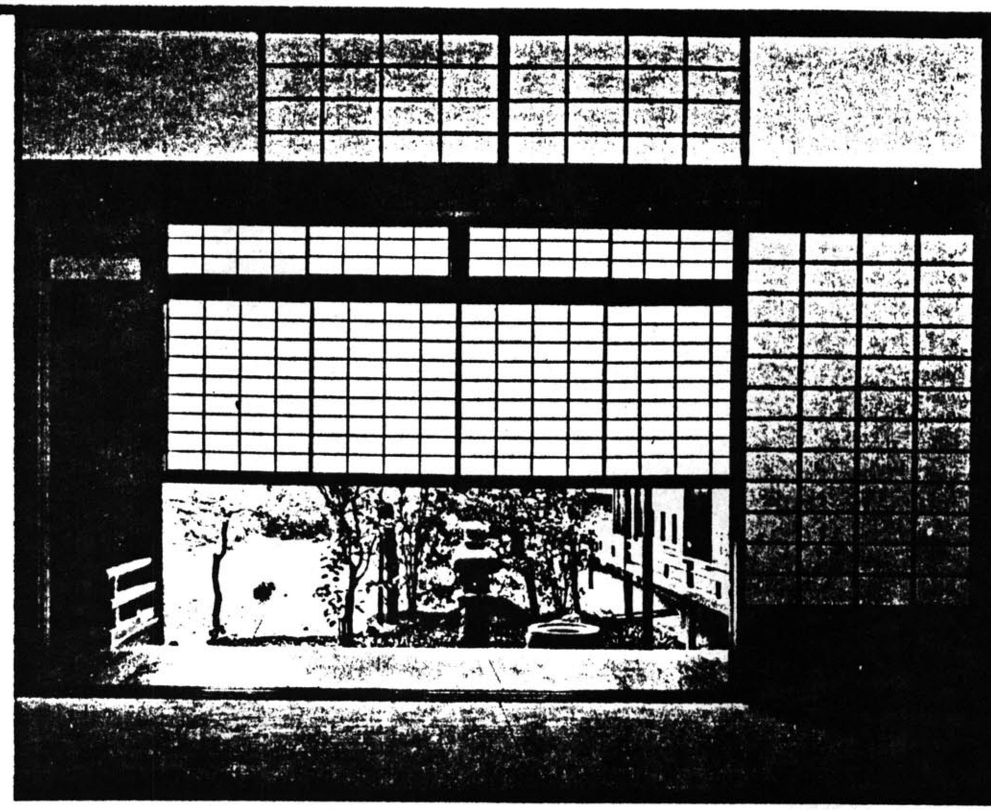
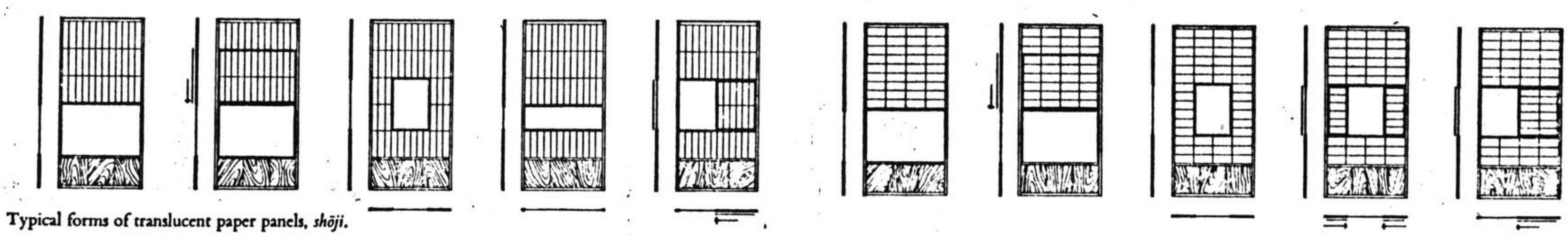
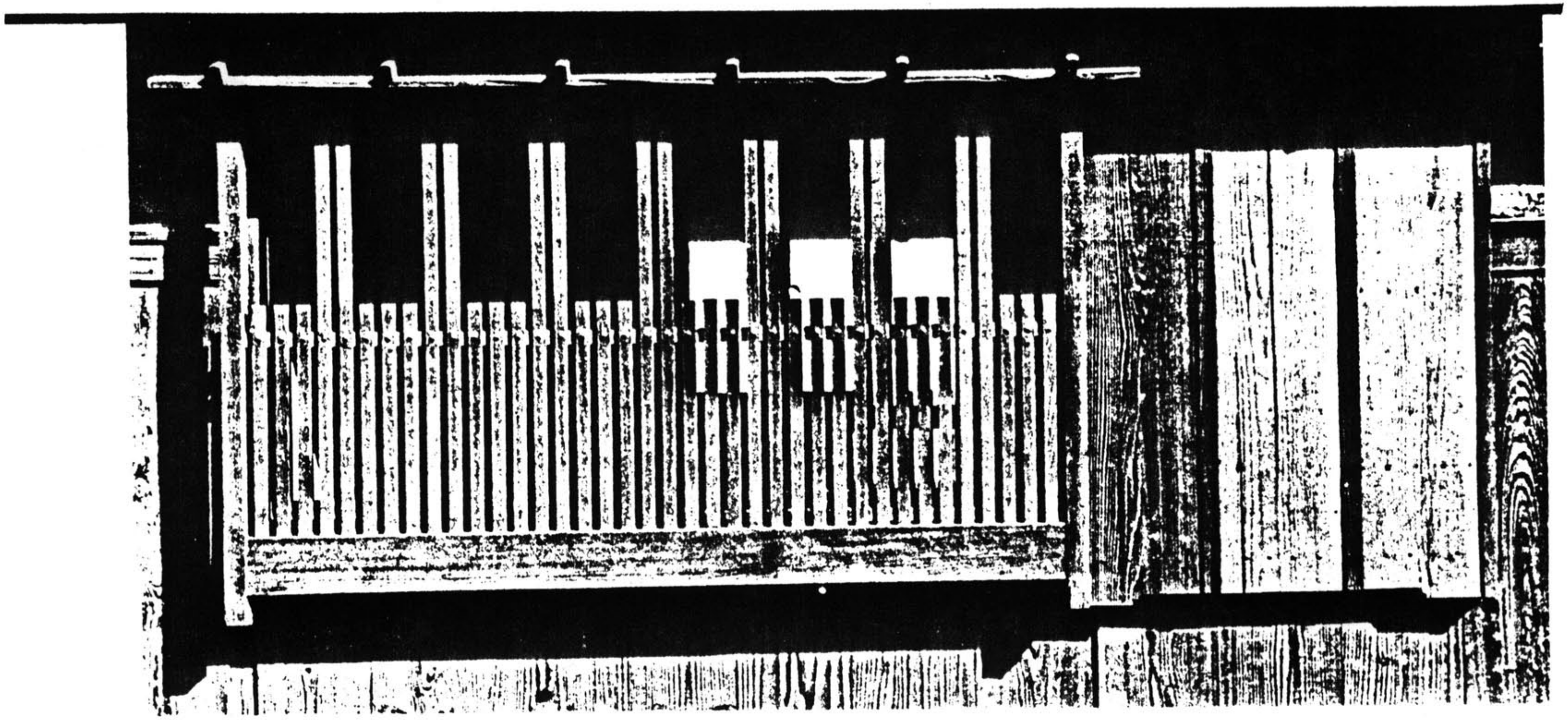




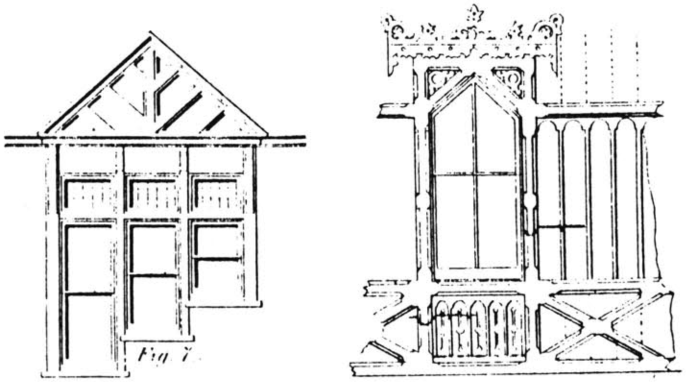
The Jikinyū-ken garden from the open west wall of the Bōsen tearoom; Kohō-an, Daitoku-ji.

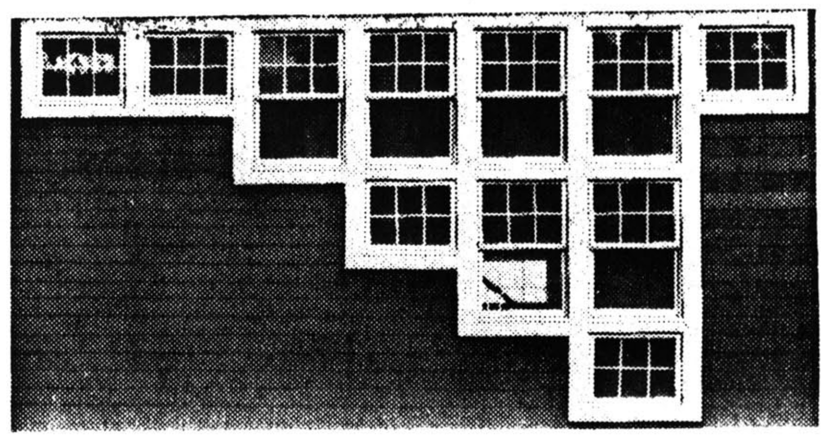


Typical forms of translucent paper panels, *shōji*.

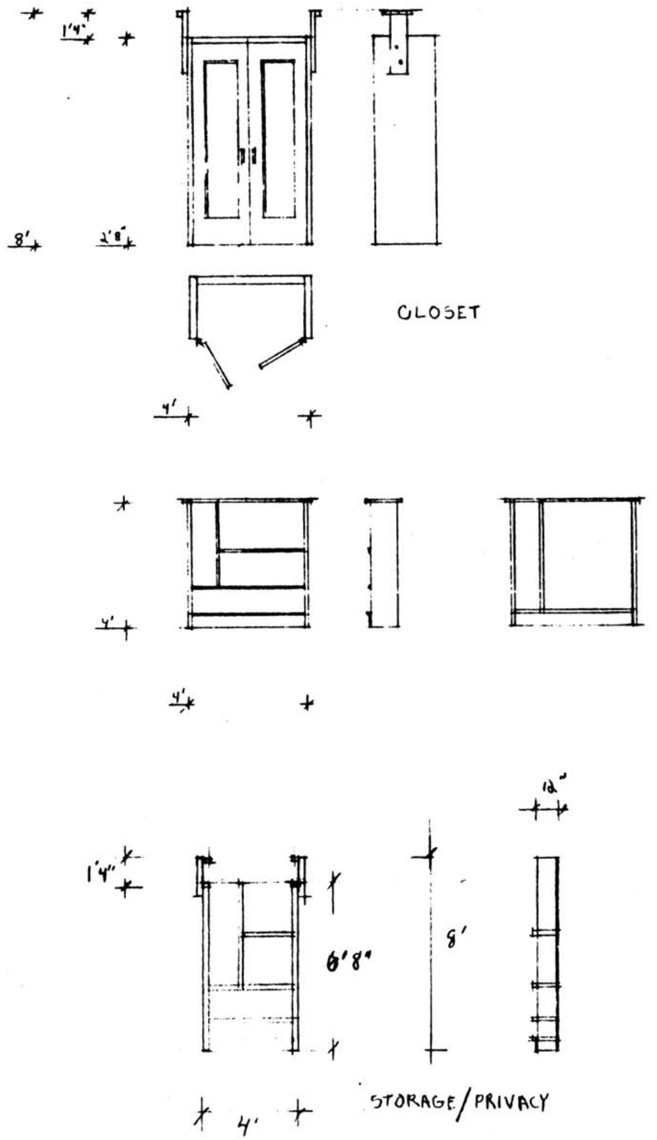


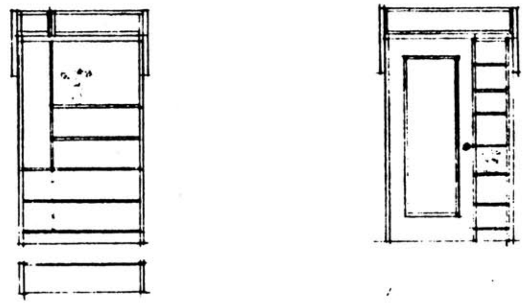
DESIGNS FOR WINDOWS

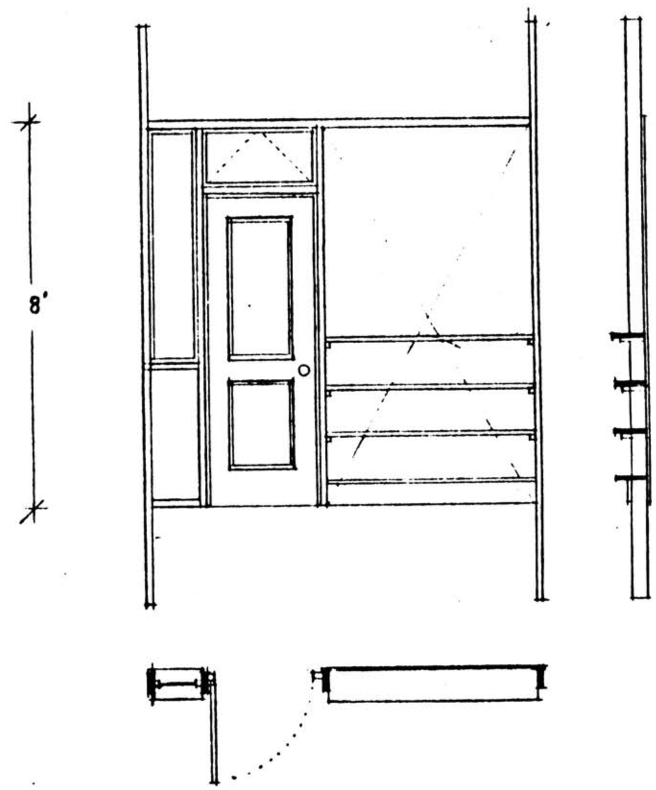


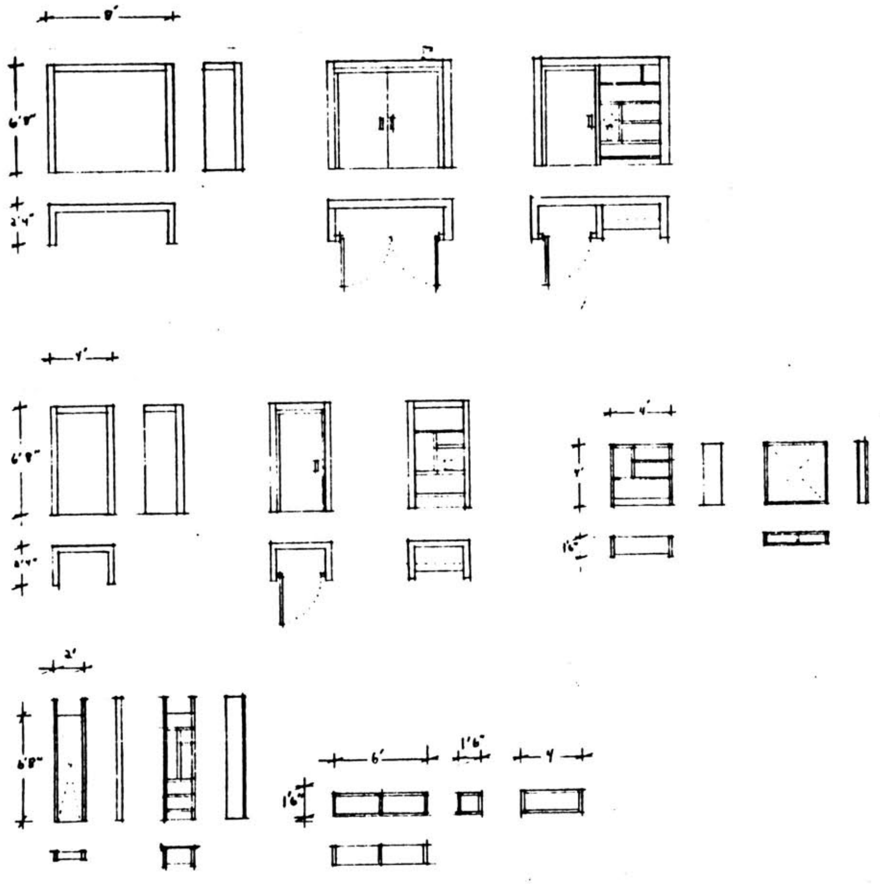


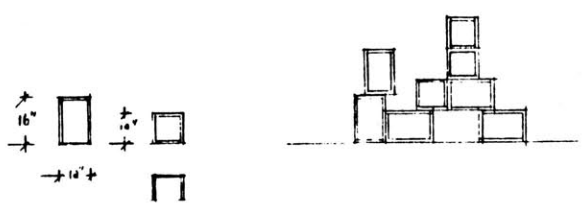
Infill



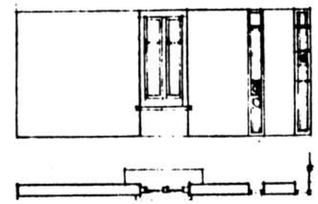


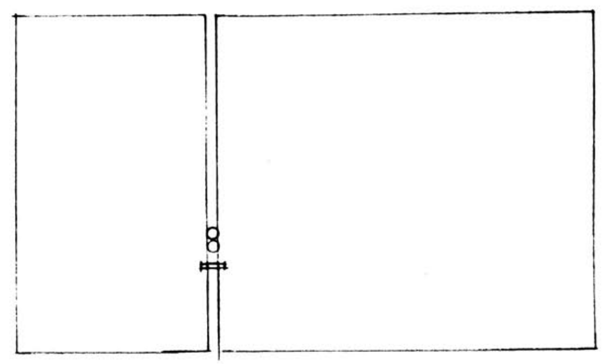


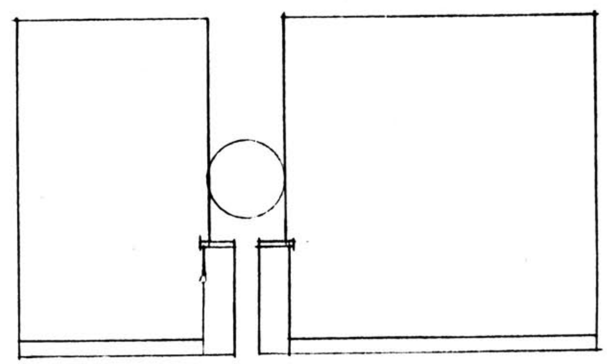


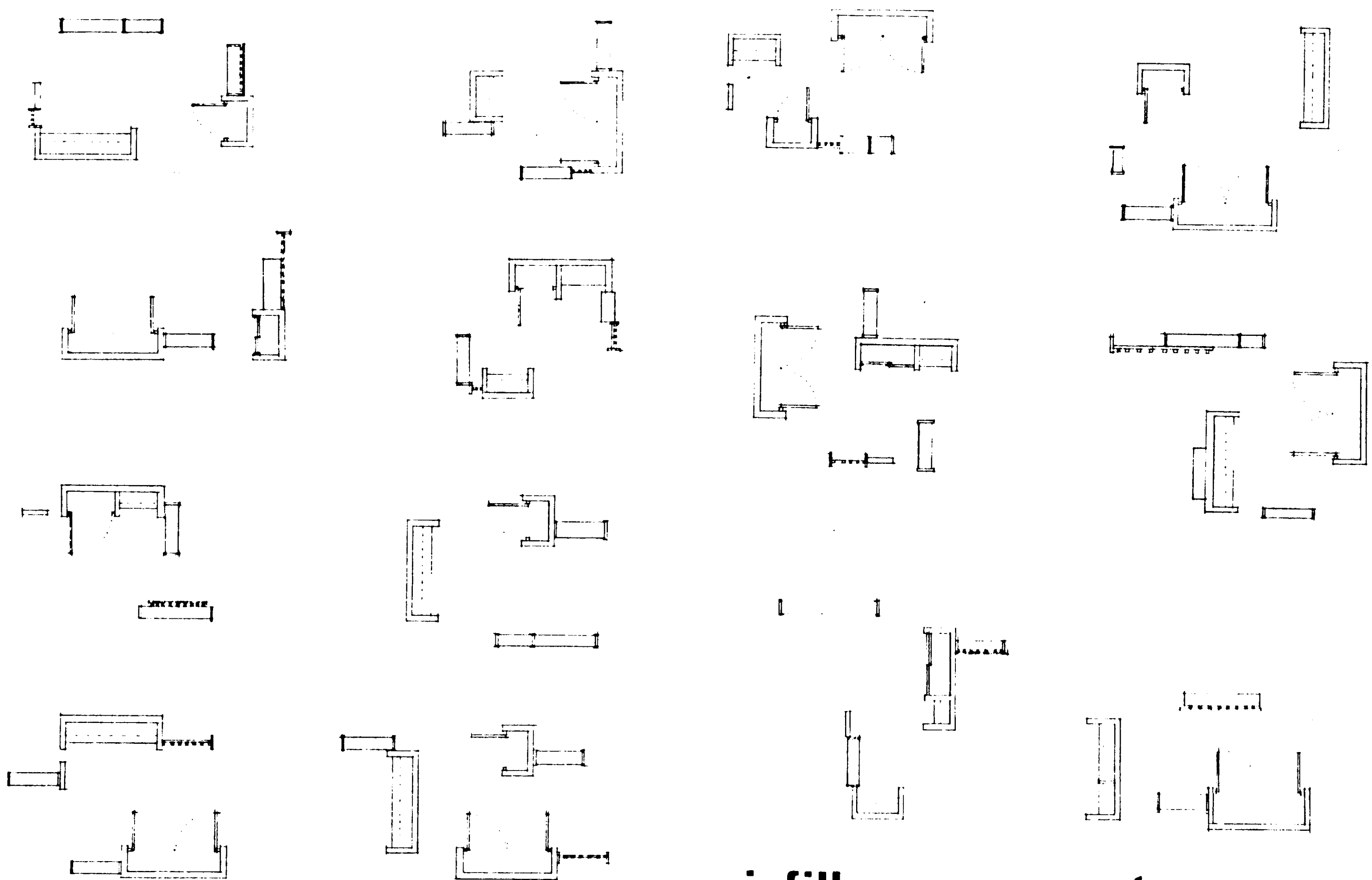


stacking boxes

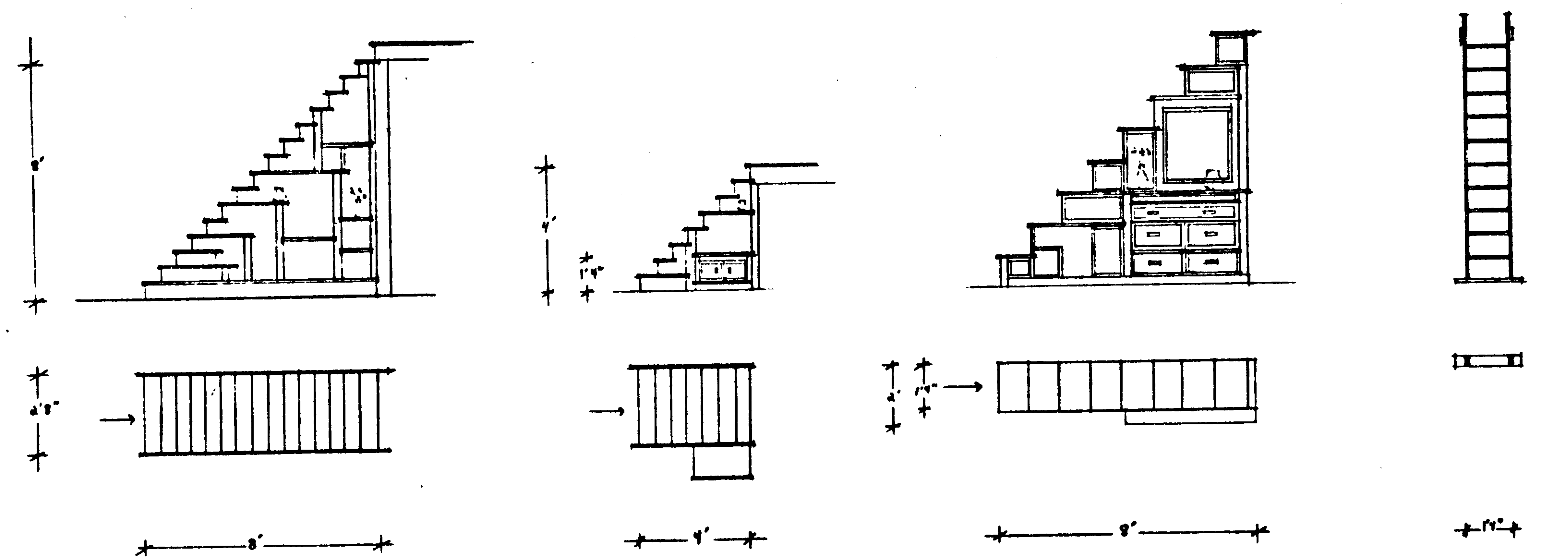








infill arrangements



stairs with storage

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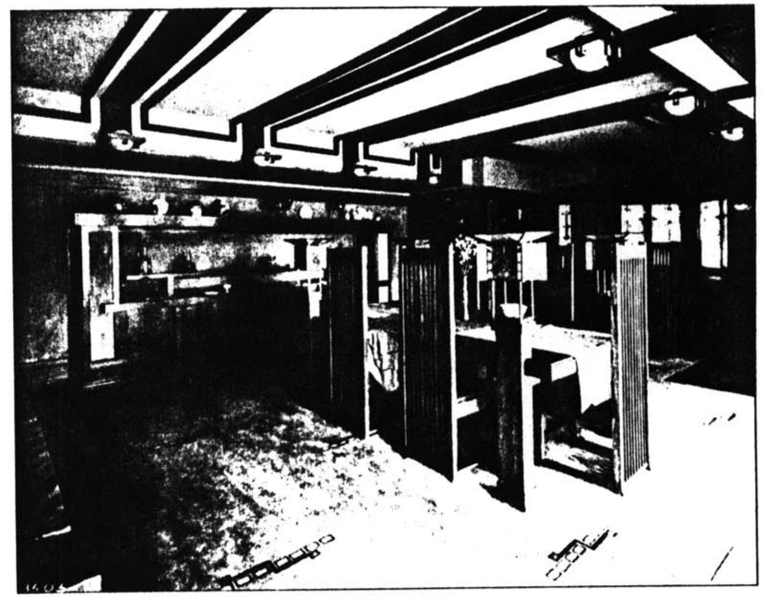
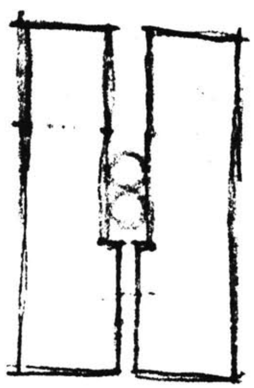


9 Dining room of Robie house, Chicago, Illinois, 1909.

Built-in furniture, like the Robie house buffet, become part of the wall. This opens up more floor area while providing optional use space.



C. SCARPA
INTERIOR PANEL

Tsukeshoin and staggered shelves of the Hiroma, Daitsū-ji.

Staggered shelves of the Mittan no Seki; Ryūkō-in Shoin, Daitoku-ji.

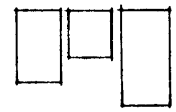
Bookcase Using Stacking Boxes

Utilization of the Panel System

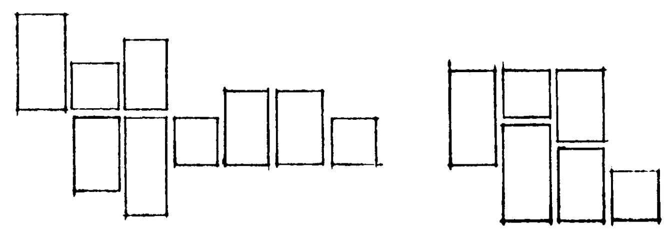
UTILIZATION OF THE PANEL SYSTEM

The proposed panel system may be used as a standardized tool for dwelling design. The following steps are used as a conceptual aid in the design of a dwelling. These steps are not in the order of the actual construction process.

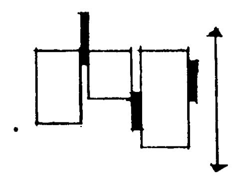
●Floor panels are organized into groups. At this point, the floor panels are manipulated in plan only. One edge of the grouping is kept consistent while the other may vary. A nominal dimension of six inches is maintained between floor panels. This allows the support wall panels to pass between.

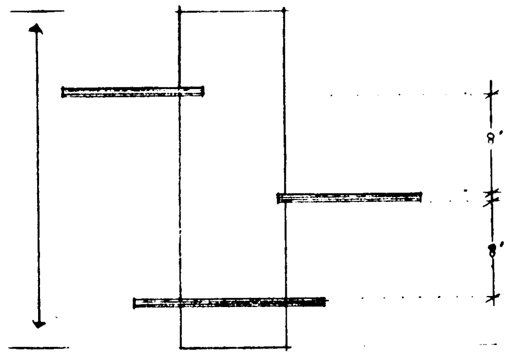


●Floor panel groupings are arranged to establish territories. The aligned edge may be placed on the inside or outside of the dwelling.



●Placement of wall supports is then determined. Support wall panels can be moved back and forth between the floor panels to establish the first order of partial definition. In areas where support wall panels are not desired, floor panels are supported by masonry or props.

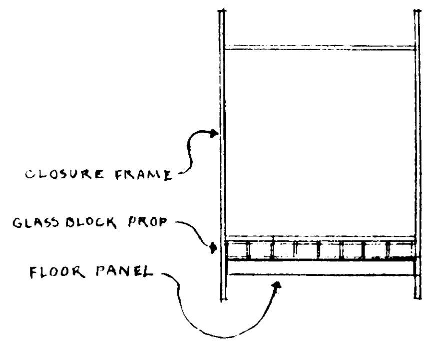




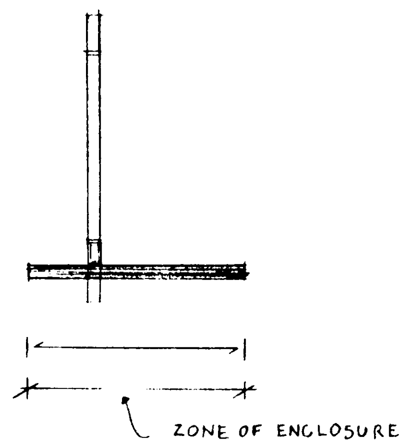
● Floor panel groupings are moved up or down along support wall panels to establish changes of level. The fact that level changes can be achieved easily is an attribute of the system. This attribute can take advantage of various topographies. Masonry and props will vary accordingly. An eight-foot floor to ceiling height is generally maintained in order to easily accommodate the infill panels.

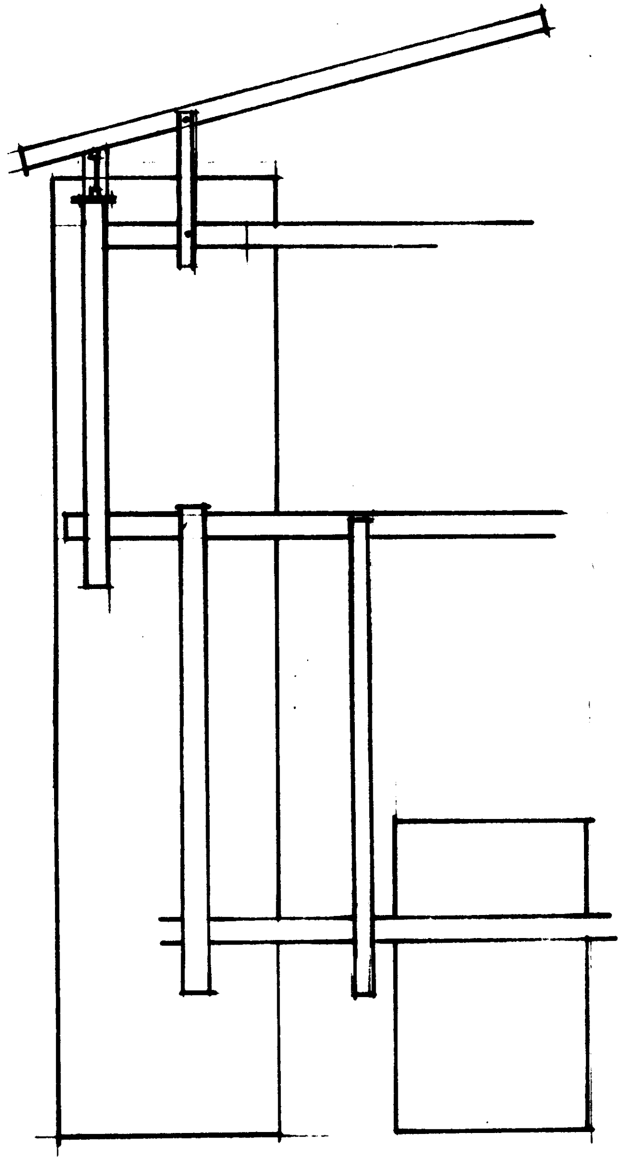
At this point the structure or shell is self-stable.

● Closure panels are selected and placed. The closure panels with extended ends may be propped off the surface of the floor panel and secured to its sides. This allows light to penetrate beneath the closure panels.



Closure panels can also move back and forth across the surface of the floor panels. The maximum distance the closure panel can be moved across the floor panel is called "the zone of enclosure." The zone of enclosure can vary depending on the desired dimension inside or outside of the dwelling. For example, when the closure panels are moved back (inward), porches and balconies are generated.





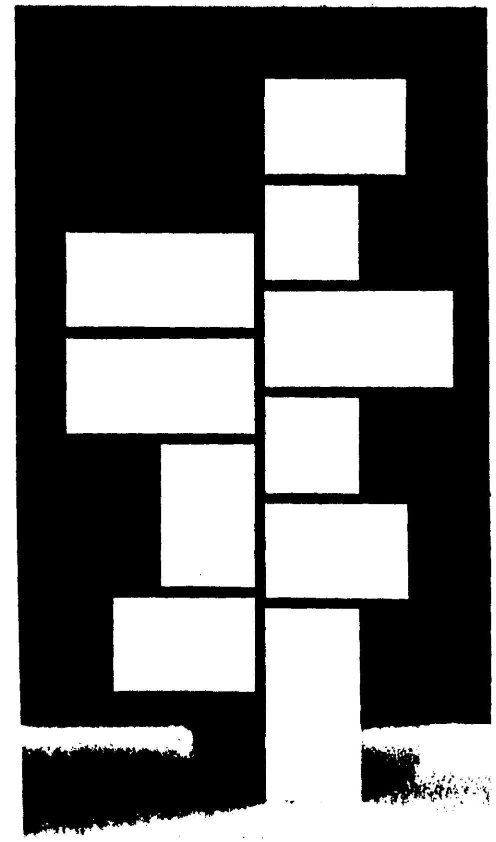
● Placement of roof panels may now begin. Each roof panel is supported independently from the others by means of props and support wall panels. The roof panels are propped off the closure panels to permit light to penetrate directly beneath the eaves. Screens and solid panels are used in this dimension to control light. Propping roof panels also provides a use dimension which allows for optional inhabitation, i.e. sleeping lofts.

