A MULTISTORY INDUSTRIALIZED HOUSING SYSTEM

by

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at the

Massachusetts Institute of Technology

June 1968

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ABSTRACT OF THESIS: A MULTISTORY INDUSTRIALIZED HOUSING SYSTEM

Francis A. Bulbulian
Joel H. Goodman

Submitted to the Department of Architecture on June 18, 1968, in partial fulfillment of the requirements for the degree of Master of Architecture.

The objective of this study was to develop a multistory, low cost housing system with a completely systemitized design and construction procedure. Important factors in the development of the presented design were: minimizing on site labor, using standard construction methods with lightweight materials, and recognition of shipping regulations.

The study began with research on existing housing systems including the mobile home industry. Apartment planning, building codes, and transport regulations were also investigated.

The multistory building types that are proposed have double loaded corridors with vertical mechanical chases serving bathrooms and kitchens located along this corridor.

This study includes the development of prefabricated housing units that are suspended from a primary structure. The unit is an individual box (12'x 55'x 10') made up of structural concrete slab/beams, four 4'-0" structural wall panels, steel studs and gypsum partitions, and a metal deck roof. The primary structure is composed of load bearing cores, prefabricated trusses, and suspension straps.

The presented housing system reduces on-site labor, is transportable over the highways, and requires minimum on-site erection equipment. It also accomodates flexible apartment planning and can be built in a shorter time than a building of the same size using conventional construction methods.

Thesis Supervisor: Eduardo Catalano
Title: Professor of Architecture

Cambridge, Massachusetts

June 17, 1968

Dean Lawrence B. Anderson
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Dear Dean Anderson,

In partial fulfillment of the requirements for the degree of Master of Architecture, we hereby submit this thesis entitled "A Multistory Industrialized Housing System".

Respectfully,

Francis Aristakes Bulbulian

Joel Howard Goodman

The authors wish to thank the following people, whose assistance and advice have contributed significantly to the development of this thesis:

Eduardo F. Catalano
Professor of Architecture
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INTRODUCTION

Construction Methods

Building in the United States has recently advanced from the traditional method of construction (complete fabrication on the site) to the current method of using some preassembled components combined with the traditional method of construction. This progress is good and has demonstrated its worth, but the process of change has been very slow. This combined method of construction still has some inadequacies and they are self-evident upon an inspection trip to most building sites. The wastage of man hours and materials and the stoppage of work due to adverse weather conditions cannot be tolerated with present and especially future econmies and building needs.

> "The idea of bulldozing a piece of land into a muddy morass and then depositing about 120,000 components into individual piles in the mud, with the expectation that a crew of men will cut, fit and pound these parts together in the rain or cold or heat, borders on the

> ridiculous. Yet, that is how it is being done. To this waste must be added excessively high labor costs .... job-site labor is costing between 9¢ and 10¢ a minute per man, figuring wages, coffee breaks, getting a bet down on a horse, taking a smoke and watching a pretty girl hang up clothes in the yard next door .... progressive builders are asking that just as many components as possible be prepared or prefabricated under factory conditions, and with the most modern materials and techniques, in order that job-site labor can be reduced and modern homes produced at costs more people can afford to pay."[1]

The next step in the evolution of the building process will be an increased use of pre-assembled, pre-finished components fabricated under factory conditions with a complimentary decrease of on-site labor. A step further, in the same direction, is the production of larger, completely industrialized elements installed with a minimum of on-site labor.

The construction of an entire building on a site is economically not feasible and certainly an entire building cannot be constructed in a factory. An optimum relationship between factory work and on-site work is slowly evolving in the building industry. (The transfer of on-site work to factory conditions and therefore factory processes is the important development.)

This developing industrialization can be primarily reasoned by the following factors: (1) labor, (2) time, and (3) control.

(1) Labor

Labor costs are responsible for a large percentage of construction costs and they are continuing to rise at a rapid rate. Industrialization of building elements can reduce some of the expensive labor input, skill content, and increase the efficiency of the labor force so it can accomodate more construction.

(2) Time

Besides a faster and larger return on an investment, other reasons have come into being for faster construction techniques. The necessity for merely a place to live will be needed by more and more people in the U.S., as is the case now in many other parts of the world.

(3) Control

Factory conditions provide a better opportunity for achieving a higher quality construction through closer tolerances and supervision.

In general the factory operation provides for a more disciplined method of construction in all its phases including management, financial co-ordination, labor and design.

Multistory Housing

Multistory housing lends itself to industrialization primarily because of the large number of repetitive planning elements. There is also a greater degree of public acceptance in multistory housing of living standards especially when compared to the individuality (in terms of expression) desired in low-rise residential construction. Finally, industrialization can aid in speeding up the construction and erection of the large anticipated housing needs.

DEVELOPMENT OF PRESENTED BUILDING SYSTEM

The presented building system consists of prefabricated housing units suspended from a primary structure. The development of the housing units, apartment plans, and primary structure occurred simultaneously. Each of these aspects directly related to one another and decisions throughout the design development were interdependent.

DEVELOPMENT OF HOUSING UNIT

The design development of the presented unit started by examining the Mobile Home Industry for the following reasons; (See Appendix B)

1. The mobile home trailer is presently the only completely industrialized unit manufactured in the U.S.

2. It is constructed of lightweight materials by simple construction methods.

3. The Mobile Home Industry is established, and appears to be successfull in terms of limiting skilled and unionized labor input.

4. The dimensions of the finished unit are the limits established by shipping regulations. (approx. 12'x60'x10')

The primary differences in preparing a housing unit for multistory buildings as opposed to a single story trailer unit are structural and fireproofing requirements.

UNIT DESIGN CRITERIA

The criteria that guided the dimensions and construction of the presented unit were as follows; (1)constuction methods, (2)weight, (3)building codes, (4)shipping regulations, (5)and planning.

1. Construction Methods

Elaborate unit fabrication procedures could require expensive and/or awkward equipment. (For example, casting or spinning entire units.) This equipment is limited usually to specific operations and would not have the flexibility to be easily set up on the site. However, on-site unit production may be desirable considering transportation costs. Therefore, it was our intent to use construction methods that would employ standard trades, techniques and equipment, so as to reduce the initial investment in the unit production, and to provide the possibility to easily set up unit production on the site. Also, the use of standard methods makes it possible to more accurately estimate the costs of unit production.

2. Weight

The unit weight is an important consideration because it directly influences shipping costs and ultimately the weight of the building. If the unit is lightweight, savings can occur in the primary structure and foundations.

3. Building Codes (Fire Regulations)

The National Building Code requires that noncombustible materials be used in residential buildings above six stories. Columns require a three hour rating, floors require a two hour rating, and partitions require a one hour rating. (See appendix C for further details)

4. Shipping Regulations

Many state highway regulations impose limits on the distance a building unit may be moved. (See appendix D)

In general, a special permit and police escort are required for dimensions that exceed 12'-0" width, 10'-0" height, and 60'-0" length.

Therefore, we adhered to these dimensions as limits for the design of the unit. This permits fabrication of large units in the factory, reducing on-site connection and finishing. It should be noted that if the factory was set up on the site, these shipping regulations would no longer be a restriction and larger unit widths could be accomodated.

5. Planning

The planning of the building was not developed without the building system in mind and vise versa. Changes in the building system affected the plans and planning requirements affected decisions concerning the configuration of the building system. A double-loaded corridor arrangement was investigated because of its simplicity and assumed economy. It also was efficiently accomodated in the preliminary development of the presented system. One unit (12'x60'x10') would contain a portion of two different apartments with a segment of

corridor between them. (see Fig. 1)
Standard apartment modules were designed, (A, B, & C, Fig. 1) and by arranging these modules, different size apartments could be constructed, with the same component plan elements. For low and moderate income apartments, two units (1 and 2) can accomodate 1-bedroom, 2-bedroom, and 3-bedroom apartments. (see Fig. 2) For more luxurious planning, a third unit size is shown. (3 in Fig. 1)

The plans fall within areas established by taking averages of existing plans for low-moderate income apartments. The gross average areas used are as follows; Efficiency 480 sq.ft., One Bedroom 670 sq.ft., Two Bedroom 896 sq.ft., and Three Bedroom 1,112 sq.ft. (see Appendix E)

The vertical chases for plumbing and ducts serving the kitchen and bathrooms are located along the corridor for convenient access. Another restriction imposed on the apartment plans is the need to minimize side openings from unit to unit. Rigidity

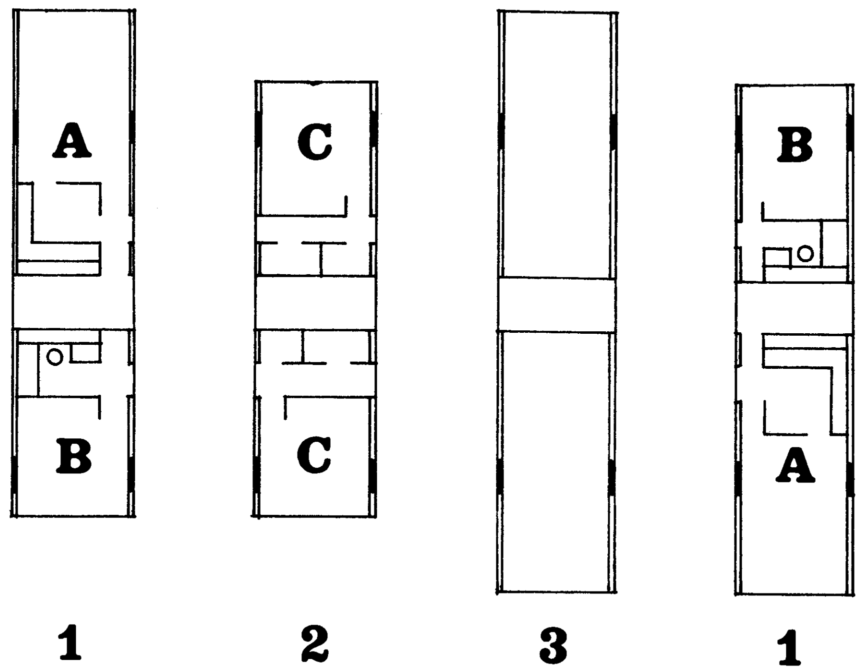

A
B
C
C
B
A
1
2
3
1

Fig. 1.

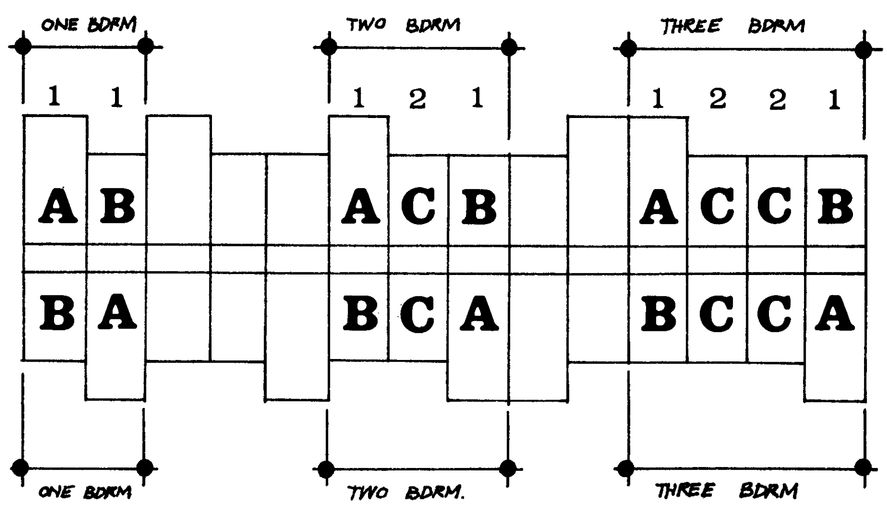

ONE BDRM
TWO BDRM
THREE BDRM
1 1
1 2 1
1 2 2 1
A B
A C B
A C C B
B A
B C A
B C C A
ONE BDRM
TWO BDRM.
THREE BDRM

Fig. 2.

in the building unit can then be better maintained during transport and fewer openings would have to be protected. We limited our investigation to one floor apartments, but other types of planning could be accomodated with the same building system concept. (For example, two story apartments and skip corridor buildings.)

CRITERIA FOR HANGING POINTS

Upon initial investigation of apartment planning, approximate dimensions were established for the length of the slabs (60'-0"). Another criteria was the limit of the supporting beam depth so as to provide an acceptable door height at openings between the units. For these reasons, and for a simplified unit construction, eight hanging points were initially chosen. (See figure 4.)

However, with eight hanging points, restrictions in planning occurred; it increased the number of relatively expensive connections, and it increased the number of primary structural members. Therefore, four hanging points were finally selected. (See figure 3.)

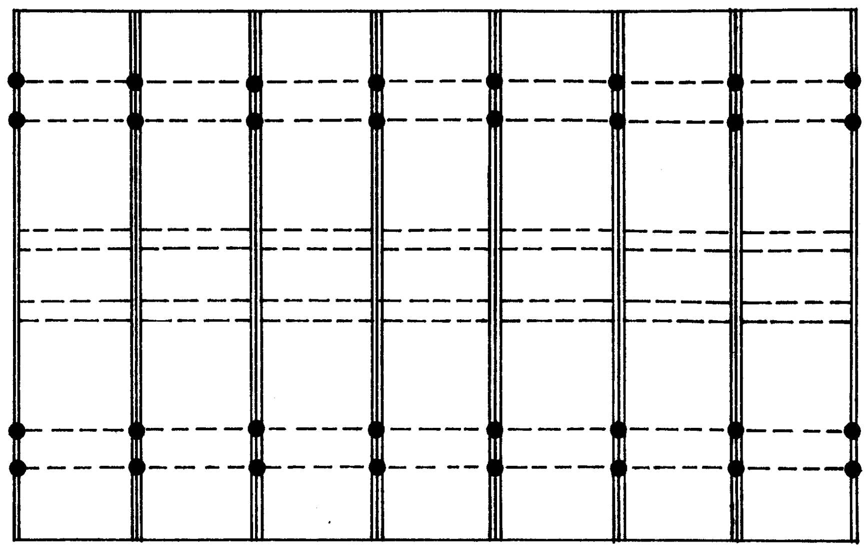


Fig. 3.

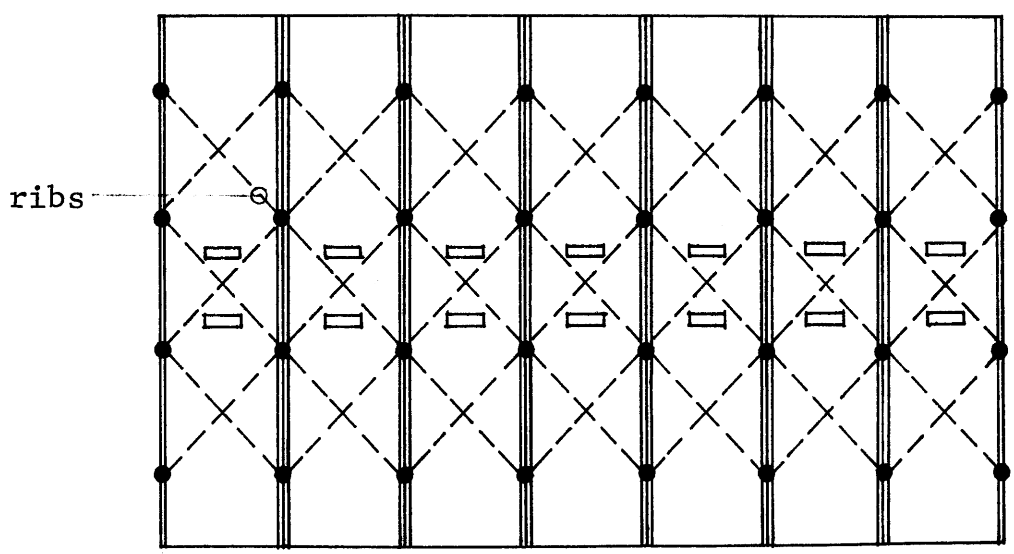


Fig. 4.

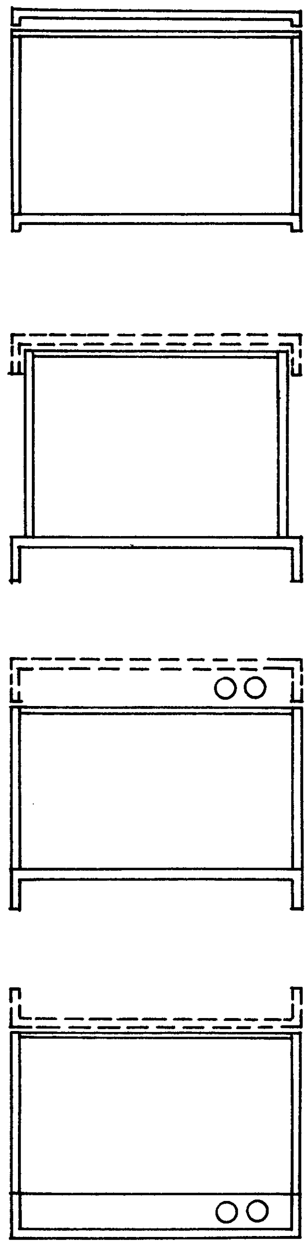
DEVELOPMENT OF UNIT CONFIGURATION

Different unit enclosures were investigated recognizing restrictions imposed by structural members and apartment needs. (primarily side openings)

Initially, the base beams were small (No. 1, Fig. 5.) because the unit was supported at 8 points. (See Fig. 4.) Therefore, the unit construction was quite simple. However, with the inclusion of relatively deep beams, due to support by 4 hanging points, (See Fig. 3) the unit design became more complex.

In No. 2, (Fig. 5) the side partitions fall within the beams, but the double wall dimension increases.

The major obstacle in No. 3 and 4, (Fig. 5.) is the added height in each unit which becomes substantial in multistory structures. However, if duct or pipe spaces would be required these schemes



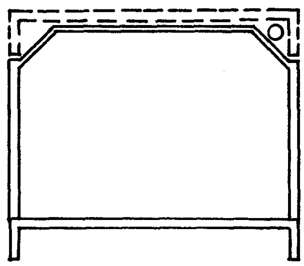
1.
The unit construction is simplified, but requires a more complicated primary structure.(8 hanging pts. per unit)

2.
Simplified unit construction, but the double wall dimension is at least 18".

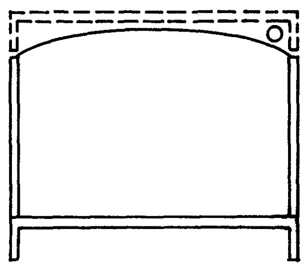
3.
The additional vertical space is wasted unless it is required for mechanical needs. Also the double wall dimension is reduced.