The weather enclosure is now completed.

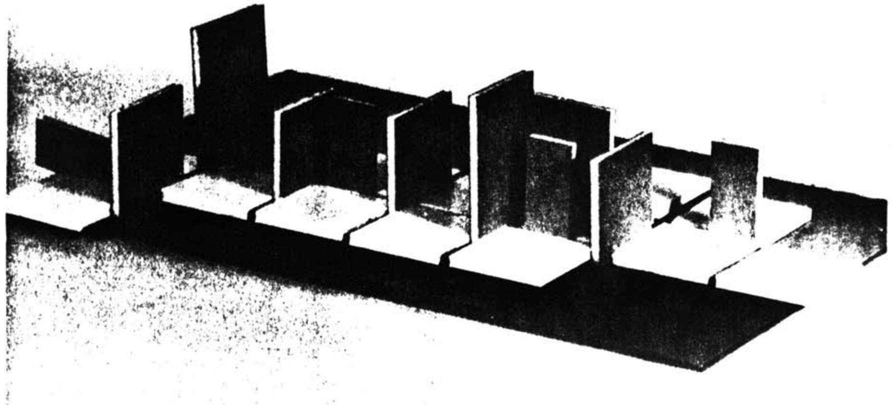
● Infill panels are deployed to provide storage and further define the interior spaces. These decisions can be made by the designer or the inhabitants.

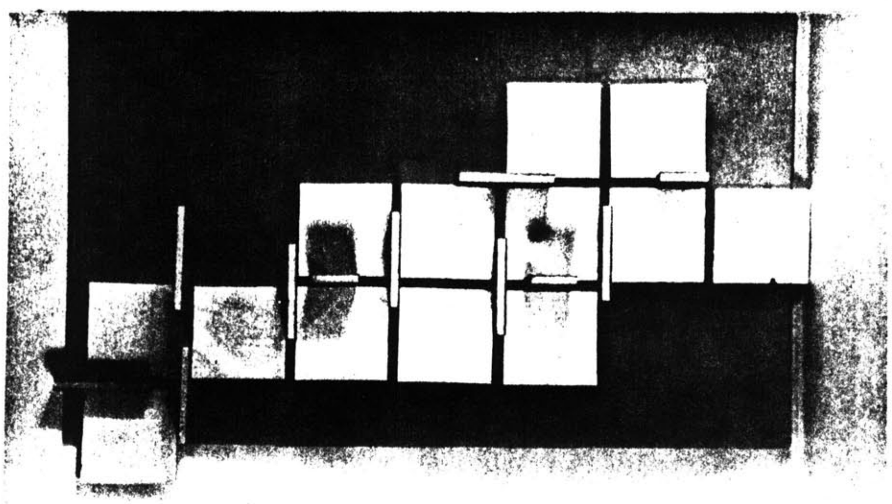
MODELS:

Utilization of the Panel System



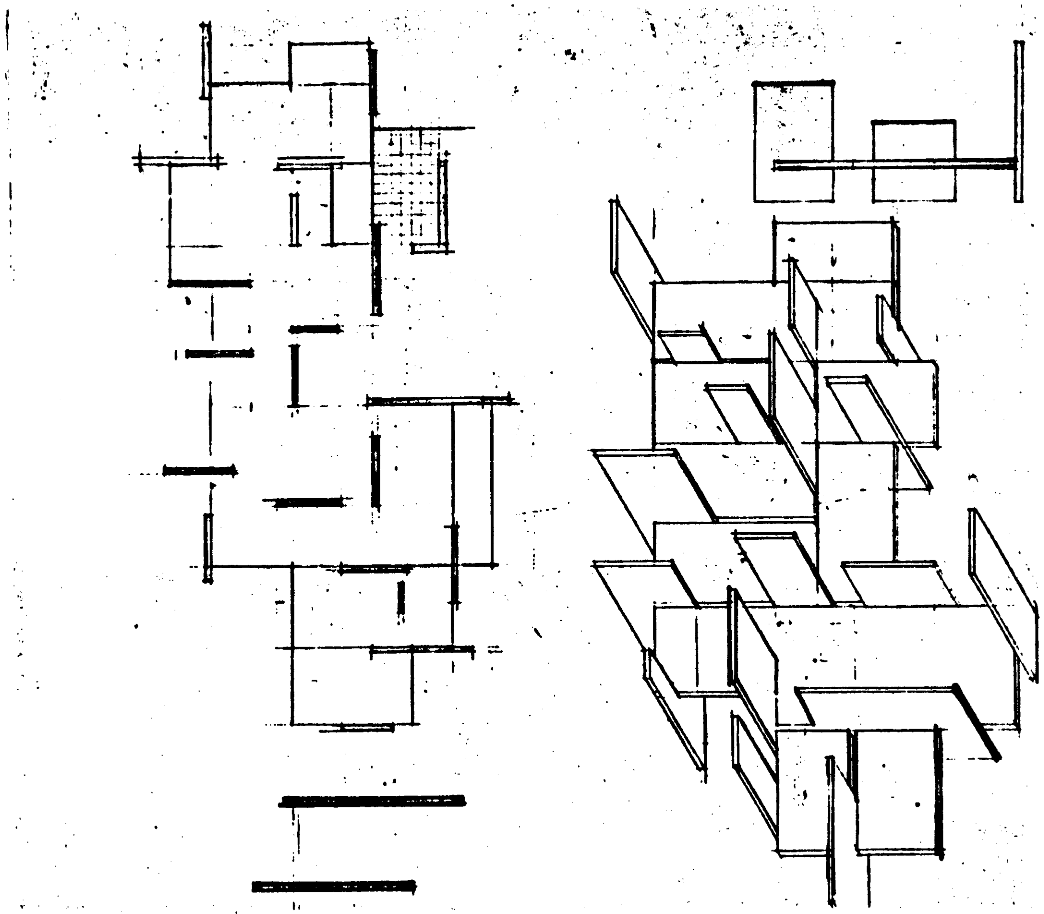
Floor Panel Organization



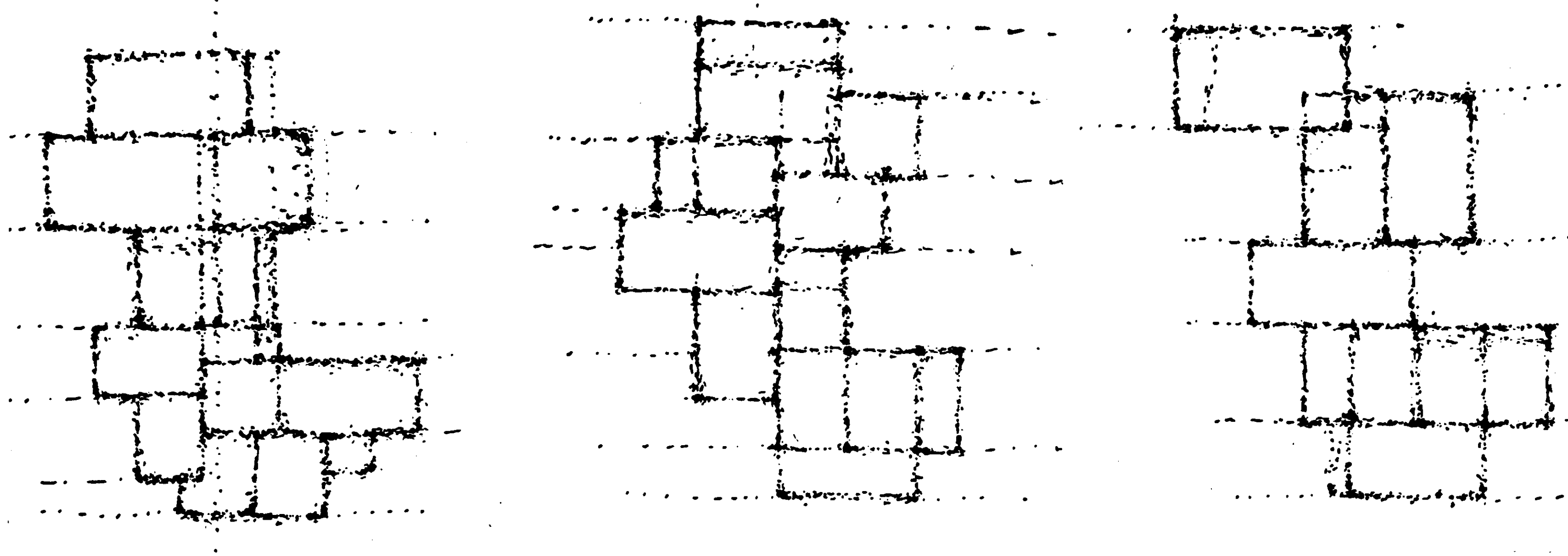


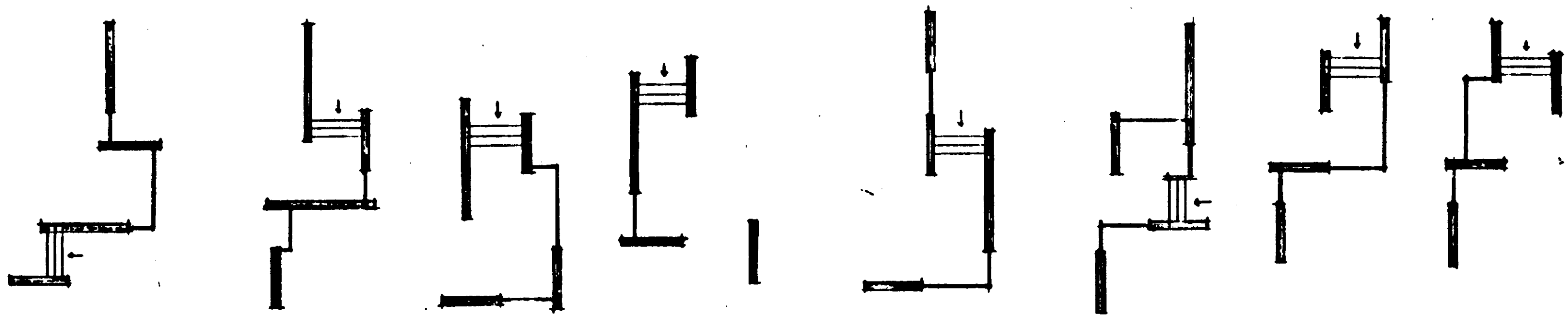
Support Wall Placement

☐ DESIGN OF A DWELLING USING THE SYSTEM

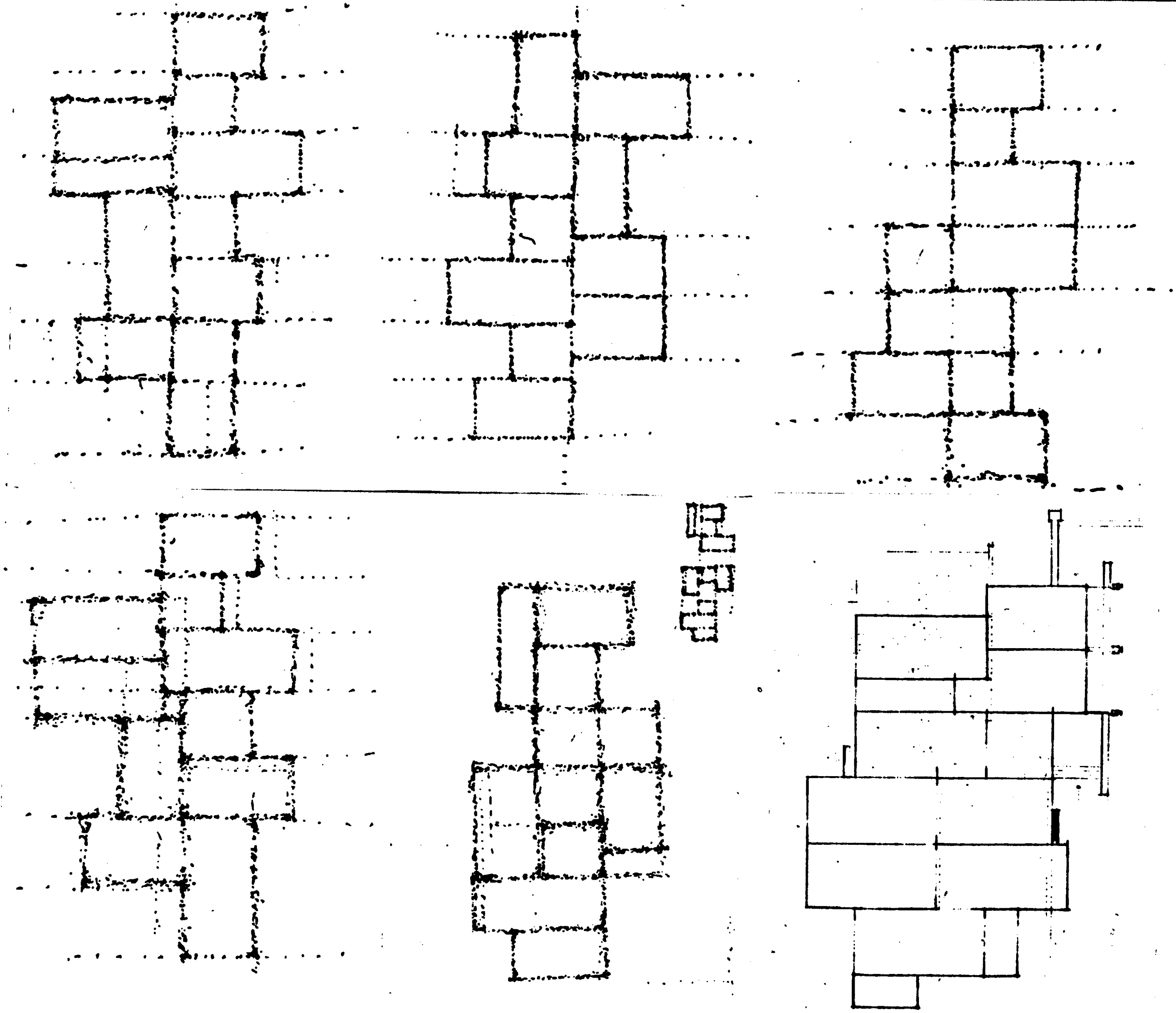


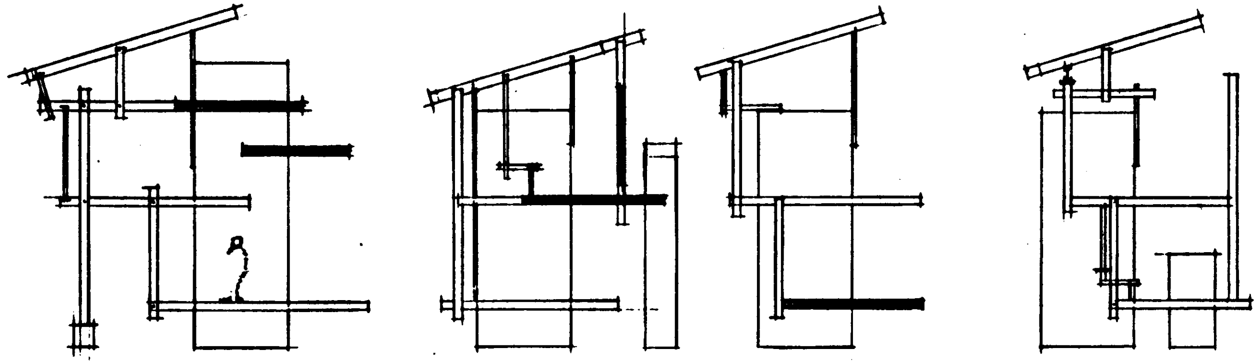
Support Study

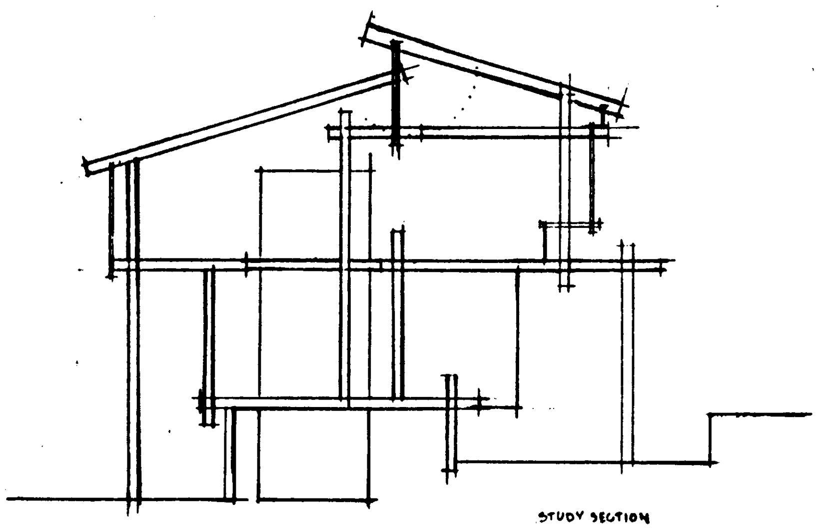


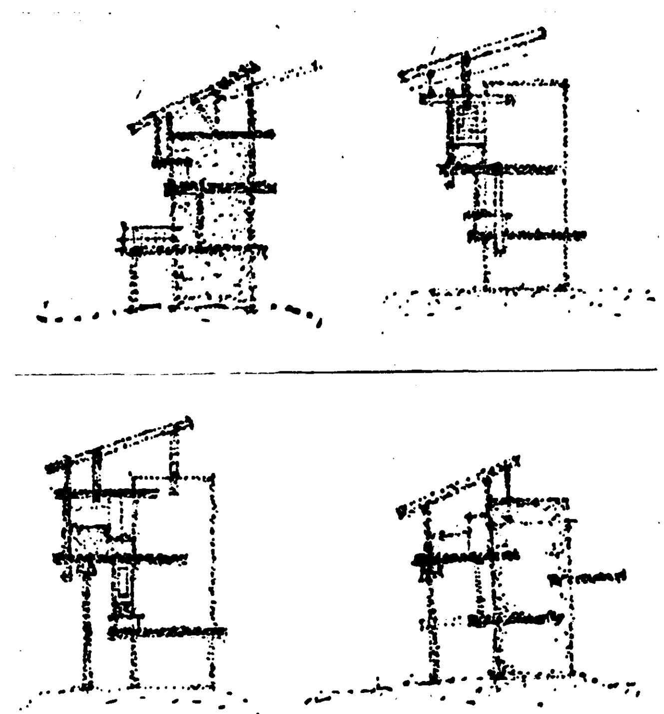


Plans: Floor Panel Assembly Studies

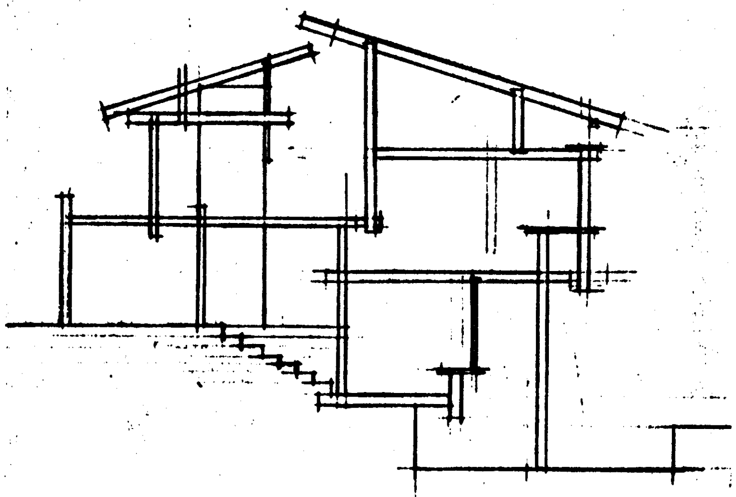




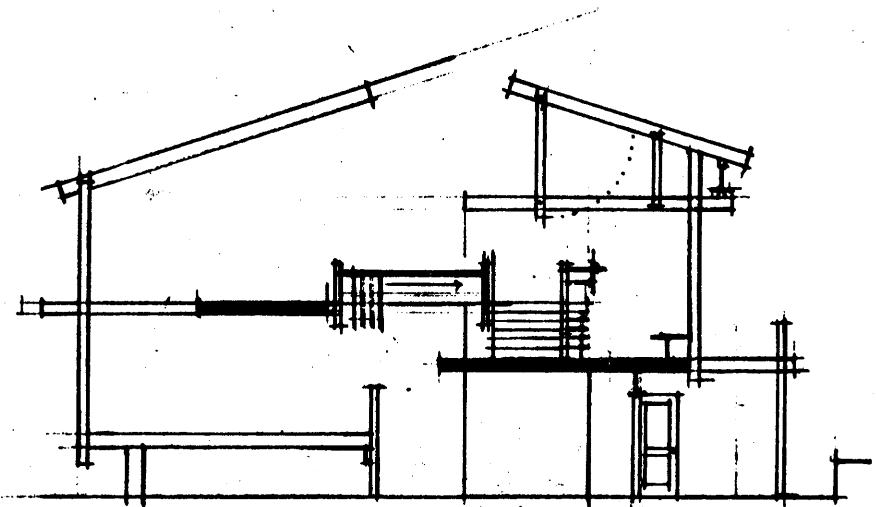




Sections: Support/Closure Studies



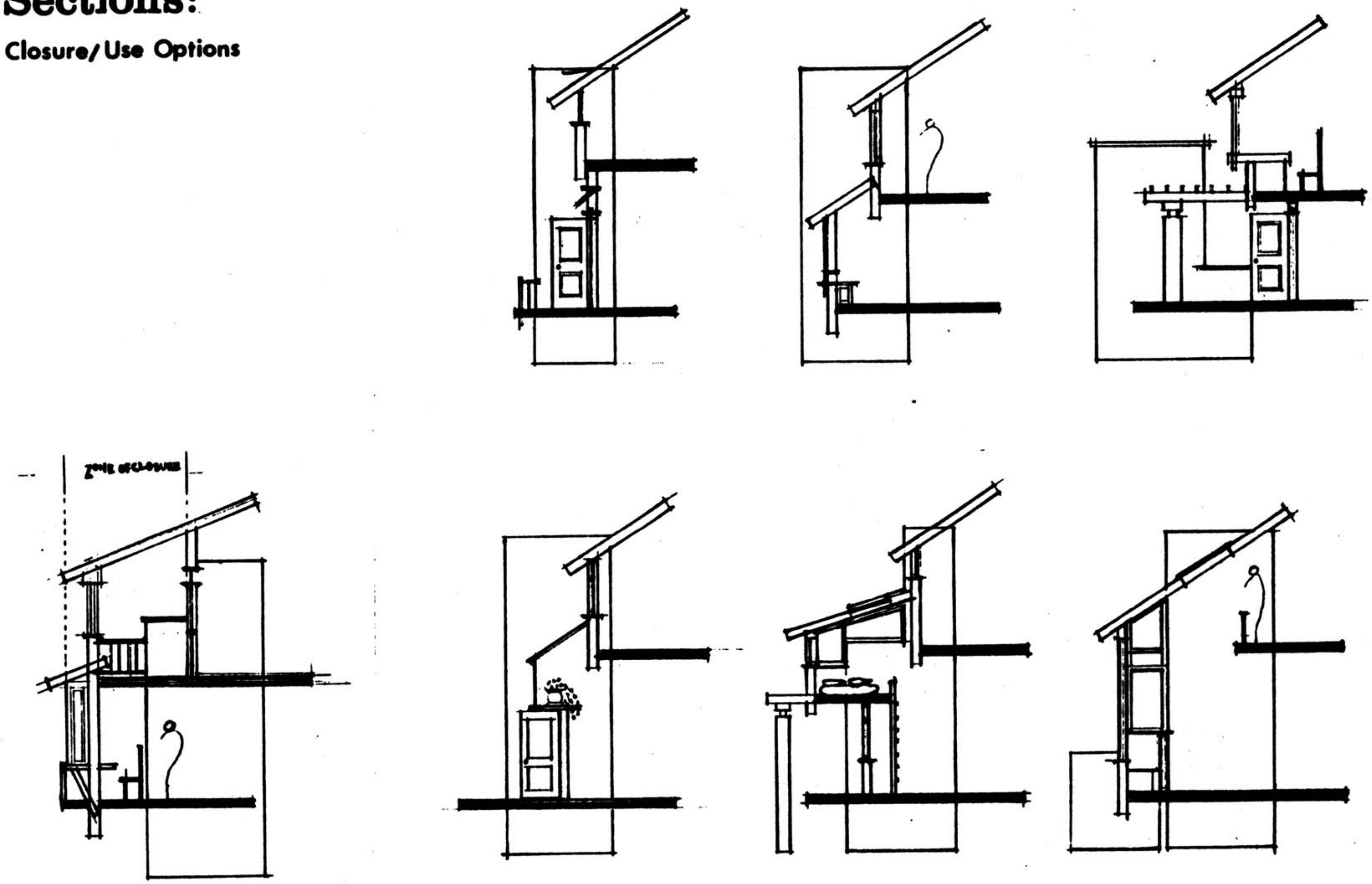
STUDY SECTION
PANEL ASSEMBLY

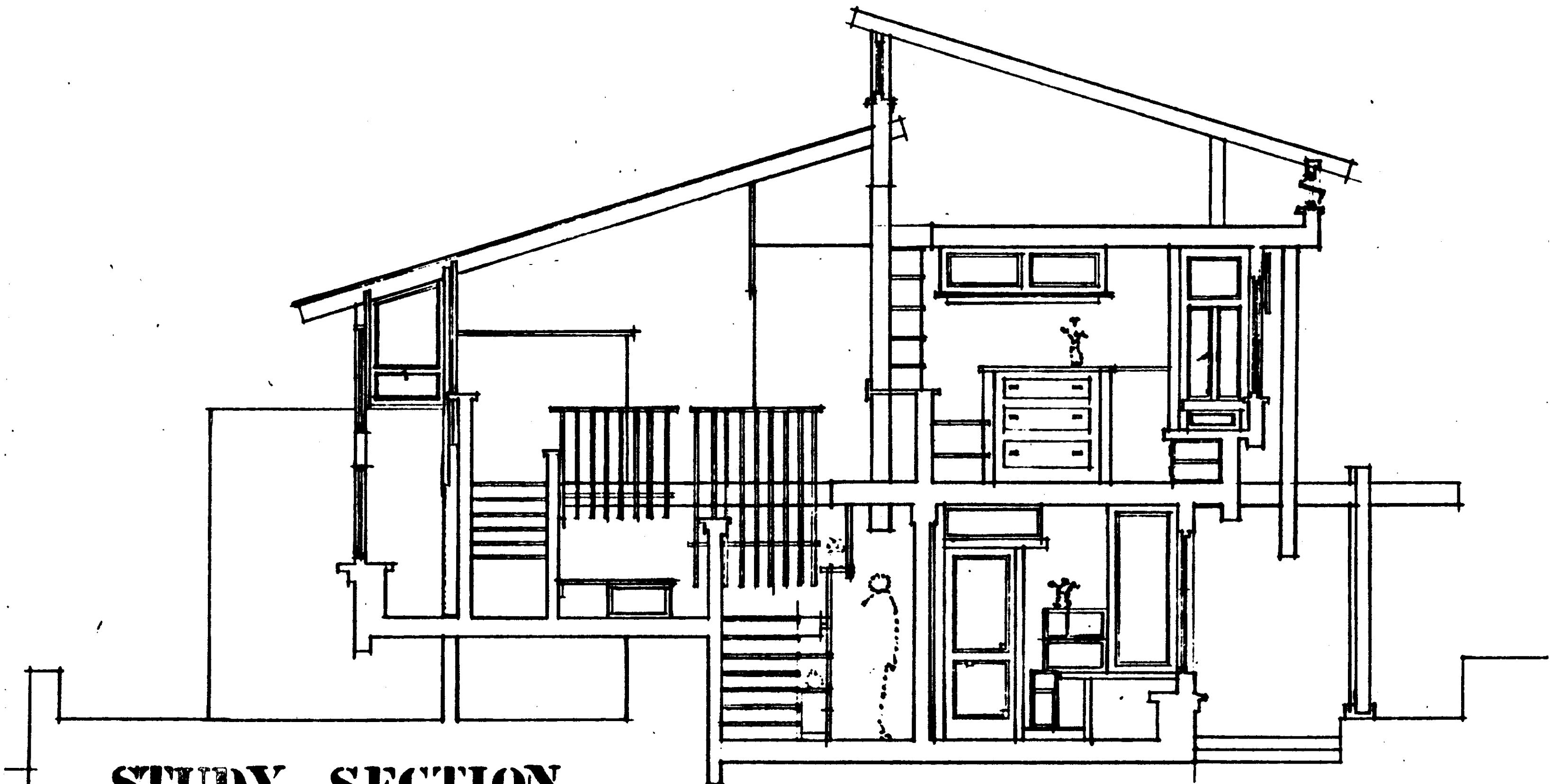


STUDY SECTION
PANEL ASSEMBLY

Sections:

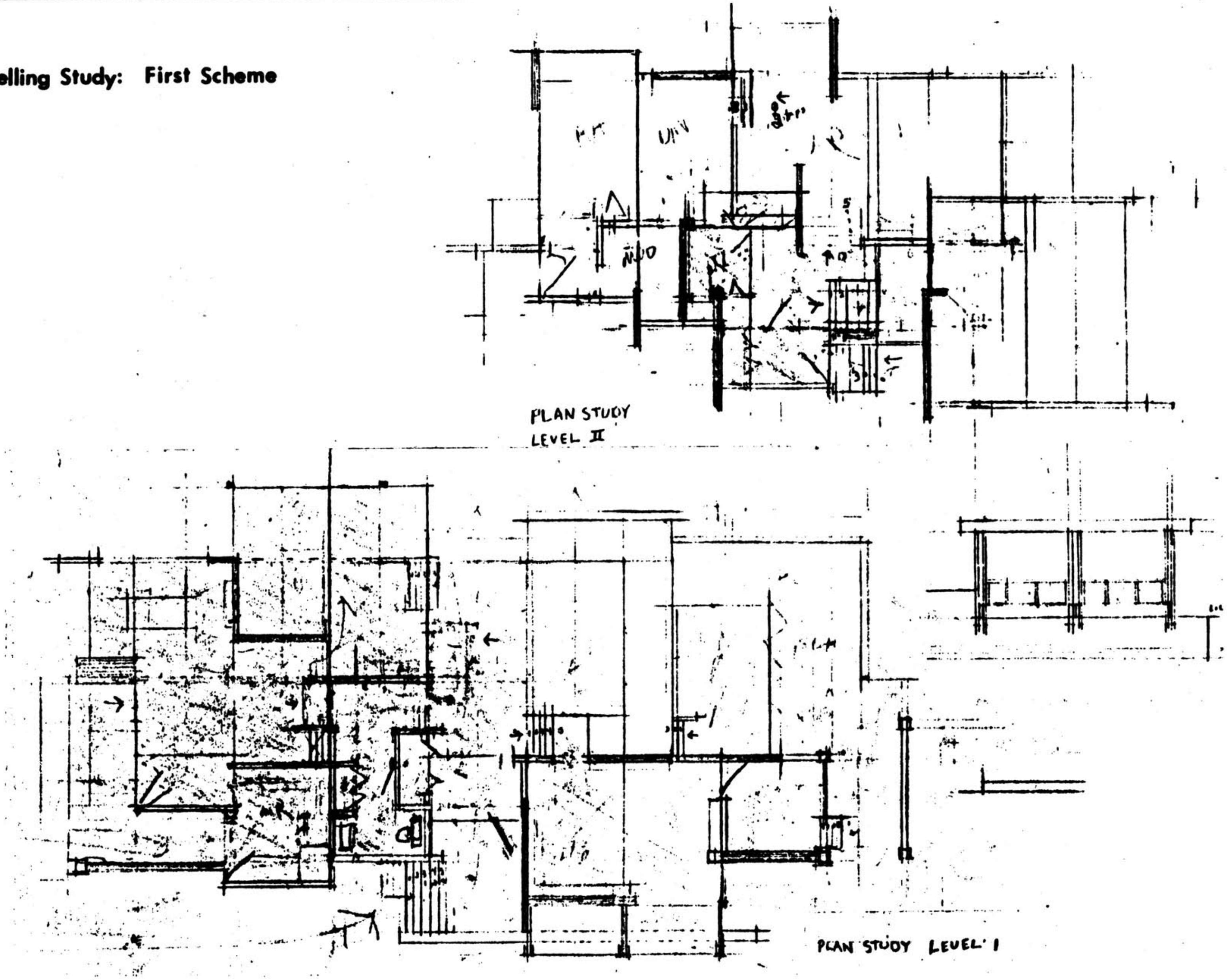
Closure/Use Options

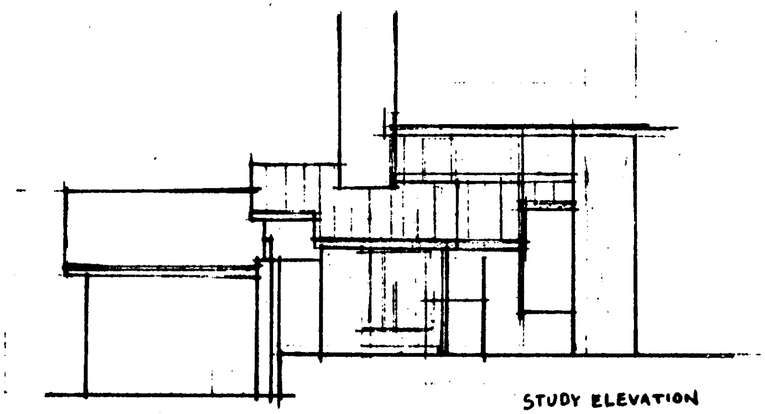




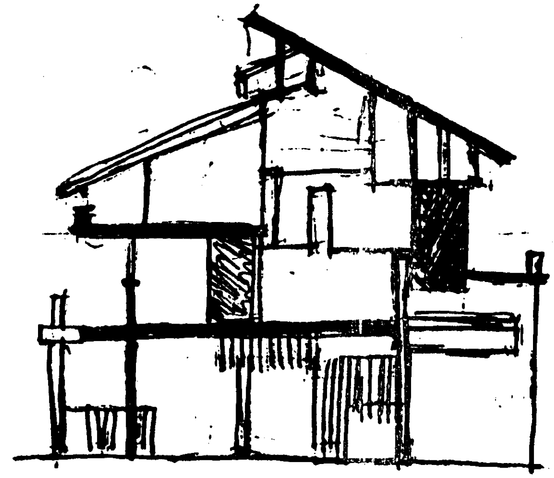
STUDY SECTION

Dwelling Study: First Scheme

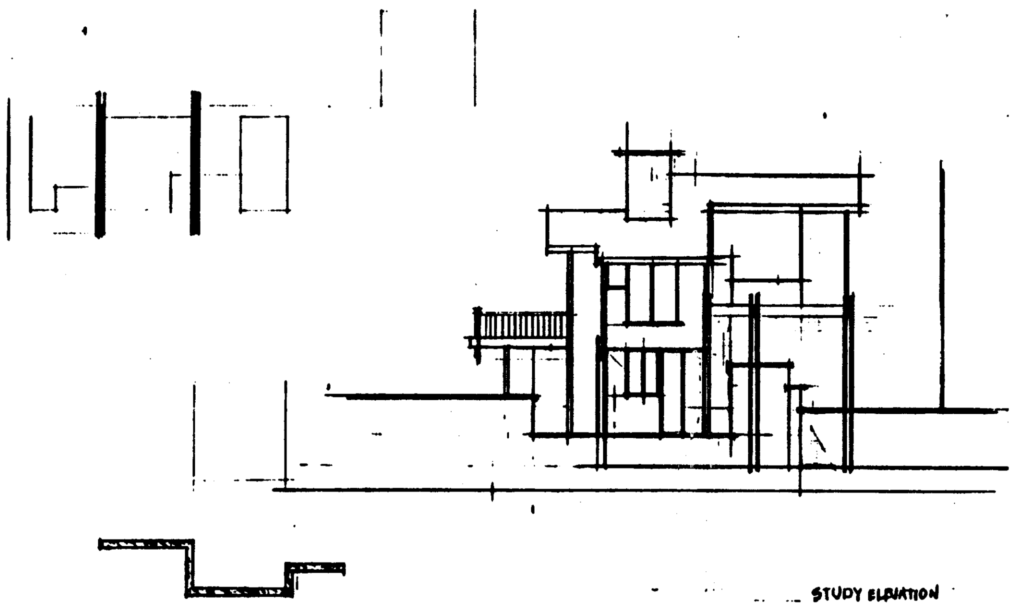


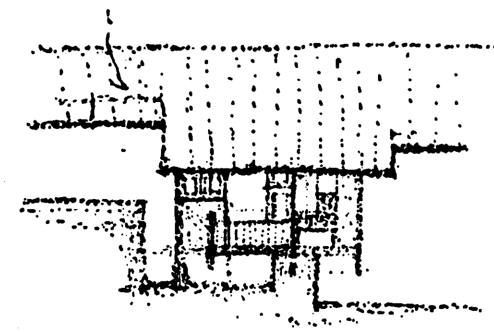


STUDY ELEVATION



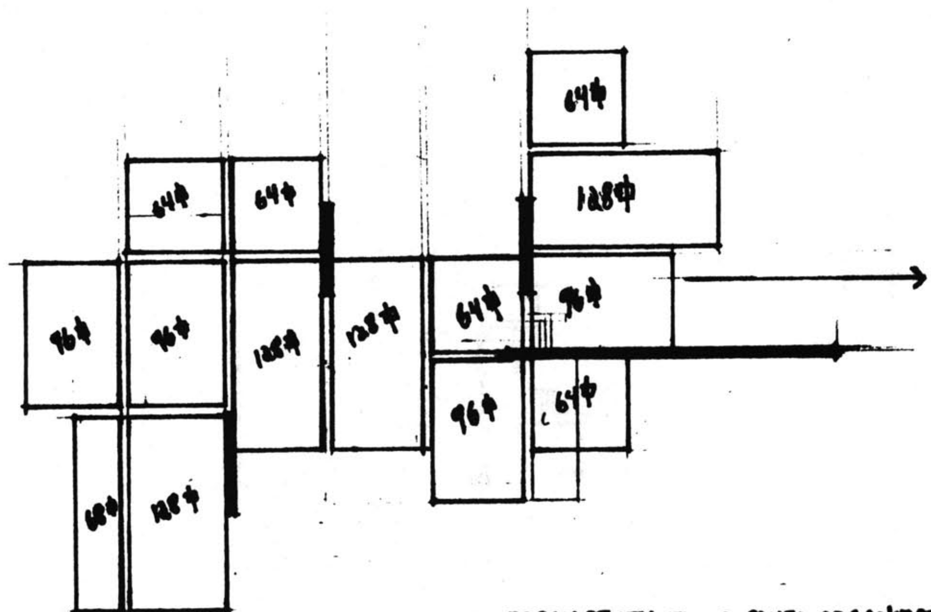
STUDY SECTION SCHEME I



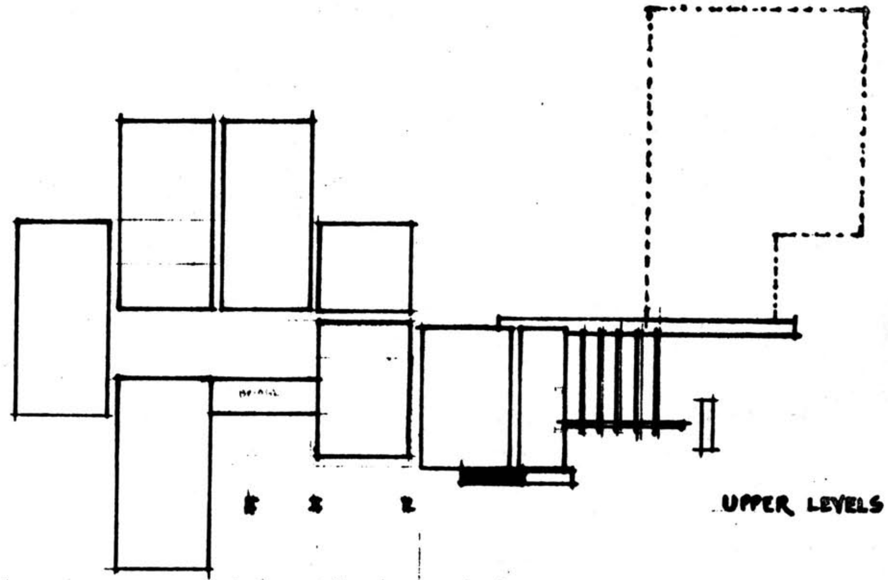


STUDY ELEVATION

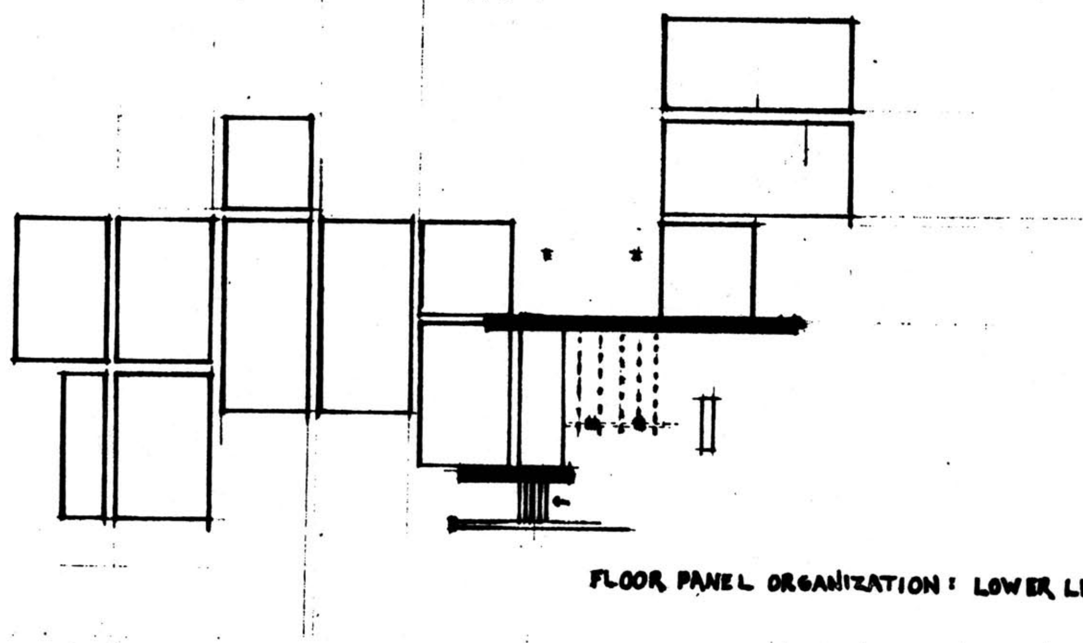
Dwelling Study: Final Scheme



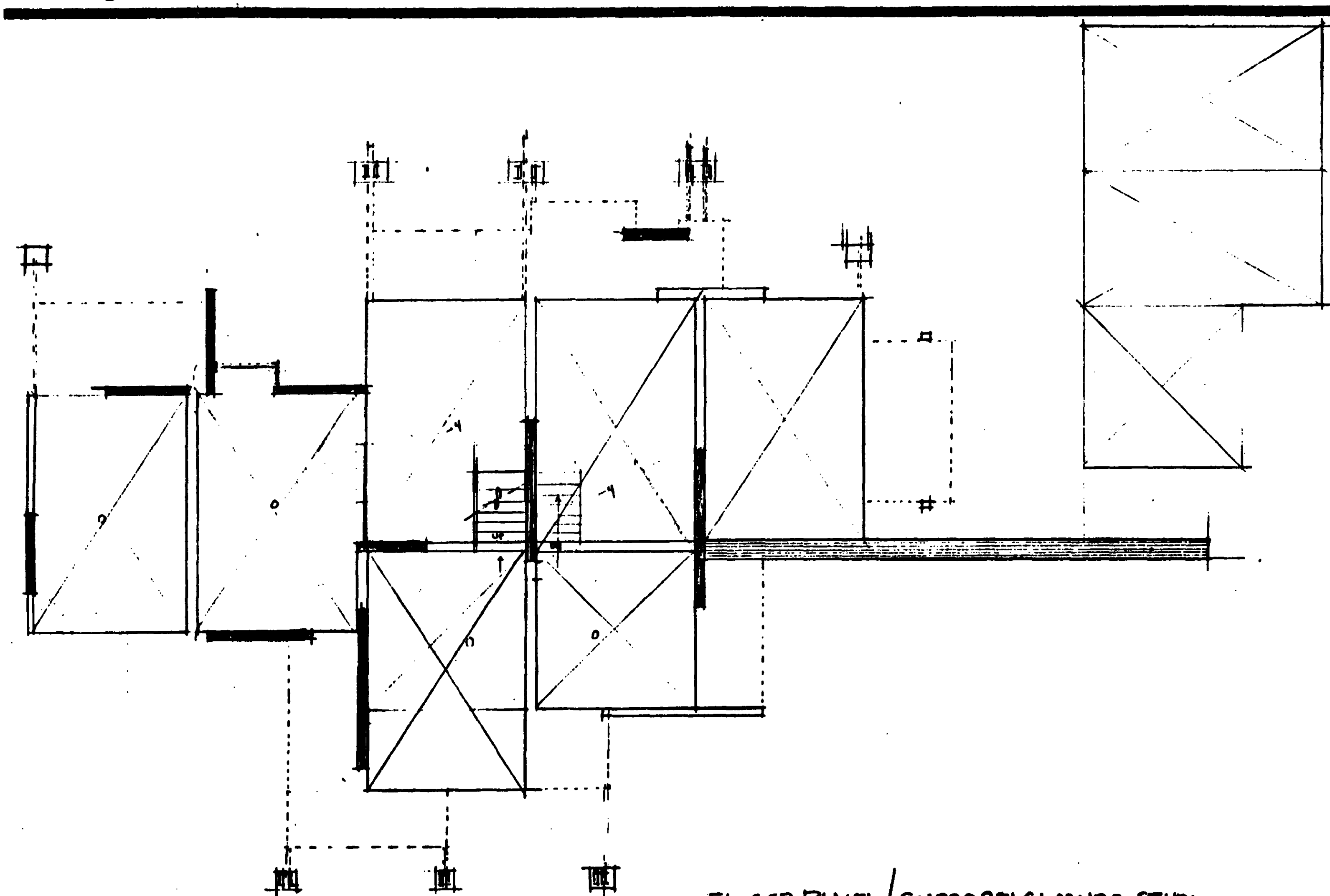
EARLY STUDY: FLOOR PANEL ORGANIZATION, LOWER LEVELS SHOWING SQUARE FOOTAGE OF PANELS