4.
This one is similar to 3. excepting an additional floor is required and the slab would be cast up side down.

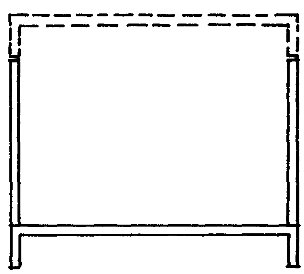
Fig. 5.



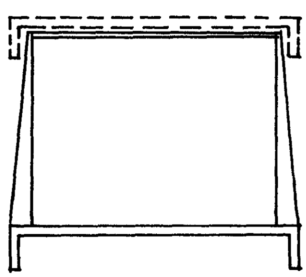
5.
Some mechanical space exists, but an un-rigid roof shape results.Also interior partitions and end walls meet the ceiling in a more complicated way.



6.
Similar to 5.



7. scheme A
High tolerances and protection to the underside of the base and interior of the unit are required.Also, a more complicated base results with the added rib construction.



8. scheme B
A modified metal stud decreases the double wall dimension while providing a rigid enclosure to the unit. Good accoustic control is inherent with double wall and ceiling construction.

Fig. 6.

would have more substance.

The ceiling configuration in No. 5 and 6, (Fig. 6.) avoid the beams but lacked rigidity and presented some problems for interior partitioning.

In Scheme A, (No. 7, Fig. 6) the underside of the base becomes the ceiling for the unit below. This scheme presented a problem in that a temporary roof cover would be required for rigidity and protection during transport.

Scheme B (No. 8, Fig. 6.) makes use of tapered metal studs cantilevered from the base. This produces a fairly rigid unit configuration and reduces the width of the double wall.

In the interest of reducing the dimension of the double wall construction and minimizing the height of the building, Schemes A & B (No. 7. & 8., Fig. 6) were selected for development.

CONSTRUCTION OF PRESENTED HOUSING UNIT

Structural Base (2-hour fire rating)

This study started by investigating a base composed of two rolled steel sections (beams) with steel deck spanning between them. Two inches of concrete was to be poured on the deck to provide fire protection and rigidity to the base. This was abandoned in favor of integrally poured beams and slab for the following reasons:

1. Reduced fireproofing problems
2. Negligible weight difference
3. Less complicated construction (fewer materials and processes)
4. Provided possibilities for pre-stressing production procedures (long casting beds and extrusion techniques)

Concrete Wall Panels (2-hour fire rating)

Four 4'-0"x7'-0"x3" reinforced concrete wall panels are secured at the hanging points of the base. They house the connection to the suspension straps, enclose and fire protect the straps, create continuity to adjacent floor levels, (See Fig. 8.) and reduce the span of the beams. (See structural analysis of housing unit)

The panels also provide a structural formwork for the stacking of housing units. They would be secured together (see stacking detail) and concrete would be poured between them forming an integral column-beam/slab structure.

Side Partitions (1-hour fire rating for double walls)

Sandwich panels composed of asbestos cement sheets and foam fill were investigated and discarded in favor of steel studs and gypsum wall board panels backed with particle board (for rigidity and protection during transport) The reasons for this selection are:

1. Lightweight
2. Easy to produce with standard construction methods
3. Relatively inexpensive

4. Provides necessary accoustical requirements

5. It is flexible for making different size wall panels

6. Acceptable interior surface

Interior Partitions (inflamable material)

A pre-assembled gypsum partition system was selected for many of the same reasons as for the side partition.

End Glazed Wall Panel (inflamable material)

A bent-up metal window wall panel which can be installed in one piece would be fabricated. The heating/air conditioning elements are an integral part of this pre-assembled panel. (See unit details)

Roof (inflamable material)

The roof acts to maintain rigidity of the unit during transport and enables a finished interior. 1½" steel deck (12' span) was chosen for the following reasons:

1. Lightweight
2. Simple installation
3. Minimized depth of roof
4. Inexpensive

FACTORY CONSTRUCTION SEQUENCE OF HOUSING UNIT

1. Structural slabs poured in two lengths, 47'-0" and 55'-0" at the casting bed. Similarly 4'-0" structural wall panels cast.

2. Structural wall panels welded to slab.

3. Floor runners which receive the partitions are secured to slab.

4. Side partitions made in jigs and set onto the floor runners.

5. Unit bathroom and kitchen installed.

6. Roof deck set and secured on top of side partitions.

7. Interior partitions set in.

8. Wiring and ducts installed.

9. End glass wall panels and heating element installed.

10. Interior finishing and painting started.

11. Openings temporarily prepared for shipment with diagonal wood bracing, and protected with polyethylene.

12. Loaded on truck for shipment to construction site.

MECHANICAL

Vertical chases are located along the corridor with access panels from the corridor serving bathroom and kitchens. The pipes and exhaust ducts were initially to be installed in the factory, leaving the connections to be made at every floor after the units were in place. Upon closer investigation of the connection and alignment problems, it was decided to only install pipes from each fixture in the factory and install all vertical pipes on the site. The vertical ductwork would be installed in the units, and connected after the units are erected. The vertical pipes and ducts are gathered at the bottom of the building and directed to the cores and basement mechanical rooms.
The unit is heated by an electric radiation unit at the end glass wall panel. (Double glass is used to minimize heat loss.)

Electric heating was chosen primarily because of the lack of duct or pipe space available in the unit. Air conditioning wall units would also be an integral part of the glass wall panel.

WEIGHT CALCULATION OF PREFABRICATED HOUSING UNIT*

Item	Pounds	Tons
Reinforced concrete slab (55'-0" x 12'-0")	20,475	10.24
Reinforced concrete structural panels, 4/slab (4'-0" x 7'-0")	2,800	1.40
Exterior walls (5/8" gyp on 2½" metal studs) 72 linear feet	5,220	2.61
Interior walls (½" gyp on 2" metal studs) 60 linear feet	3,480	1.74
Prefab bath unit (5'x8'x7')	500	0.25
Kitchen Equipment		
Dishwasher	165	
Disposal	28	
Range	173	
Refrigerator	400	
Sink Cabinet	75	
Accessory Cabinets	220	
	1,061	0.53
Corrugated steel deck 1½"	1,320	0.66
Dead Load (Unit Shipping Load)	34,856	17.43
Live Load @ 40lbs./Sq.Ft.	26,400	13.20
Dead Load + Live Load	61,256	30.63

* The different unit layouts vary in weight between 25.5 - 30.6 tons.

UNIT STRUCTURE

Maximum moment at the middle span = M

$M = ws^2/2 - [R1(18.17') + R_2\ (14.17')]$

$M = 545 lbs./ft.(21.5')^2/2 - [6,500(18.17') + 6,5--(14.17')]$

M = 86,000 lb. ft.

Area of Structural Material

$A = M/\ depth\ ^{(Fy)}$

A = 86,000 lb ft./ 1.67(Fy)

A = 51.4 kips

A steel = 51.4 kips/30 KSI

A = 1.72"sq. ∴ three 7/8" bars

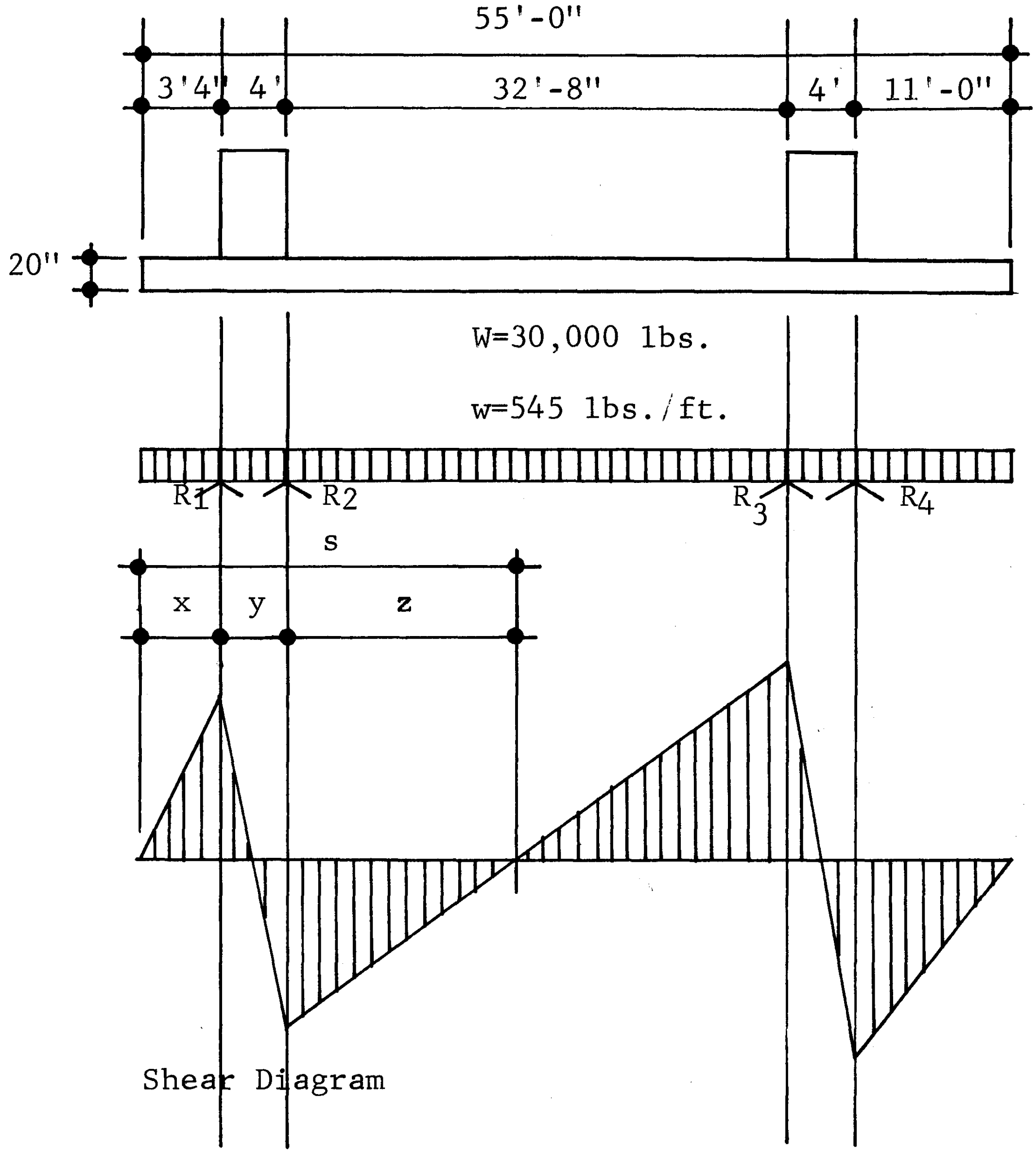
A (concrete) = 51.4 kips/ 1.5 KSI

A(concrete)= 34.5" sq. (compression)

The moment resulting from the 11'-0" cantilever (5,995 lb ft) is not as significant as limiting the deflection. In order to do this, the following guides were used.

Cantilever (ft) = 6.5 x depth (ft)
6.5 x 20" = 130" - 10.83' ⟶ 11'0"
Mid span (ft) = 3 x cantilever = 19.5 x depth
3 (10.83) = 32.49' ⟶ 32" - 8"

UNIT STRUCTURE



R_1 & R_2 = 6,500 lbs.
R_3 & R_4 = 8,500 lbs.
s= 21'-6"
x= 3'-4"
y= 4'-0"
z= 14'-2"

Fig.7.

Rigid Frame Behavior

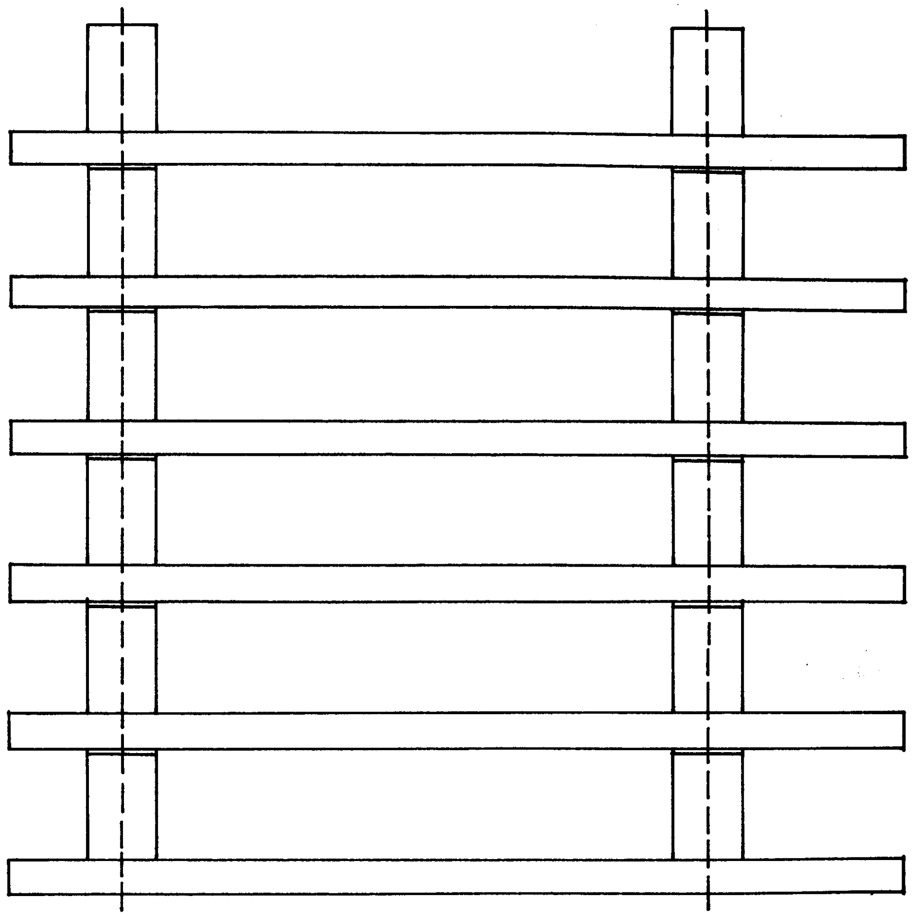


Fig. 8

The adjustment mechanism(see unit suspension detail) enables a sort of post-tensioning to occur vertically along the concrete wall panels. This induces a continuity from one floor to the next (rigid frame behavior) to resist lateral loads.

DEVELOPMENT OF PRIMARY STRUCTURE

In a multistory housing concept the primary structure provides the following functions; vertical circulation of people and mechanical services, stability against gravity and wind forces. The solutions possible for the primary structure, in analysis, seemed to fall into three catagories.

1. Stacking housing units
2. Plugging housing units into a "cage"
3. Suspending units from a primary structure

Each catagory has its own advantages and disadvantages and can be justified under different circumstances. After studing each catagory and analyzing their relative merits, the last mentioned catagory was chosen for the following list of criteria. They are in order of their importance.

1 - Fast and efficient on-site construction

2 - Low site equipment costs

3 - A relatively reduced building weight; (due to lightweight housing unit) directly affecting the cost of primary structure and foundations

4 - Free space at ground level between cores

5 - Efficient use of steel as a tension member, and its resultant (small) cross-sectional area.

STRUCTURAL COMPONENTS

In this study, the primary structure for a 20-story/3-core housing block was calculated.

The following components form the primary structure; vertical service cores, trusses, truss stabilizing planks, and suspension straps. After these components are in place they support the prefinished housing units which are produced in the factory or on the construction site. The primary structure components are designed with the following criteria in mind:

- Minimum on-site fabrication
- Repetitious components and erection methods
- Adaptability to various grouping and density requirements

The concrete cores are the main vertical support points of the building, they are slipformed on the construction site and house the elevators and stairs.

The trusses which span between core points, eventually support the housing units. They are fabricated from standard rolled channel sections, fire-proofed with 1½" lightweight concrete, and transported to the site. Then each section is lifted into position by a crane and secured to the cores, forming a continuous set of trusses. (See site construction drawing.) There are three lengths of truss that make up the spanning members.

The truss stabilizing planks (Flexicore) span between the lower and upper chord of the trusses, providing lateral stability for the truss, and at the same time form roof facilities for the housing block.

The housing units are suspended at four points by a pair of high strength steel straps, their cross-sectional area varyies according to the load carried. The straps are shipped to the site in 35'-0" sections, connected with splice plates, and bolted to form a continuous suspension line. (Upon calculating the deflection limits of the 1" x 7" - 50 ksi steel, it was found that sections beyond 35'-0" length would undergo permanent deflection under its own weight during lifting and connection procedures.) In the process of connecting, the steel straps are gradually raised to a vertical position, and mechanically fastened to overhead trusses. Once in place the straps are secured to the ground and form the guides on which the housing units are then raised. The guides restrain the units against wind loads during the lifting process.

When the units are in place the steel straps will slightly elongate. Greatest increment of elongation will appear at the top and decrease directly towards the base units. To correct this, an adjustment mechanism is located at each connection point to the unit, which is then adjusted from within each unit. The adjustment mechanism also serves to transmit the unit load from the lifting cables to the suspension straps during the placing of housing units, and finally it serves to induce continuity to the structure.

SITE CONSTRUCTION SEQUENCE

1. Foundations for cores prepared.

2. Core walls slipformed.

3. Prefabricated trusses lifted up in sections, and secured to cores.

4. Center spans of trusses lifted and secured.

5. Lifting device lifted into position on truss.

6. Suspension straps, and truss stabilizing elements lifted into position.

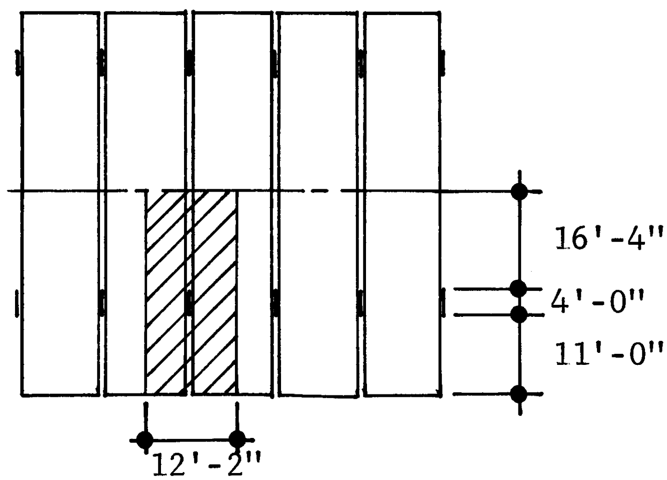
7. Straps tied to the ground.