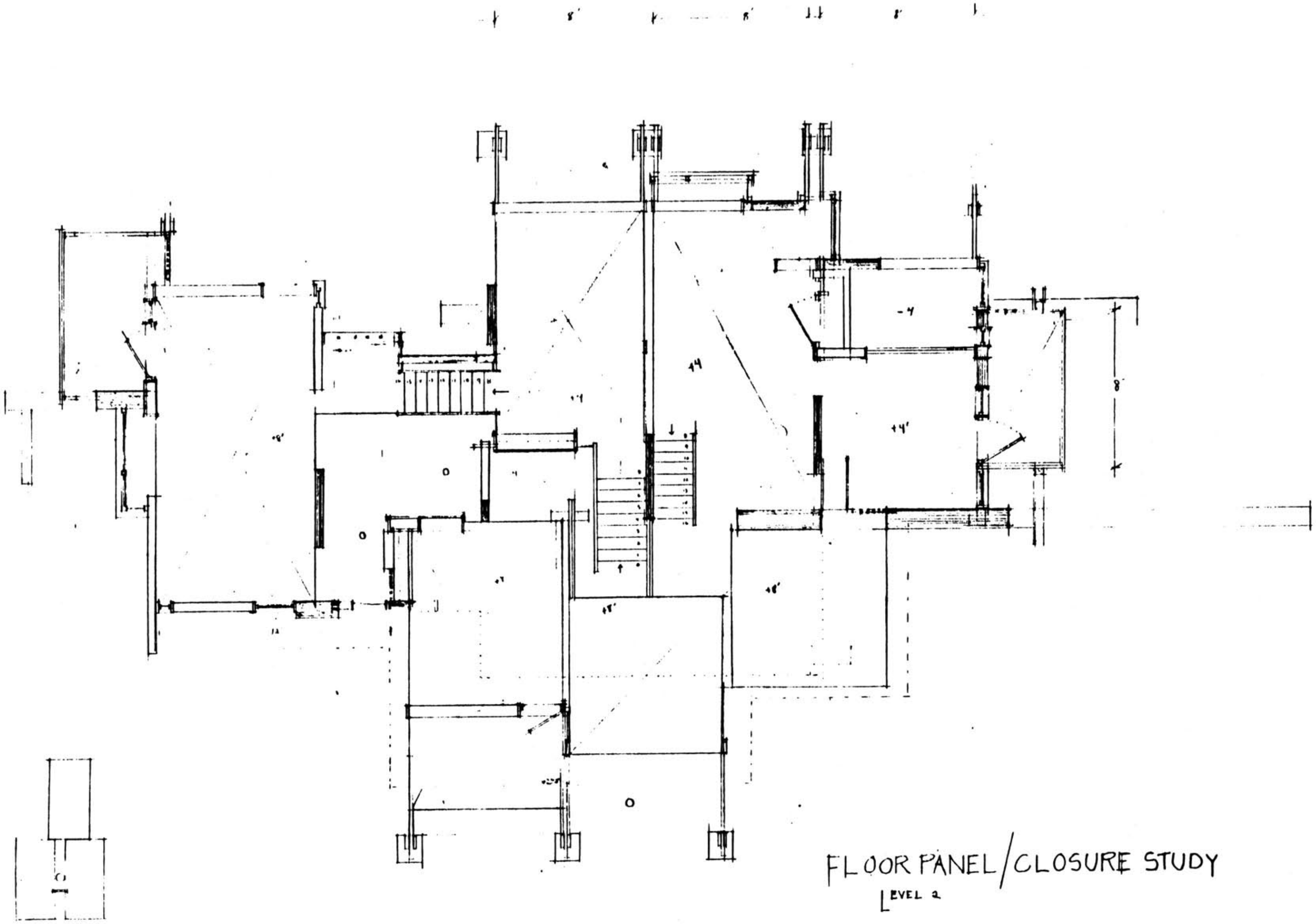
UPPER LEVELS



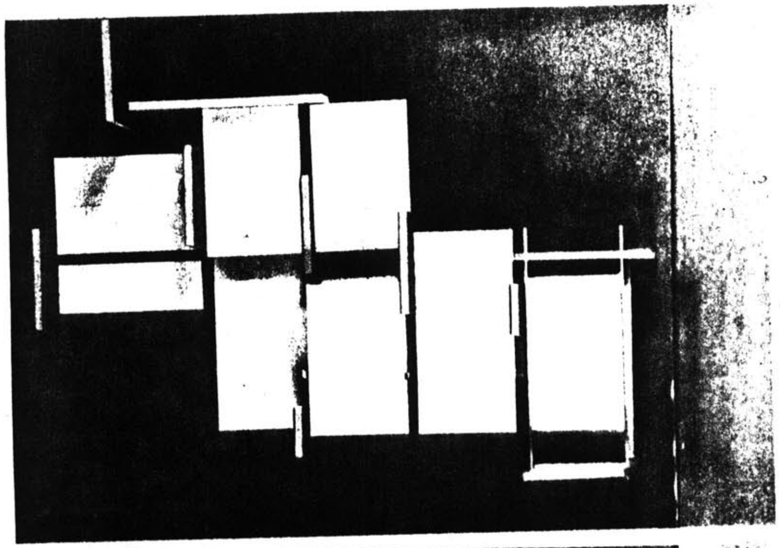
FLOOR PANEL ORGANIZATION: LOWER LEVELS

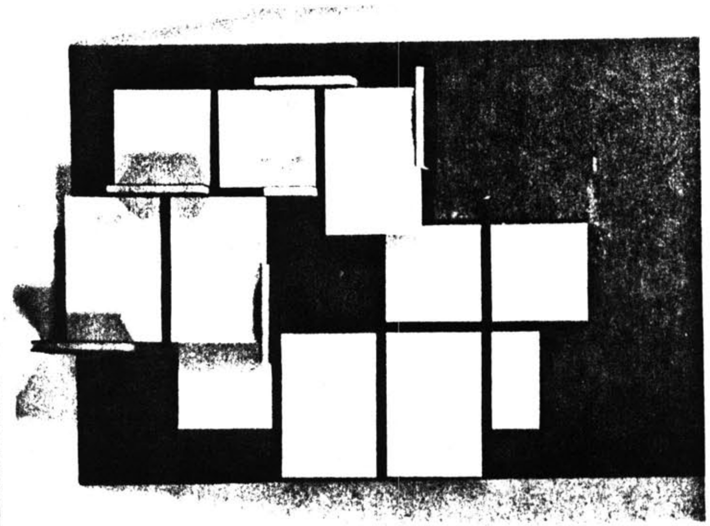


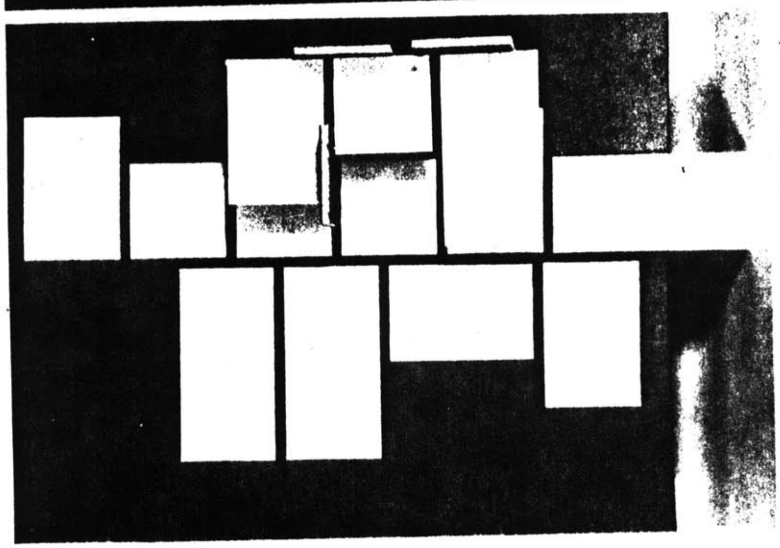
FLOOR PANEL/SUPPORT&CLOSURE STUDY
LEVEL 1

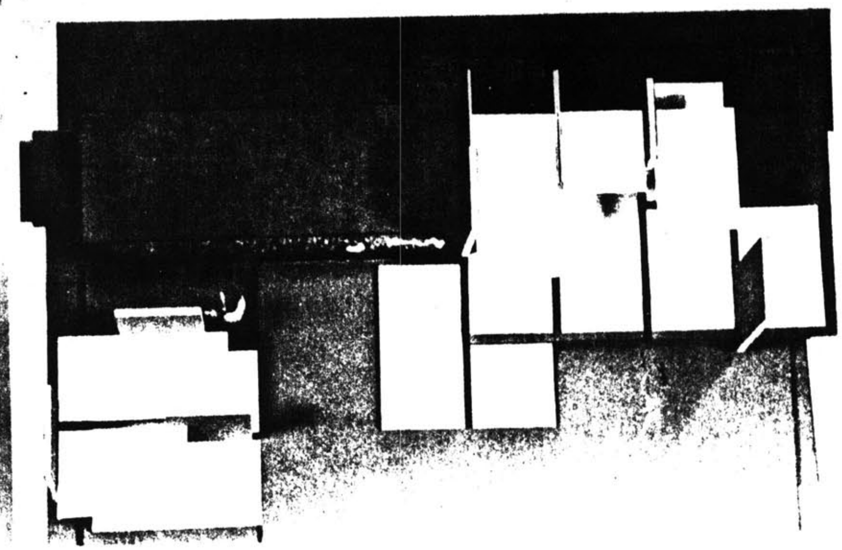

FLOOR PANEL/CLOSURE STUDY
LEVEL 2

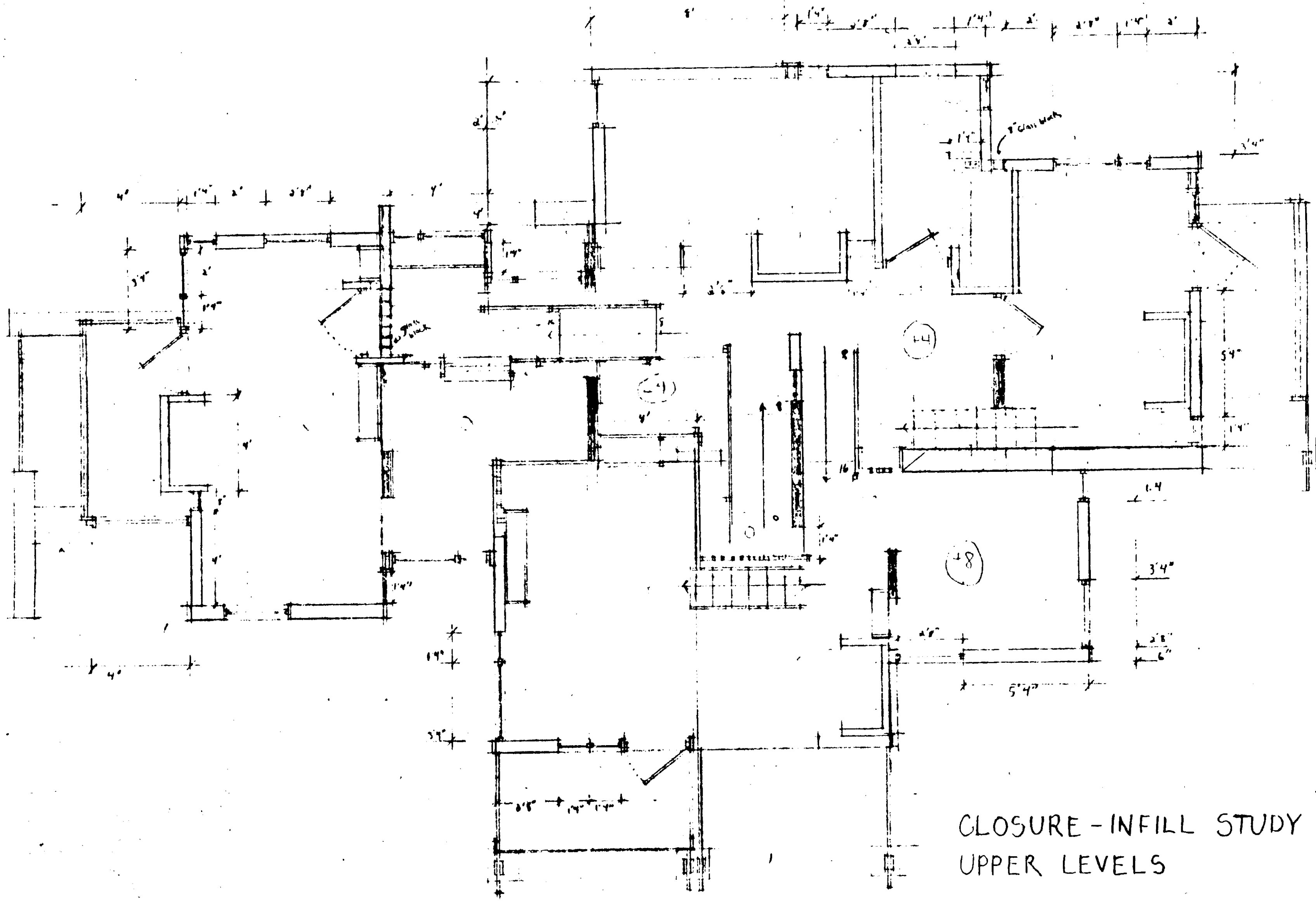
MODELS: FLOOR PANEL / SUPPORT WALL ASSEMBLY STUDIES





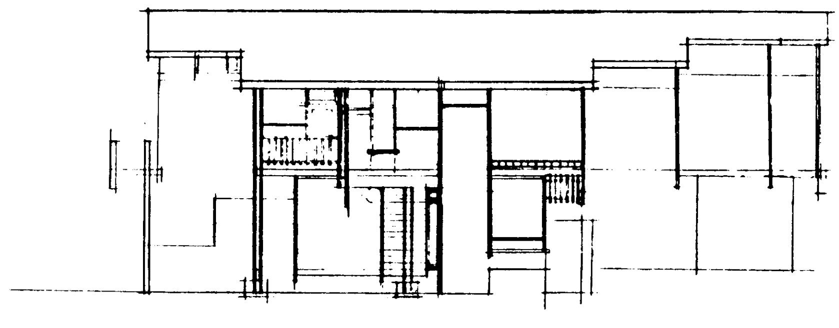


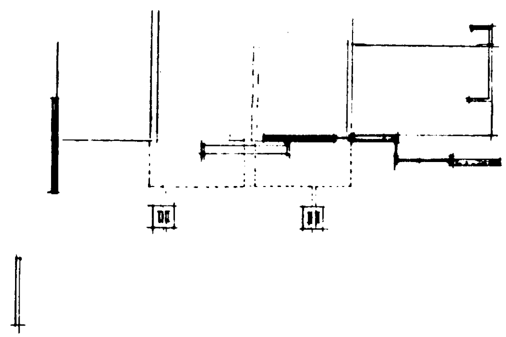


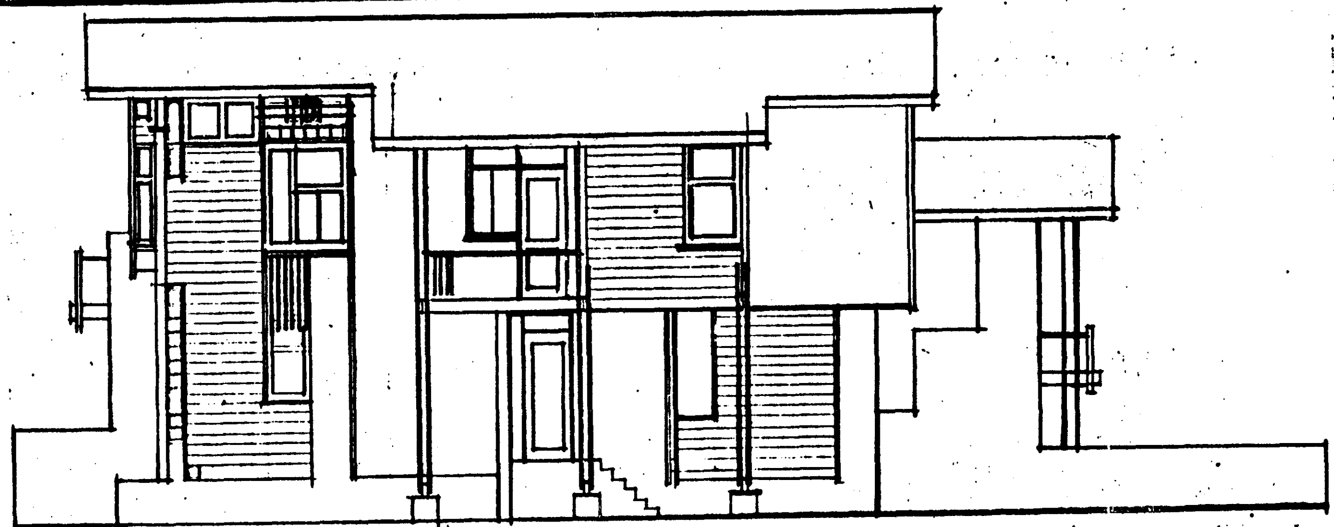


CLOSURE - INFILL STUDY
UPPER LEVELS

Elevation Studies

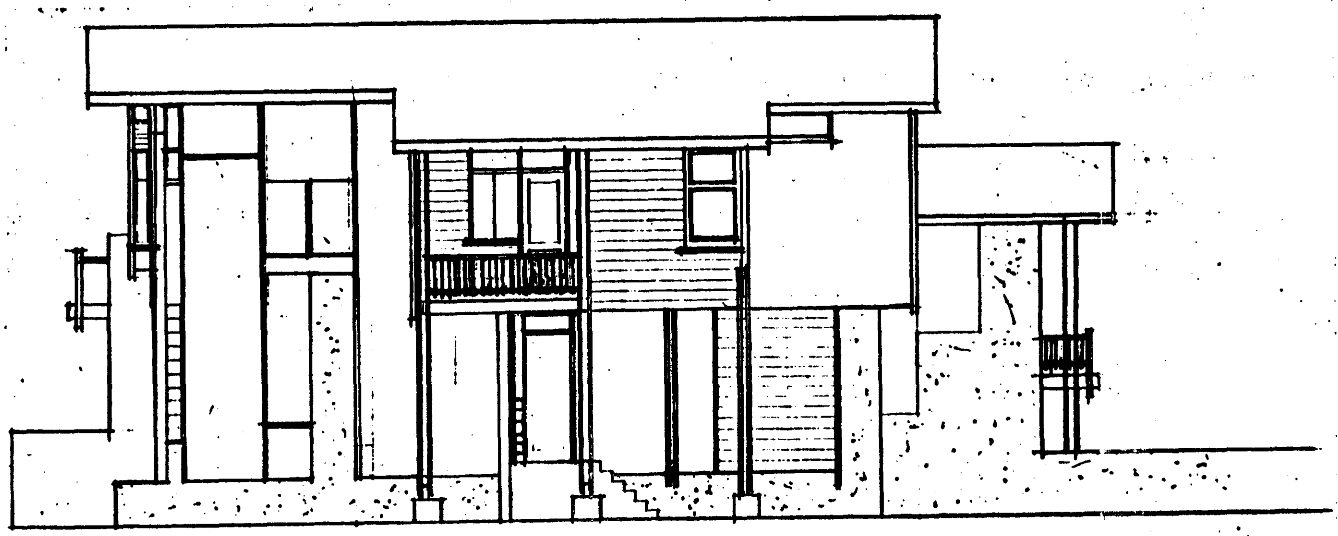






STUDY ELEVATION

DEC 02 1989



STUDY ELEVATION

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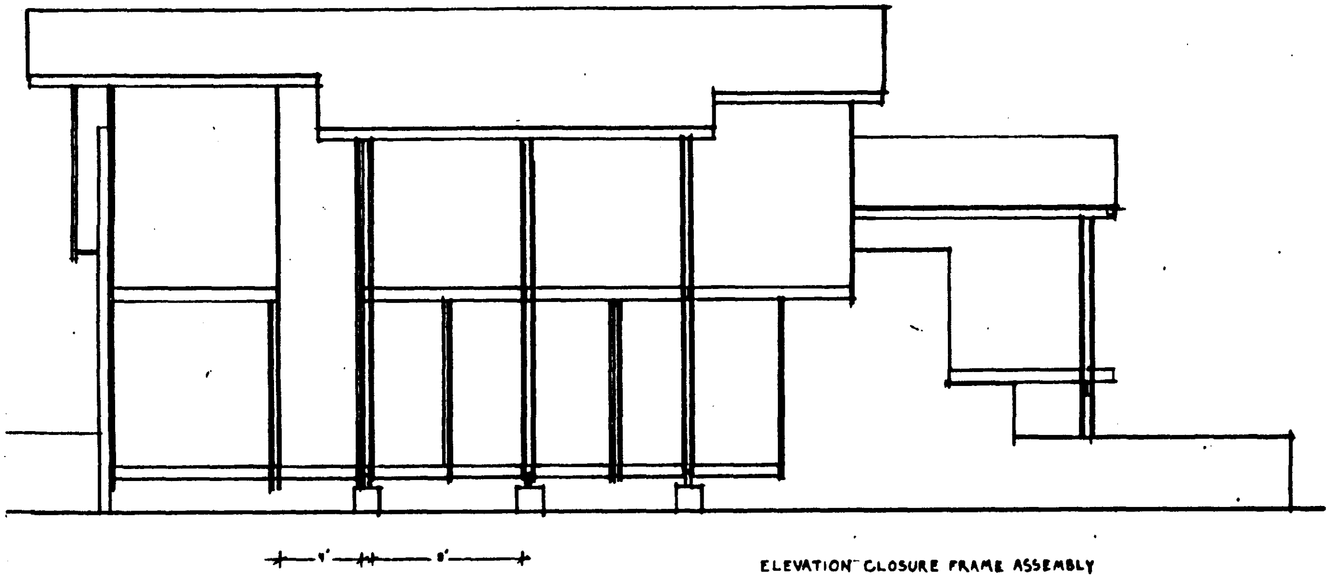
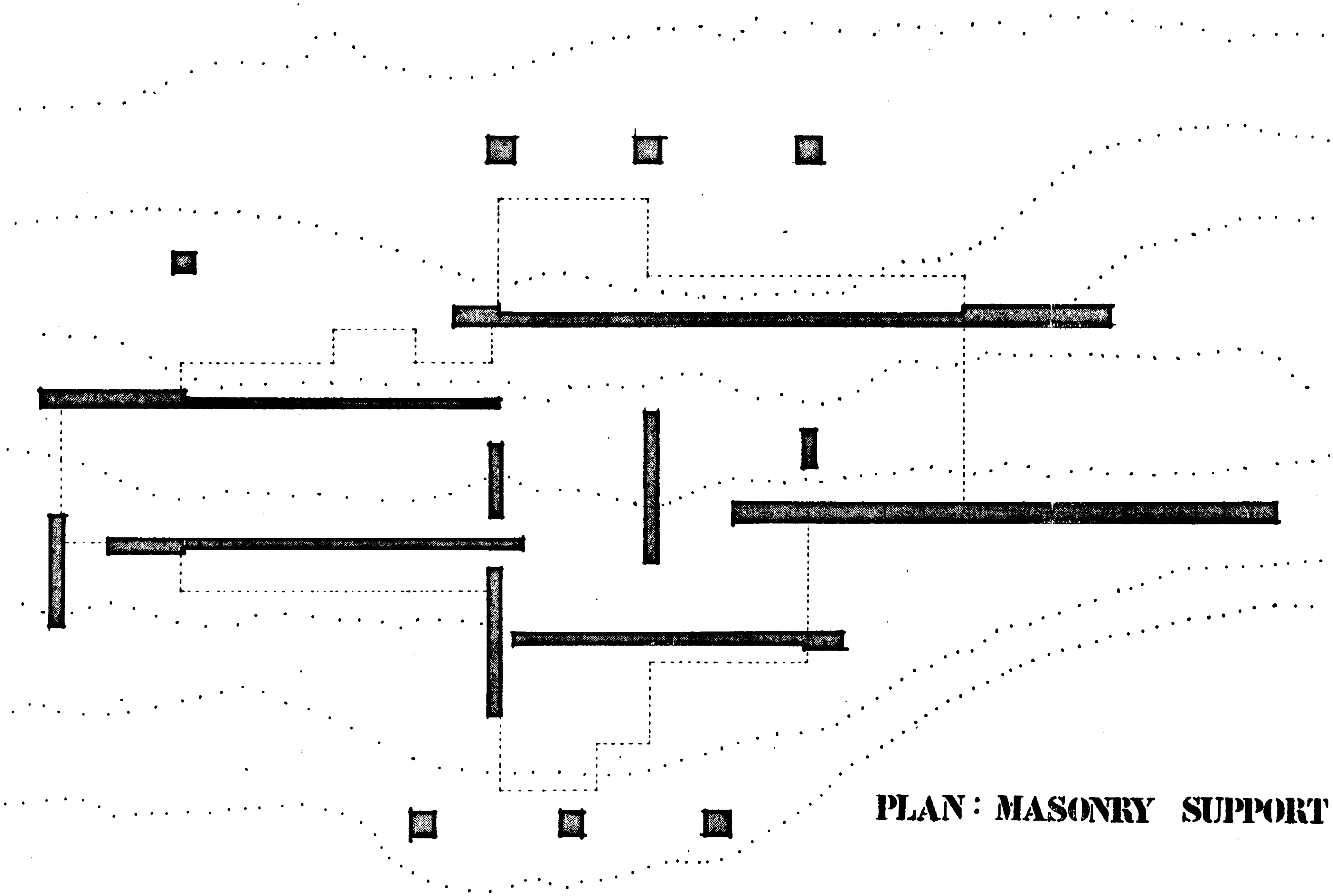
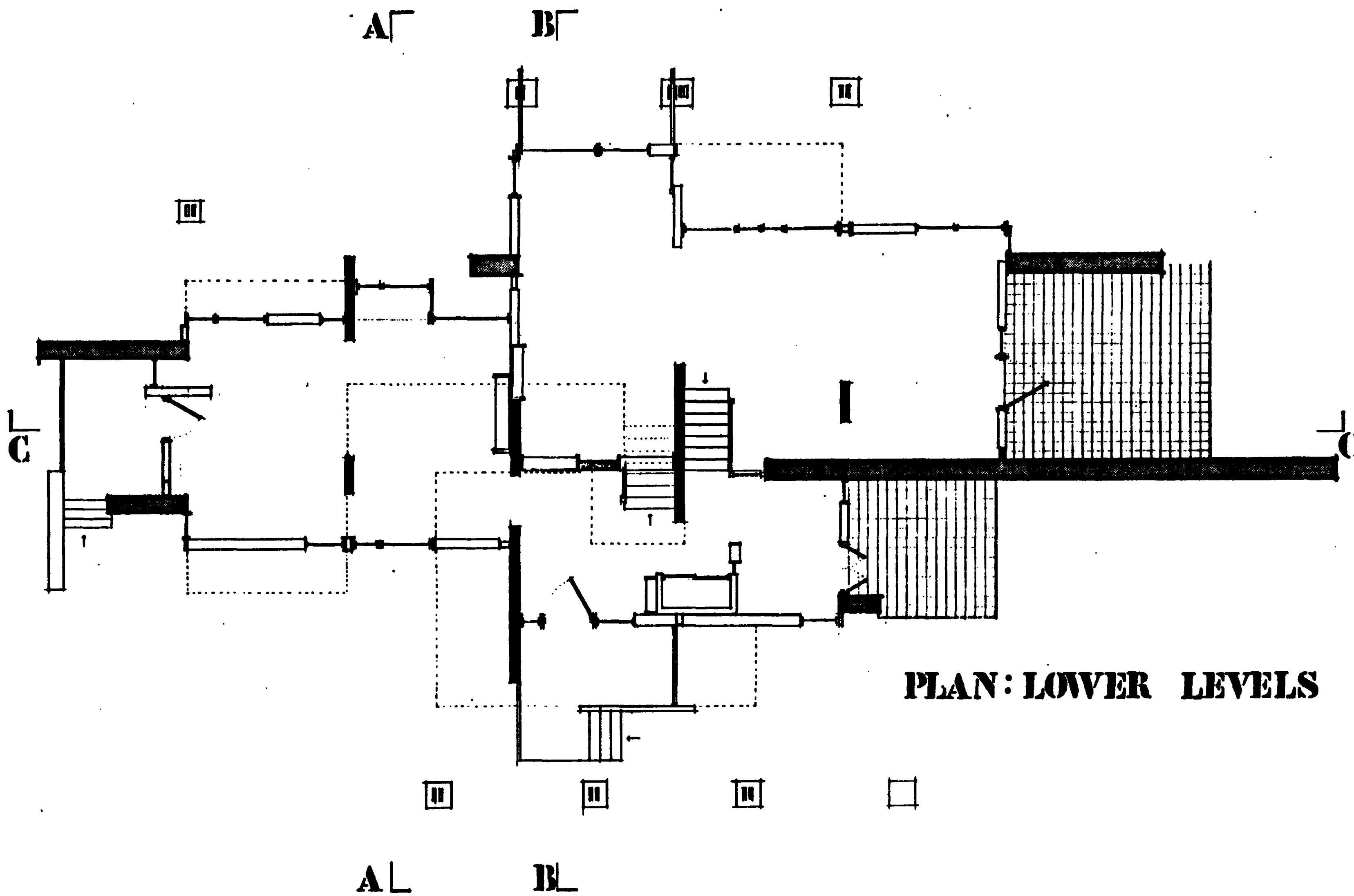


ELEVATION CLOSURE FRAME ASSEMBLY

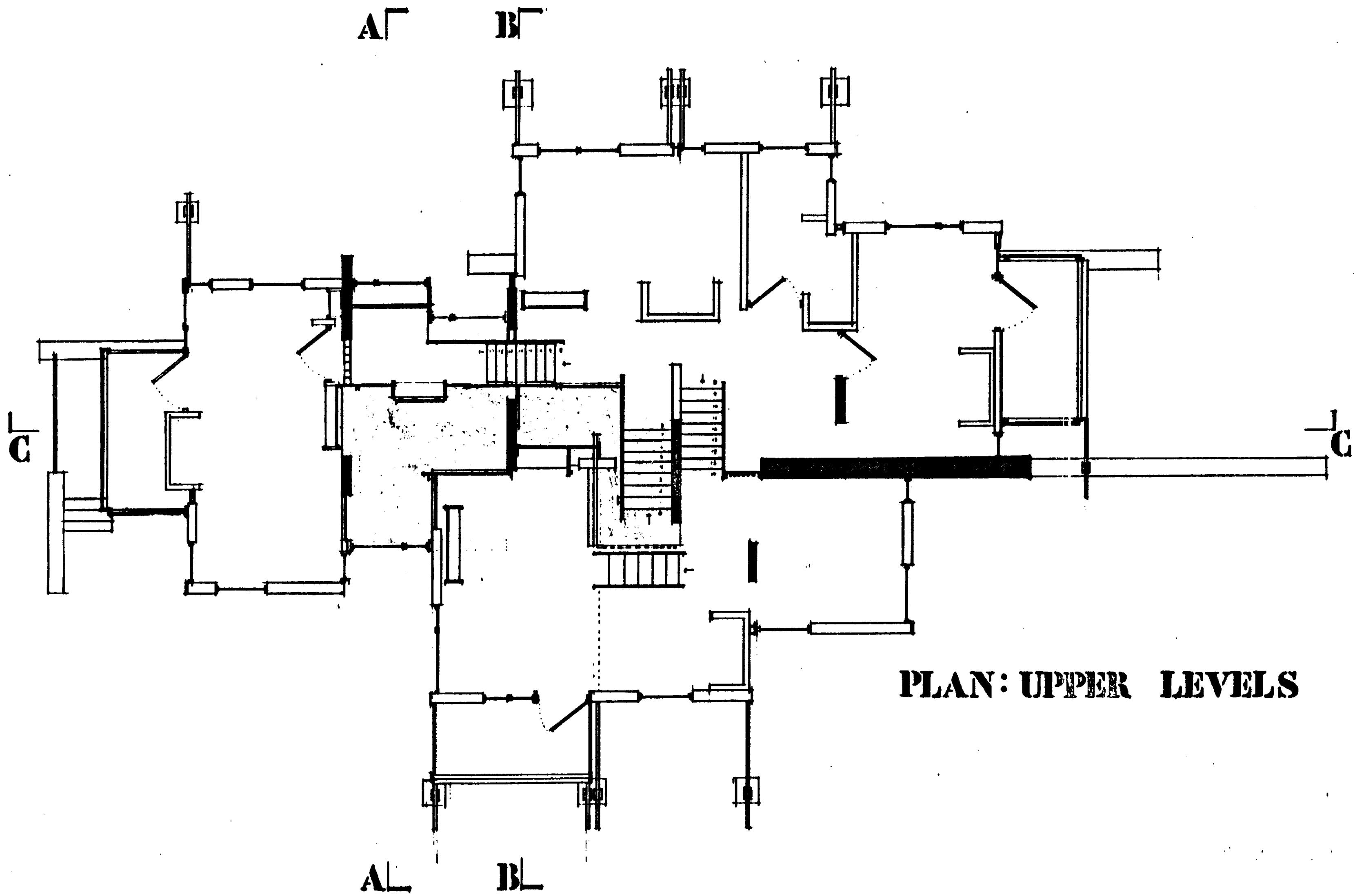
A PANELIZED DWELLING



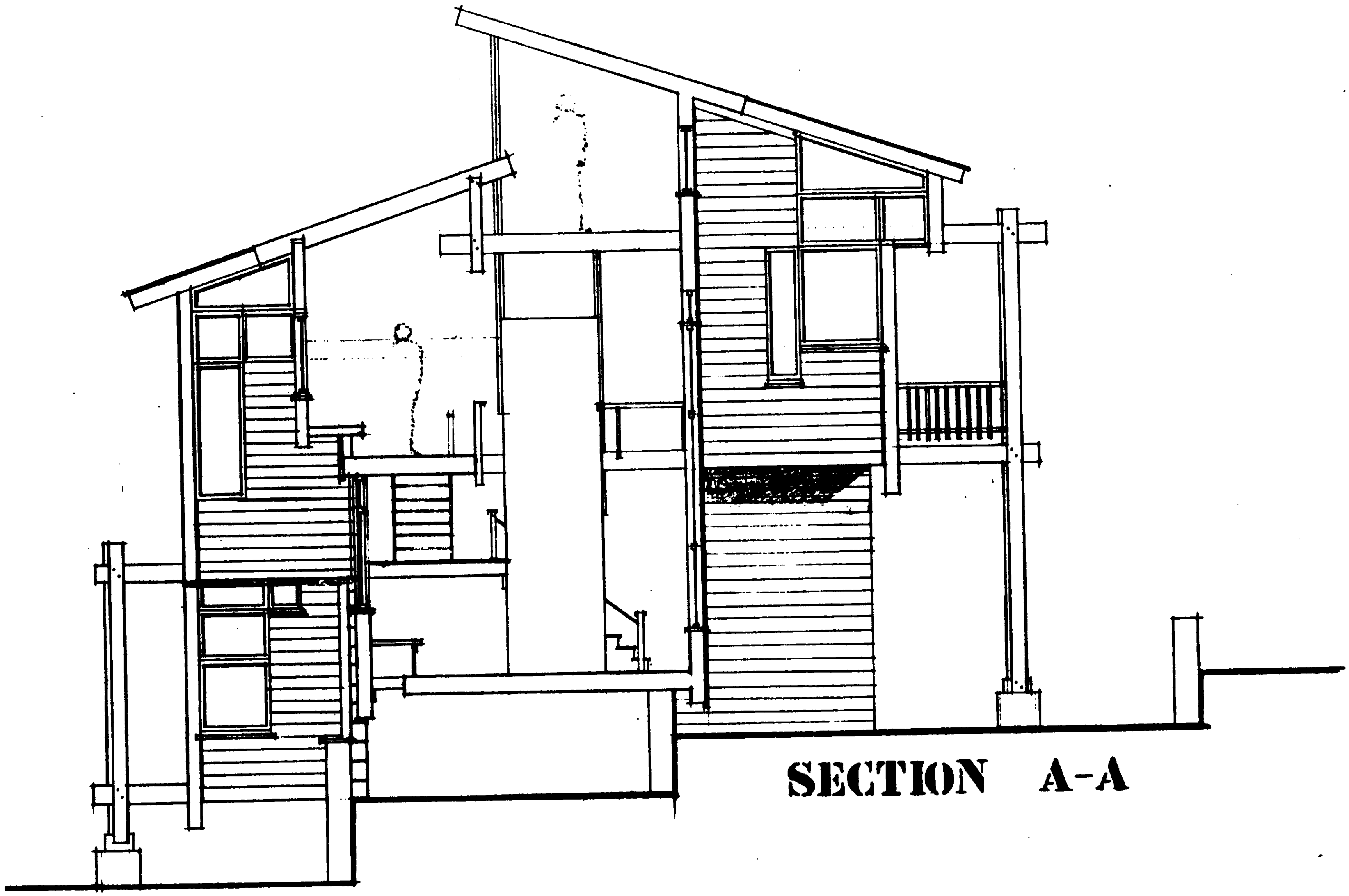
PLAN: MASONRY SUPPORT



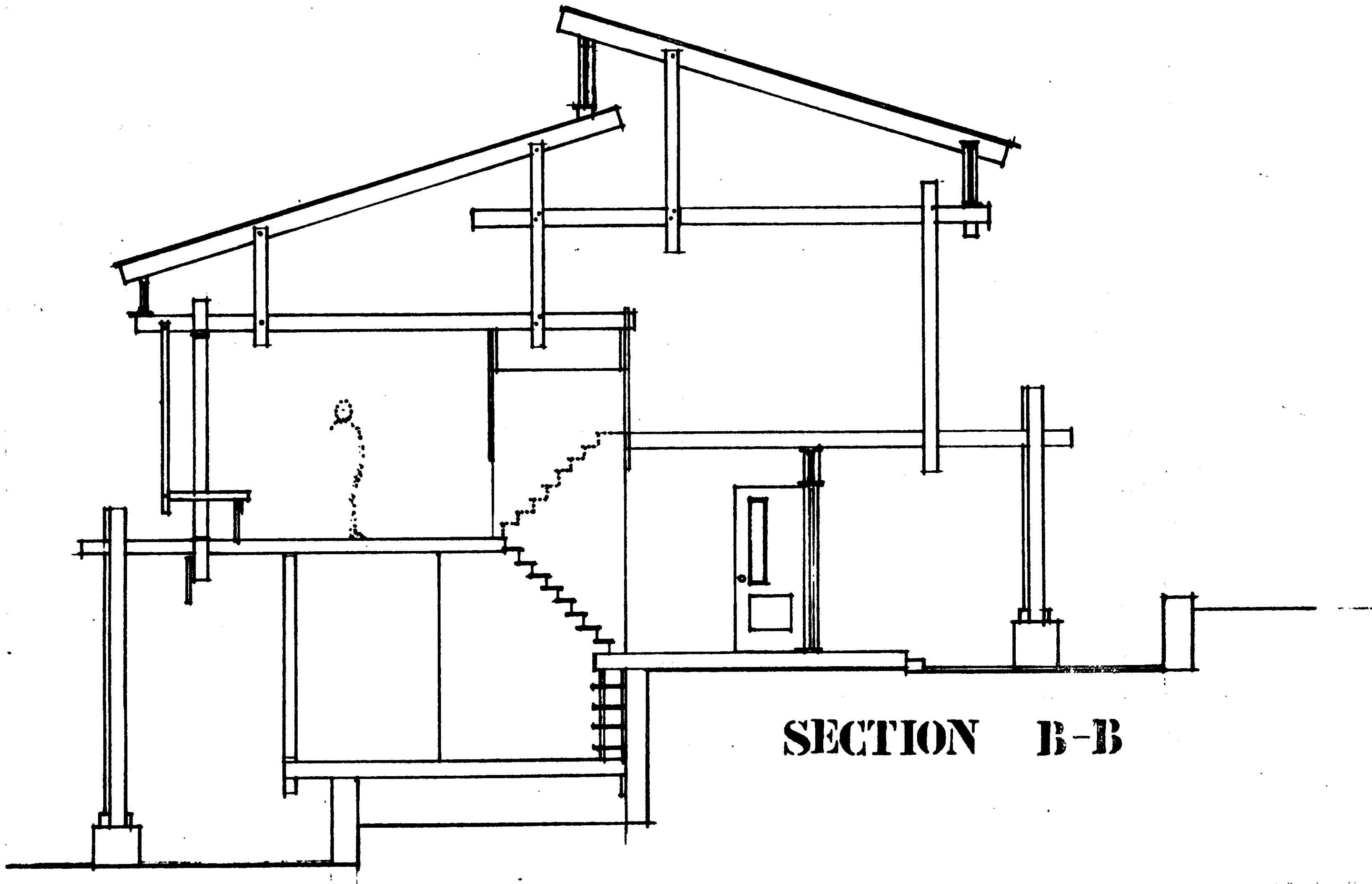
PLAN: LOWER LEVELS



PLAN: UPPER LEVELS



SECTION A-A



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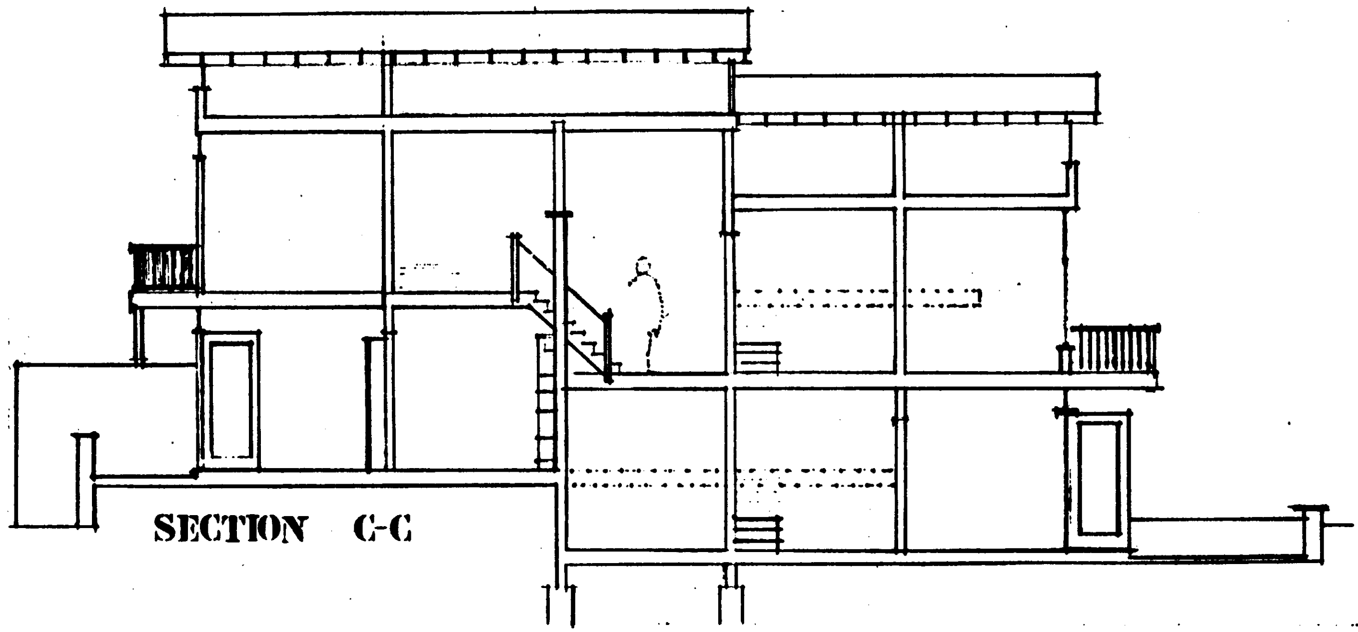
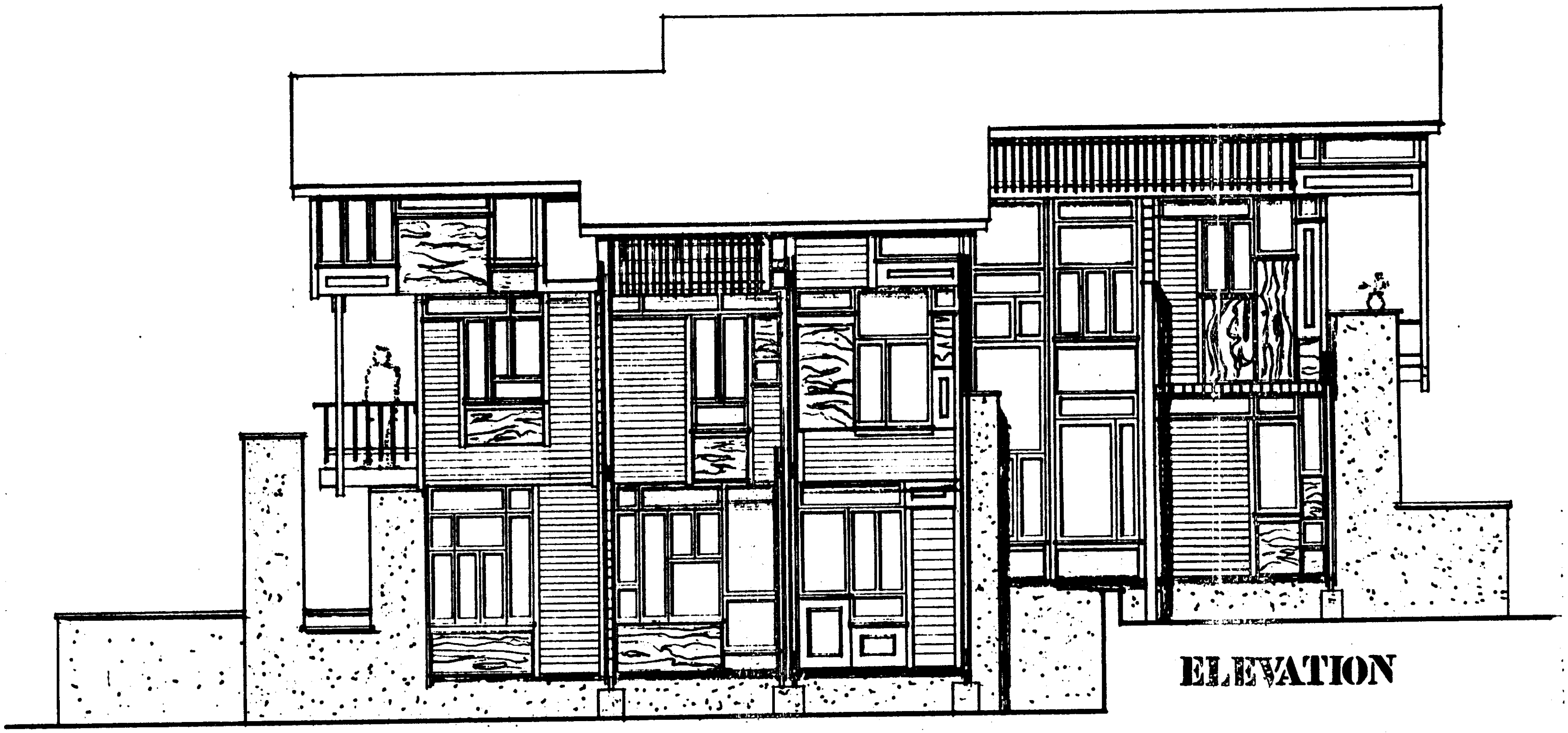
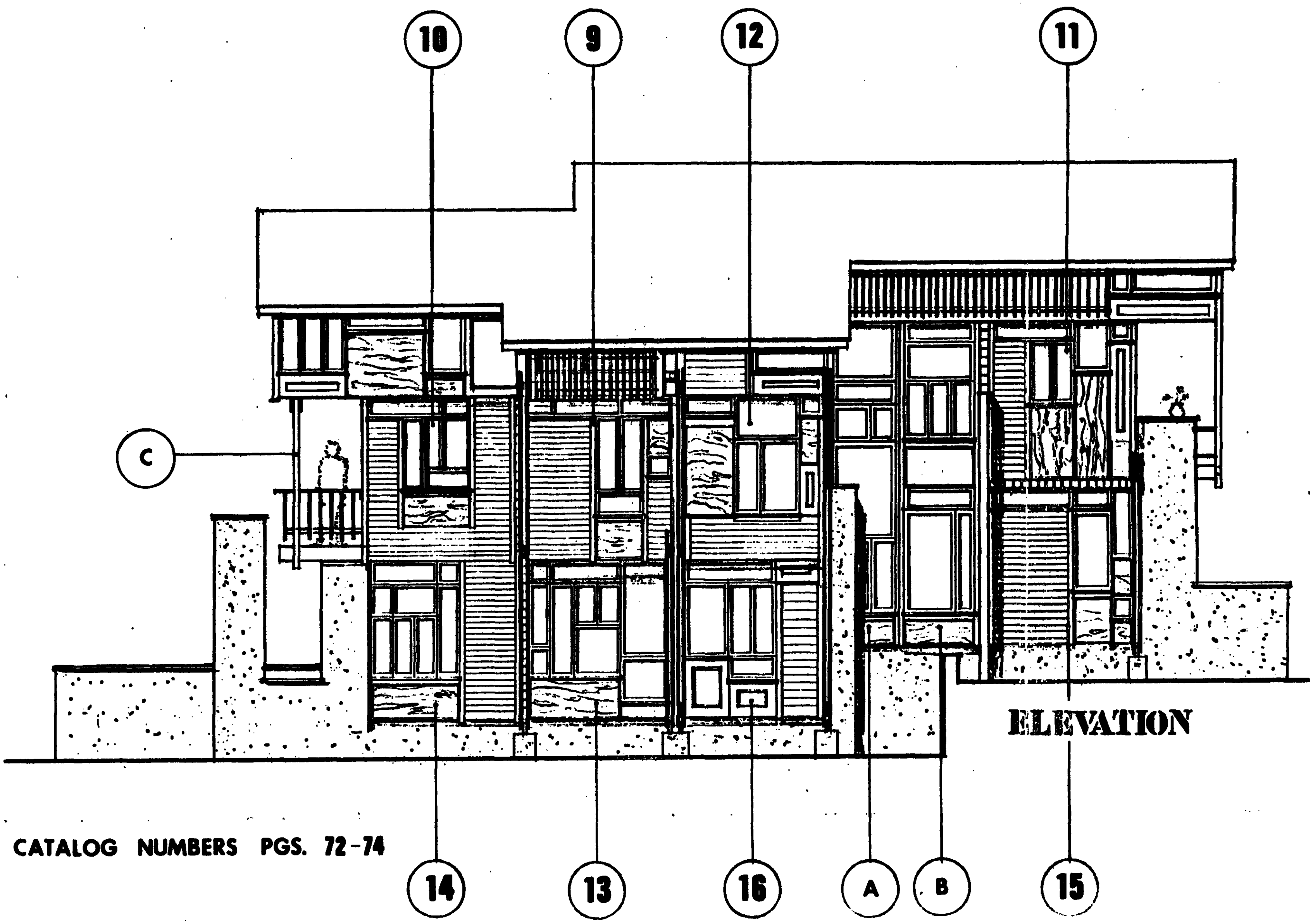


SECTION C-C



ELEVATION

CLOSURE PANEL ASSEMBLY:



CATALOG NUMBERS PGS. 72-74

Early Support/ Panel System Studies

- post & girder support/panel infill
- support wall panel/box beam
- peripheral support wall panels

Early explorations of panel systems included three distinct methods of building. Each study examines a different method of support. The advantages and limitations of each support are considered in terms of their ability to provide a wide range of spatial options. The ability to change floor levels easily, in response to topographical conditions, is also considered. Due to my time limitations, the comments on each exploration are kept in general terms.

● POST AND GIRDER SUPPORT WITH PANEL INFILL

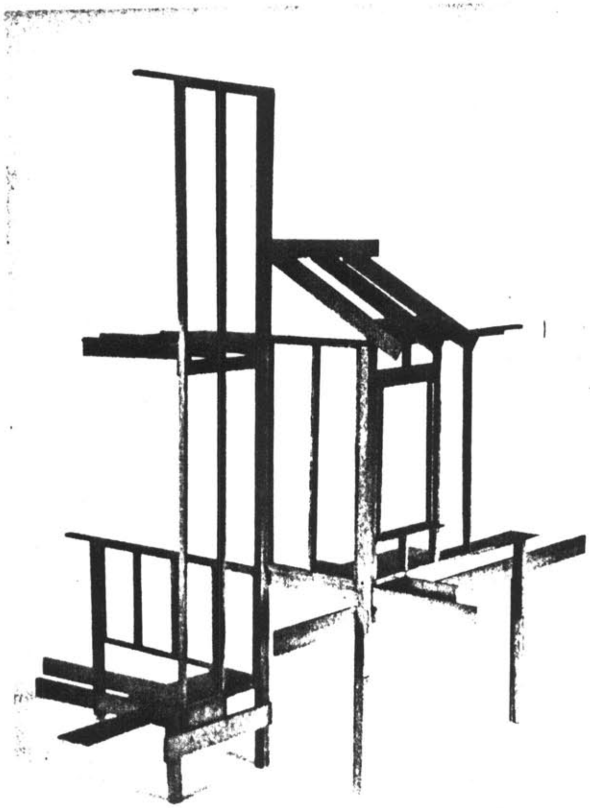
The first exploration of support offers a wide range of spatial options through its ability to change floor levels easily. This also allows the system to adapt to a wide range of topographical conditions. The support is comprised of a post and girder framework. Changing the floor level is achieved by moving the girders up or down along the posts. The floor, roof, closure, and infill panels are used as a secondary system, operating independently of the support framework.

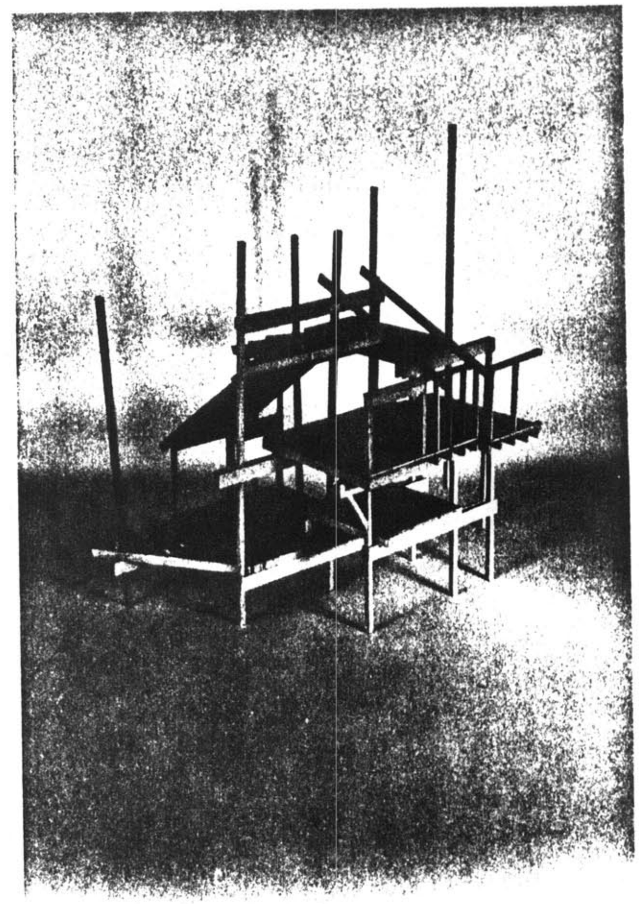
The support framework only carries loads. It does not directly contribute to any other aspect of the building such as partially defining interior and exterior spaces. Conversely, the component panels do not contribute to the support.

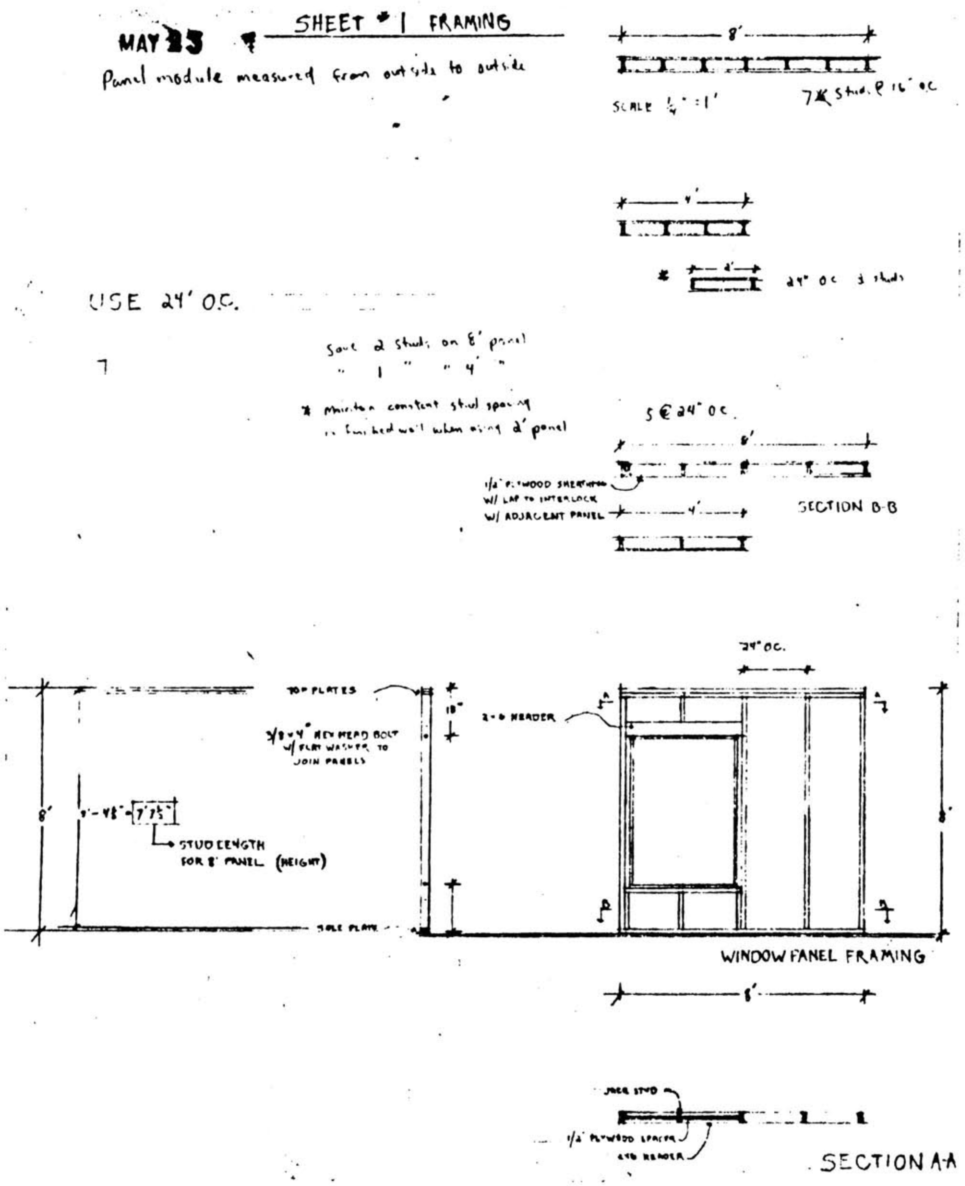
In order to maximize the use of the panels, there must be a more direct relationship between the support and the panels. For example, the panels should be used to carry loads in addition to partially defining use territories of the building.

Models:

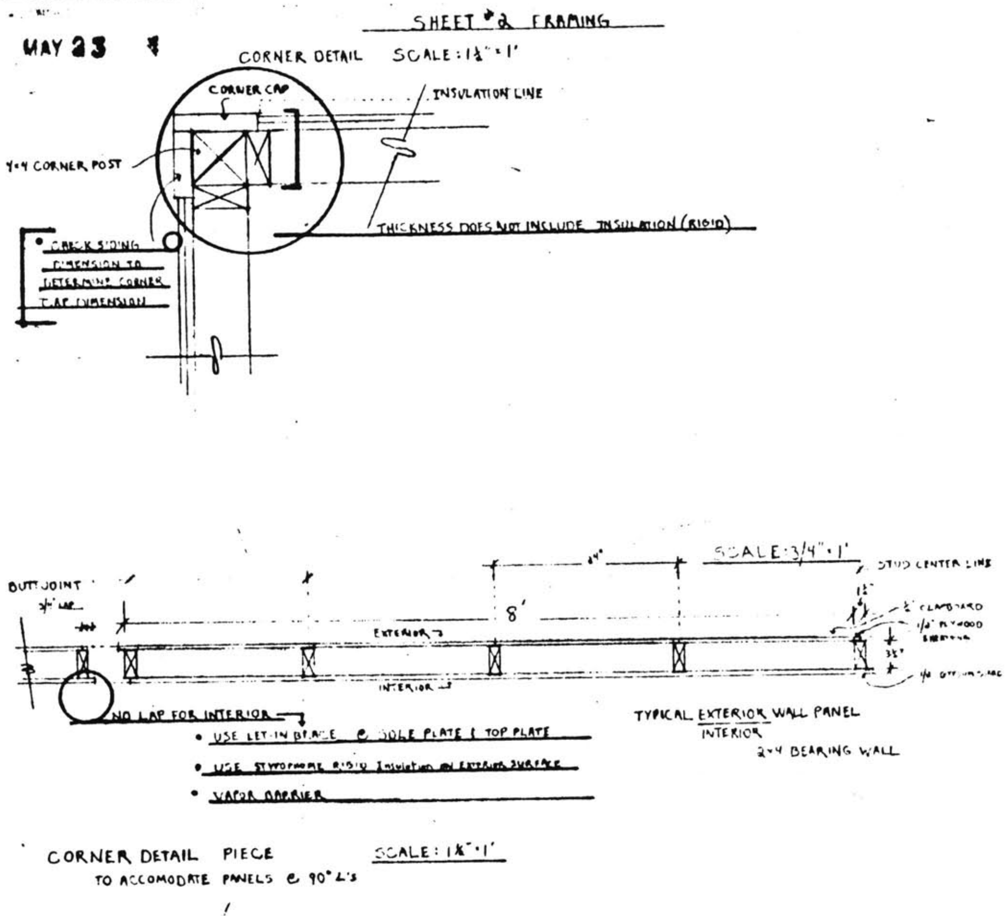
Post & Girder Support / Panel Infill Studies



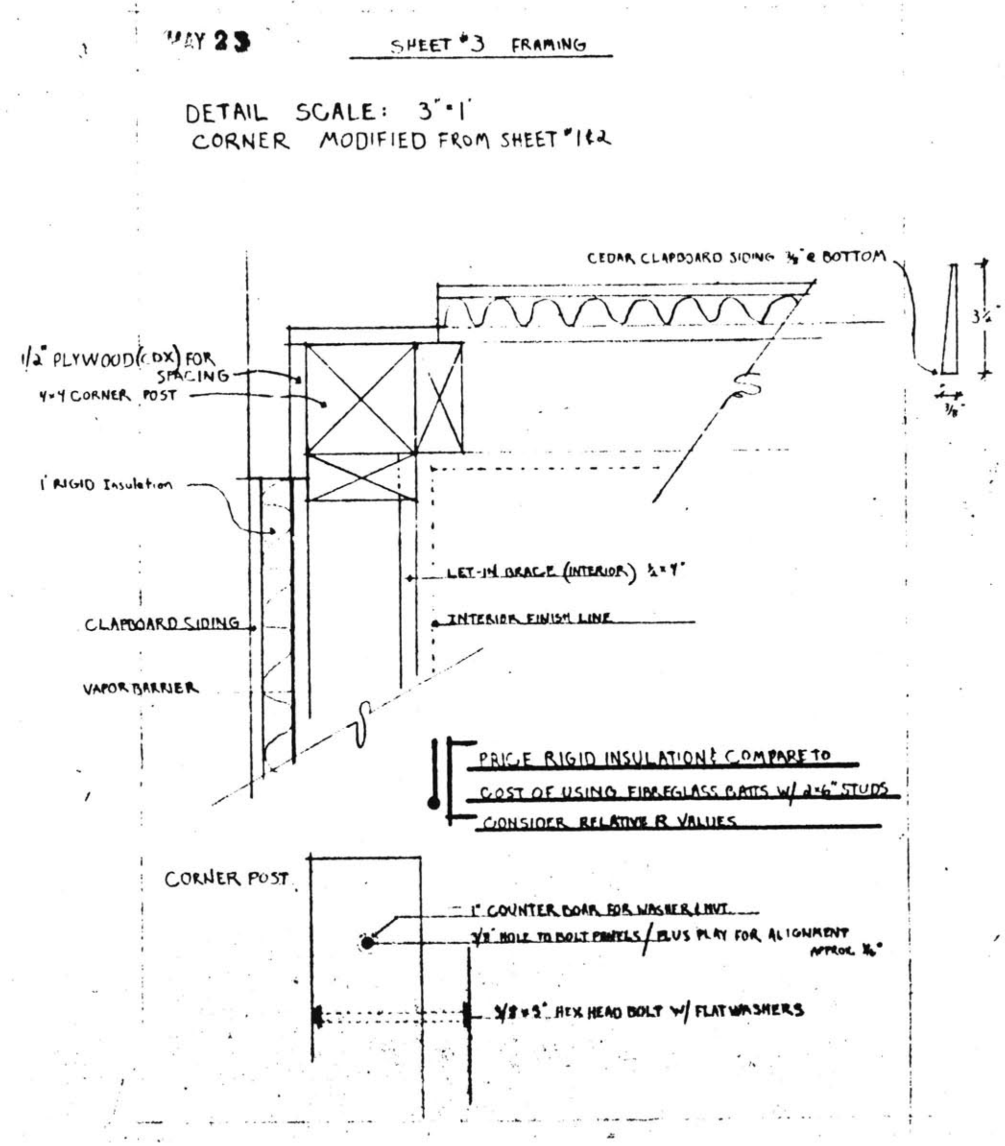


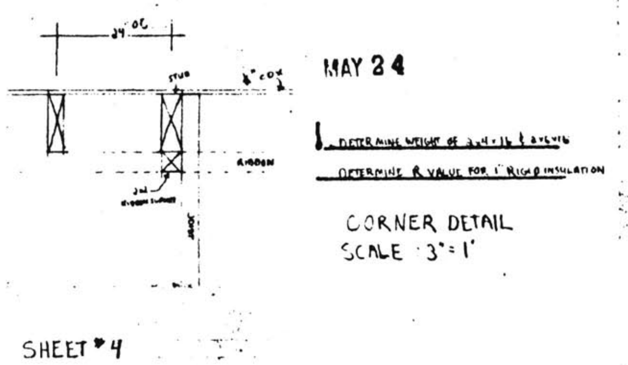


Panel Details

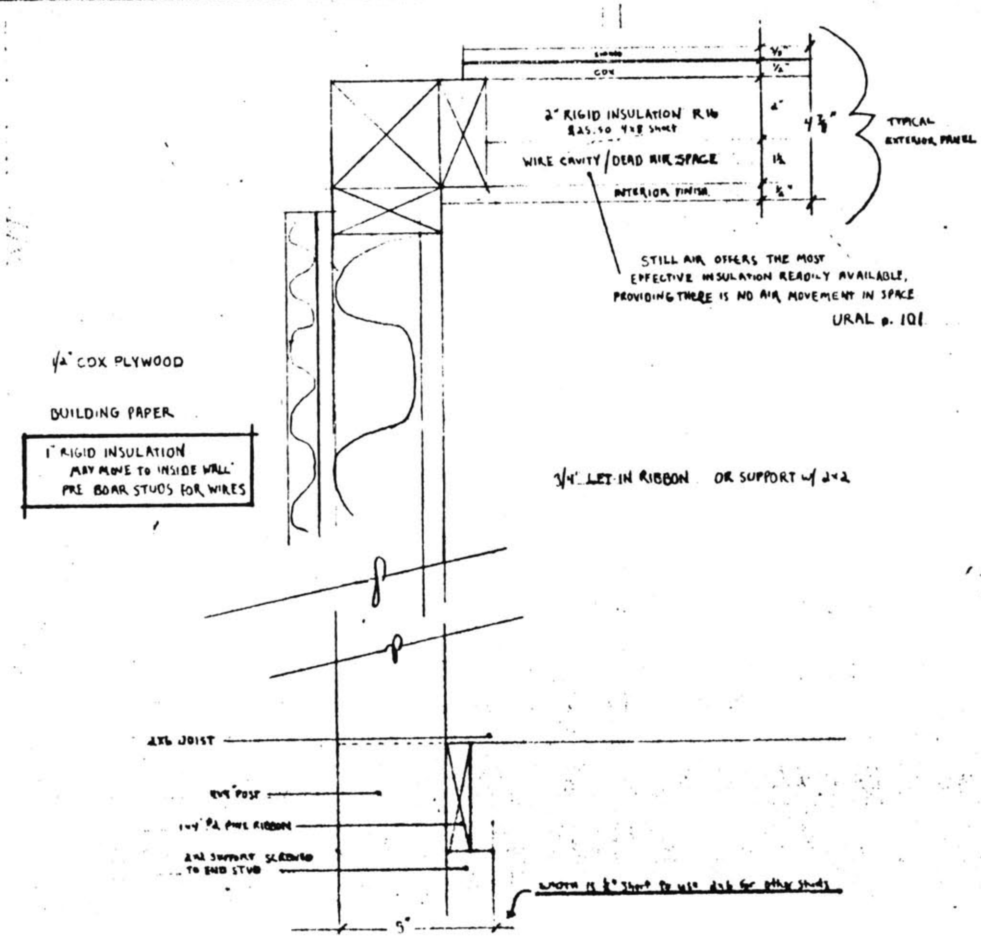


Panel Details


MAY 23
SHEET #3 FRAMING
DETAIL SCALE: 3"=1'
CORNER MODIFIED FROM SHEET #1&2
CEDAR CLAPBOARD SIDING ½" @ BOTTOM
3½"
1/2" PLYWOOD (CDX) FOR SPACING
4×4 CORNER POST
1' RIGID Insulation
LET-IN BRACE (INTERIOR)
INTERIOR FINISH LINE
CLAPBOARD SIDING
VAPOR BARRIER
PRICE RIGID INSULATION & COMPARE TO
COST OF USING FIBREGLASS BATTS W/ 2×6" STUDS
CONSIDER RELATIVE R VALUES
CORNER POST
1" COUNTER BOAR FOR WASHER & NUT
HOLE TO BOLT PANELS / PLUS PLAY FOR ALIGNMENT
HEX HEAD BOLT W/ FLAT WASHERS



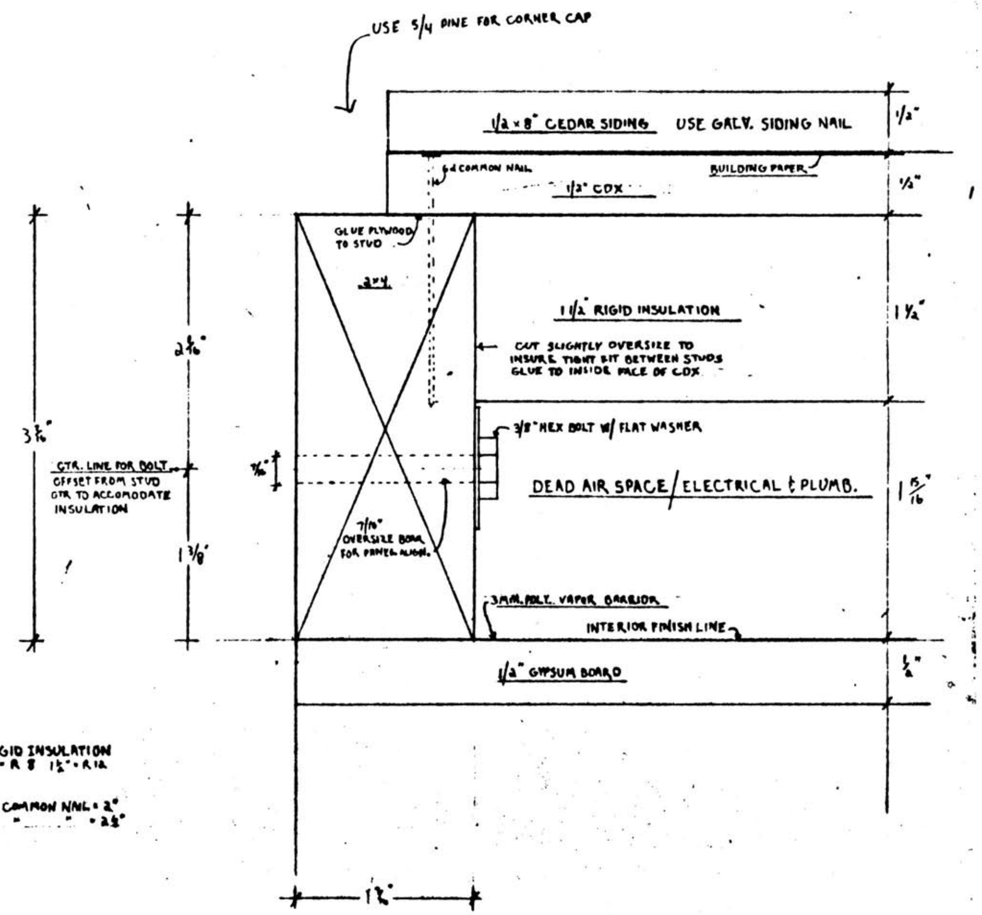
Panel Details



MAY 24 SHEET #5

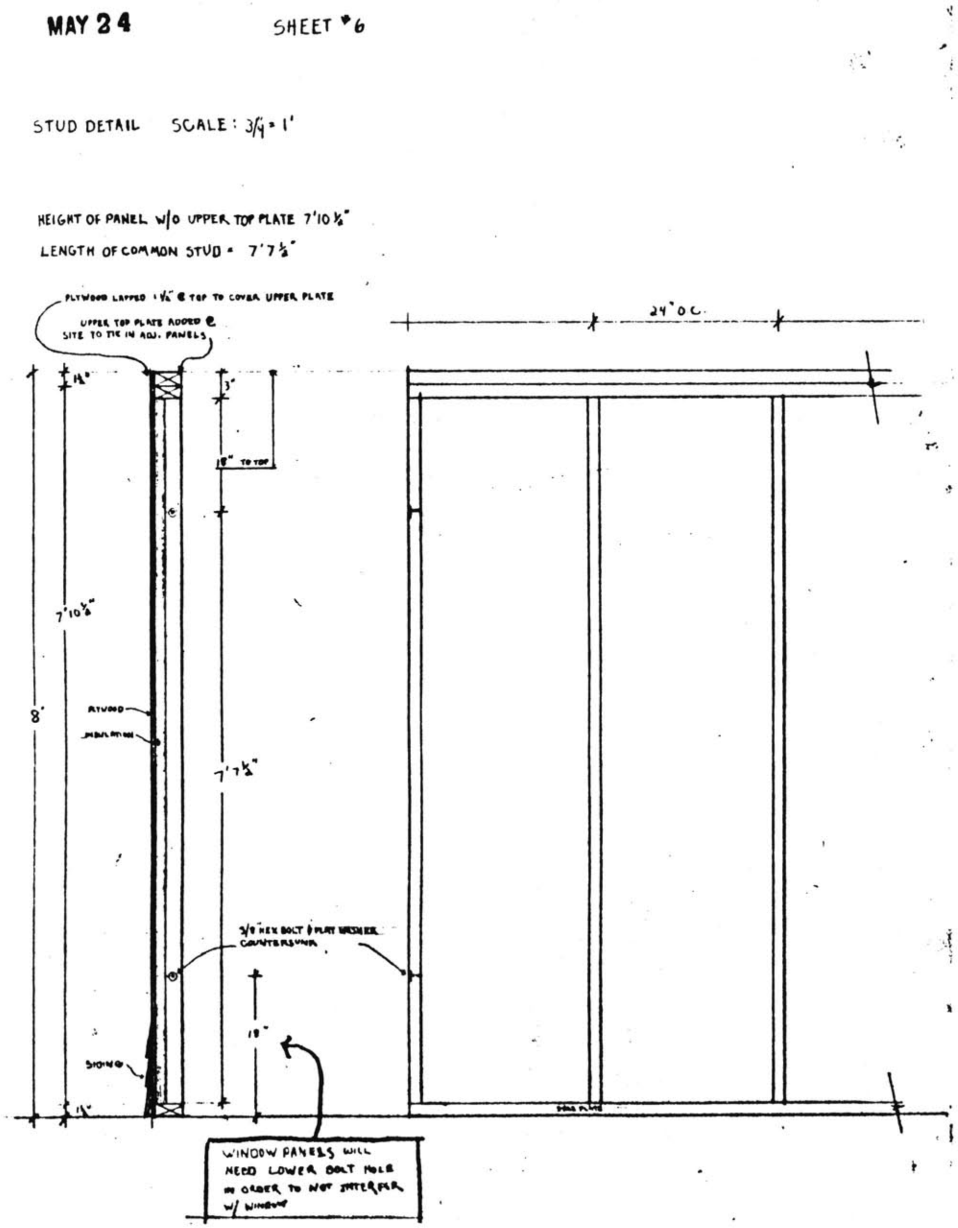
DETAIL - SCALE: FULL PANELCORNER (EXTERIOR)

NOMINAL 2x4 : ACTUAL 1 5/8" x 3 5/8"

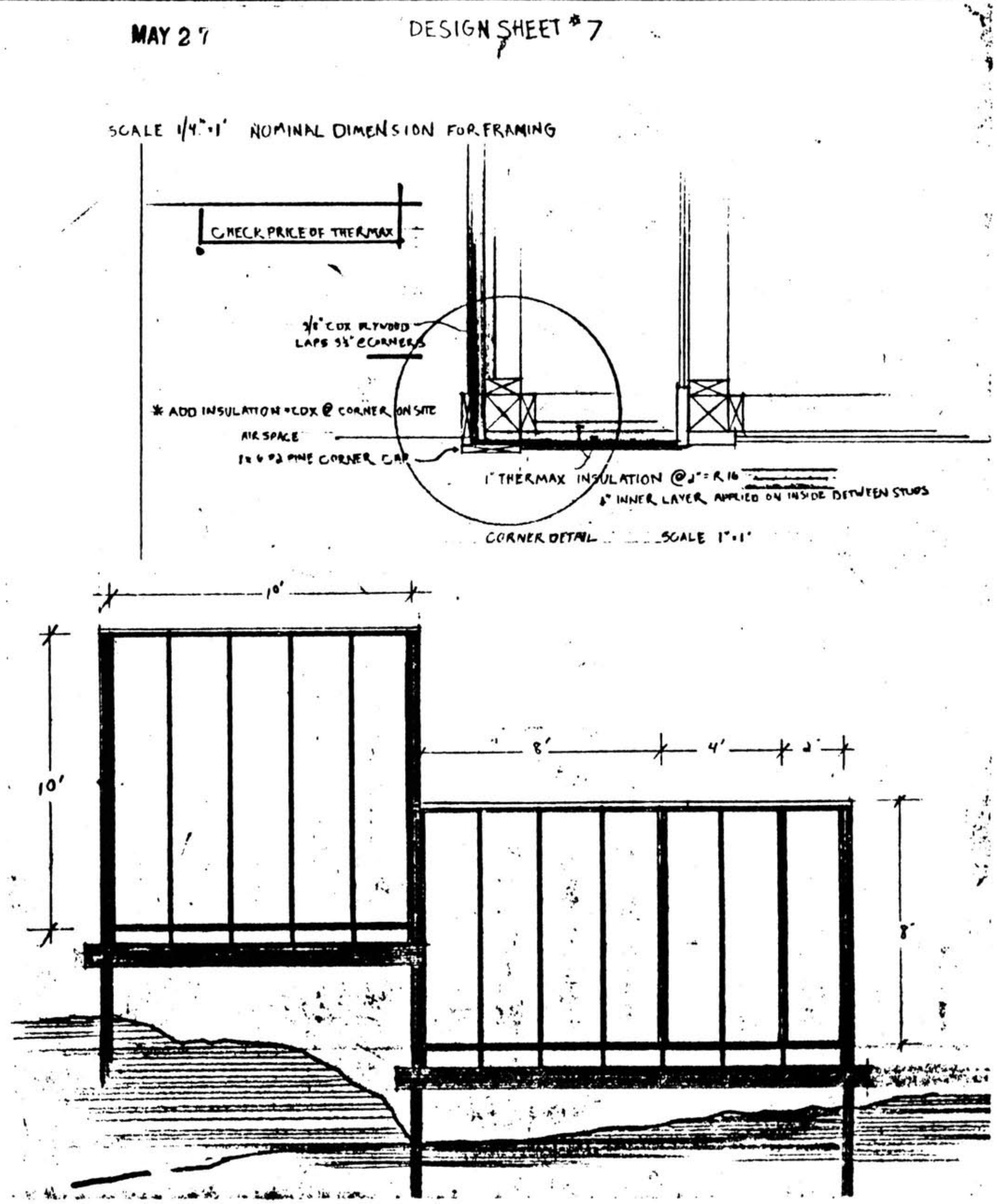


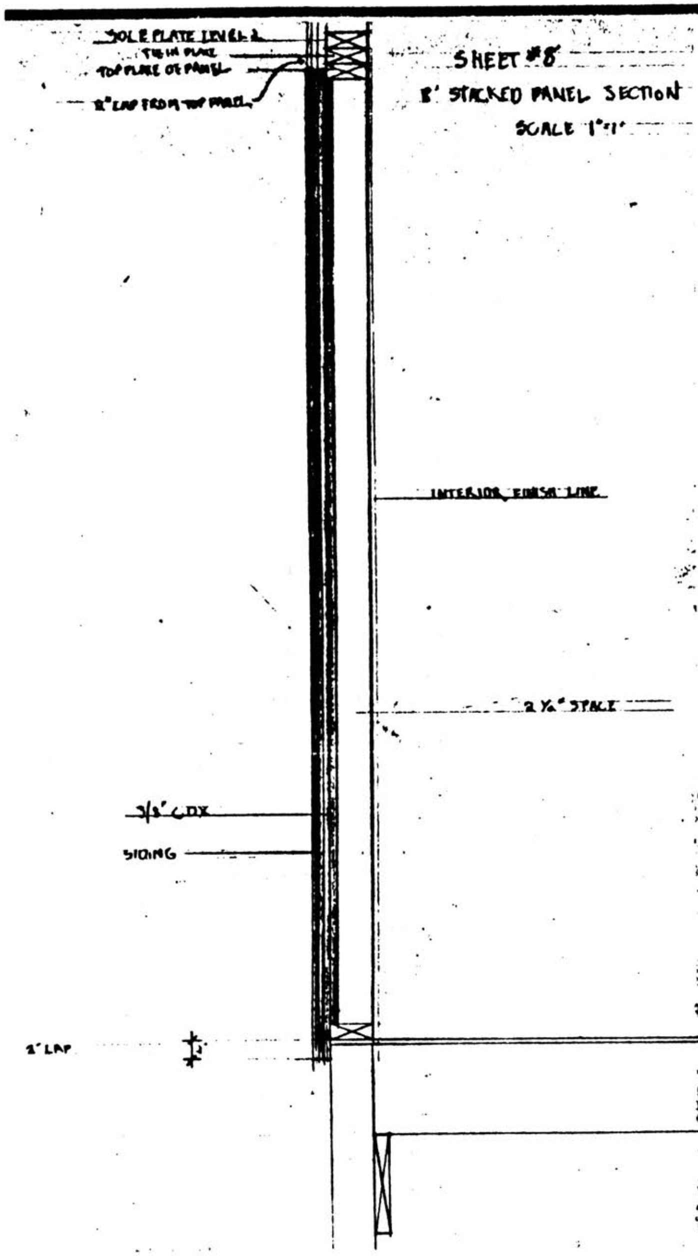
RIGID INSULATION
1" = R 8 1 1/2" = R 12

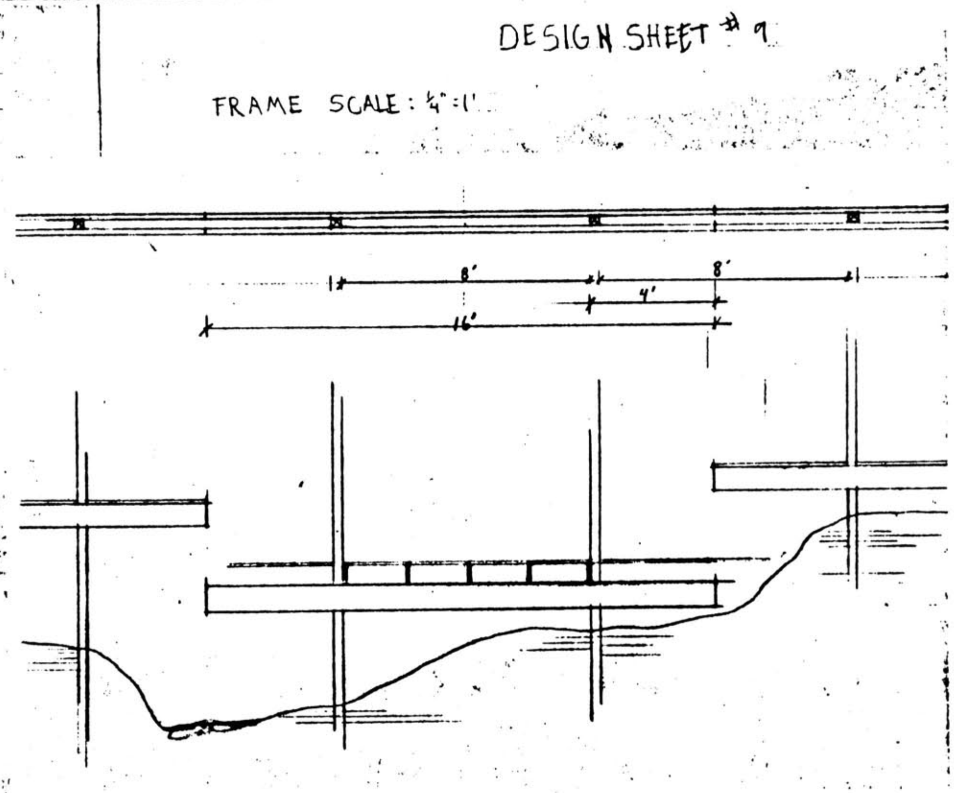
6d COMMON NAIL = 2"
8d " " = 2 1/2"



Panel Details


MAY 27
DESIGN SHEET #7
SCALE 1/4" = 1' NOMINAL DIMENSION FOR FRAMING
CHECK PRICE OF THERMAX
LAPS 3½" @ CORNERS
* ADD INSULATION + COX @ CORNER ON SITE
AIR SPACE
1" THERMAX INSULATION @ 2" = R 16
CORNER DETAIL
SCALE 1" = 1'
10'
8'
4'
2'





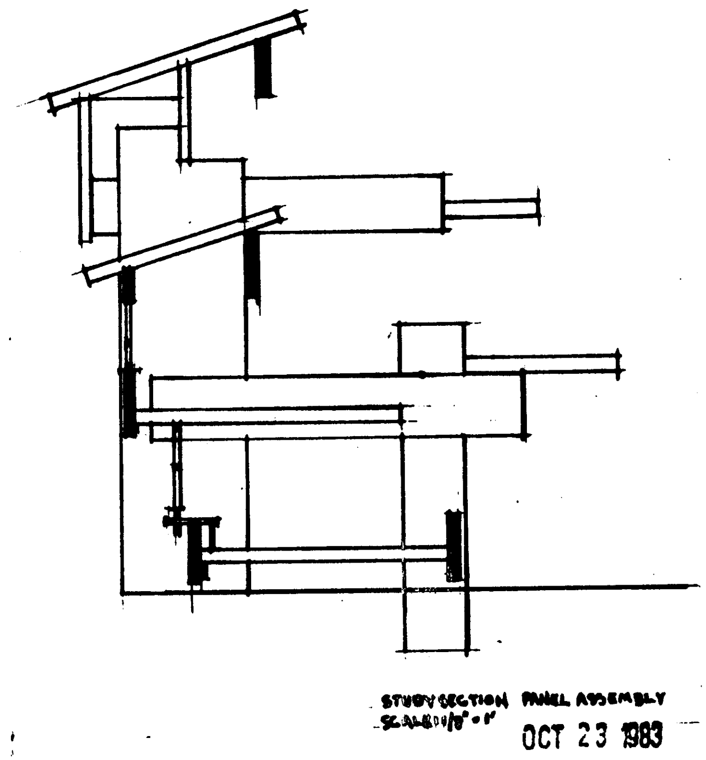
Panel Details

● SUPPORT WALL PANEL WITH BOX BEAMS

In the second exploration of support, the post and girder framework is abandoned completely. The support is comprised of two basic elements: support walls and box beams. The support walls carry the loads of the box beams and roof panels to a masonry foundation. The box beams carry the loads of the floor, closure and infill panels.

The depth of the box beams are two, three, and four feet. The lengths range from eight to forty feet, progressing in intervals of four feet. In terms of construction cost, the longer box beams are more efficient to use than the shorter ones.

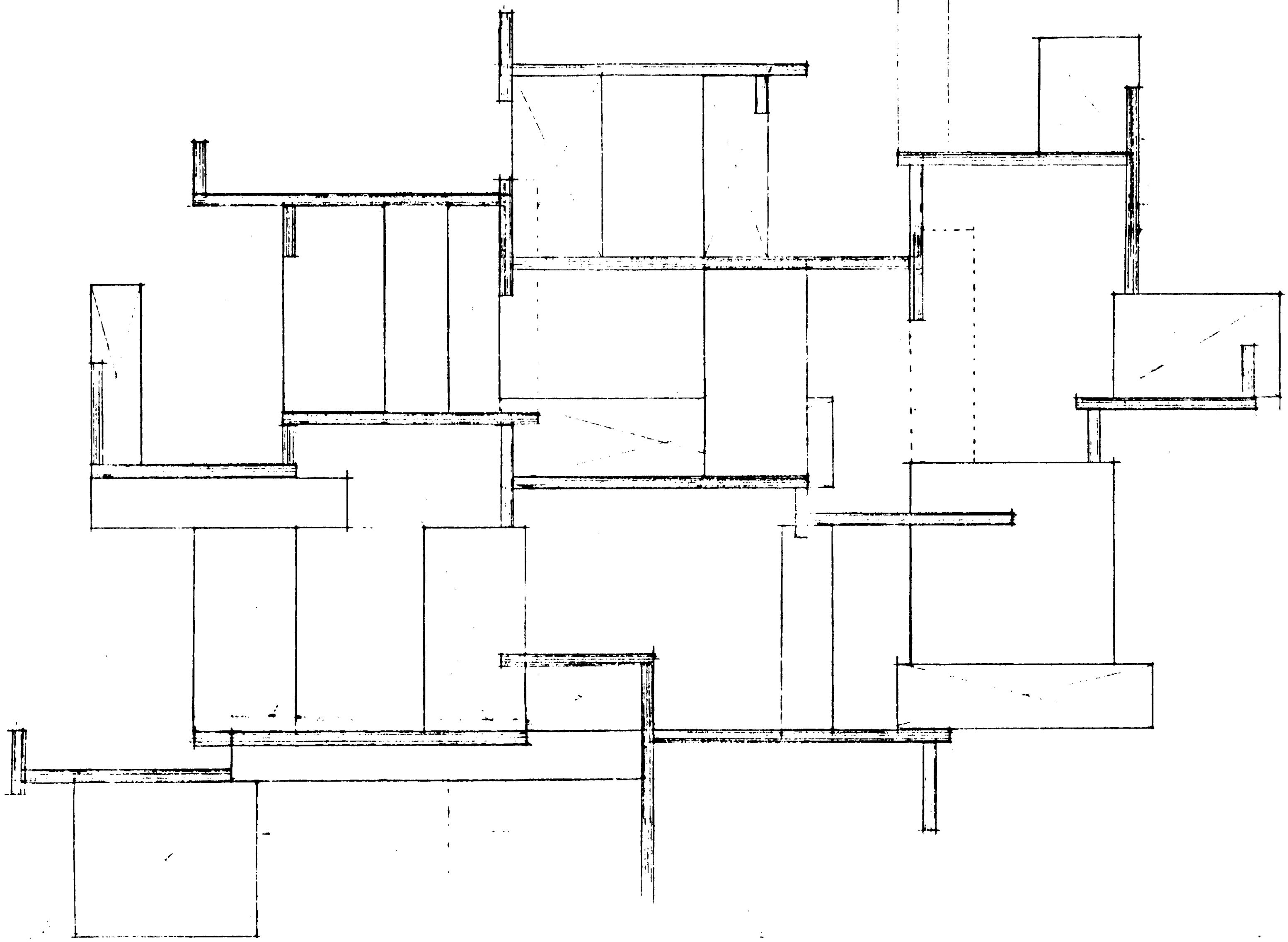
Large changes of floor level are accomplished by moving the box beams up or down along the sides of the support walls. Small changes of level are accomplished by moving the floor panels up or down along the sides of the box beam.



Once the support elements are in place, closure panels are hung from the outer surface of the box beams. The closure panels consist of three basic types: solid, window, and screen. Light is controlled by the positioning of the solid panels. Window and screen elements are then placed between the solid panels to complete the enclosure.