8. Housing units positioned underneath their final location, and lifted gradually by overhead lifting device.

9. Housing unit connected to straps when in final position, and adjustment made at each unit.

10. Cover panels at connection points installed, interior trims and corridor finished; and exterior trims and water-proofing finished.

ANALYSIS OF SUSPENSION STRAPS



HOUSING UNIT WEIGHT = 30 TONS (DL+LL)
HOUSING UNIT AREA = 660 SQ. FT.
UNIT WEIGHT = 91 LBS/ SQ. FT.
AREA OF STEEL = 14 SQ. IN. (TWO 1"x7" STRAPS)
F_y (STEEL) = 50 KSI

TRIBUTARY AREA/FLOOR = 363.6 SQ. FT.

LOAD/FLOOR (SUSPEND BY 14 SQ. IN. STEEL) =
363.6 SQ. FT. x 91 LBS./SQ.FT. =
33,087.6 LBS. = 33.09 KIPS

MAX. CAPACITY OF STEEL STRAPS (50 KSI) =
14 SQ.IN. x 50 KIPS/SQ. IN. = 700 KIPS.

MAX. NUMBER OF FLOORS (SUSPENDED BY STRAPS) =

$$\frac{\text{MAX. CAP. OF STRAPS}}{\text{LOAD/FLOOR}} = \frac{\text{700 KIPS}}{\text{33.09 KIPS}} = \text{21 FLOORS}$$

ANALYSIS OF PRESENTED PROTOTYPE BUILDING

The prototype building chosen for the purpose of this study is a 20-story housing structure. Three cores and two overhead trusses support 480 prefabricated housing units. They are lifted into place and form 360 apartments. Each floor is made up of 24 prefabricated units, with an average of 18 apartments per floor.

The presented prototype structure contains the following distribution of apartments.

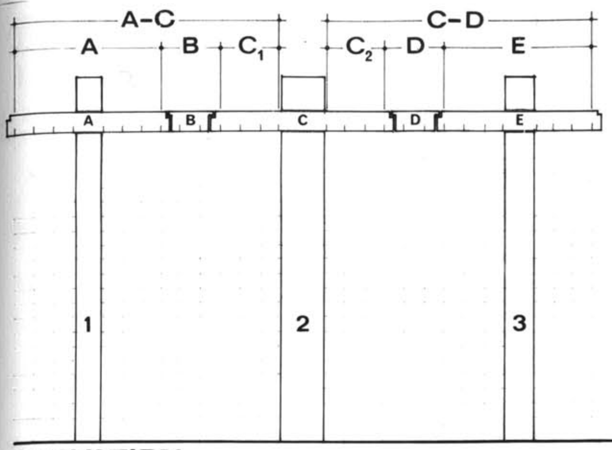
Type	Number	Percentage
Efficiency	40	11%
One Bedroom	80	22%
Two Bedroom	200	56%
Three Bedroom	40	11%

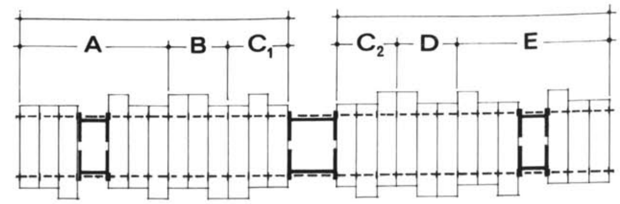
The above distribution can vary according to specific program needs.

CRITICAL PATH ANALYSIS

For the purpose of understanding the full construction process of both the primary structure and unit fabrication, a preliminary Critical Path Method (C.P.M.) network was prepared.

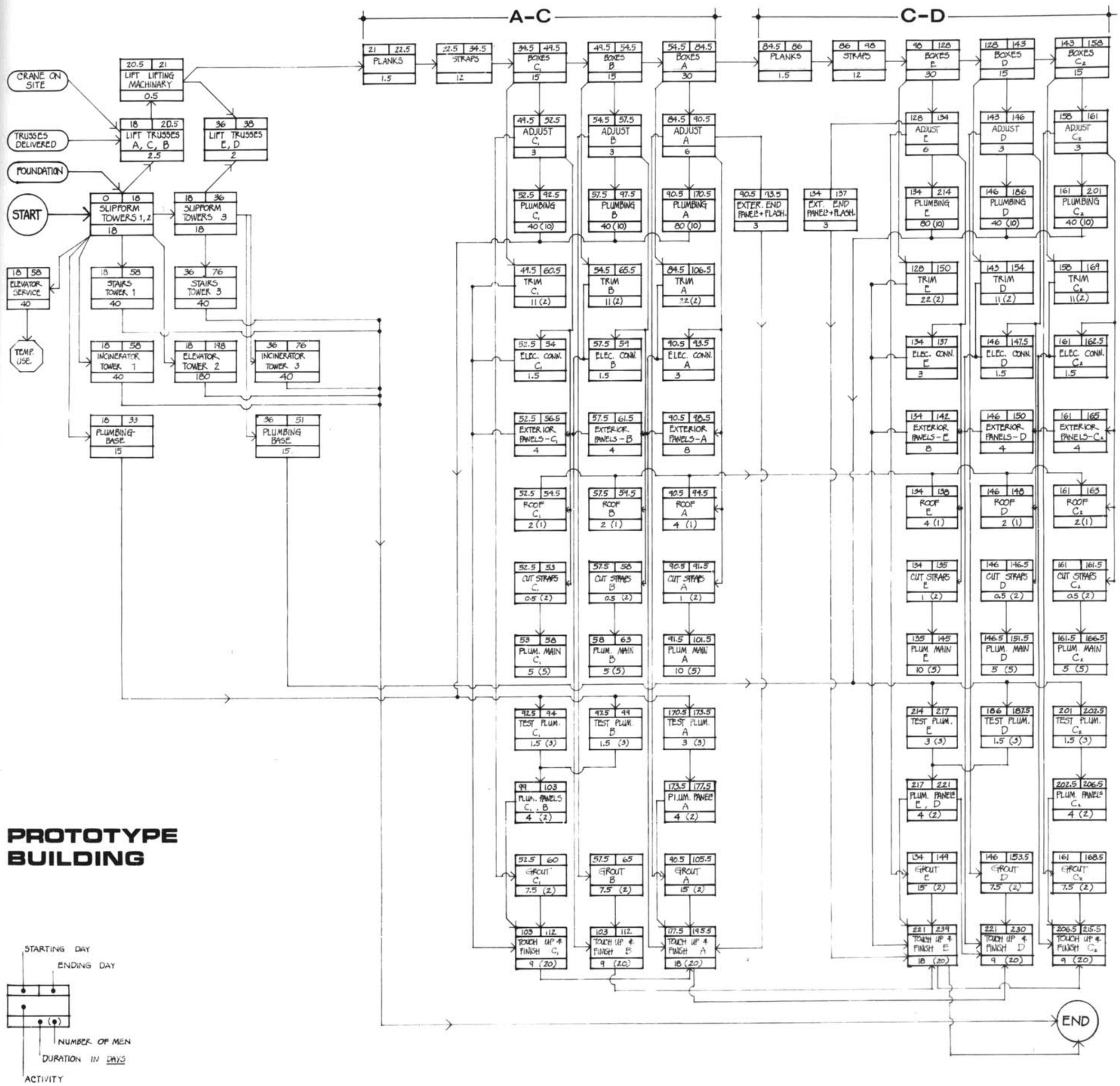
The C.P.M. network is a diagram of the construction operations. The operations are diagrammed step by step, calling out each individual construction activity, its duration and its relationship to other construction activities. From the C.P.M. network a list of material, labor, and equipment input was collected and became the source for the cost estimates.





ELEVATION

PLAN

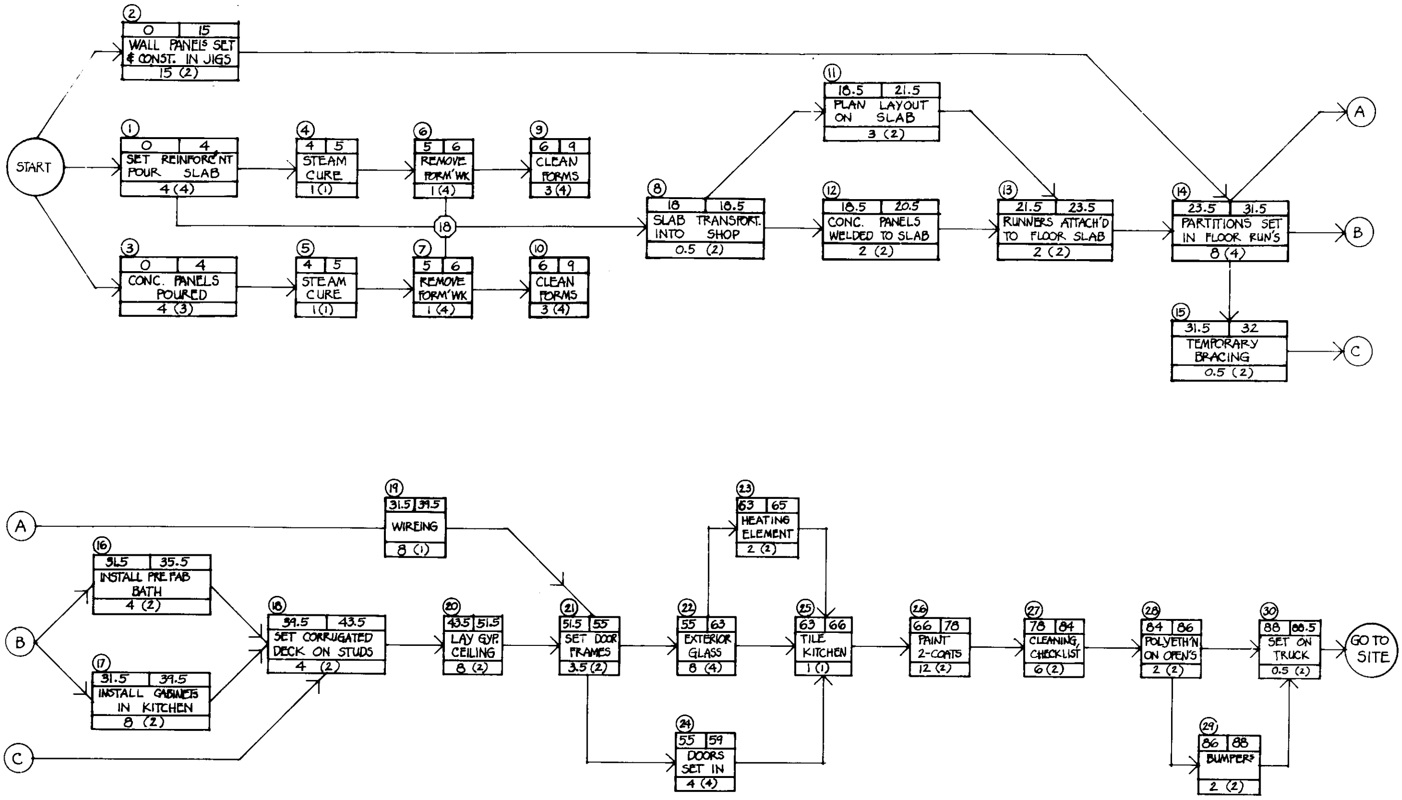


PROTOTYPE BUILDING

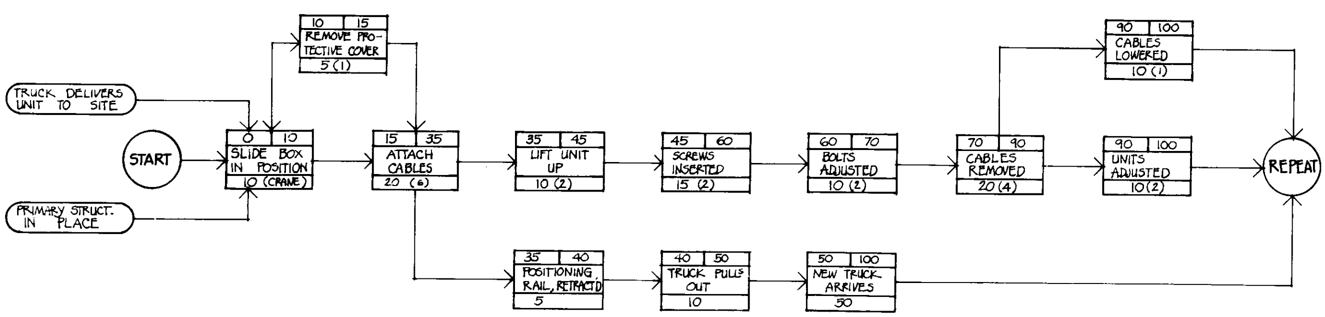
C. P. M. NETWORK

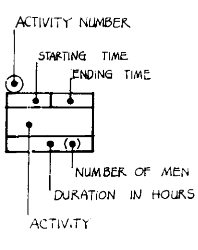
MULTISTORY INDUSTRIALIZED HOUSING

UNIT PREFABRICATION CYCLE



LIFTING CYCLE
OF HOUSING UNITS





C.P.M. DATA SHEETS------------------------PRIMARY STRUCTURE
MATERIALS LISTING

ITEMS	UNIT	AMOUNT	$-UNIT RATE	$-TOTAL COST
Trusses	Pound	167,400	0.15	25,100.00
Lifting Equipment	Per Mon.	7	300.00	2,100.00
Bar Joist	Tons	20	250.00	5,000.00
Concrete Planks	Sq. Ft.	10,000	1.10	11,000.00
Straps	Pound	414,400	0.14	58,000.00
Connectors	Pound	38,400	0.16	6,070.00
Housing Unit	(See Unit	Data Sheet)		
Plumbing Drainage	Lin. Ft.	37,600	6.35	240,000.00
		(Labor Included)		
Supply	Lin. Ft.	23,200	4.70	109,200.00
Joints		349,200	0.10	34,920.00
Ductwork	Pounds	44,000	0.80	35,000.00
Interior Trim Panels	Pounds	21,400	0.80	17,200.00
Exter. Pa'ls	Pounds	9,900	1.00	9,900.00
Roof	Sq. Ft.	1,752	0.75	1,320.00
Plumbing Mains-Drain	Lin. Ft.	300	13.25	3,975.00
Supply	Lin. Ft.	600	13.95	8,400.00
Grout	Sq. Ft.	960	3.60	3,450.00
			TOTAL	581,817.00

C.P.M. DATA SHEET ------------------------ PRIMARY STRUCTURE

LABOR AND EQUIPMENT

Operation	Conc. Fin.	Carpenter	Oper. Engin.	Steel Worker	Plumber	Elec.	Paint.	Laborer	$-TOTAL COST
Rates/ Day $	36.00	43.20	90.00	48.00	49.20	47.60	40.40	32.80	
Slip-form (see summary sheet)									
Truss (Crane 1-week @ $ 1000.00)									1,000.00
			5	35					2,130.00
Lift Device (1-day @ $335.00)									335.00
			1	7					426.00
Bar Joist & Planks			3	21					1,128.00
Straps (Truck with Lifting Device-1 Mon. @ 720.00)									720.00
			48	168					12,320.00
Hous'g Unit (Small Yard Crane - 6 Mon. @ 1000.00/Mon.)									6,000.00
		240	240	1200					97,600.00
Adjust Units				240					11,520.00
Elect. Conn.						24			1,142.00
Cut Straps				8					385.00
Test Plum'g					60				2,950.00
Plum'g Panels		32							1,380.00
Grout	120								5,100.00
Touch Up and Finish							440	1000	62,800.00
							TOTAL		206,936.00

C.P.M. DATA SHEETS-------------------------PREFABRICATED UNIT

MATERIAL LISTING

ITEMS	UNIT	AMOUNT	$-UNIT RATE	$-TOTAL COST
Concrete	Cu. Yds.	9.3	18.20	170.00
Mesh	Sq. Ft.	600	0.06	37.80
Reinf.	Tons	0.4	280.00	112.00
Misc.	(10%)			31.98
Wall Pan'ls				
Studs	Lin. Ft.	536	0.13	69.70
Gyp 5'8"	Sq. Ft.	640	0.09	60.80
Part.Bo'd	Sq. Ft.	640	0.08	51.20
Insulat'g	Sq. Ft.	140	1.75	245.00
Insulat'g 2" Fiberglass		24	0.13	3.12
Trim	Lin. Ft.	75	0.19	14.40
Runners	Lin. Ft.	70	0.18	12.25
Kitchen Unit				
Range			210.00	210.00
Garbage Dis.			50.00	50.00
Refrigerator			265.00	265.00
Cabin. Base			93.00	93.00
Wall			41.60	41.60
Counter Top			36.00	36.00
Sink			120.00	120.00
Hood			56.00	56.00
Unit Bathroom			675.00	675.00
Corrugated Steel Deck	Sq. Ft.	600	0.23	138.00
Wiring	($200.00 Per	Apartment:	1.25)	160.00
Light Fixtures				120.00
Wiring Outlets		10	9.10	91.00

(CONT.)

C.P.M. DATA SHEETS--------------------------PREFABRICATED UNIT

MATERIALS LISTING (CONT.)