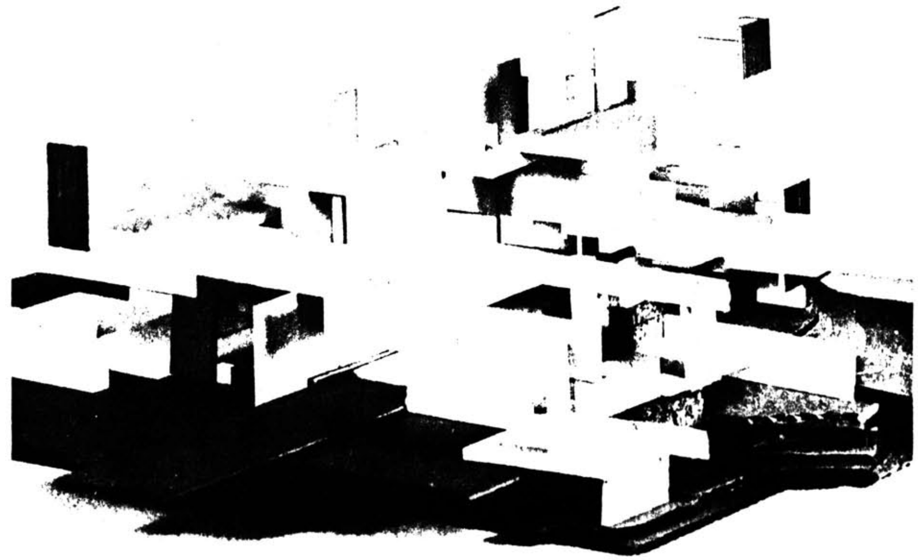
In order for the box beam to provide any partial definition, its upper edge must extend past the surface of the floor panels. This presents the major disadvantage of this type of support. The box beams control the edges of the floor panels. This condition does not allow the floor to be easily extended past its support.

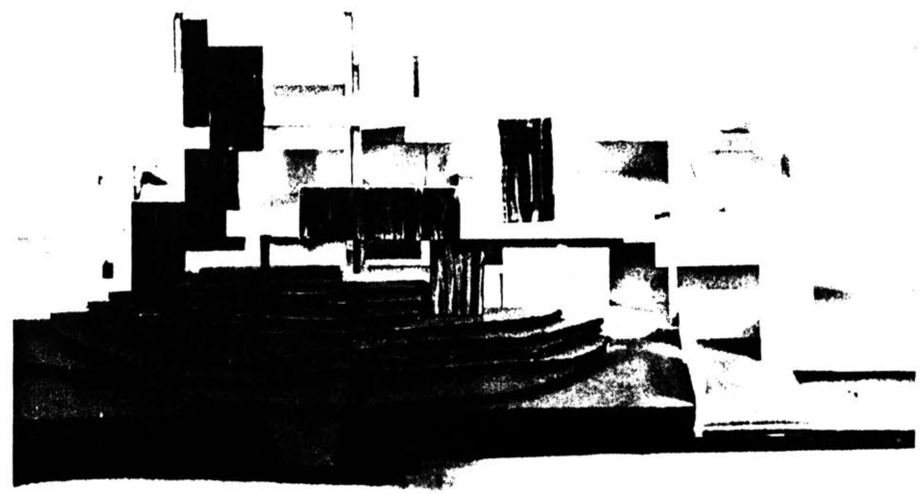
Extending the floor panels requires a break in the continuity of the box beam. Whenever this situation arises, shorter box beams must be used. Therefore, as the system offers more spatial options, it becomes less efficient to use.

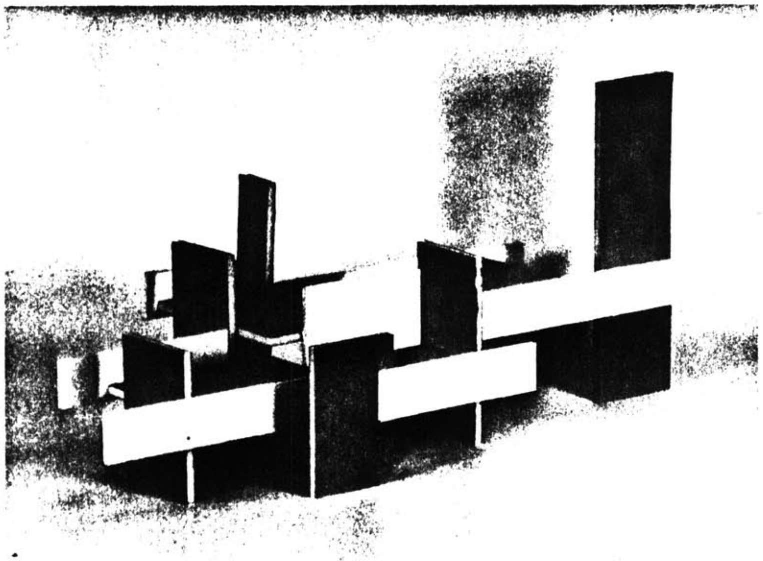


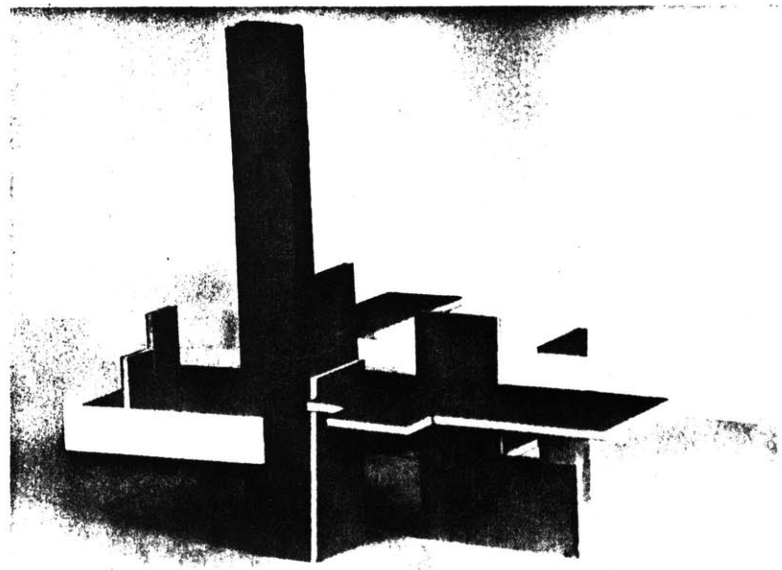
MODELS:

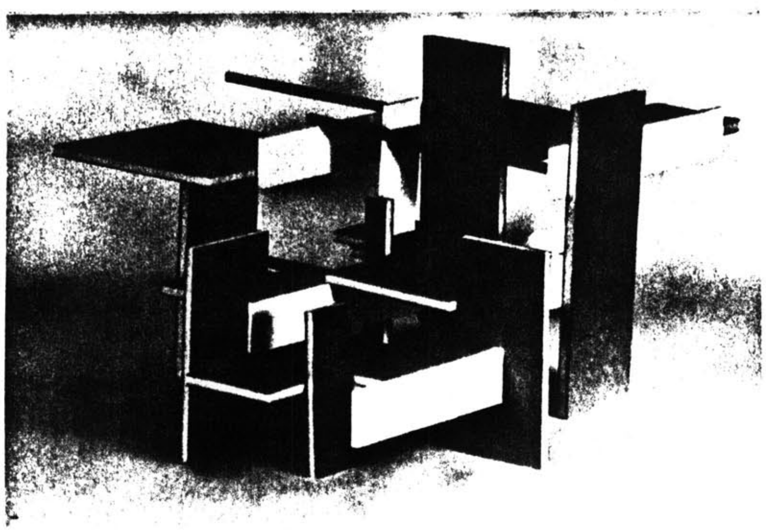
Support Wall Panel /
Box Beam Studies

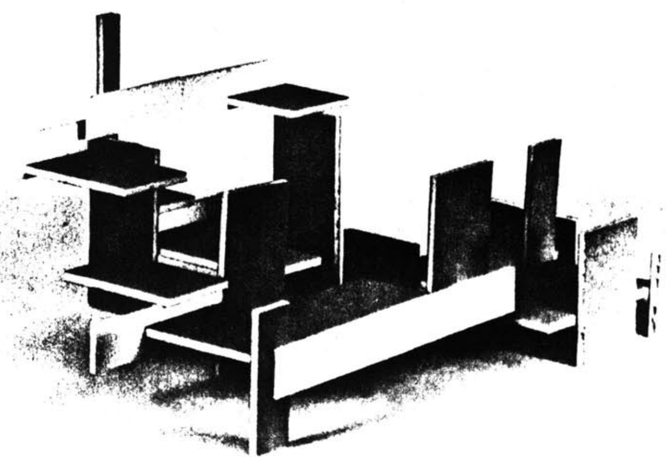


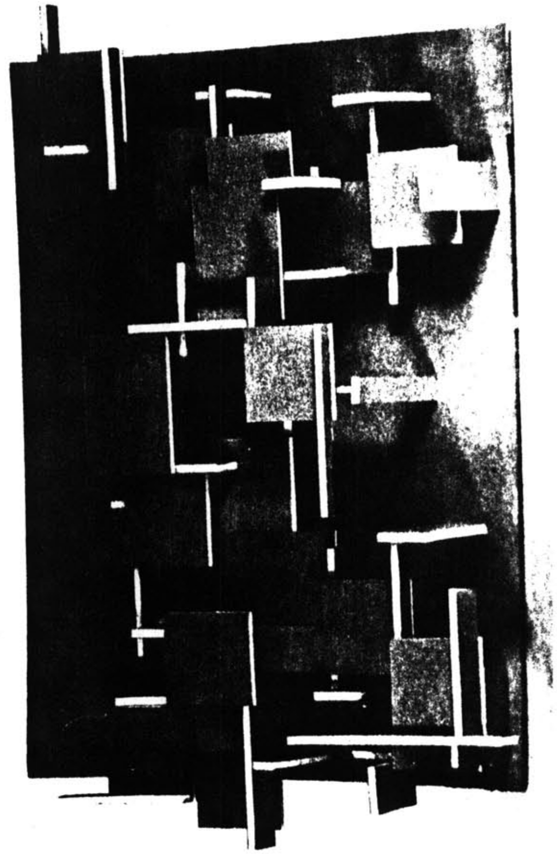


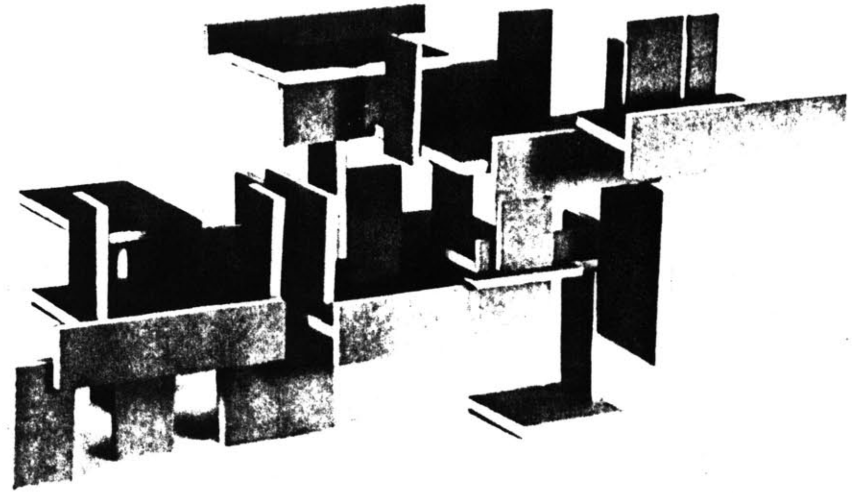


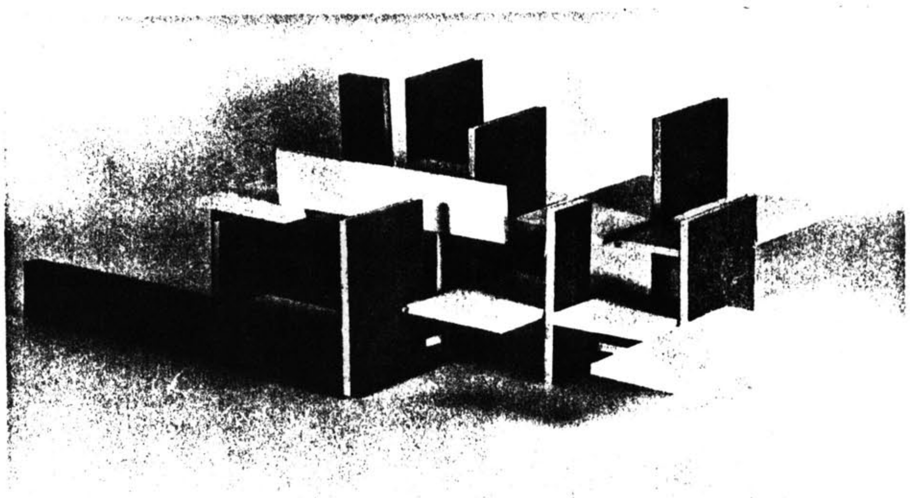


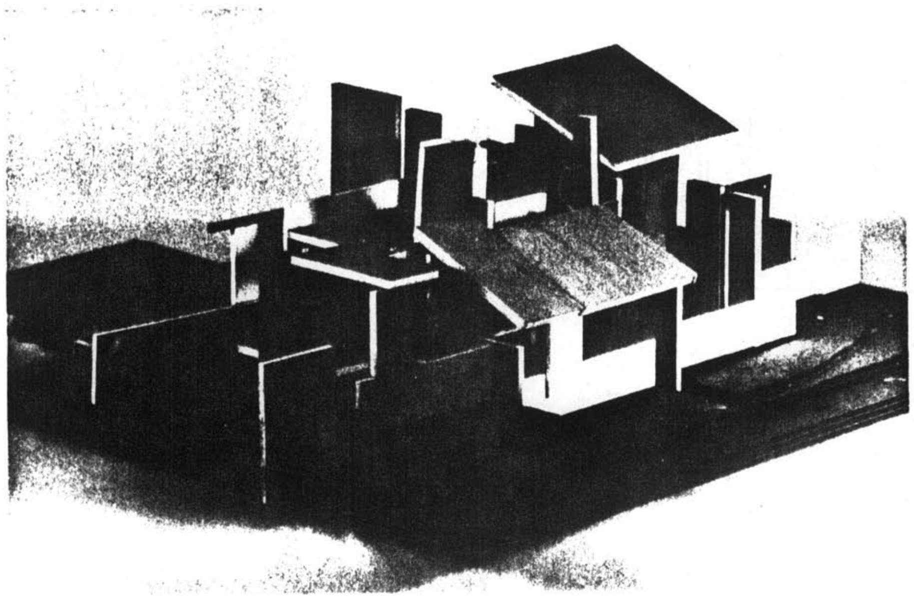


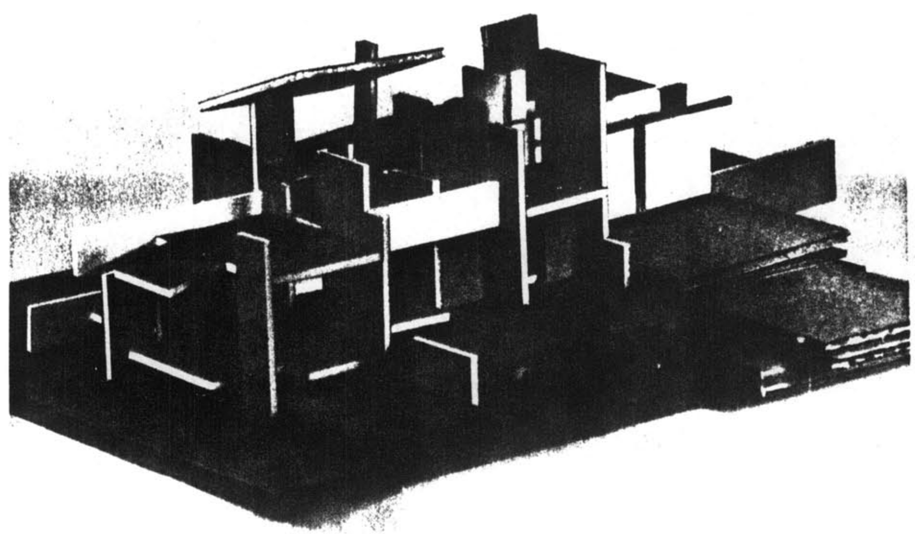


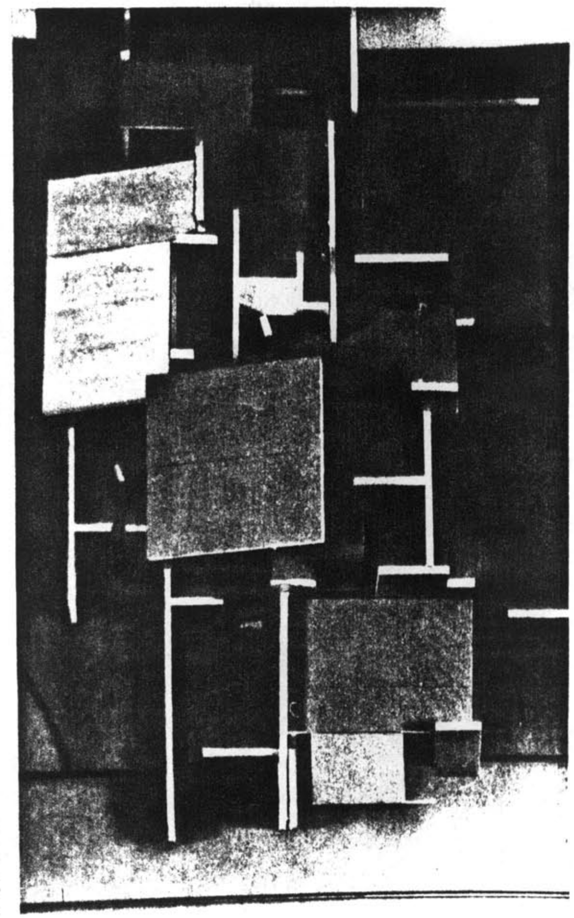


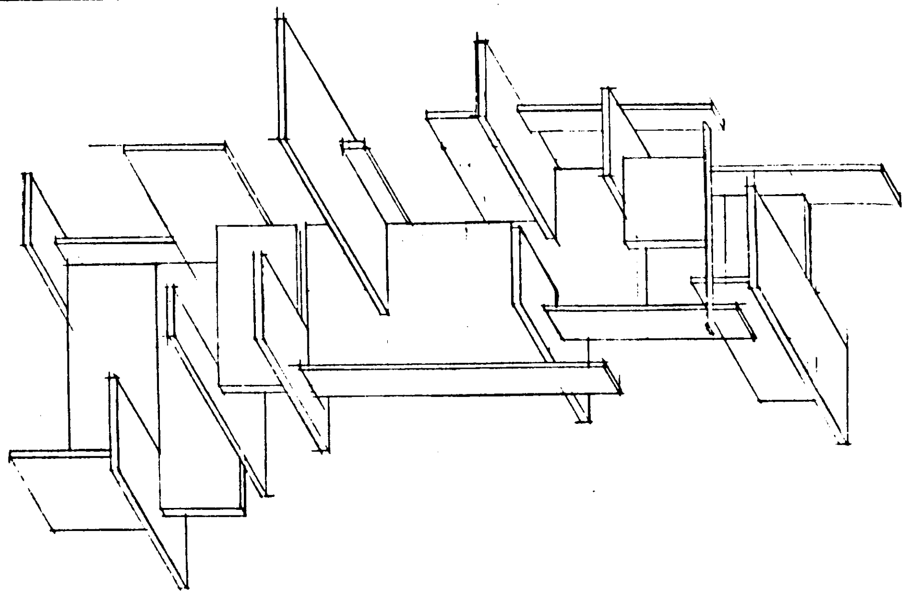


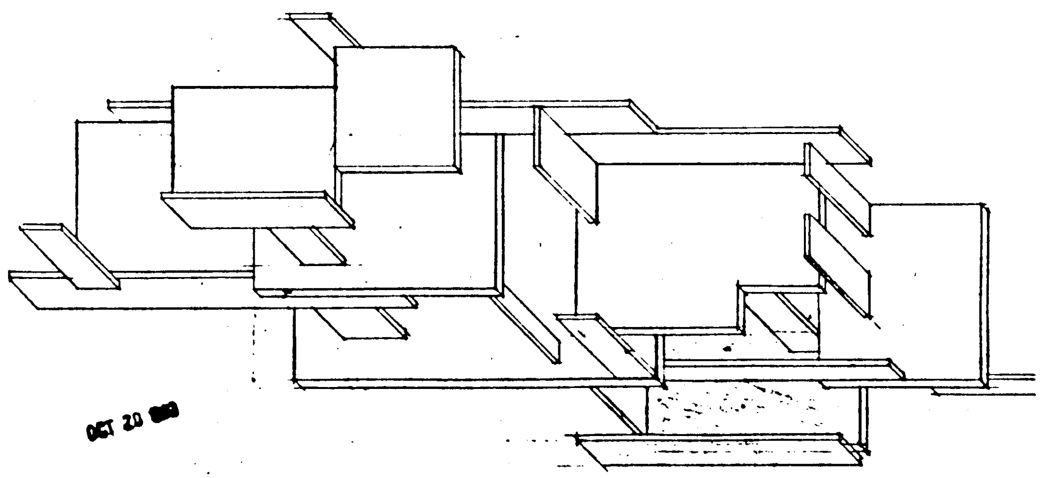






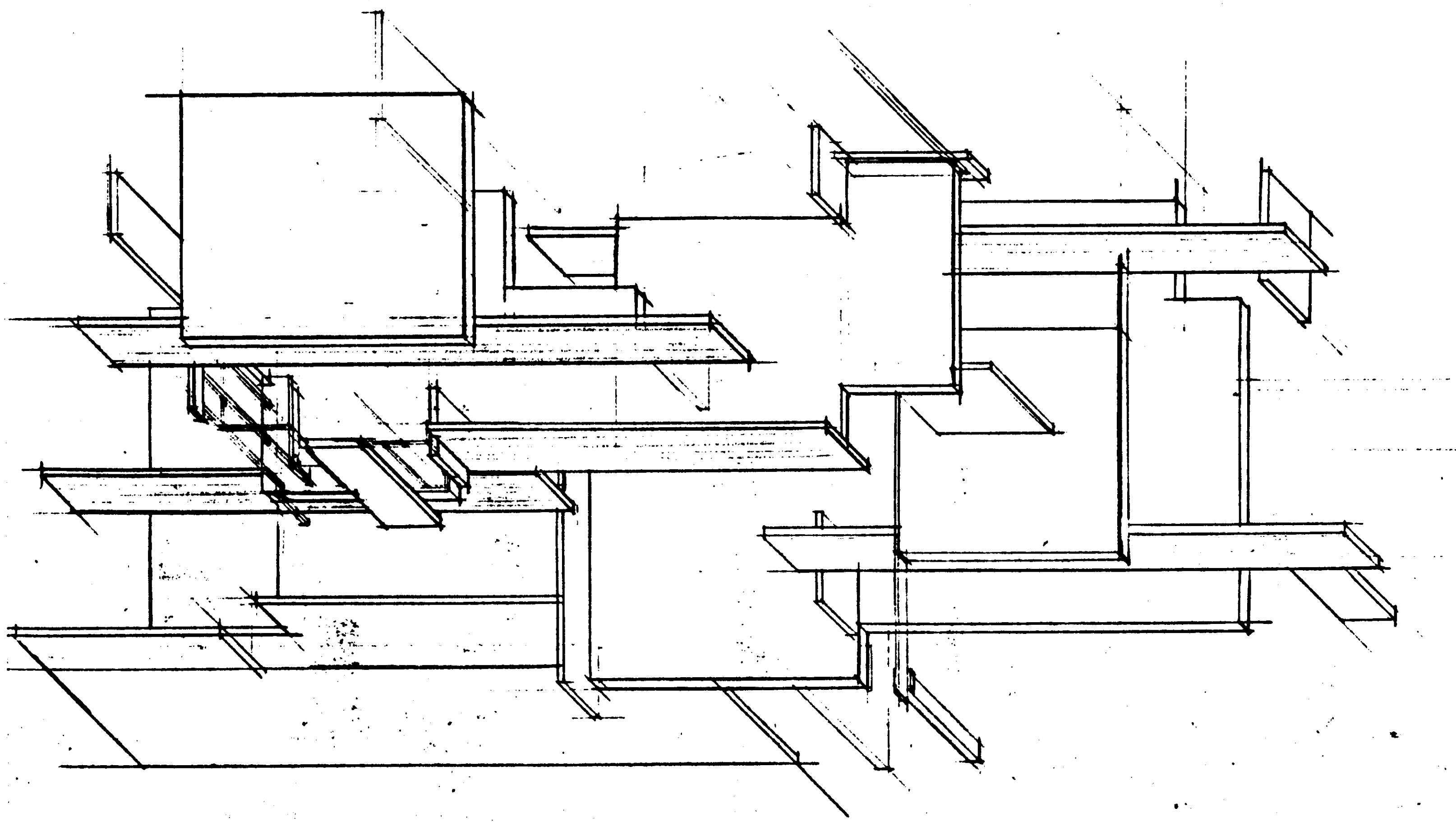


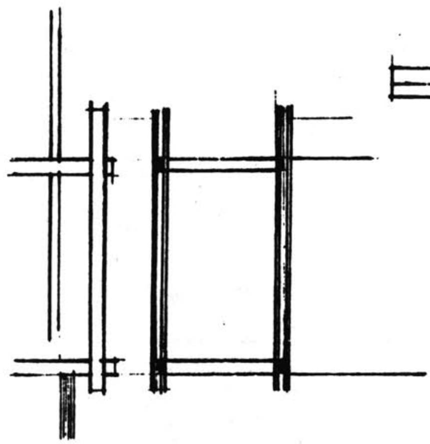


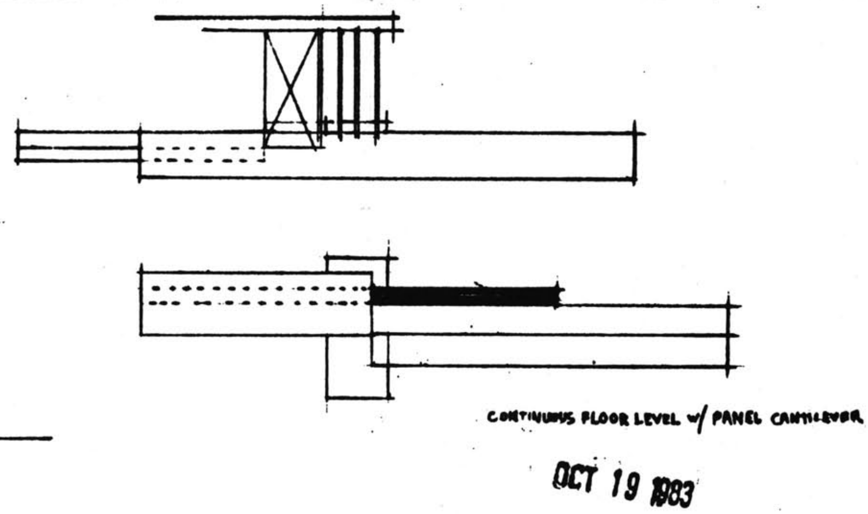


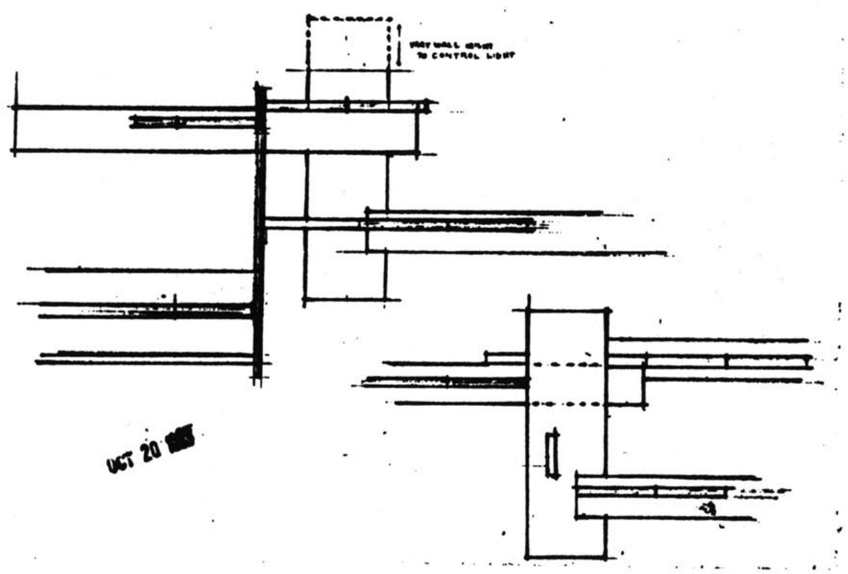
AXONS :

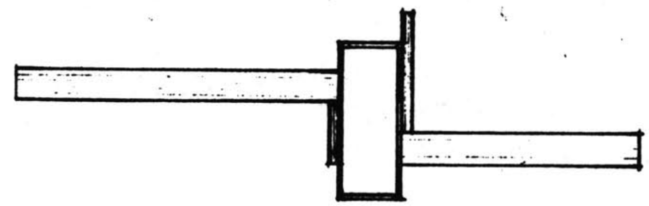
Support Studies



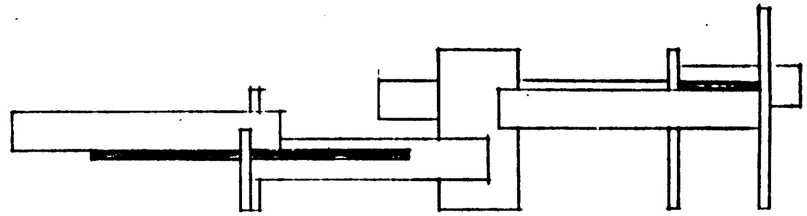




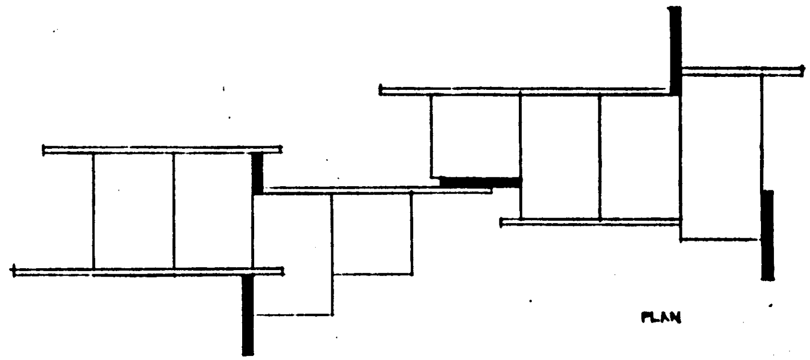




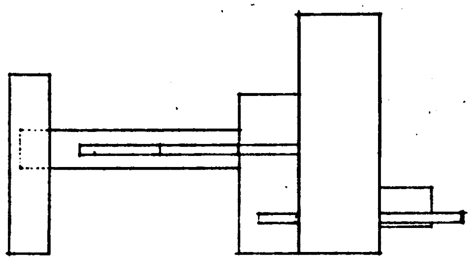
Support Assembly Studies

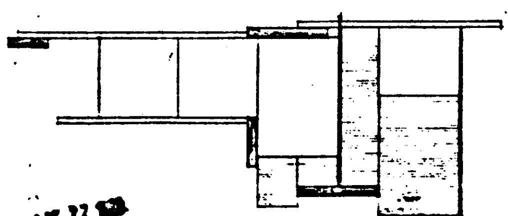


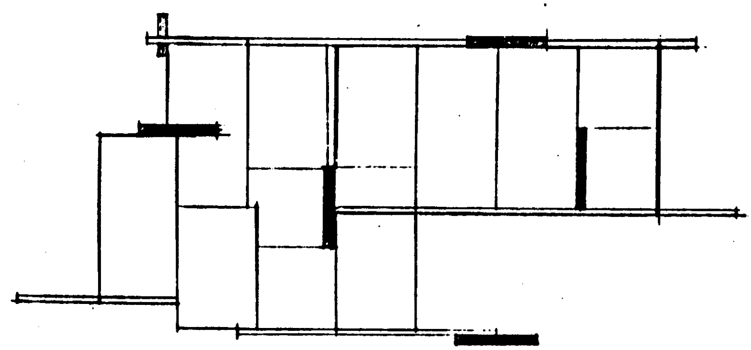
ELEVATION

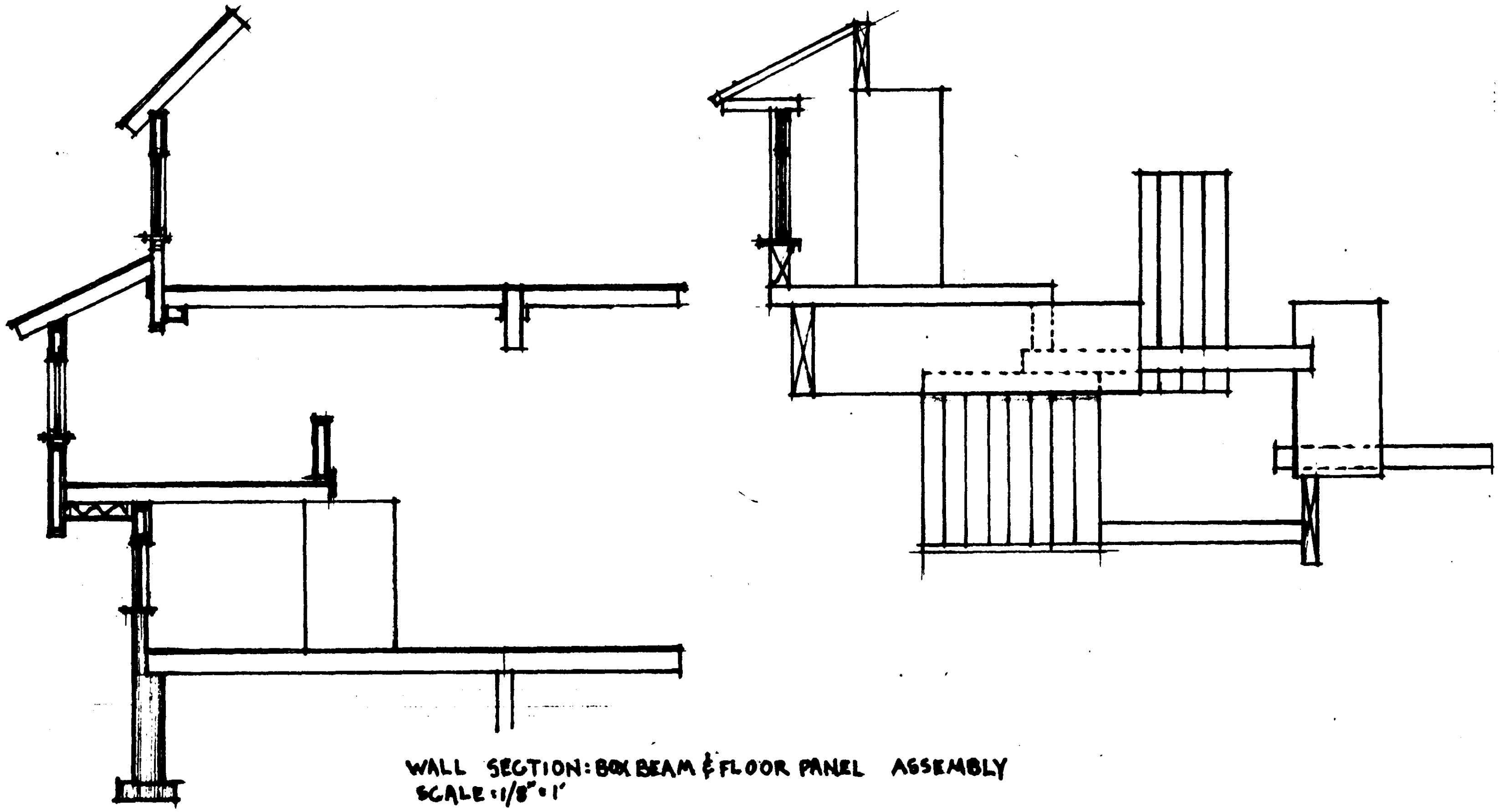


PLAN

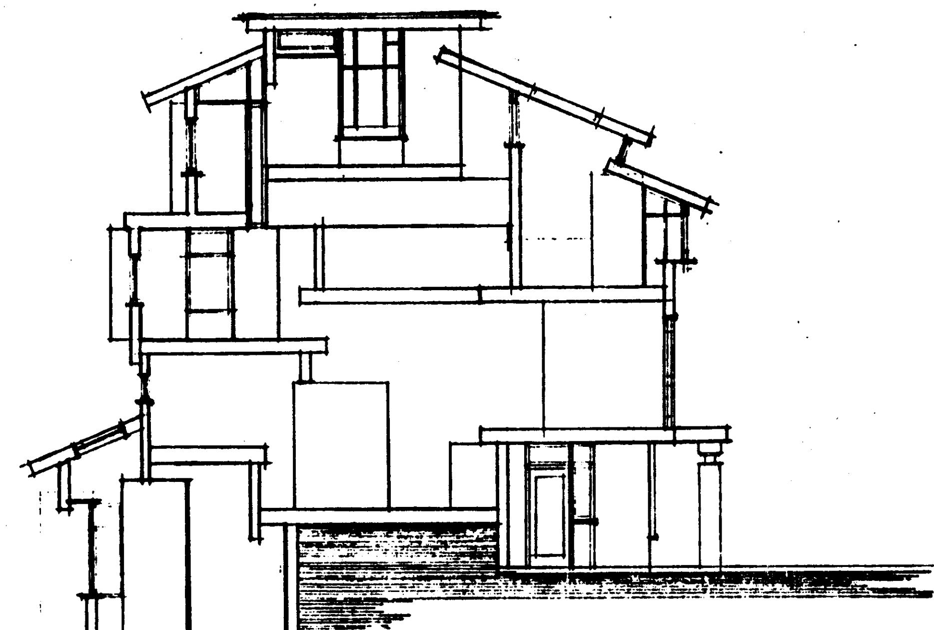




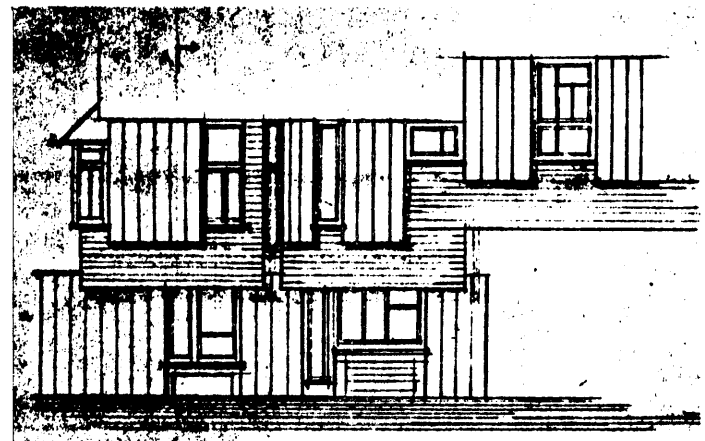




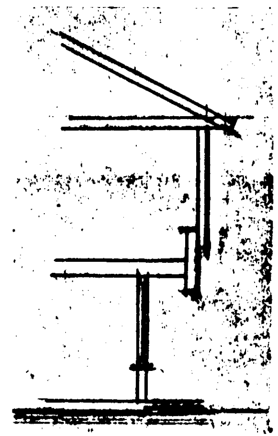
Support Assembly Studies



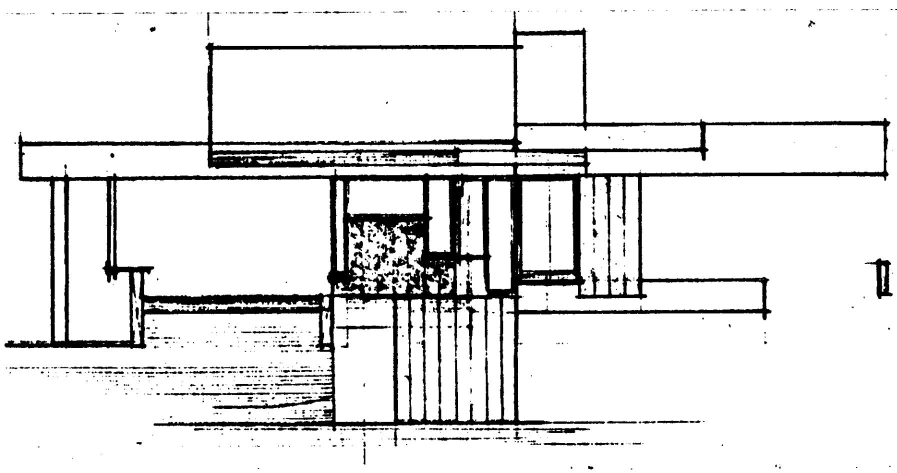
STUDY SECTION PANEL ASSEMBLY
SCALE : 1/8" = 1'
OCT 0 3 1983

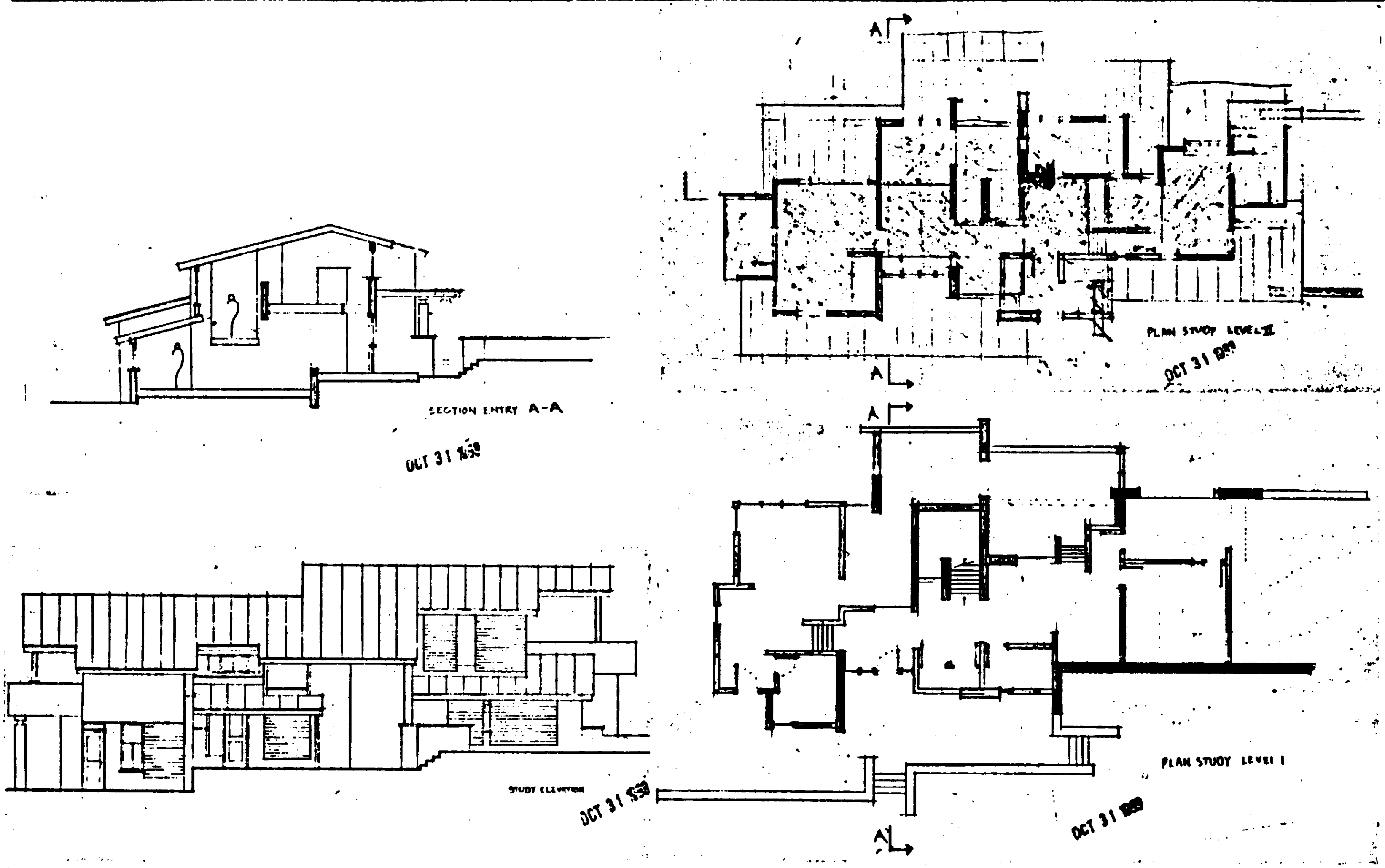


STUDY ELEVATION
OVERLAPPING PANELS
SCALE 1/8" = 1'
OCT 0 3 1983

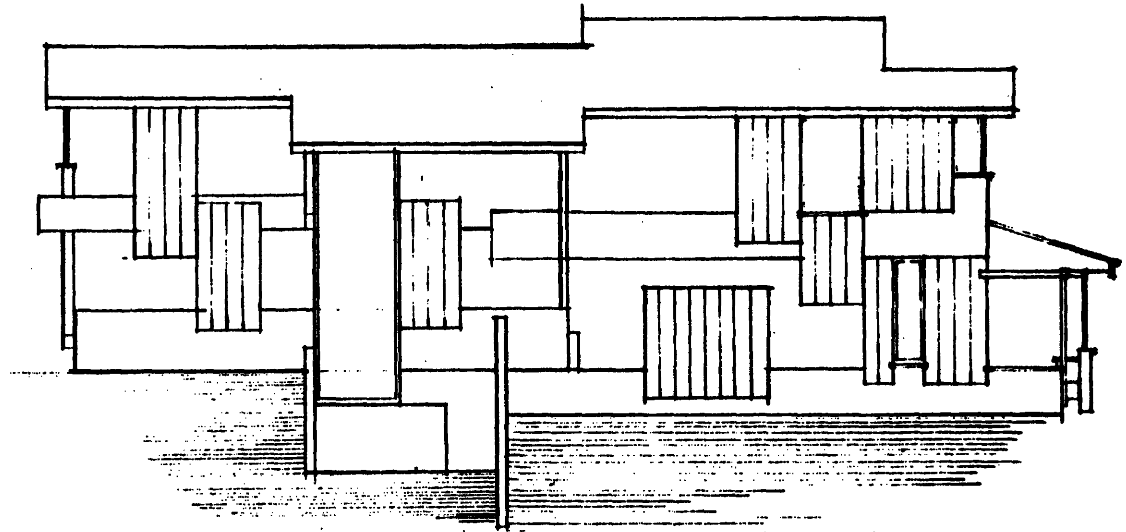


SECTION AA

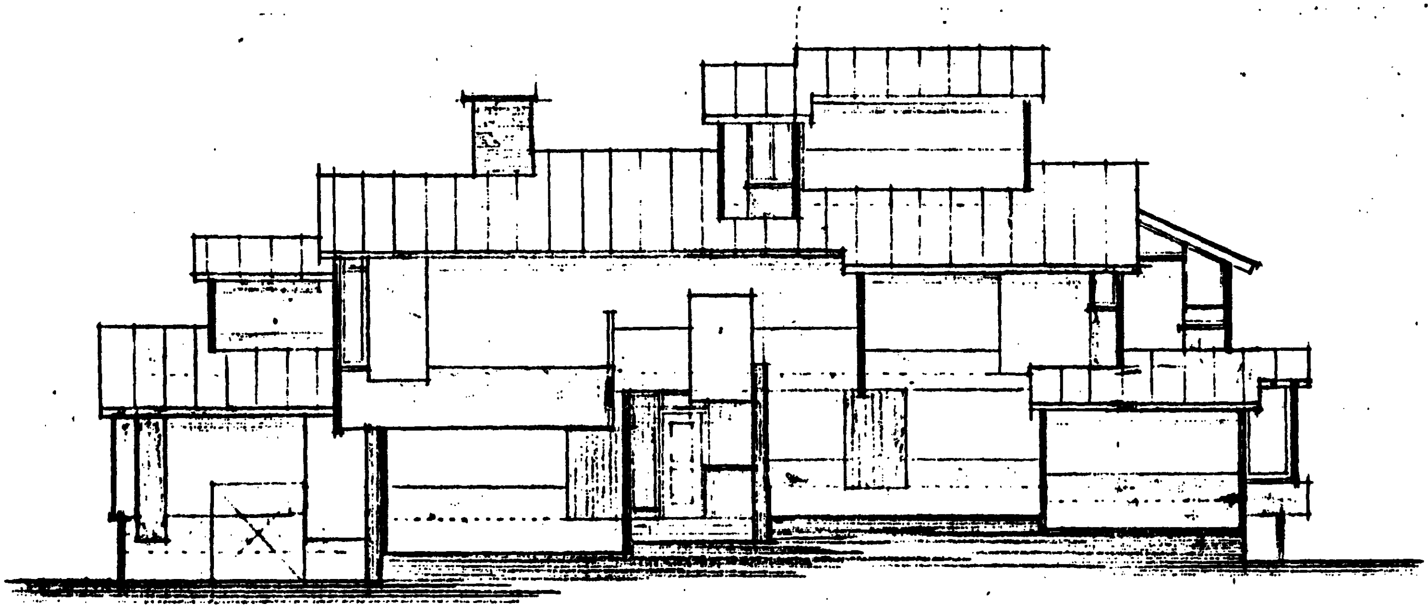


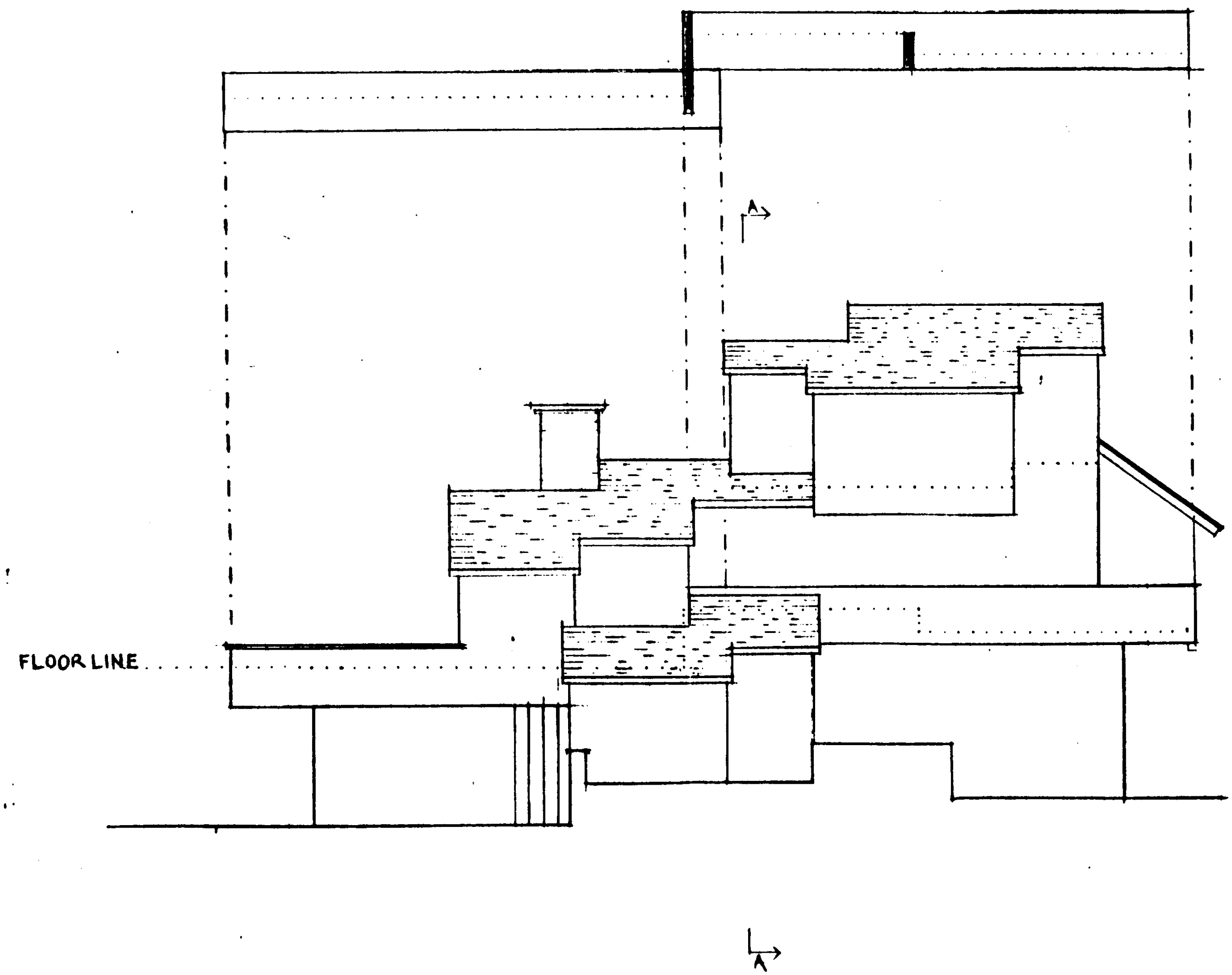


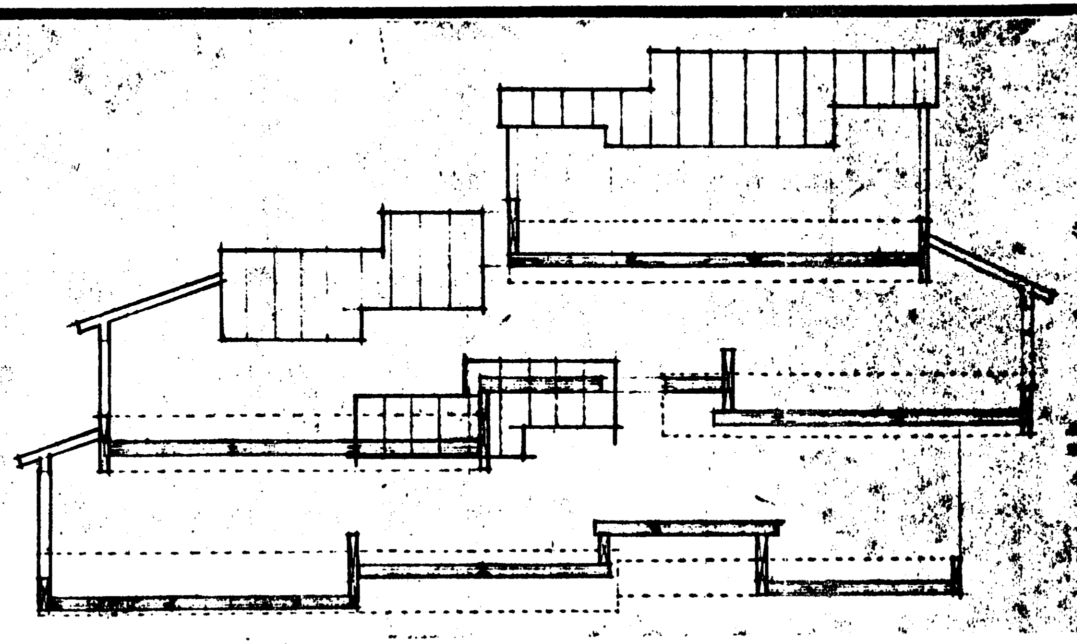
Support Wall/Box Beam Dwelling Study

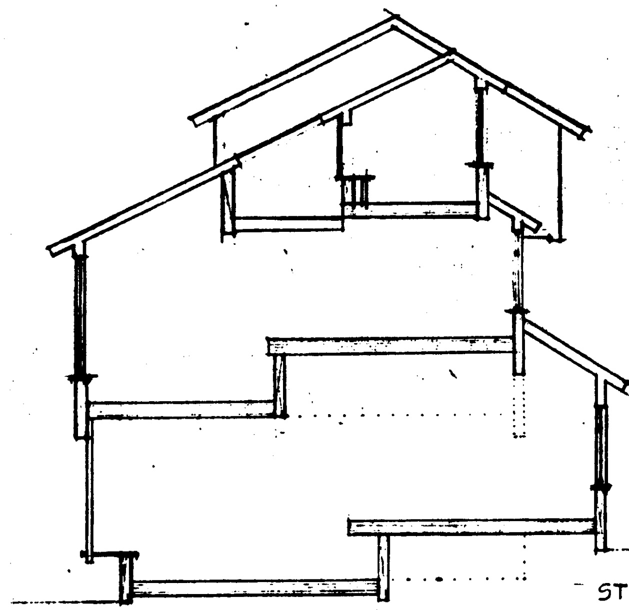


STUDY ELEVATION
PANEL ASSEMBLY



FLOOR LINE
A
A





STUDY SECTION A-A

Nailed Plywood & Lumber Beams

FABRICATION

There are just three simple steps in constructing a plywood-and-lumber box beam.

1. Determine the layout of stiffeners and the plywood butt joints.

   The plywood joint locations illustrated in the sketches provide the required minimum 2-foot stagger between panel butt joints on opposite sides of the beam. They also locate all butt joints within the middle half of the beam. This technique allows the stiffeners to act as web shear splices. Vertical stiffeners should be added in the layouts so that they are no farther apart than 4 feet.

   The 6 inches (0.5 foot) added to the clear spans shown in the load-span tables represent the bearing length of double end stiffeners.

2. Build the framework of lumber flanges and stiffeners.

   Dry lumber should be used (less than 20% moisture content, KD15 for southern pine). Select full-length flange lumber which is free of warp or characteristics that would produce gaps greater than 1/8" between lumber and plywood.

   Lay out stiffeners and flanges accurately in the pattern selected in Step 1. Fasten flanges to stiffeners with 8d common nails. Stiffeners should be flush within 1/8" of flanges. If two or more laminations, or members, are to be used for the top and bottom flanges, they may be added one at a time with 10d common nails.

   Double end stiffeners may be installed between flanges. Frequently, however, it is desirable to extend the end stiffeners through the depth of the beam to allow use of shorter-length flange lumber. On other occasions, it may be desirable to extend the top flange lamination beyond the beam end to tie into the wall framing.

3. Fasten the plywood webs to the framework.

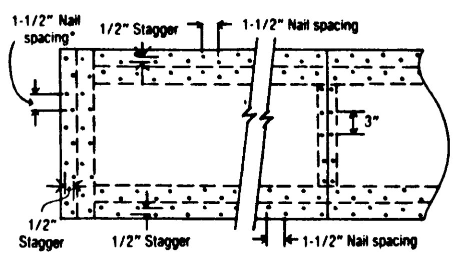
   First, inspect plywood panels to be used in the end 15% of the header. Assure that no core gap exceeds 1/4" width in 3- or 4-ply panels, or 1/2" in panels with 5 or more plies. Also, core gaps must be separated by at least 1".

   The flanges should be marked to show location of stiffener centerlines. Plywood should be installed with its face grain in the same direction as the flanges, and with butt joints occurring over stiffeners, as determined in Step 1.

   All beams in the load-span tables function with 8d common nails spaced 1-1/2" on center on each side of each flange lamination. The spacing may be doubled to 3" on center in the middle half of the beam. Use corrosion-resistant nails if beam is exposed to moisture. If staples, or nails of other sizes or types are used, the spacing must be adjusted in proportion to the allowable lateral load for the fasteners selected. For instance, fasteners allowed half the lateral load of 8d common nails would be spaced half as far apart. For the lower capacity fasteners the closer spacing can be used because there is less tendency to split the lumber.

   Although the nailing shown is structurally adequate for loads presented in the tables, additional stiffness can be developed by including glue at the interfaces also. Any type of available wood adhesive will contribute to performance, but do not use it instead of any of the nails required in the design.

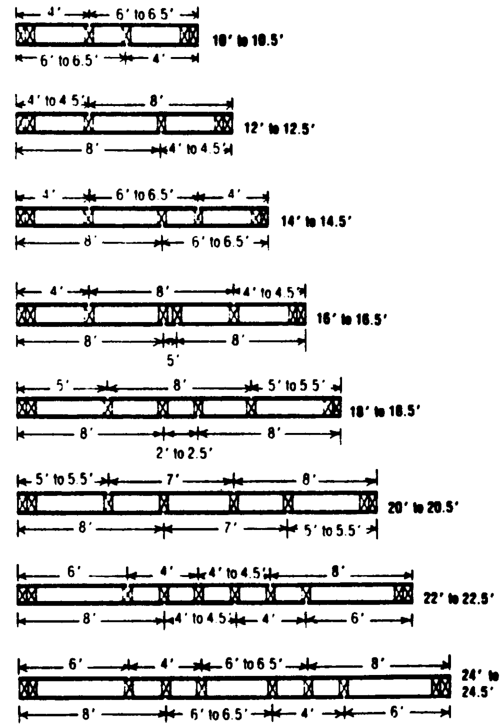
Nailing Layout



*When end stiffeners extend through the beam, nail spacing is the same as for flanges, except space nails 1 in. on center when double end stiffeners are used in beams with three members per flange (cross-section C). When end stiffeners are inserted between flanges, nails may be spaced 3 in. on center.

DETAILS:

Joint and Stiffener Layouts

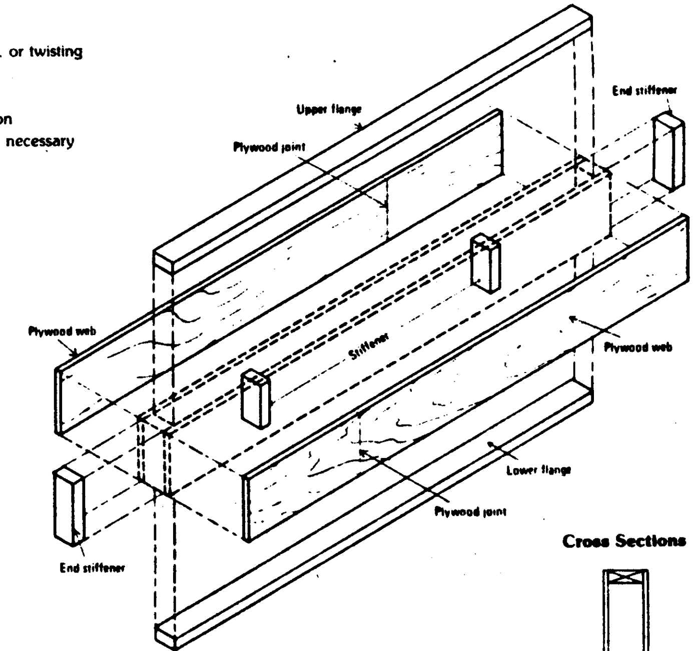


ALLOWABLE LOAD[a] FOR 24"-DEEP ROOF BEAM OR HEADER (lb/lin ft)

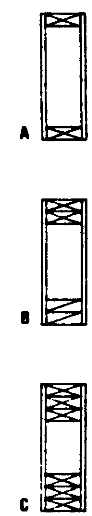
Plywood	Cross-Section	Approx. Wt per Ft (lb)	Span (ft) 10	12	14	16	18	20	22	24
1/2" 32/16	A	9	733	611	456	349	276	223	184	155
1/2" 32/16	B	11	—	—	520*	455*	405	364	323	271
3/4" 48/24	B	14	1061*	884	758	611	483	391	323	271
3/4" 48/24	C	17	—	—	—	639*	568	511	422	355

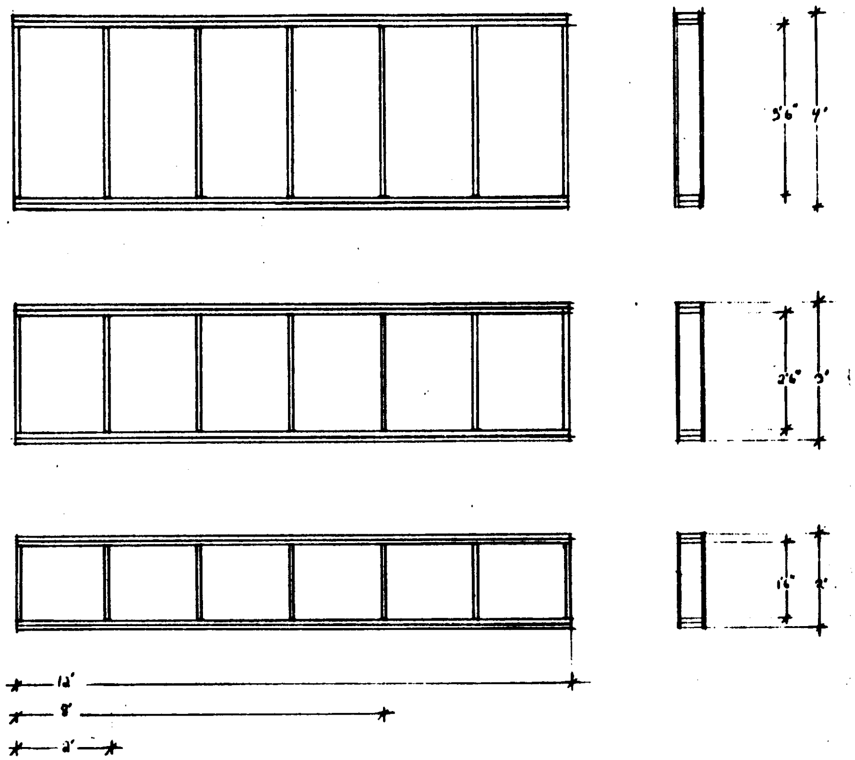
(a) Includes 15% snow loading increase
* Lumber may be No 2 Douglas fir or No 2 KD15 southern pine

- Stiffness and strength
- Light weight
- No shrinkage, warping, or twisting
- Ease of fabrication
- Materials availability
- Speedy, easy installation
- Easily insulated, where necessary

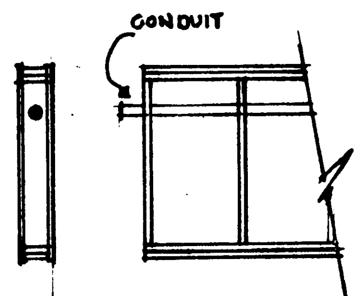


Cross Sections





BOX BEAM FRAMING



BOX BEAM WIRING/PLUMBING

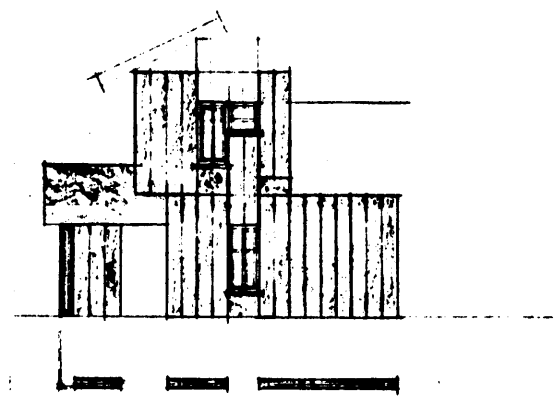
● PERIPHERAL SUPPORT WALL

In the third exploration of support, the box beams are eliminated completely. A series of dimensioned support wall panels are used to support the floor panels directly. Two methods of connecting the floor panels to the support wall panels are used. Floor panels may rest directly on top of the support walls, or the ends of the floor panels may be attached to the sides of the support walls by means of a ledger strip.

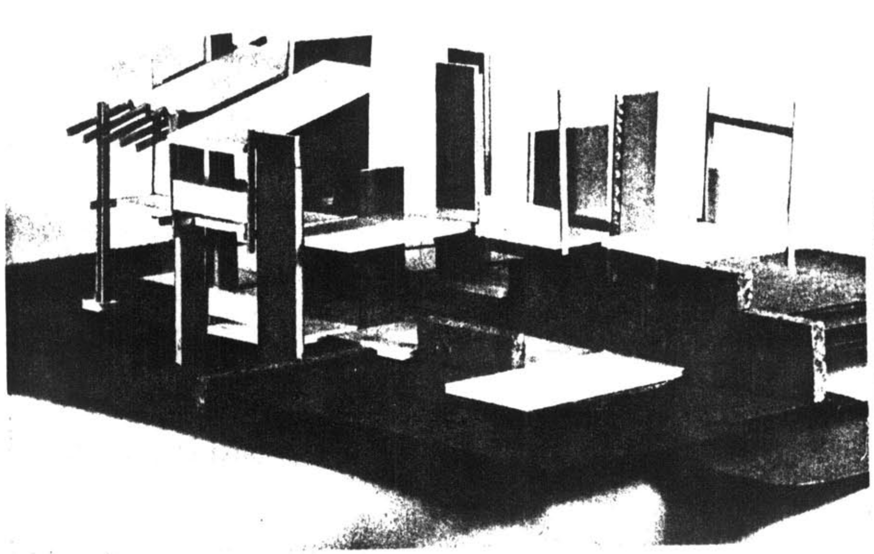
Changes of level are achieved either by varying the height of the support wall, or by moving the ledger strip up or down along the side of the support wall.

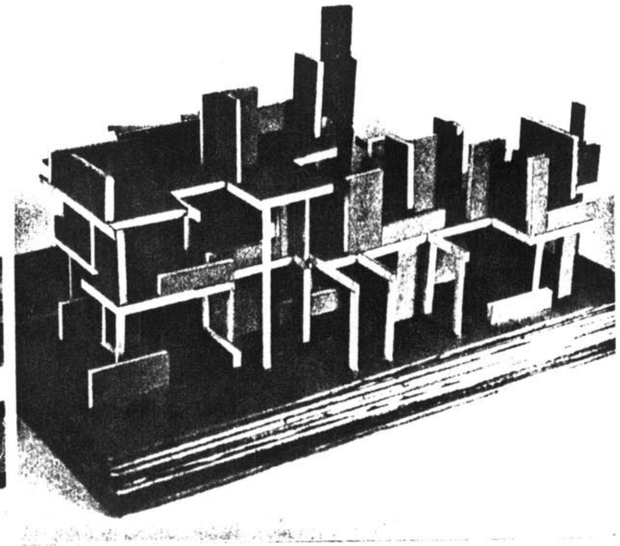
The enclosure, as in the second exploration, is made by placing windows and screens between the support wall panels. Windows and screens are optionally propped out from the surface of the support wall panels to yield a use dimension.