ITEMS	UNIT	AMOUNT	$-UNIT RATE	$-TOTAL COST
1/2" Gyp	Sq. Ft.	600	0.075	45.00
Door Frames	Each	5	19.00	95.00
Inter. Doors	Each	3	19.00	57.00
Glazing	Sq. Ft.	160	2.70 (Includ. Labor)	432.00
Window Mullions	Lin. Ft.	124	0.85	105.40
Operable Sash	Lin. Ft.	44	2.00	88.00
Electric Heat	Lin. Ft.	44	16.50	363.00
Interior Trim	Each	5	26.00	130.00
Exterior Trim	Each	1	55.00	55.00
Paint	Sq. Ft.	1800	0.02	36.00
Polyethylene	Sq. Ft.	660	0.35	230.00
Bumper	Lin. Ft.	110	0.60	66.00
Flashing	Lin. Ft.	16	1.05	16.80
			TOTAL	4,583.05

C.P.M. DATA SHEETS------------------------PREFABRICATED UNIT
LABOR AND EQUIPMENT

*Item No.	Conc. Fin.	Carp-enter	Oper. Engin.	Steel Worker	Plum-er	Skill. Labor.	Lab-orer	Gla-zer	$-TOTAL COST
Trade Rate Hour	5.30	5.40	5.65	5.90	6.15	5.50	4.10	5.10	
1.	(Slab forms avg. 600 Sq. Ft. @$5.00/Sq. Ft. = $ 3000.00 No. times form used-120								25.00
	12hr						4 hrs.		79.00
2.	(Panel forms 60 Sq. Ft. @ 5.00/Sq.Ft. = $ 300.00) No. times form used-120								10.00
	8 hrs						4 hrs.		58.80
3.		30hrs							162.00
4.	(Steam cure estimated 600 Sq.Ft. @ $ 0.10/Sq.Ft.)								60.00
5.	(Steam cure estimated 112 Sq. Ft. @$ 0.10/Sq.Ft.)								11.20
6.			1hr.				3hrs.		17.95
7.							2hrs.		8.20
8.							12hrs.		49.20
9.							1hr.		4.10
10.							6hrs.		24.60
11.						6hrs.			33.00
13.		4hrs							21.60

(CONT.)

* See C.P.M. Network Diagram for related item numbers.

C.P.M. DATA SHEET---------------------------PREFABRICATED UNIT
LABOR AND EQUIPMENT (CONT.)

Item No.	Elec-tric.	Carp-enter	Oper. Engin.	Steel Worker	Plumb-er	Paint	Averg. Labor	Gla-zer	$-TOTAL COST
Trade Rate/ Hour	5.95	5.40	5.65	5.90	6.15	5.05	4.10	5.10	
14.		32hrs.							172.00
15.							1hr.		4.10
16.		10hrs.			6hrs.				90.95
17.		4hrs.			4hrs.				46.20
18.				8hrs.					47.20
19.	(See materials sheet)								
20.		16hrs.							86.40
21.		8hrs.							43.20
22.		32hrs.						32hrs.	336.00
23.	2hrs	2hrs.							22.70
24.		16hrs.							86.40
25.							1hrs.		4.10
26.						24hrs.			121.20
27.							7½hrs.		30.75
28.							4hrs.		16.40
29.							1hr.		4.10
30.		4hrs.							21.60
							TOTAL		2,183.20

SUMMARY OF C.P.M. DATA SHEETS

Items	Unit	Amount	Unit Rate	$-Total Cost
Slipform Towers 1, 2, and 3	Cu.Yd.	4,630	100.00	463,000.00
Stairs (conc. fill. tread)	Risers	1,232	37.00	45,600.00
Elevators (est. on similar building type)		4	50,000.00	200,000.00
Incinerators (chimney 20"x24")	Lin. Ft.	900	12.25	11,200.00
Materials Listing				581,817.00
Labor & Equipment				206,936.00
	Sub-Total			1,508,553.00
	Overhead, contract profit insurance bond, fees and, misc. =20% of primary structure sub-total			1,508,553.00 X 20%
	Total Cost, Primary Structure			1,710,263.00
Site Equipment Large Crane Small Crane Rail & Dollys				 12,000.00 1,843.00 8,000.00
Lobby Floor				27,000.00
Roof Level				97,920.00
Prefabricated Housing Units. Materials Labor & Equip.				 4,583.00 2,183.00
	Cost of one prefab. unit			6,766.00

(Cont.)

SUMMARY OF C.P.M. DATA SHEETS

Items	$-Total Cost
10% Profit overhead	6,766.00 X 10%
Cost of one prefab. unit	7,443.00
480 Prefab. housing units 480 X 7,443.00	3,582,640.00
TOTAL COST ESTIMATE OF PROTOTYPE BUILDING	5,439,666.00

The total area for the 20-story prototype building was calculated to be 342,600 SQ.FT. Gross, and 292,800 SQ.FT. Net. Therefore, the square foot cost was calculated to be approximately $ 16.00. Not included in this calculation was landscaping and transportation

The following references were used during the preparation of the above estimate:

1. Building Construction Cost Date, 1965, Robert Snow Means Co. 26th Edition, Duxbury, Massachusetts

2. Nationally Averaged Rental Rates for Construction Equipment 18th Edition, 1967, Associated Equipment Distributors.

The C.P.M. and cost estimates indicated that savings would occur due to two major factors; the reduction of on-site labor and the shorter time period required for construction of the entire building (for example, a sooner return on investment and lower interest rates).

The cost analysis was based on present union labor wages. Advantages in labor savings could be achieved if the factory procedure, in the presented design, could be similar to the type of labor that is used in the mobile home industry. Also, greater economies could be achieved if more than one structure would be built. (the cost estimate was based on one 20-story structure - 480 units) It is currently common for 2 or 3 structures of this size to be build in close proximity to one another.

Any accurate estimate of actual savings in the presented housing system would take a more complete and thorough investigation for the most efficient organization of the critical path of construction.

CONCLUSION

Transportation-

In trying to optimize the relationship between on-site construction procedures and factory procedures, we developed an industrialized housing unit whose dimensions were primarily established by the limits of highway shipping regulations. This was done in order to reduce the quantities of connections and finishing that would have to be done on the site and maximize factory work. We feel we have exaggerated this aspect considering present and predicted costs of transport. However, some justification can be found in the continued increase of labor costs and the predicted large volumes of housing that will be needed.

> "Transportation acts as both a technical and an economic constraint to advances in prefabrication. Currently, the construction industry has the capability of building and finishing an entire dwelling unit in the factory. However, there is no known economical method of getting the finished unit from the factory to the site (excluding the mobile home). The

> restrictions placed upon highways by both state and federal governments negates attempts to use motorized carriers--and efforts to use helicopters and other forms of air-borne carriers have not proven to be economically feasible. Consequently, total unit prefabrication of houses produced at a central factory off-site can never become a reality until this technical barrier is resolved."[2]

Another aspect, in the presented design, of transport dimension limitations is the minimum width that is established. The limit is 12'-0". This means living areas will have a dimension of less than 12'-0" when you subtract the partition dimensions. This dimension could be increased if the factory was set up on the site or if units could be transported over water.

Construction Methods

Through out the project development the use of standard methods of construction were emphasized. We have taken some of the work that is done on the site and put it in the factory. The actual construction procedures are the same, hopefully they will be organized and done more efficiently in the factory. The next step in the production of housing elements should be in the direction of automation. If the assumptions about increasing labor costs and the decreasing skilled labor force holds up, just putting standard construction methods in a factory will not be enough if the predicted housing market occurs.

Alternative System

The presented building system includes a completely finished industrialized housing unit in the form of an individual box. An alternative system that is similar, but does not depend on an enclosed box is described in the following partial erection sequence. This alternative system may be more in tune with present building economies and techniques.

1. Cast the slabs on the site or in a factory (the slabs can be stacked during transport)

2. Place unit bathrooms and kitchens on the slab along with a package of pre-cut, pre-finished wall panels, and other finish materials. (this procedure would take place on the site)

3. Lift slabs into position. (same lifting procedure as in presented system)

4. Connect, grout, and secure slabs to the cores. (the details and connection procedures would become simplified)

5. Complete construction and finishing on erected platforms.

This procedure is suggested for the following reasons:

1. The cost of shipping individual units could be prohibitive.

2. Double wall and ceiling construction would be eliminated.

3. Usable areas would be increased with a reduction of material.

4. Tolerances would not be as stringent as in the presented solution.

5. Apartment planning would accomodate more flexible planning. (the 12'-0" width limit would removed).

Environment

This industrialized housing study was based primarily on economic and technological criteria. The psychological implications of multistory housing have not been emphasized.

In dealing with industrialized housing systems, the occurrence of repetition appears much to the advantage of economic and technological criteria. However, if this repeating system cannot accomodate variation, environmental criteria will suffer. This can be illustrated by looking at some existing housing systems, the Russian box system probably being the most poignant example.

The presented apartment plans accomodate minimum acceptable standards and are grouped in a conventional double loaded corridor. Grouping of residential units is a most important aspect of residential design. Establishing a sense of community cannot be overlooked in the design of housing. It makes little difference if the units are suspended prefabricated boxes or traditionally built single-story suburban bungalows. Hopefully, future studies will pay more attention to this aspect, and possibly building systems could be generated from residential grouping requirements. A sense of the resulting environment must always be kept in mind, because this industrialization of building components is only a tool, a means to an end, that end being an advancing contribution to the environment.

FOOTNOTES

1. Building Research Council, Adhesives in Building. Partial Proceedings of 1960 Spring Conference. (Washington D. C.: National Research Council, 1960) pp. 78-9.

2. Report To The Building & Construction Trades Department AFL-CIO, The State Of The Art Of Prefabrication In The Construction Industry. (Columbus, Ohio: Report by Battele Memorial Institute, Sept. 29, 1967) p. 133.

APPENDIX A

Graduate Class
Feb. 5-May 24, 1968
Prof. E. Catalano
Prof. W. Zalewski

Housing Systems

The purpose of this project is the study of multi-story housing based on complete systemized design and construction. It will aim at satisfying low middle income families with income up to 8000 dollars a year.
The construction will be approached on entirely industrialized basis and will be based on the following element:

1. Cage: Designed in steel or pre-cast concrete frame, to support the factory made housing units. Fire codes should be considered.

2. Housing units: Modular industrialized units for different family sizes, with or without balconies.

3. Utilities: Study of easy maintenance and operation of central systems, with energy supplied by the building, the urban complex or the city utility plants.

Study Program:

a) Compilation of data of all modular industrialized units built in the country, specially directed to mobile-home construction. Presentation of plans and sections all drawn at the same scale. Description of services provided, materials used, construction and structural details. Cost and areas comparison.

   Presentation to be made in illustration boards, 30"x40" with unified drafting techniques, in black ink.

b) Study of family needs to determine common denominator for design of several modular unit plans. Special study of kitchen modules and equipment and bathrooms. Determination of modules of units affecting the design of the structural supporting cage.

c) Study of the cage.

Being that the housing is multi-story it could be approached on a variety of sizes and heghts.

d) Study of building code (BOCA) regarding fire-proofing requirements and exits, related to materials, height and distances.

e) Study of energy to be used for heating-cooling and general services. Advice outside the department of Architecture should be looked for.

f) Cost study of design proposal and comparison with housing project of similar scope but built with present standard methods.

g) Proposal of construction and erection techniques. Working drawing for cage and structure at modular unit.

h) Presentation:

1) Preliminary studies a) b) c)
2) Design of Housing System -- in illustration boards 30"x40" with ink. Unified drafting techniques to be discussed.
3) Models
4) Photos of model -- 8x10 mounted on boards 30"x40"
5) Report

Minimum number of sheets = design and details: 10

The project could be study as part of a large urban development. In such a case a complete site plan is required, inclusing studies of general community services, and transportation network.
Parking for housing can be considered as part of the overall design concept at a retio not less than 75 cars per 100 units.

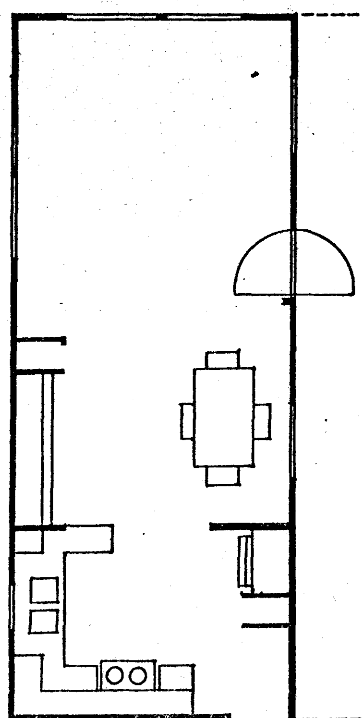
APPENDIX B

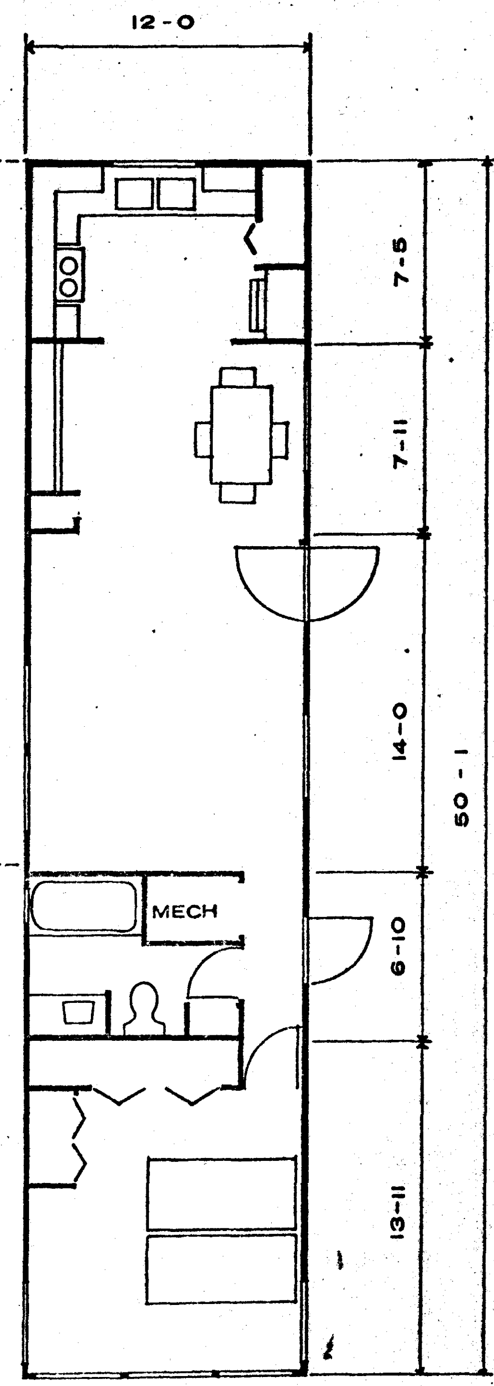
Typical Mobile Home Plans; One Bedroom, Two Bedroom, and Three Bedroom.

Section Drawing Through a Mobile Home.

Exploded Perspective Veiw of a Mobile Home.

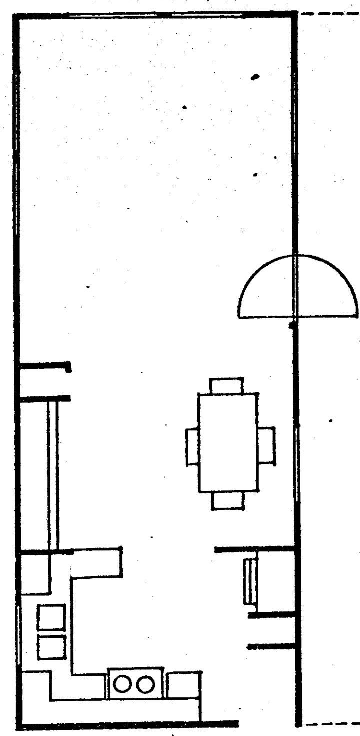
ALTERNATE PLAN



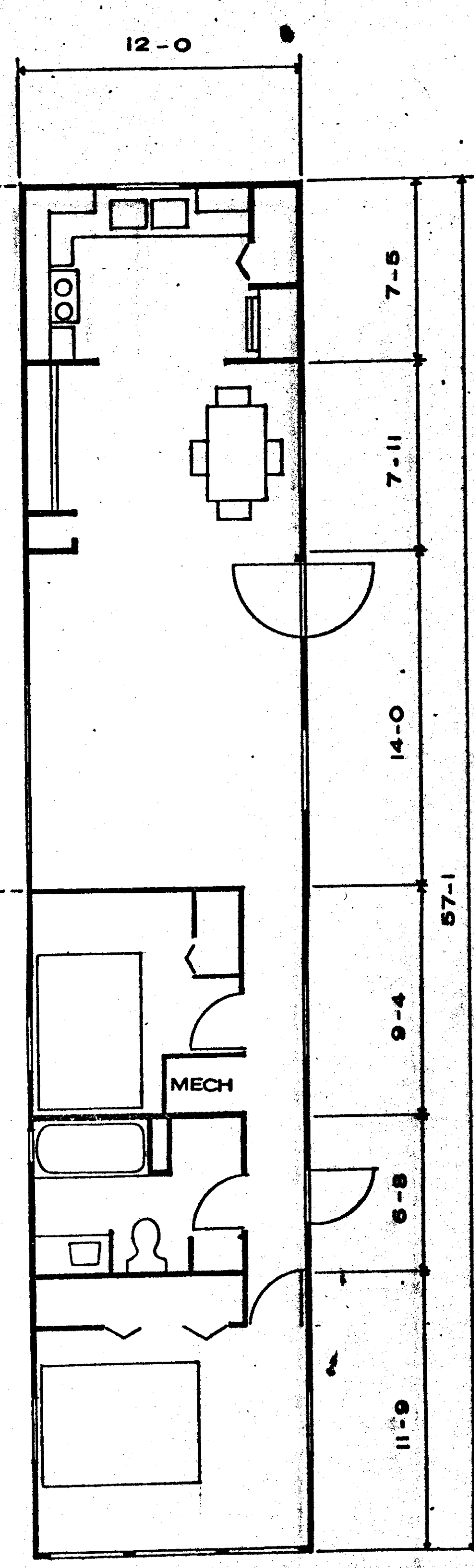


living	186
dining	95
kitchen	80
bedroom	135
bath	40
circulation	25
storage	42
mechanical	15
TOTAL	600 sq.ft.

MOBILE HOME - ONE BEDROOM

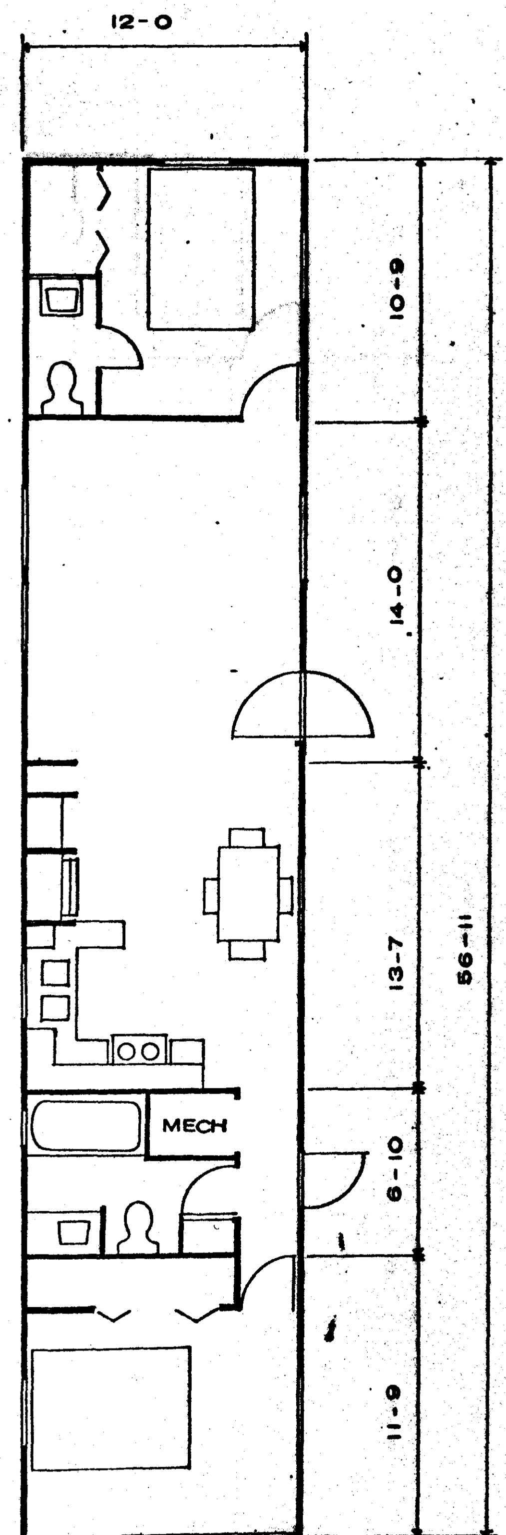


ALTERNATE PLAN



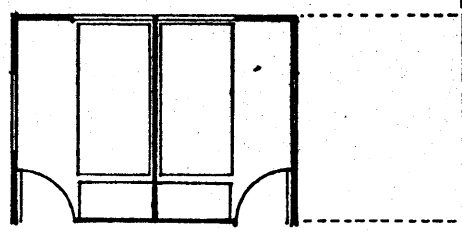
Living	168
Dining	95
Kitchen	89
M.Bedroom	141
Bedroom	81
Bath	64
Circulation	40
Mechanical	9
TOTAL	685 sq.ft.

MOBILE HOME - TWO BEDROOM

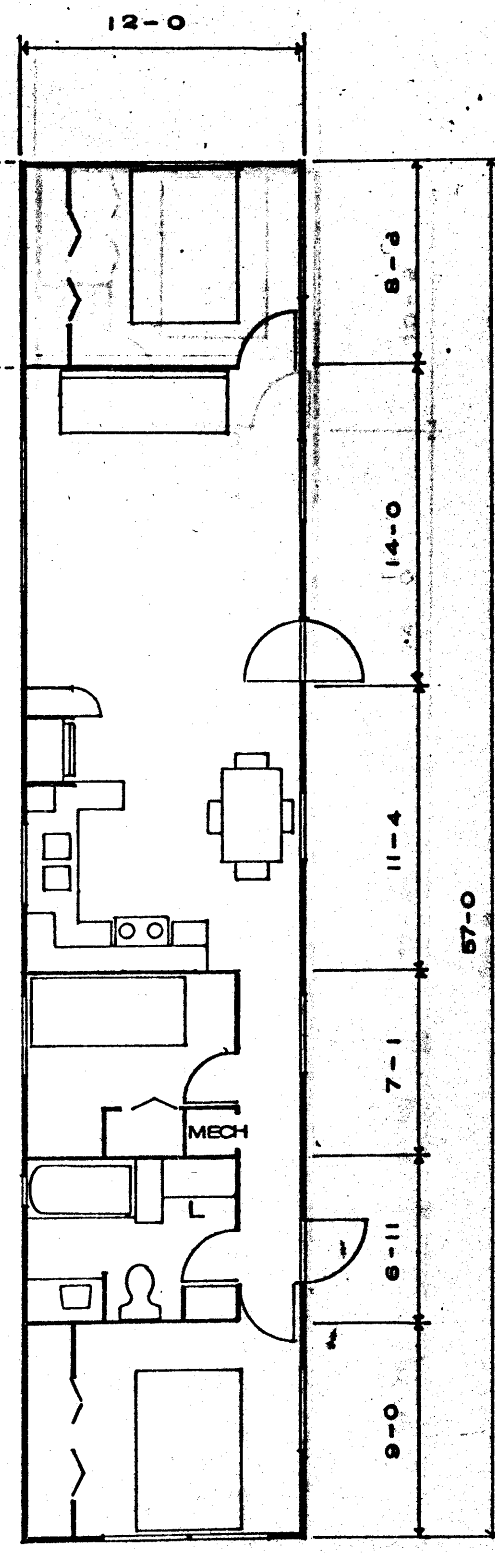


living	160 sq.ft.
kitchen - din.	150
master bedroom	106
bedroom	89
circulation	23
bathroom	59
storage	43
TOTAL	684 sq.ft.

MOBILE HOME - TWO BEDROOM

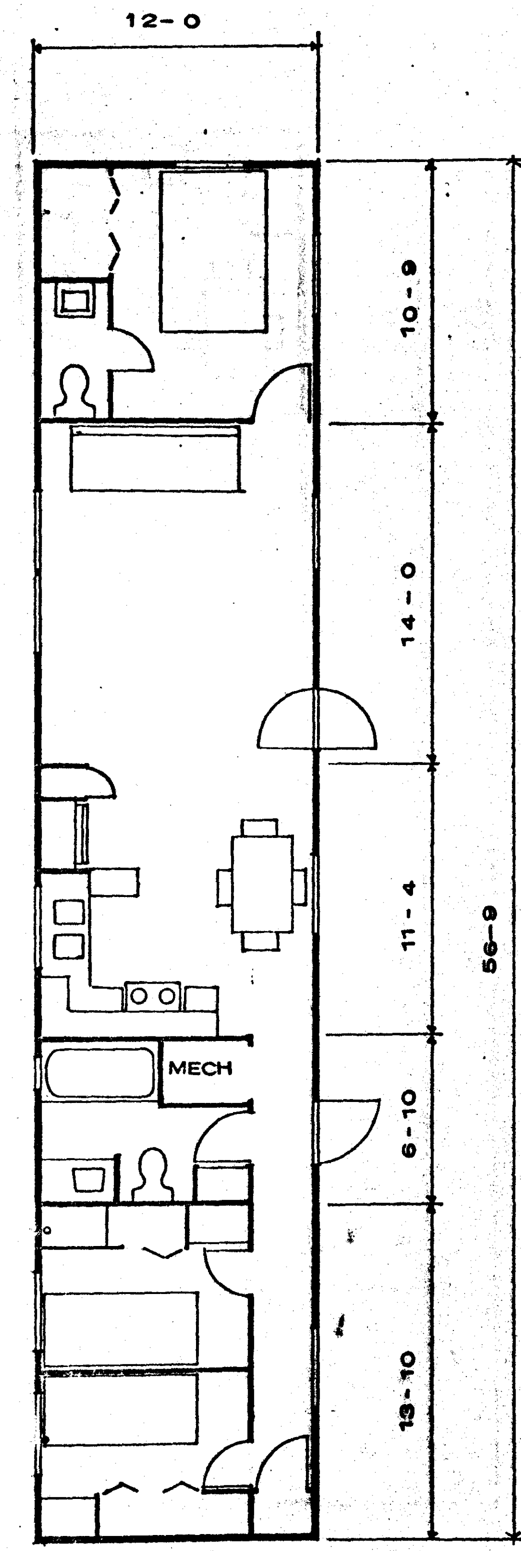


(2) Bedrooms, ea. 52 sq.ft.



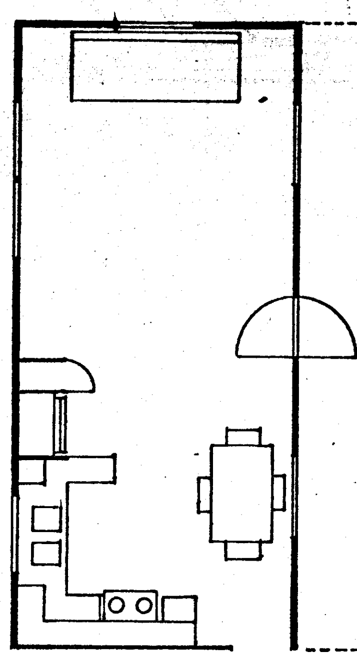
living rm	168
kitchen - dining	136
master bed rm.	108
bed rm.	104
bed rm.	67
bath	66
circulation	35
TOTAL	684 sq.ft.

MOBILE HOME - THREE BEDROOM

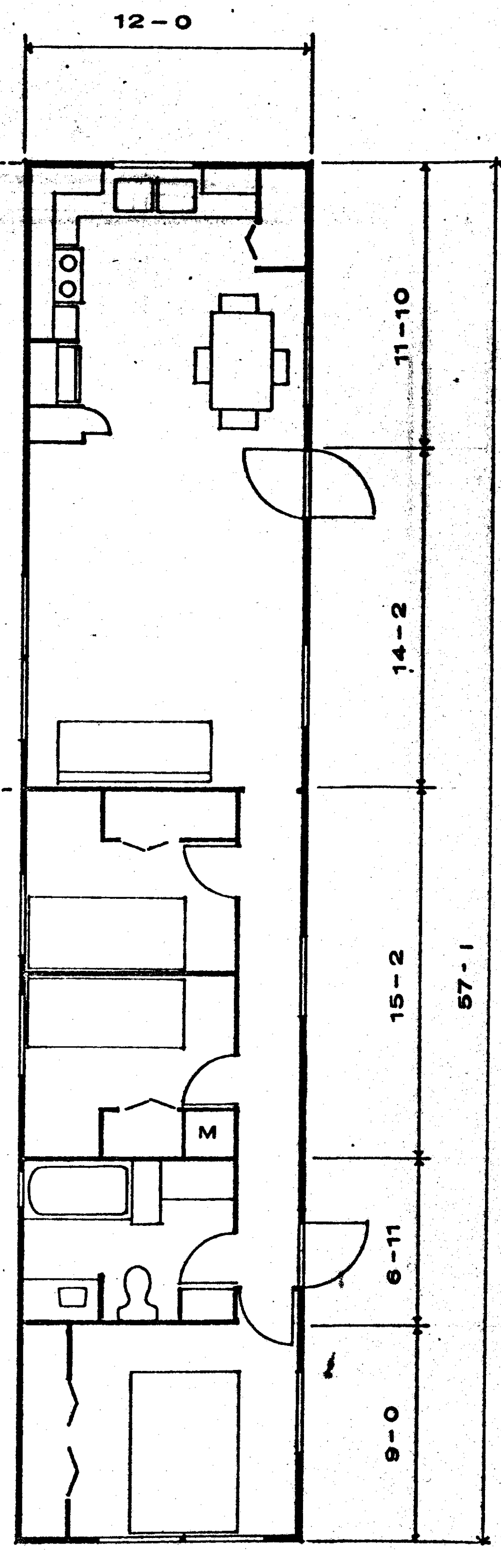


living	168 sq.ft.
kitchen - din.	136
master bedroom	129
bedrooms (2) ea.	67
bath	66
circulation	52
TOTAL	675 sq.ft.

MOBILE HOME - THREE BEDROOM

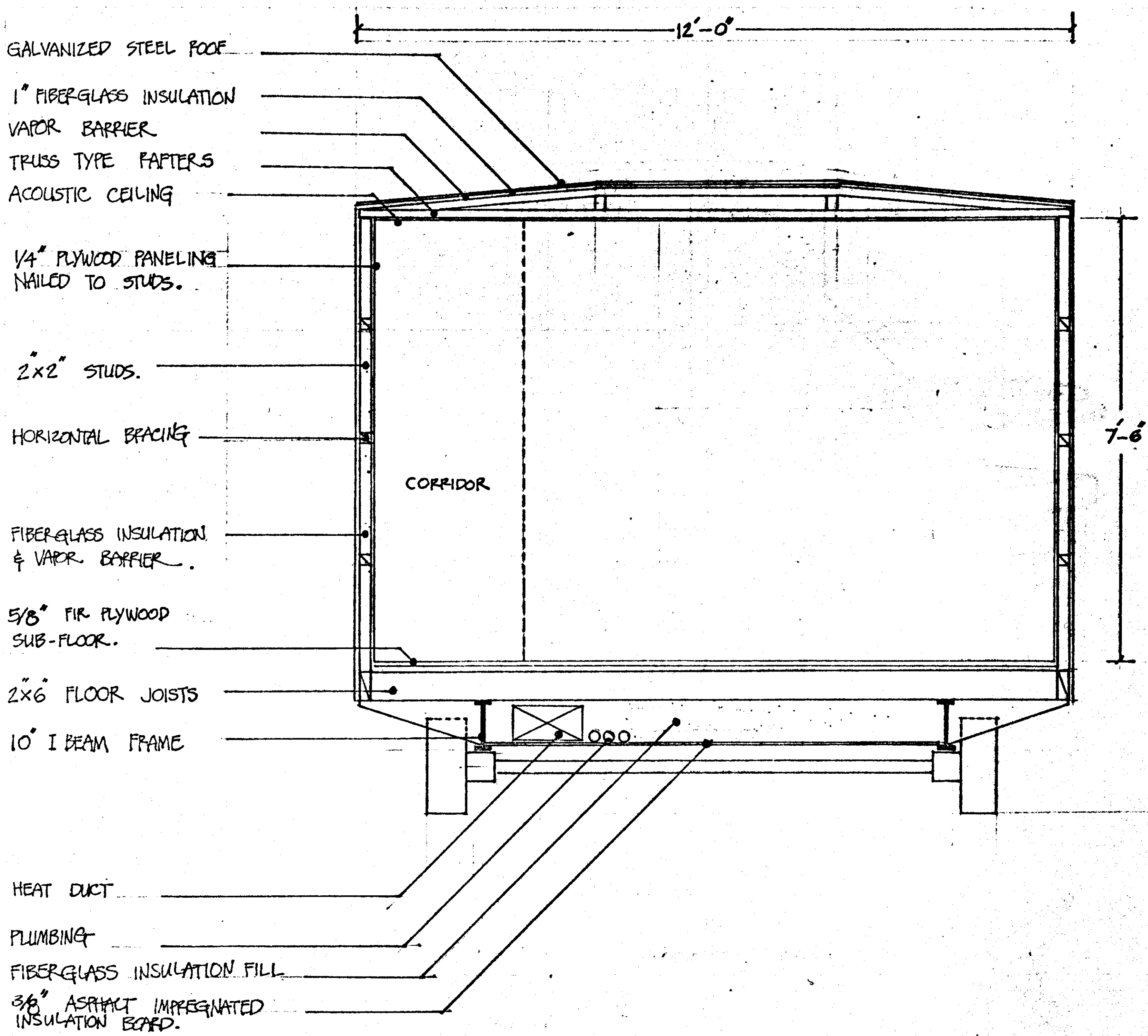


ALTERNATE PLAN

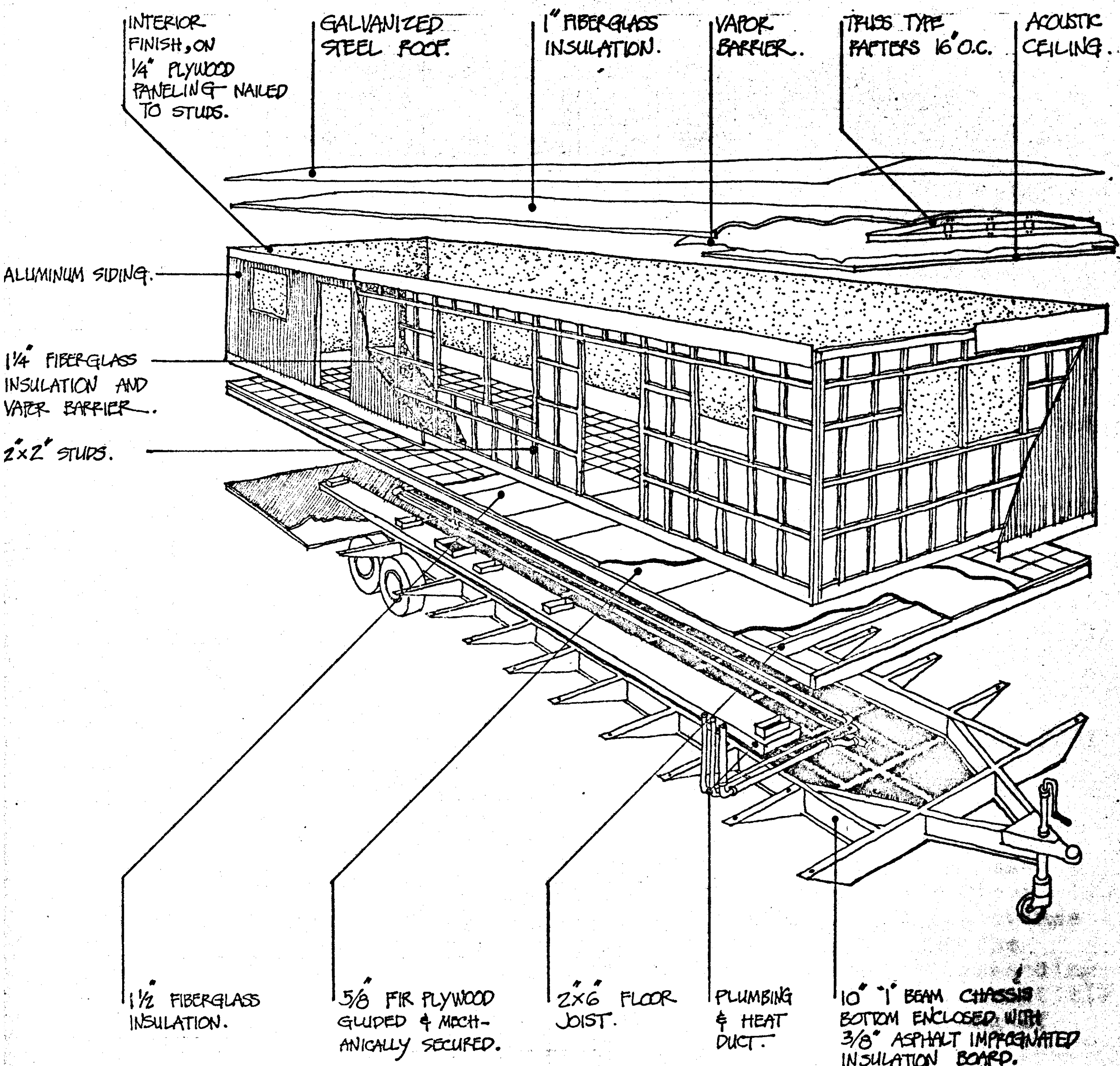


living room	170 sq.ft.
kitchen - din.	142
master bedroom	108
bedrooms (2) ea.	72
bath	66
circulation	55
TOTAL	685 sq.ft.