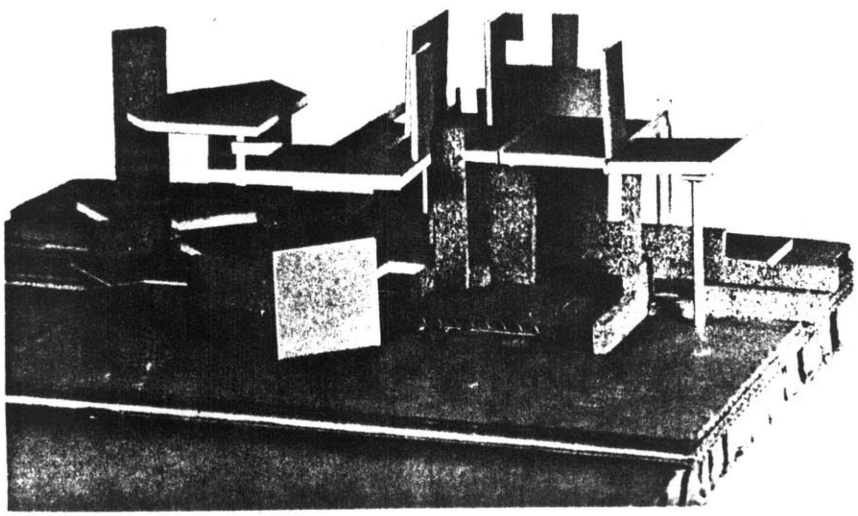
In this exploration, the support walls tend to operate at the building's periphery. This did not allow the support wall panels to contribute to the establishment of partial definition within the building.



STUDY ELEVATION

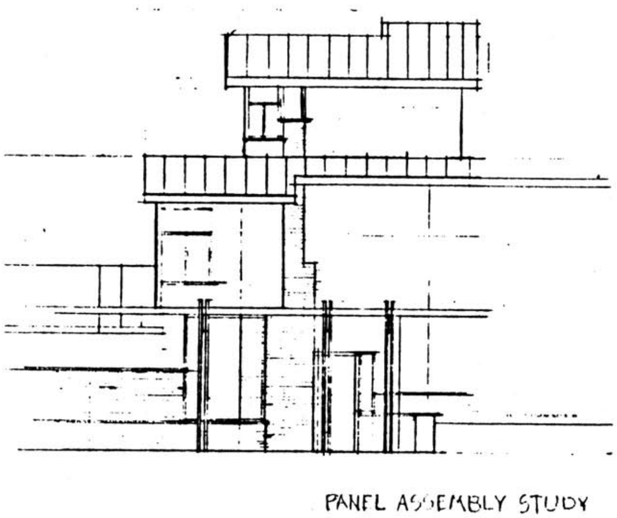


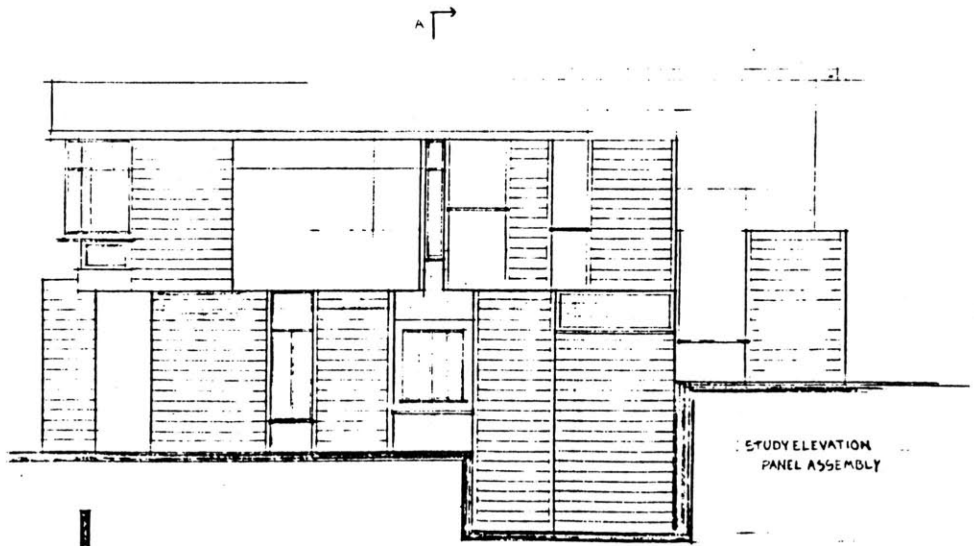


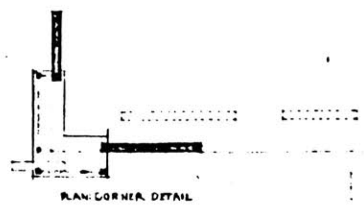


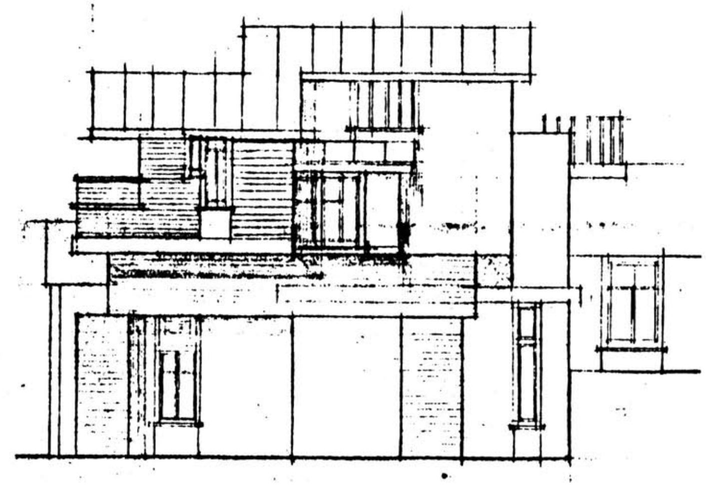
MODELS:

Peripheral Support
Wall Studies



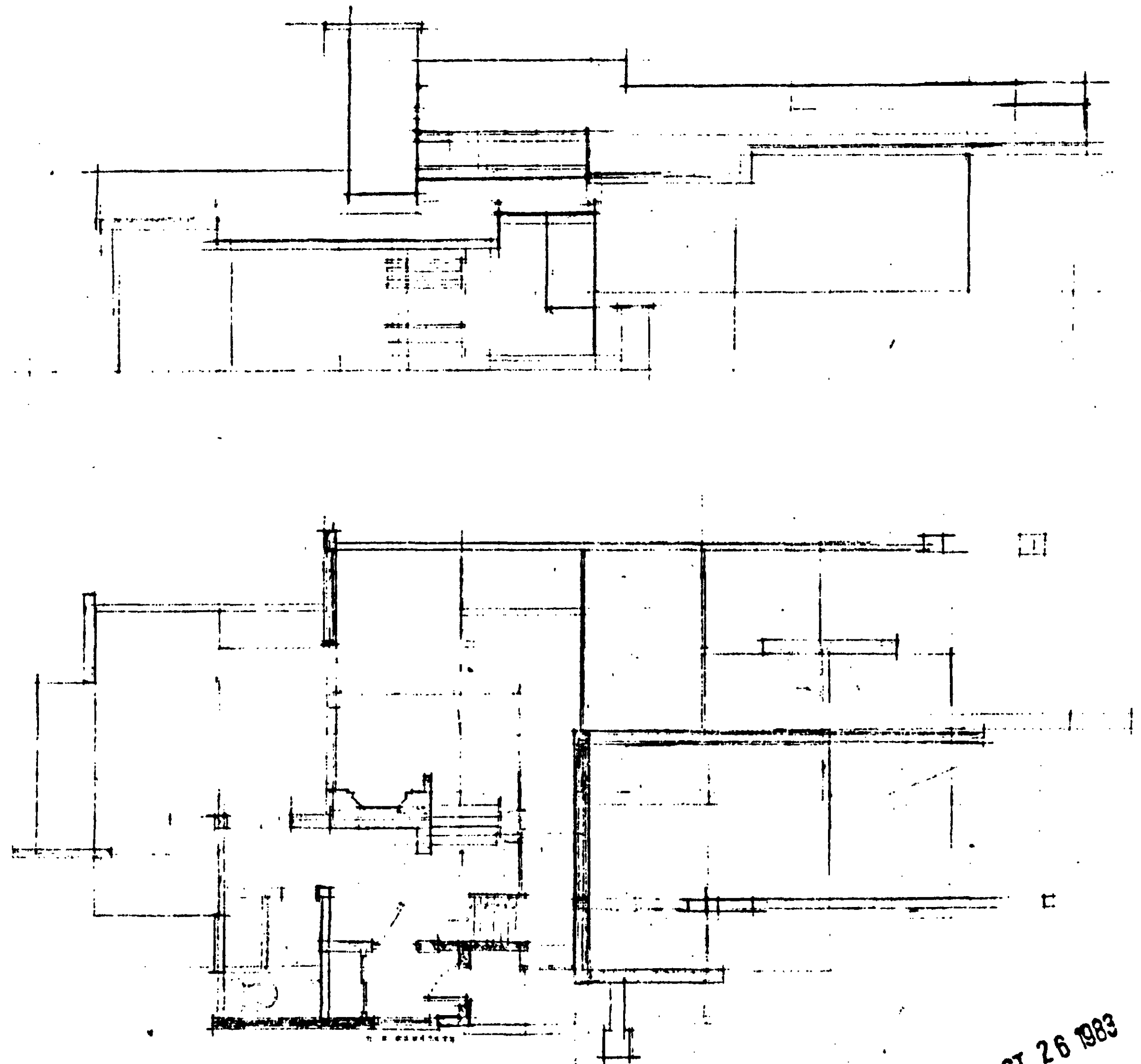






Elevation Studies

Peripheral Support Wall
Dwelling Study



Each support demonstrates an ability to change floor levels easily. This allows the building system to respond to a wide range of topographical conditions while providing a variety of spatial options. In all cases, the support fails to provide a clear partial definition of use territories, from which further spatial options may grow.

The final support exploration considers the attributes of the early studies while generating partially defined use territories.

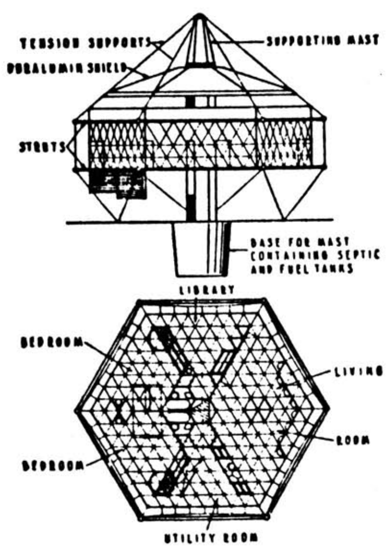
In some cases, it may be desirable to combine support elements from each of the early studies. I have considered only a few of the options in my proposed panelized system.

• • •

EARLY EXAMPLES OF FACTORY HOUSES

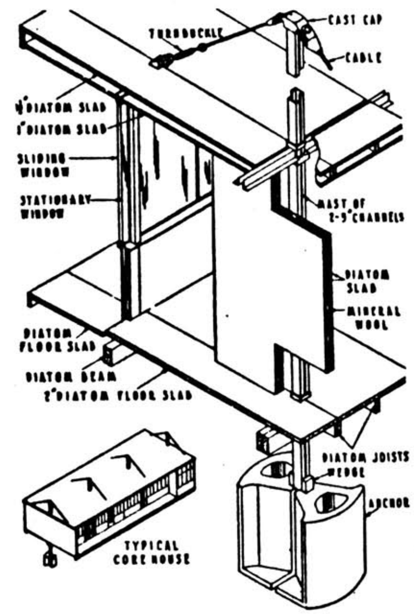
EARLY EXAMPLES OF FACTORY HOUSES

The Dymaxion House, designed by Richard Buckminster Fuller, employed a central mast that supported a hexagonal volume by radiating tensile cables.



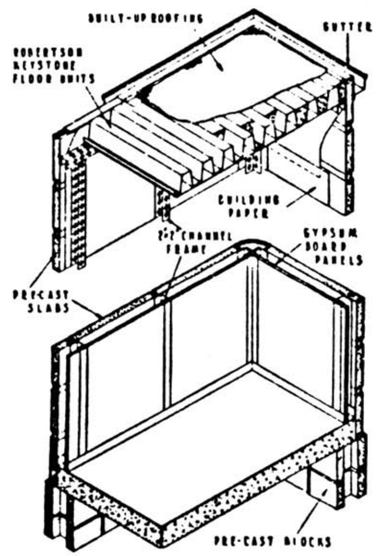
Buckminster Fuller's
Dymaxion House, 1928.

The One Plus Two Diatom House, designed by Richard Neutra, incorporated preformed wall and floor components, made of light weight diatomaceous earth, and a suspension support system.



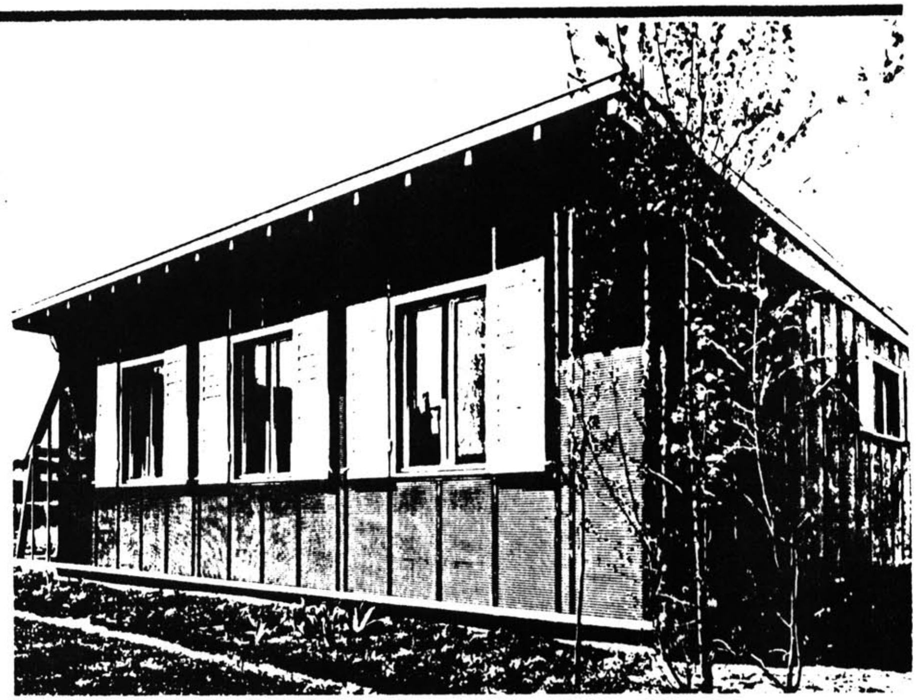
One-Plus-Two Diatom House
by Richard Neutra, 1934.

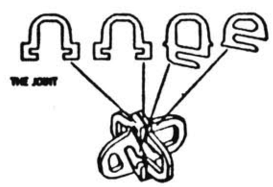
The "E" Frame, developed by Bemis Industries, employed a lightweight metal frame from which interior and exterior panels were hung.



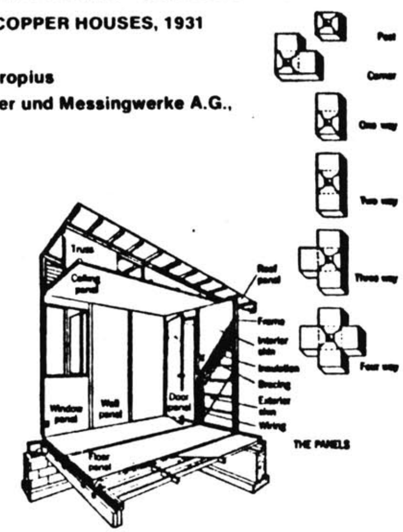
"E" Frame Steel Construction, 1934.

The General Panel System, designed by Walter Gropius and Konrad Wachsmann was unique in two ways. First, it was built on a modular plan using only one panel size. Panels could be placed either horizontally or vertically for all dimensioned surfaces, i.e., floors, walls, roofs, etc. Second, it employed a universal connector which joined two, three or four panels in a line, or at right angles. All panels were ten feet by three feet four inches. Using this dimension, the panels were available in six forms: the basic wall panel, a panel with a window, a panel with a door, a ceiling panel, a roof panel, and a floor panel.



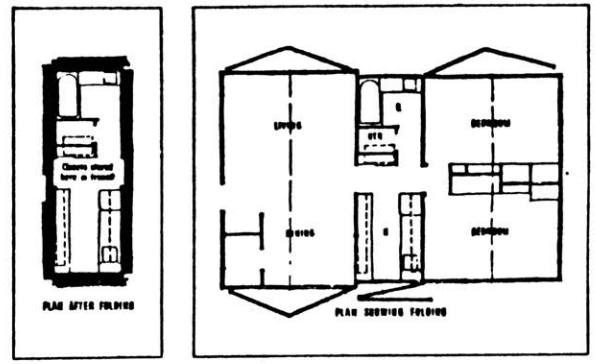


PREFABRICATED COPPER HOUSES, 1931
Finow, Germany
Architect: Walter Gropius
Client: Hirsch Kupfer und Messingwerke A.G., Berlin



The General Panel System of Walter Gropius and Konrad Wachsmann, 1943.

The Acorn House of 1948, designed by Carl Koch and Associates, used lightweight panels of cross-laid corrugated paper, bounded between plywood faces. At the factory, the house was assembled in a folding arrangement, which could be collapsed to make a transportable package, nine feet by twenty-four feet. At the building site, the house was unfolded to twenty-four by thirty-five feet, blocked up in position, and bolted to eight pre-cast concrete posts.



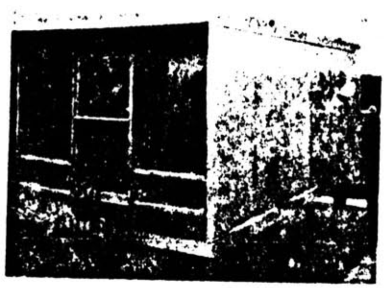
Plan and Erection View of Carl Koch's Acorn House, 1948.

The Techbuilt House, also designed by Carl Koch and Associates, was one of the first factory houses to use the "stressed skin" panel for its walls, floors, and roof. Based on a four-foot module, the panels were designed to maximize the use of sheet materials, e.g., plywood and gypsum board.

The Techbuilt House by Carl Koch, 1953.

Suitcase House, designed by William Stout, was constructed to fold out from both sides of a center section. From a three hundred sixty cubic foot package, floors on both sides were unfolded down, roof sections up, and walls out, in an accordian fashion, to form a building with two hundred fifty square feet of floor space. This process took approximately twenty minutes to complete. The building, intended for invasion operations, consisted of a wooden frame covered with homosote, and weighed less than two thousand five hundred pounds.

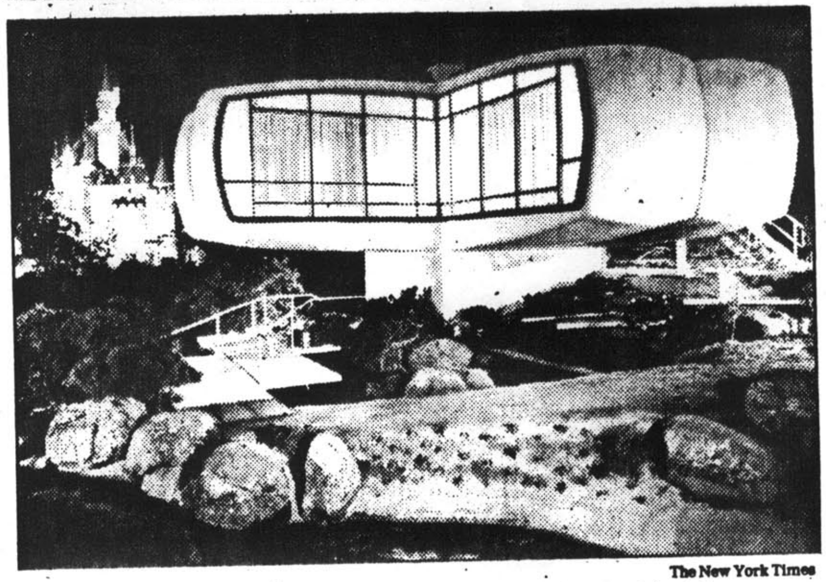
William Stout's Suitcase House.



3M's House Joined with Adhesive Tape, 1960.

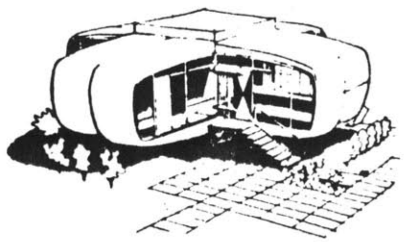
The 3M House, developed by the Minnesota Mining & Manufacturing Company, was a simple panel structure which was propped off the ground by three pier-supported beams. The company's experimentation was directed toward assembly techniques. All the panel connections were made with adhesive tape.

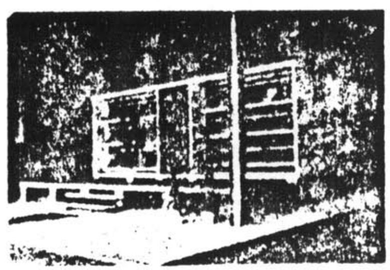
The Monsanto House, developed through the work of Marvin Goody and Richard Hamilton, was comprised of four canti-levered wings, centered around a re-inforced concrete core. Each wing was assembled from four, eight by sixteen foot bents, made of Fiberglas-reinforced polyester over urethane foam cores.



The New York Times

'The Monsanto House of the Future, at Disneyland from 1957 to 1967, had four rooms made of 16 plastic parts.





The Samton and Humes Paper House, 1962.

Paper House, designed by Samton and Humes, was intended for use in under-developed countries and vacation homes in the United States. In 1962, for less than $2,000, Paper House provided a twenty by twenty-four foot floor area. The walls, roof and floor consisted of honeycomb cored panels which were sur-faced with a treated paper board and joined with a steel spline fastening system.

CLOSING REMARKS

Some of the difficulties I had developing this system stemmed from my inability to disregard what I thought a "house" is. In the initial explorations, my dimensioning and organization of spaces always corresponded to an archaic, formal arrangement of activities, i.e. a kitchen for cooking, a dining room for eating, a living room for entertaining, a bedroom for sleeping, etc. I found it useful to think of a dwelling in less formal terms. In providing partially defined use territories, inhabitants may further define areas themselves that are more suitable to their own way of living.

Appendix:

Usonian House Details

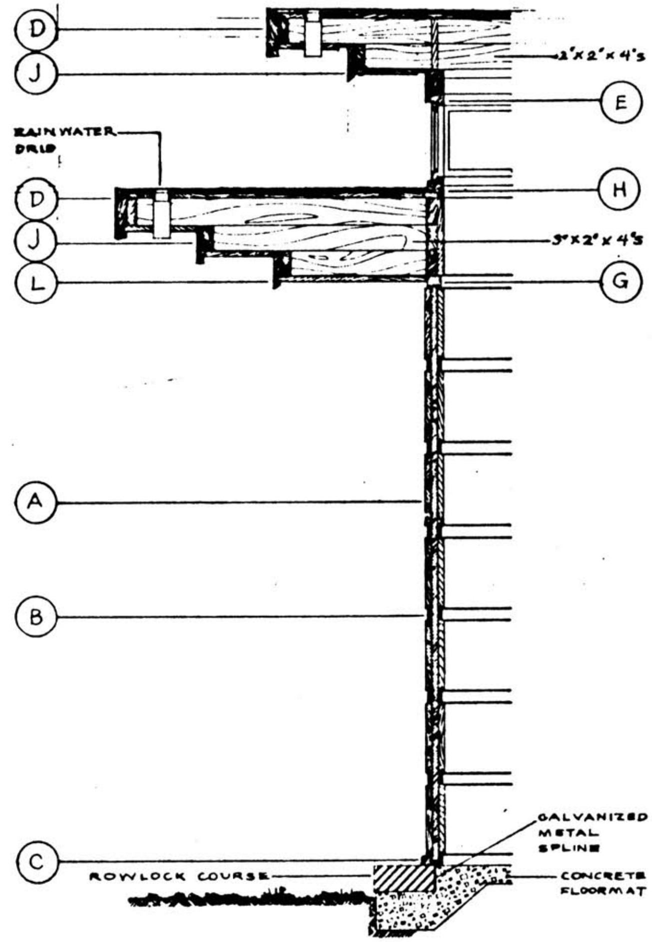
"Each house was planned to fit a particular site and to conform to the client's needs. What they had in common was the structural system — Mr. Wright called it the 'grammar' — which gave them a family resemblance despite their variety. . . . The plans for each house were accompanied by a Standard Detail sheet which was used over and over again."[79] These details were developed along with the concept, probably from the Hoult project of 1935. They were certainly fully developed in the Jacobs house in 1936. In later years, copying the sheet was one of the first assignments in drawing for a new apprentice. The information given on the sheet was as follows:

A cross section of the standard window and sash; the standard board and batten; the interior partition and the exterior wall; the full-scale detail of the perforated boards; connection of the roof with the outside brick wall; plate and cap for the outside wall; dimensions for the depth of concrete below grade and the depth of grade below the floor; the dimension of the mullion; and specifications for the hinges, the metal stripping and the floor coloring.[80]

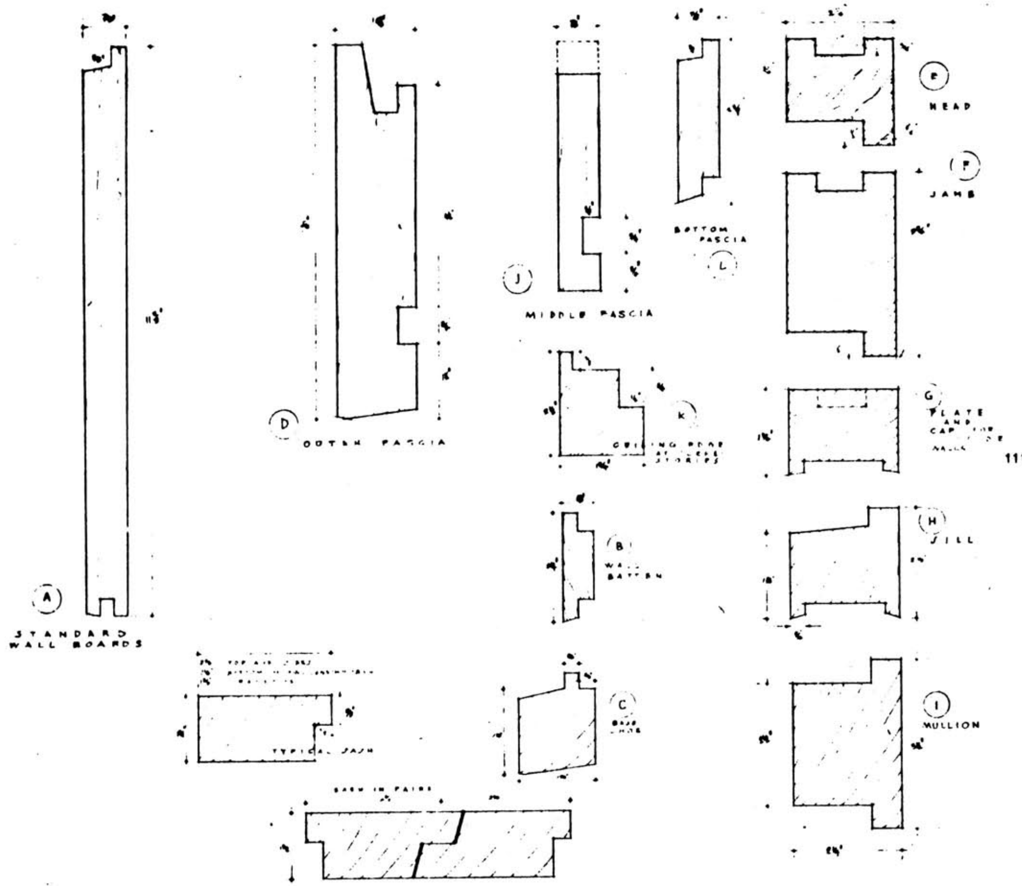
Once on site the standard detail sheet required interpretation. Here the attendance of the apprentice on site was justified.

The Usonian plans were laid out in a two- by four-foot module but without detailed dimensions. Every time you got to a doorway, a corner or intersection where special conditions prevailed, the dimensions had to be modified one way or another. Builders always wanted to know why they couldn't have been just like any other plans, i.e., worked out dimensionally. I think Mr. Wright wanted to emphasize the system concept; and the plans certainly looked prettier without dimensions![81]

In practice the system probably slightly extended construction time because of the need to educate the contracting tradesmen. The living costs of an apprentice for constant on-site supervision seem to have been an acceptable expense. As a learning experience for a student architect, it is difficult to imagine a more ideal technique.



Typical section through the wall of a Usonian house.



Assembly drawings: some standard Usonian details.

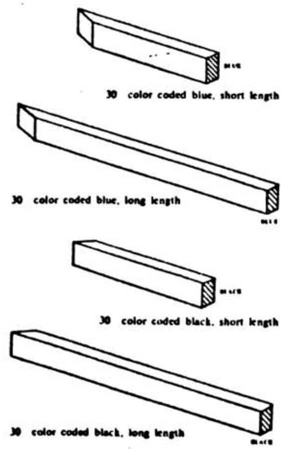
The Monterey Domes Basic Home Package.

Standard Stud Identification

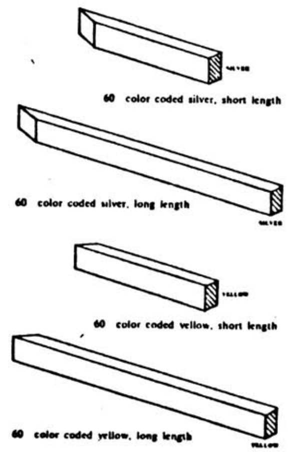
Each pentagon triangle and each hexagon triangle has an additional four (4) standard studs. Each standard stud is a single length of 2" X 4", compound angle cut on one end, and simple angle cut and color coded on the other end.

These various studs are easily identifiable by their shape and color coding (see illustration 26). There should be the following color codes and quantities:

Pentagon Standard Studs

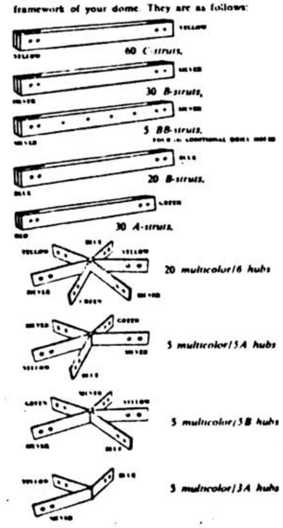


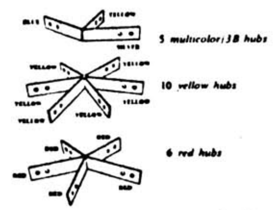
Hexagon Standard Studs



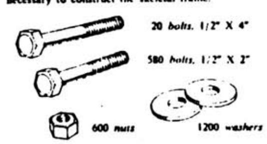
Framework Assembly: Hubs and Struts

There are one hundred forty-five (145) struts and fifty-six (56) hubs necessary to construct the skeletal framework of your dome. They are as follows:





In addition to the hub and struts, the Basic Dome Package also comes with the following hardware necessary to construct the skeletal frame.

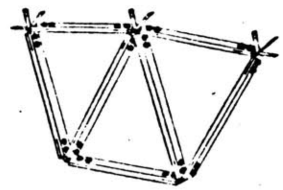


Framework Component Organization

In the center of your dome floor, lay out all of the hub, strut, and hardware containers as follows:

- stand the hub boxes on end, side by side, and open the tops;
- place the hardware container(s) in front of the hub boxes and remove the lid(s);
- lay the individual bundles of struts, side by side, approximately two feet apart, behind the hub boxes, then cut and remove the metal banding straps from the bundles *taking care not to allow the strap to spring loose and injure you* (tin snips work well to cut the strap).

Base Tri-Triangle Pre-Assembly

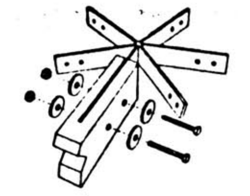


In a clear area on the dome floor, lay out the following hubs and struts in the positions indicated in the illustration

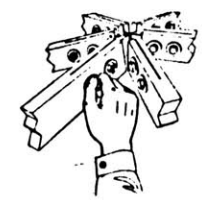
- 1 *yellow hub*
- 1 *multicolor/5A hub*
- 1 *multicolor/5B hub*
- 1 *multicolor/3A hub*
- 1 *multicolor/3B hub*
- 4 *C-struts*
- 2 *B-struts (blue/blue)*
- 1 *BB-strut*

Next, connect the hubs and struts together observing the following:

- the hub flanges should be oriented inward, toward the floor as the work lays on the floor;
- the color coded end of each hub flange should match the color coded end of the strut it is being connected to.
- the hubs and struts should be secured with 1/2" X 2" bolts, nuts, and washers.



- the *bolts and nuts should only be finger tightened at this time;*



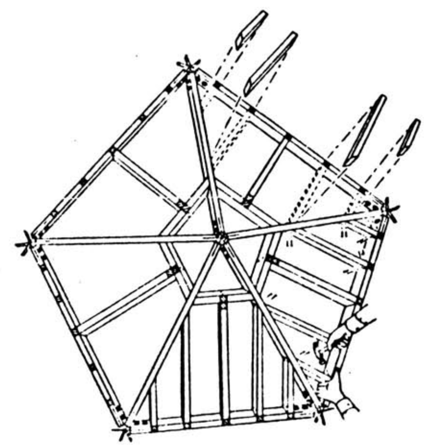
Now, set the completed "base tri-triangle" next to the closest riser wall.

Lay out the materials for four (4) more base "tri-triangles" and assemble them in the same manner as the first one. Set one next to each remaining riser wall.

Standard Stud Installation in Pentagon Triangles

Install the standard studs in the pentagon triangles observing illustration 27, and the following:

- all orientation is from the outside of the dome;
- the terms "left" and "right" as employed in this section refer to the left and right of a triangle whose base is horizontal and toward the ground relative to its apex.
- install the studs as illustrated, taking care to align the color coded end of each stud with the indicator placement mark on the base strut;
- the base of each stud should be toe-nailed into place with four (4) #10d nails, two (2) nails on either side of the base;
- the top of the stud should be toe-nailed into place with two (2) #10d nails;
- the studs should be flush, both to the inside and to the outside of the surrounding struts.



December 14, 1983

Mr. David Borenstein
58 Atherton Street
Somerville, MA 02143

Dear Mr. Borenstein:

Because of the significant number of improvements in both our product and our customer services, we are planning a price increase for 1984 of approximately 9 percent. You have had some time now to review your brochure. If there are any questions, please do not hesitate to contact us and begin your planning for a Hearthstone home in 1984. Orders received prior to January 1, 1984, will be processed at 1983 prices.

Business analysts anticipate a brisk year for home building in 1984. Should this materialize, the cost of building a new home will escalate significantly. Many building materials are at three to five year low points and the increase in demand should significantly increase the cost of building materials. Also, the outstanding interest in our product leads us to believe that we will have a significant backlog of orders by early Spring in 1984. The prospect of increased general building costs, of potential backlog, and the Hearthstone price increase for 1984 combines to suggest that you should contact Hearthstone or one of our representatives as soon as possible concerning your plans for 1984.

We look forward to serving you and hope that you have an enjoyable holiday season.

Sincerely,

HEARTHSTONE BUILDERS, INC.

Randy K. Giles

Randy K. Giles
President

RKG/djg

Hearthstone Builders, Inc. Route 2, Box 434, Dandridge, TN 37725 615-397-9425

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