MOBILE HOME - THREE BEDROOM



SECTION THRU MOBILE HOME @ 3/8" - 1'-0"



EXPLODED PERSPECTIVE VIEW OF MOBILE HOME

APPENDIX C

National Building Code 1967

Section 316 - Multifamily Houses
Section 401 - Height and Area Restrictions
Section 601 - General (Means of Egress)
Section 602 - Number of Exits and Doorways
Section 603 - Location of Means of Egress
Section 604 - Interior Stairways
Section 700 - Classification of Construction
Section 702 - Fire Resistive Construction-Type A
Section 703 - Fire Resistive Construction-Type B
Section 704 - Protected Noncombustible Construction

Building materials and construction details which will satisfy fire resistive construction requirements of National Building Code are found in the Underwriters Laboratory, Inc. (Building Materials List), 1965.

Section 316:

Multifamily Houses (65 ft. or 6 stories for ordinary construction -Sec.707)

-first floor fire resistance rating of two hours.

-or if first floor is of noncombustible material place on the ground and other floor and ceiling assemblies have a fire resistance rating of not less than one hour, and the floors are subdivided into areas not exceeding 3,500 sq. ft. , by partitions of noncombustible material having a fire resistance rating of not less than 2-hours.

Section 601:

General (Means of Egress)

-gross area per occupant 125 sq. ft.

Section 602:

Number of Exit Ways and Doorways

-every story used as a residential occupancy for 10 or more occupants and every story in a multifamily house having one or more dwelling units above the second story shall have not less than two separate exit ways; except that a single exit way is permitted for multifamily houses of fire resistive construction not exceeding two stories in height and containing not more than 12 dwelling units, or of heavy timber,non-combustible or ordinary construction not exceeding two stories in height and containing not more than 8 dwelling units.

Section 603:

Location of Means of Egress

-100 ft. for residential

-where a floor is subdivided into smaller areas such as rooms in hotels, multifamily house, and office buildings, the distance to an exit doorway shall be measured from the corridor entrance of such rooms.

Section 604:

Interior Stairways

-elevators shall not constitute part of a required exit way for 45 or more occupants or any story it serves shall be not less than 44 inches. The unobstructed width of a stairway in a required exit way for less than 45 occupants on each story it serves shall be not less than 36 inches. Handrails attached to walls may project into the required width of a stairway not more than 3½ inches at each side.

-the unit of stairway width used as a measure of exit capacity shall be 22 inches. Fractions of a unit shall not be included except that an allowable of one-half may be made for 12 inches of stair width added to one or more 22-inch unit of stair width.

-the aggregate width of exit stairways serving any story shall be based on the number of occupants of that story.(125 sq. ft. per occupant for residential).

-number of occupants per story per unit of exit stair width (22") is for residential occupancy.

Section 702

<u>Fire-resistive Construction-Type A</u> (From Sec. 401 no height limit, no area limit.)

-columns and piers - 4 hours

-floors - 3 hours

-roof - 2 hours

-girders and beams supporting one floor 3 hours

-girders and beams supporting more than one floors - 4 hours

-interior bearing walls - 4 hours

-interior walls (noncombustible)

-exterior walls (0 to 3 hours depending on spacing and percentage of window to wall Table 702.6)

-interior partitions enclosing elevator shafts and stairways - 2 hours for more than 4 stories (1 hour for less)

Section 703:

<u>Fire-resistive Construction-Type B</u> (From Sec.401 85 ft. height limit, no area limit)

- -columns and piers - 3 hours
- -floors - 2 hours
- -roof - $1\frac{1}{2}$ hours
- -beams, girders and trusses supporting one floor or roof - 2 hours
- -beams, girders and trusses supporting more than one floor - 3 hours
- -interior bearing walls - 3 hours
- -interior walls noncombustible
- -exterior walls (0 to 3 hours depending on spacing and % of window to wall - Table 703.6)
- -interior partitions enclosing elevator shafts and stairways - 2 hours for more than 4 stories (one hour for less)
- -fire retardive treated lumber may be used for partitions located entirely within the dwelling unit or used to separate dwelling units only.

(Buildings of fire resistive-type B construction may be of unlimited height provided those portions of building above 85 ft. are used for business or residential occupansies.)

Section 704:

<u>Protected Noncombustible Construction</u> (75 ft. height limit, 12,000 sq. ft. area limit -Sec. 401)

- -all structural members shall be of noncombustible material with fire rating of one hour

-interior bearing walls - 2 hours

-exterior walls (0 to 3 hours depending on spacing and % of window to wall - Table 704.4)

-elevator shafts and stairways - 2 hours for more than four stories, 1-hour for less than four stories

-all other permanent partitions - 1 hour (see details for type A&B construction)

APPENDIX D

The following is from the State of Illinois, Bureau of Traffic Codes, Article III Sec. 7-303.

Permit Regulations for Oversize and Overweight Movement.

Width Range	Maximum Distance
8'-0" to 10'-0"	Unlimited
10'-1" to 12'-0"	25 miles
12'-1" to 14'-0"	15 miles
14'-1" to 18'-0"	10 miles
18'-1" to 20'-0"	8 miles
20'-1" to 24'-0"	5 miles
24'-1" to 30'-0"	3 miles
30'-1" to 34'-0"	2 miles
over 34'-0"	½ mile

APPENDIX E

Comparative Area Study, Harvard University, 1958.

Unit Area (U): Habitable space excluding circulation, bath, storage, and exterior space.

Gross Area(G): Total square footage excluding exterior space and public building circulation and service.

EFF.		1-BR.		2-BR.		3-BR.	
U	G	U	G	U	G	U	G
386	532	300	380	530	684	625	727
354	462	440	634	434	473	768	980
446	560	468	580	551	840	854	1288
476	600	686	845	608	870	883	1156
240	360	768	930	763	970	780	1260
246	288	555	660	585	774	732	1260
388	544	435	625	820	1090	755	1152
		494	642	663	850	735	1152
		440	762	867	1140	613	972
		533	857	753	984	621	960
		423	777	488	707	661	1000
		360	555	552	830	764	1152
		315	476	522	889	638	850
		538	759	820	1160	717	1059
				684	1260	960	1330
				491	740	736	1048
				926	1200	707	1100
				493	740	632	900
				619	805	1174	1640
				564	890	887	1260
				771	1130		
				520	810		
				557	765		
				687	893		
Average Square Foorages.							
362	478	482	670	636	896	763	1112
Percentage of Bath, Storage, and Circulation.							
25%		27%		29%		31%	
Recommended Square Footage for Low Cost Housing.							
300	400	448	600	568	800	690	1000

APPENDIX F

Comparison of Unit Systems

Project	Dimensions	Area	Weight (Dead Load)
Habitat	17'-6x38'-6" x10'-0" high	673.75	90 tons
Hilton Palacio del Rio Hotel; San Antonio, Texas	32'-8"x13'-0" x9'-0"; 29'-8"x13'-0" x9'-0"	424.58	37 tons
Presented system	12'-0"x55'-0" x9'-0" 8'-0" floor to ceiling height	660	22 tons
Russian Box System (cement asbestos shells)	18'-4"x9'-2" x9'-2"	168.1	13 tons
Mobile Home	12"x57'-0"x10' 7'-6" floor to ceiling height	684	18 tons

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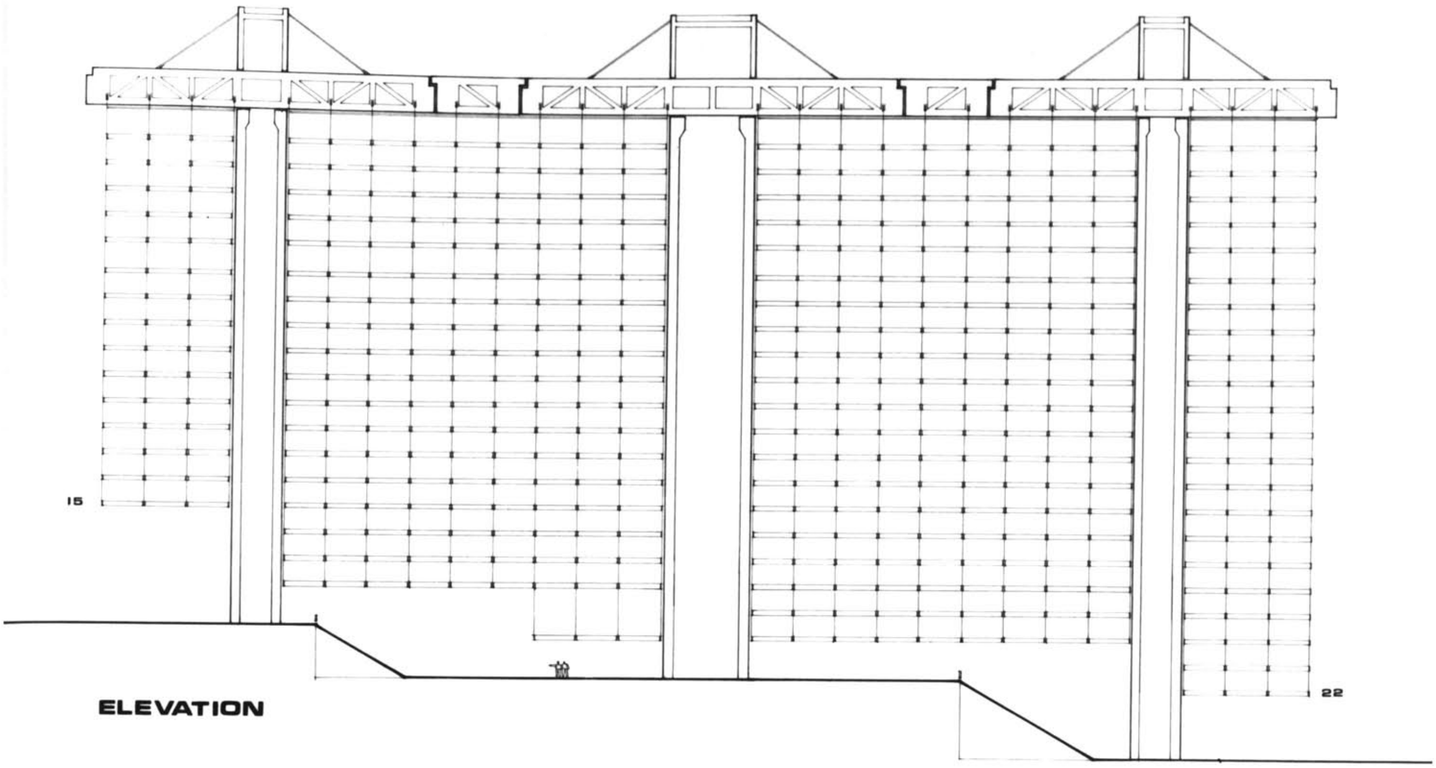
Tavelo Mobile Homes, Saginnaw, Michigan.

Vagabond Mobile Homes, Brighton, Michigan.



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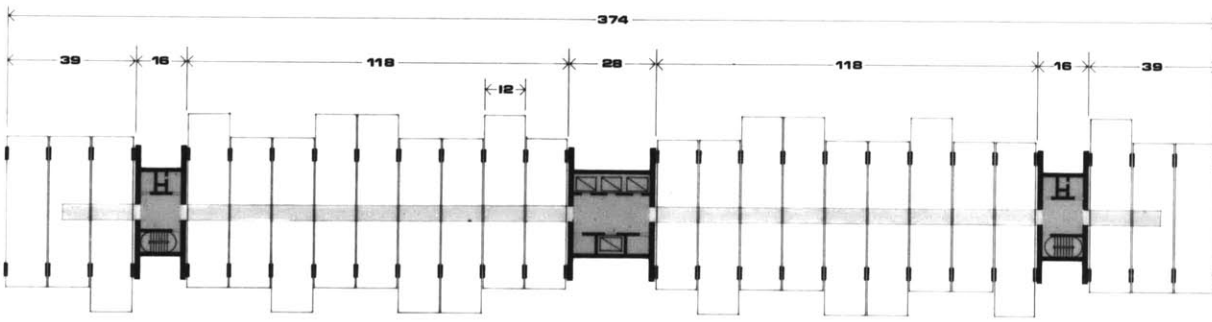

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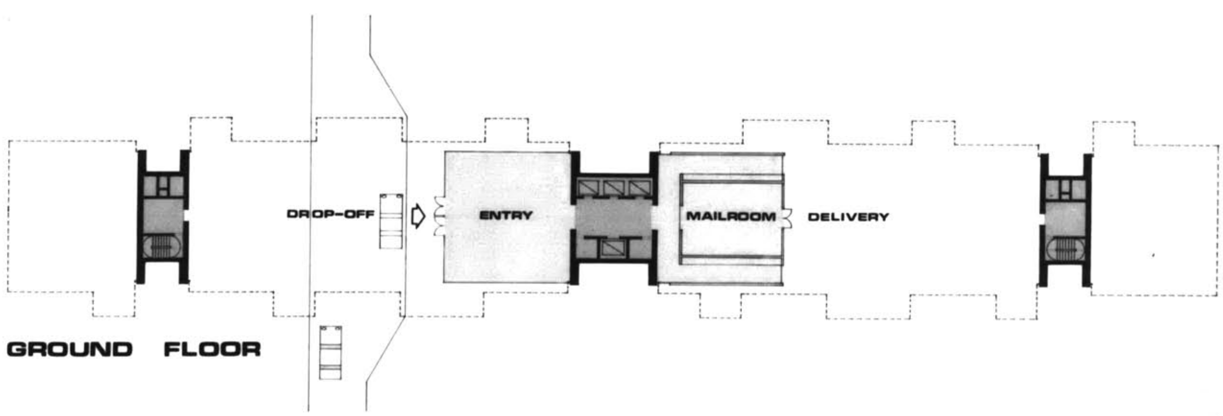

GROUND FLOOR

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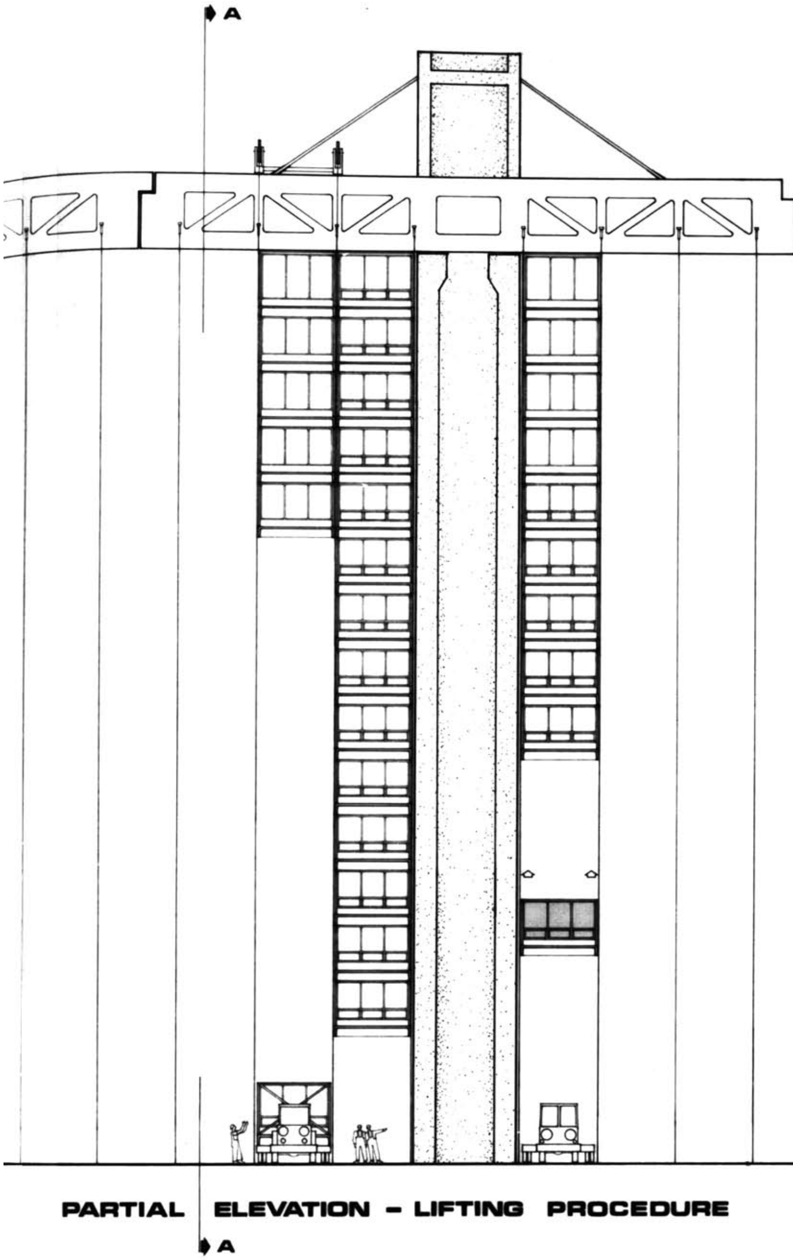

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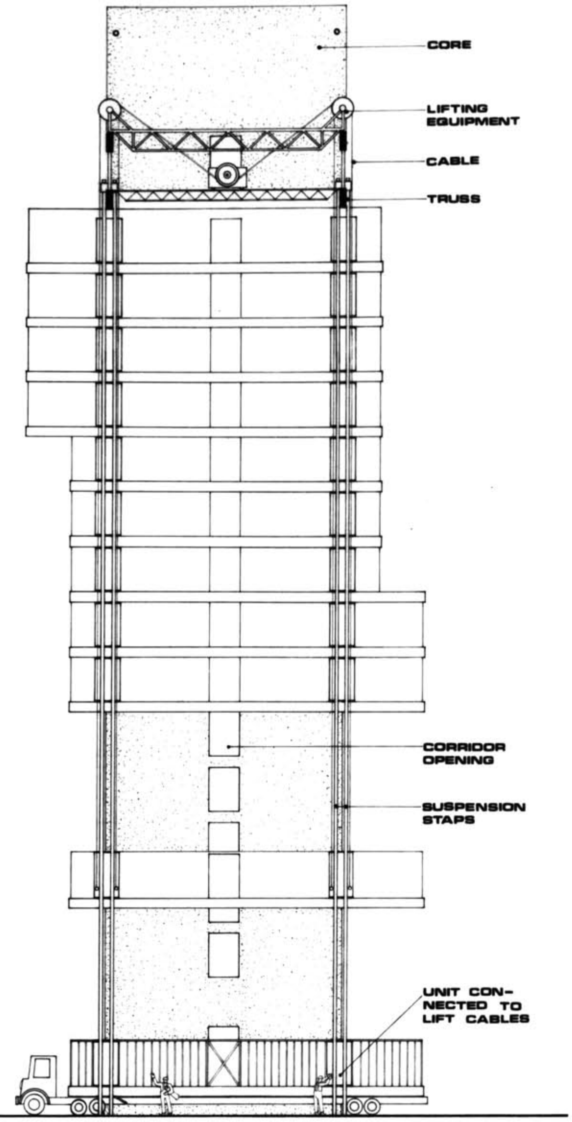

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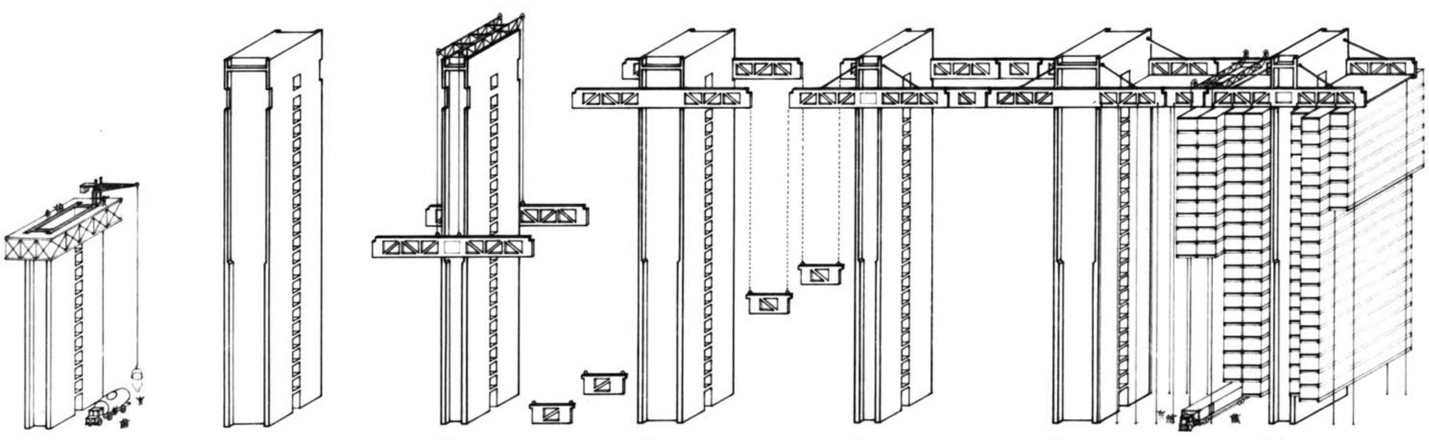

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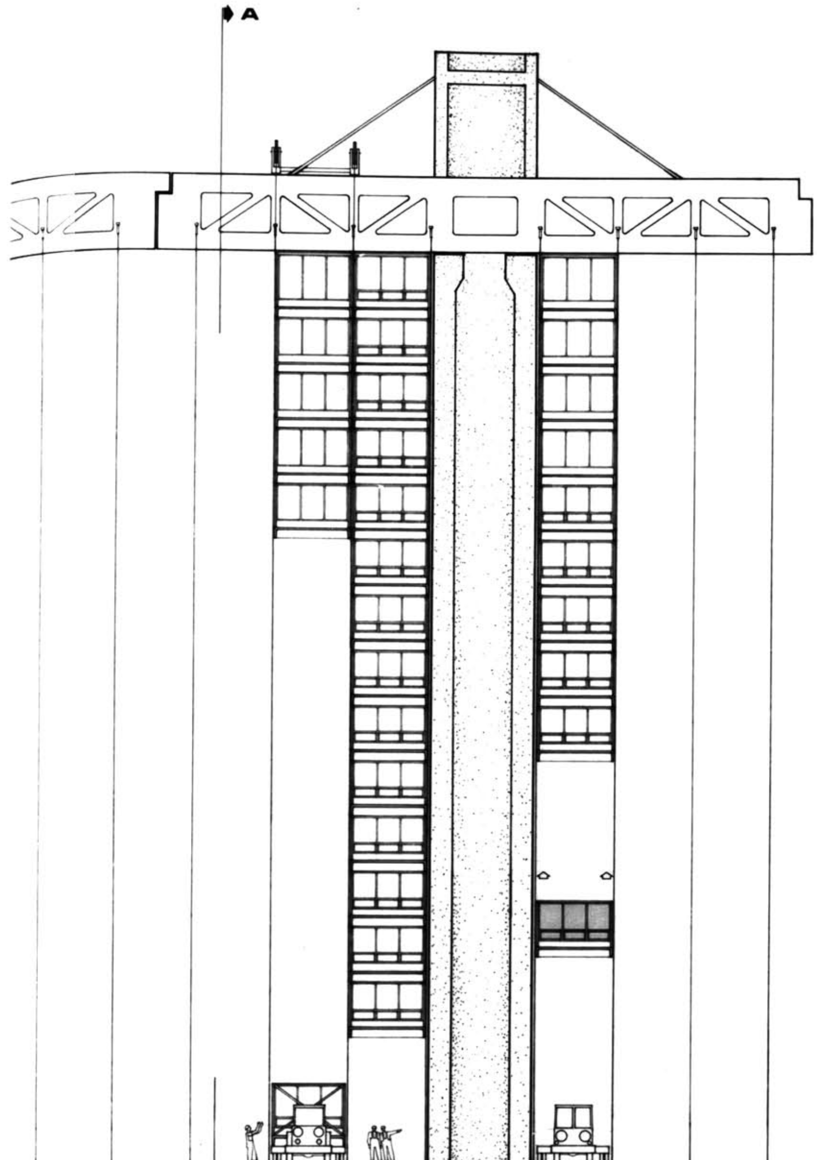

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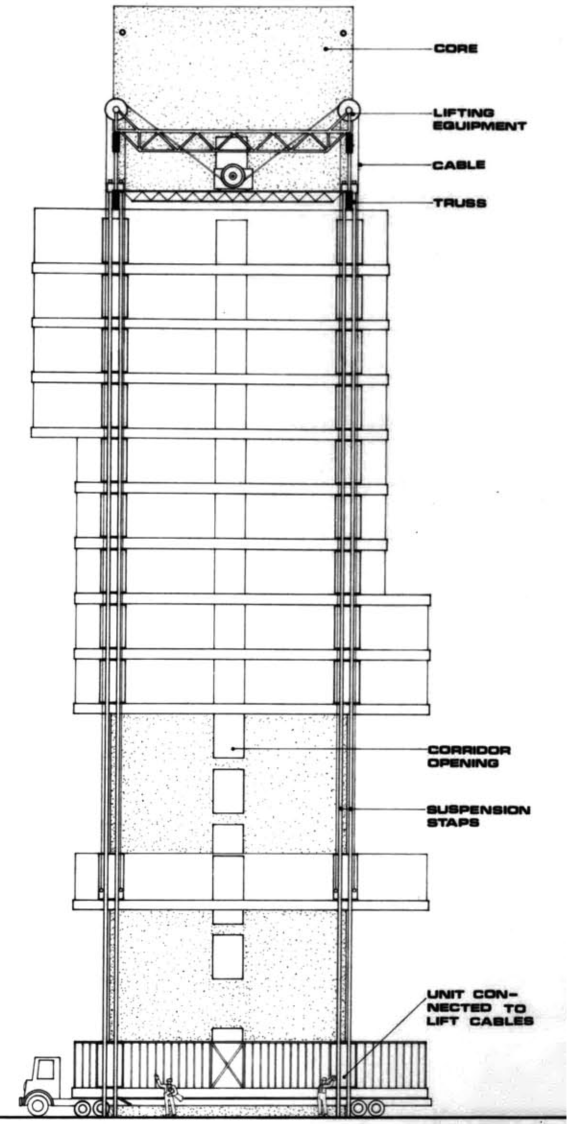

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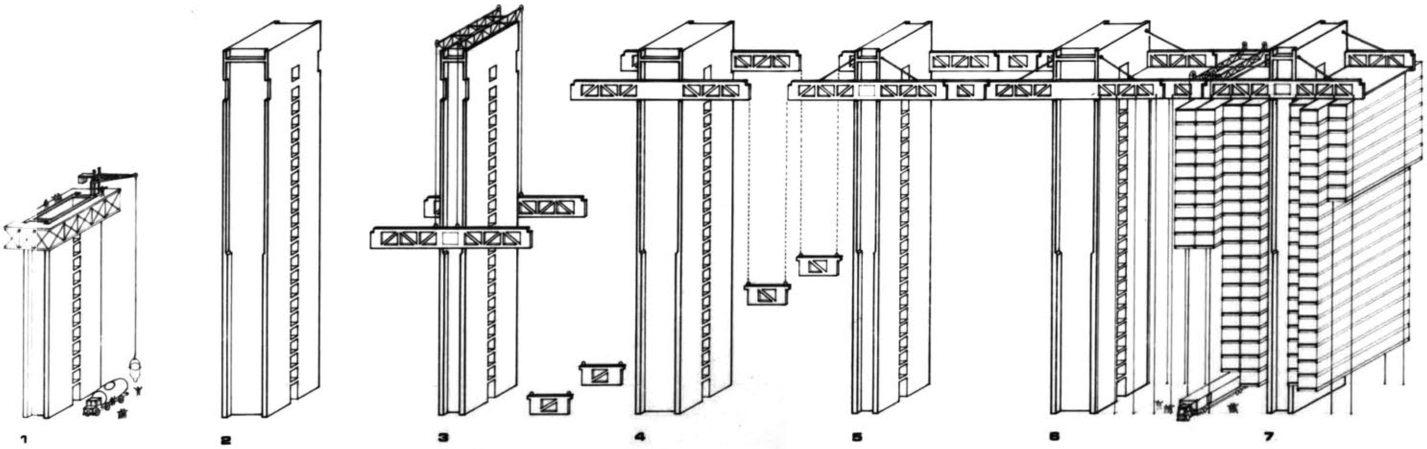

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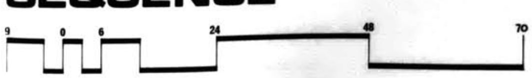

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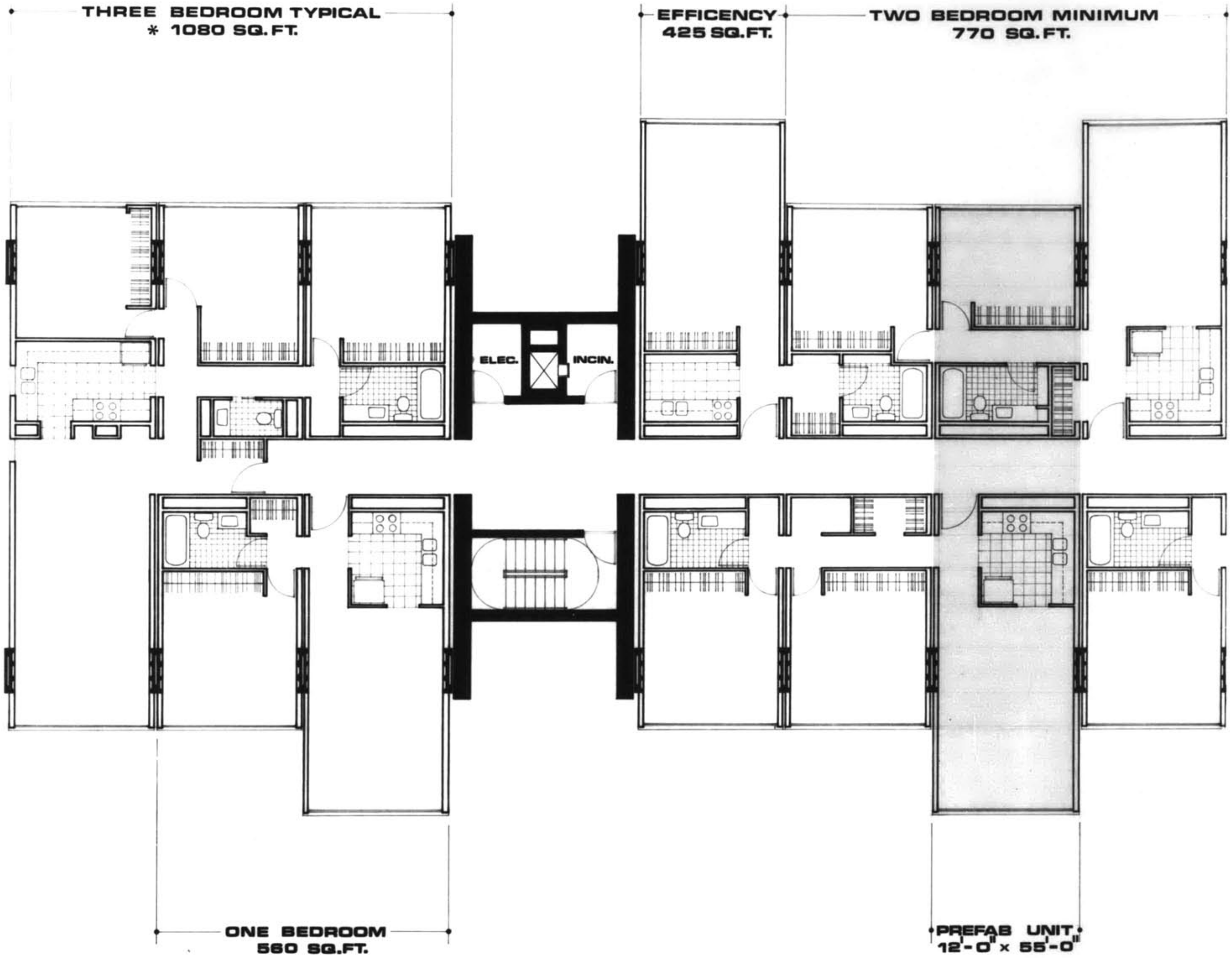

* ALL GIVEN SQ. FT. ARE GROSS AREAS

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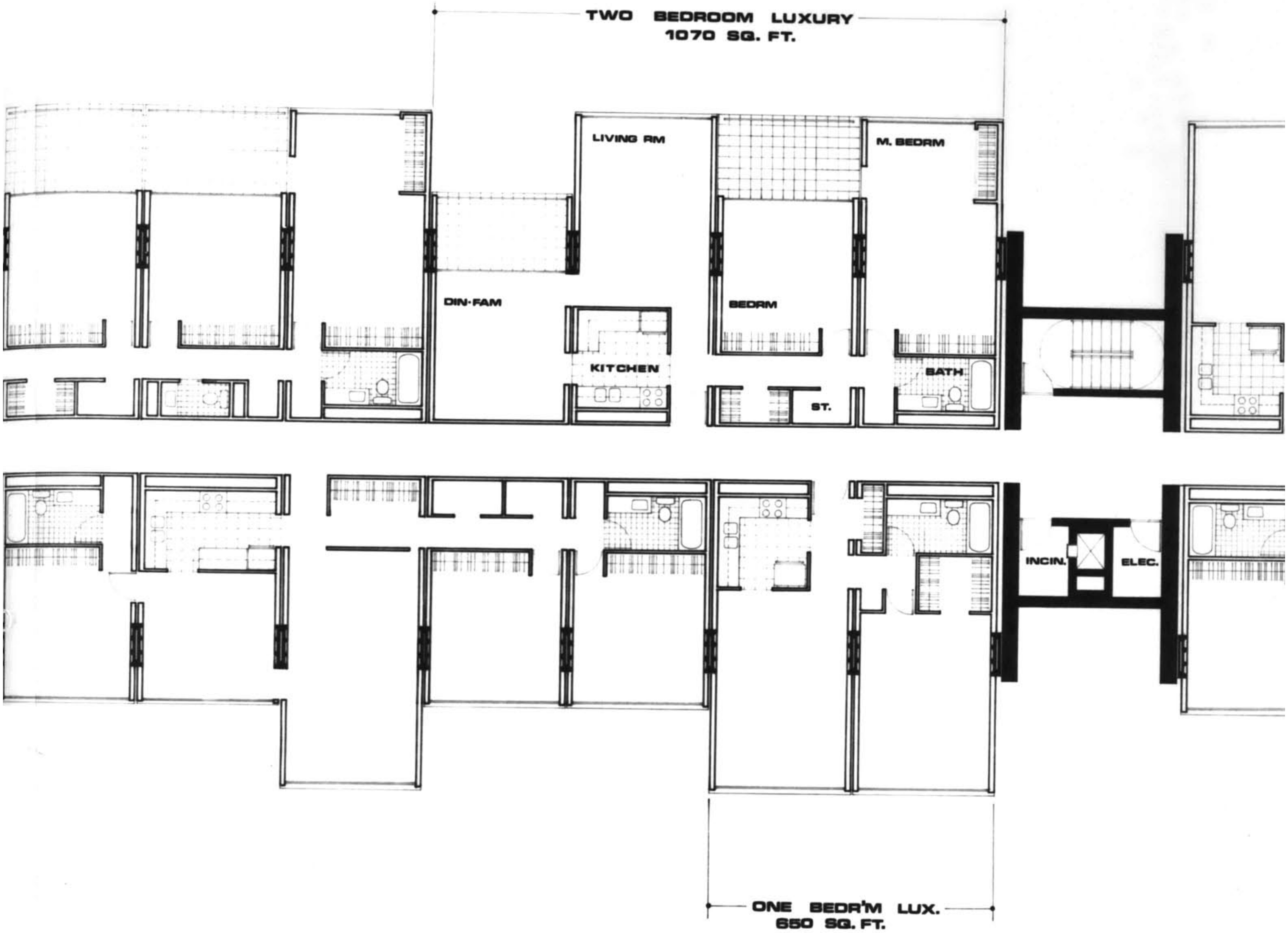

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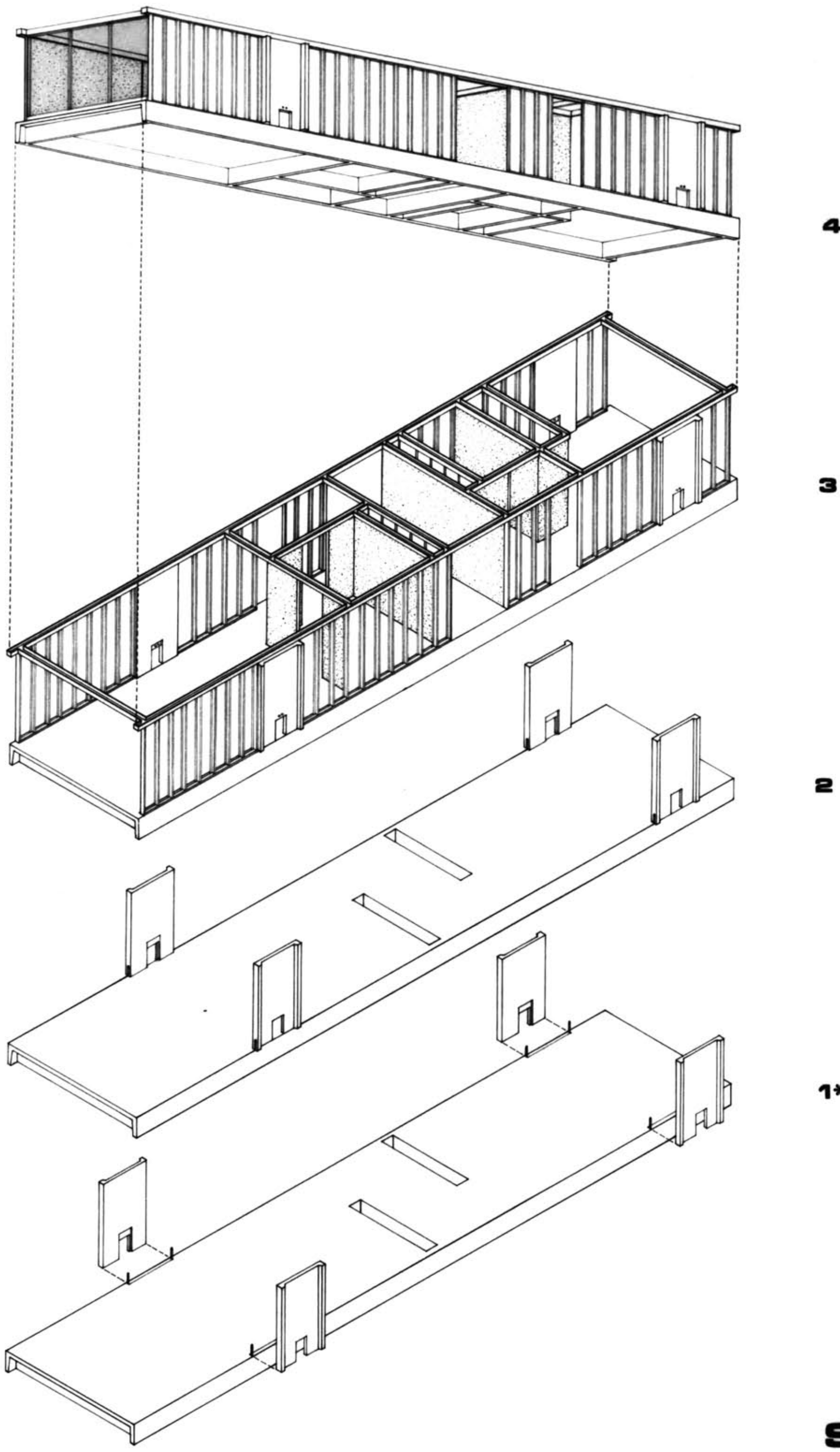

SCHEME A

* FABRICATION PROCEDURE SIMILAR TO SCHEME - B

UNIT FABRICATION SEQUENCE scheme A

1 0 3 9 18 36

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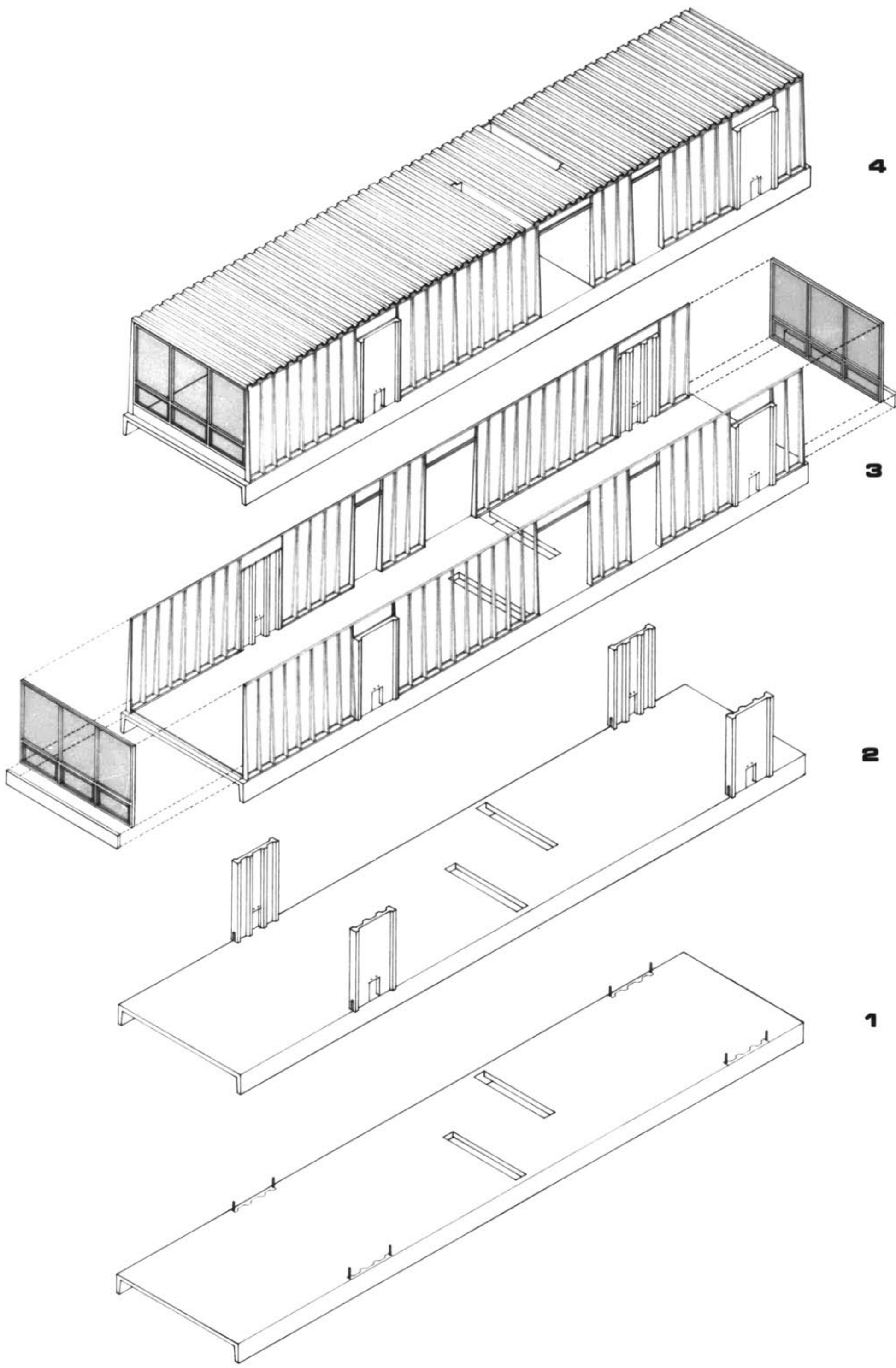

4 CORRUGATED METAL DECK ATTACHED TO CEILING RUNNERS.

PLUMBING AND WIRING.

DOOR BUCKS & WINDOW FRAMES SET IN.

UNIT PAINTED, CARPETED AND READY FOR SHIPMENT.

3 METAL RUNNERS ATTACHED TO CONCRET FLOOR SLAB.

EXTERIOR & INTERIOR WALL PANELS ARE PREPARED IN STANDARD SIZE JIGS WITH GYPSUM ON METAL AND ARE SET ONTO THE FLOOR RUNNERS.

KITCHEN AND BATH FIXTURES SET IN.

2 PRECAST WALL PANELS WELDED TO THE SLAB.

1 STRUCTURAL SLAB & PANELS CAST IN CASTING BEDS & MOVED TO ASSEMBLY SHOP.

SCHEME B

UNIT FABRICATION SEQUENCE scheme B

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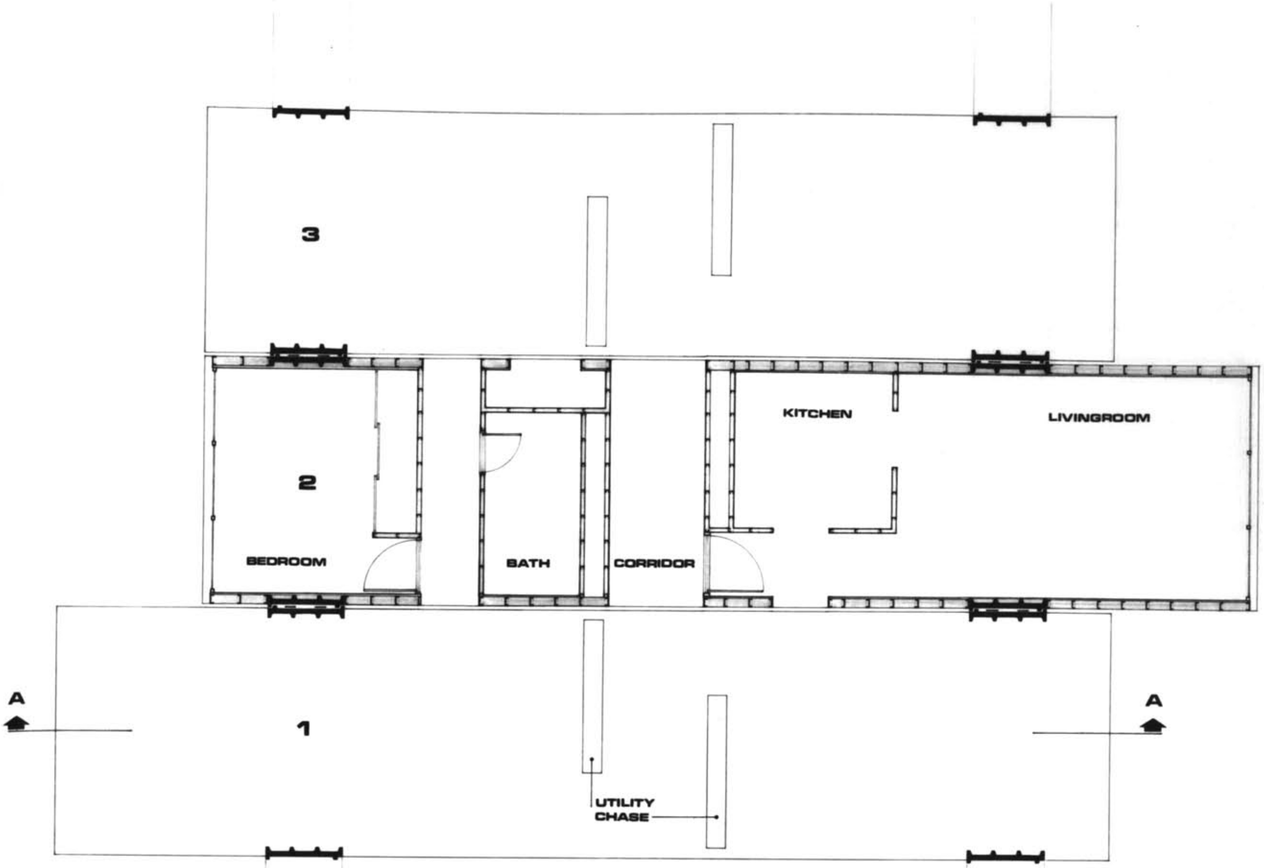

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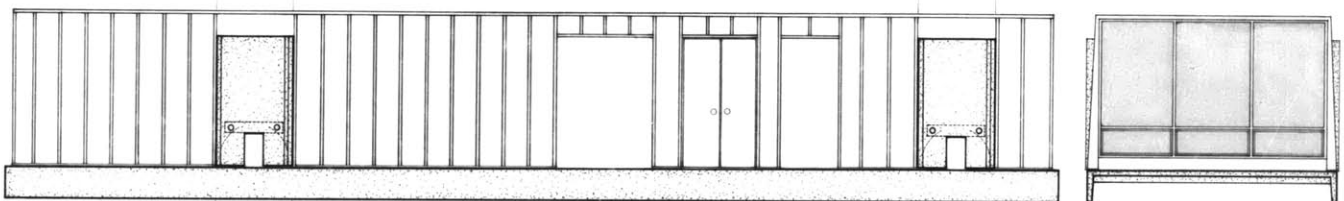

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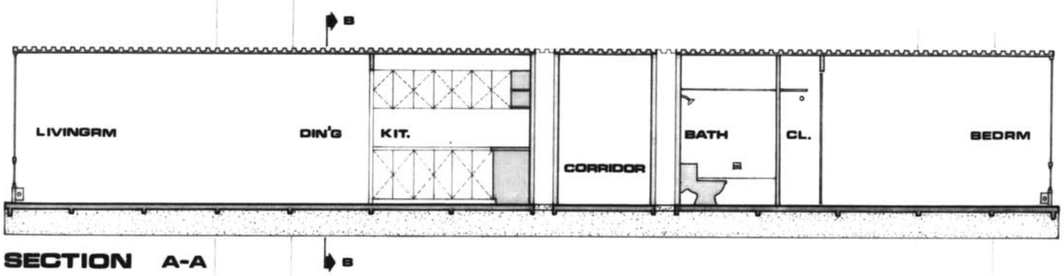

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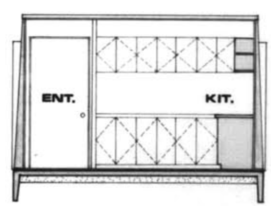

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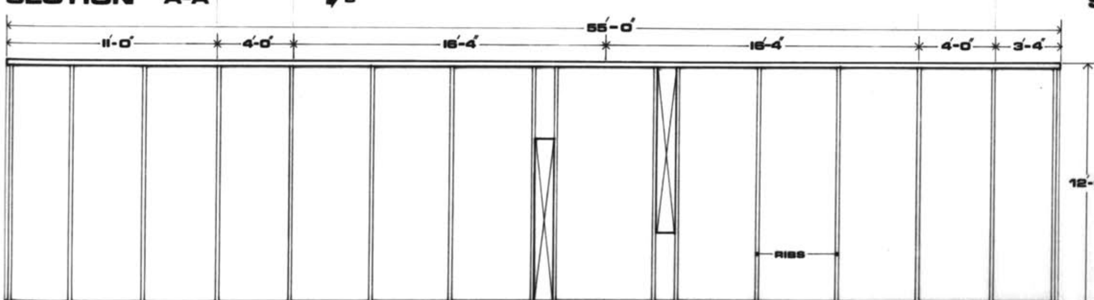
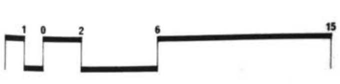


REFLECTED SLAB PLAN

UNIT DETAILS



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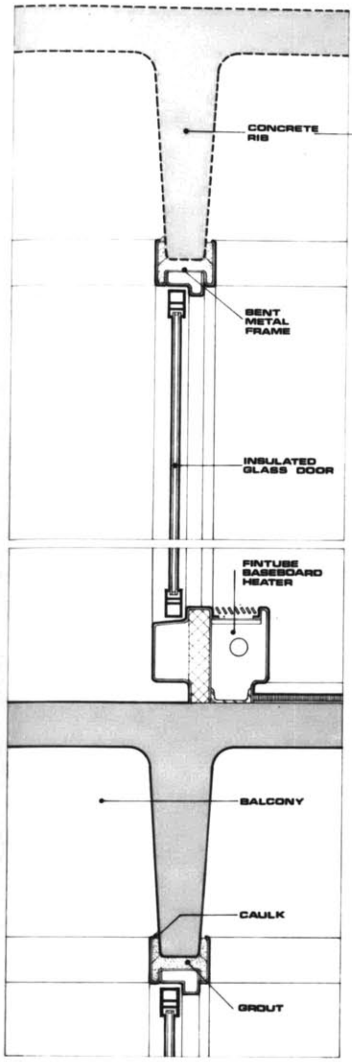

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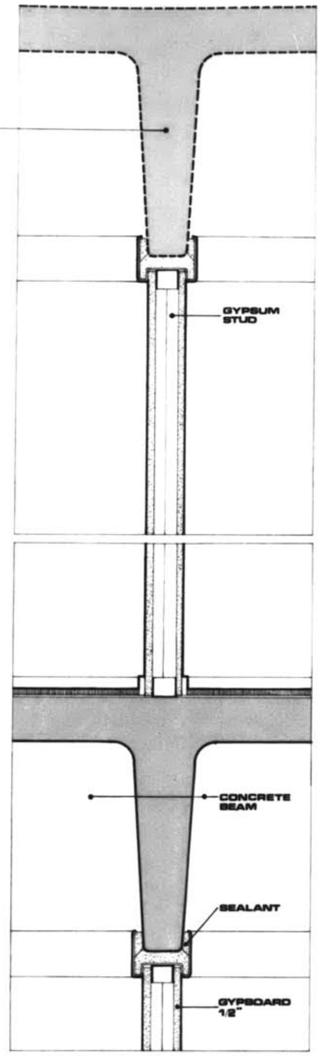

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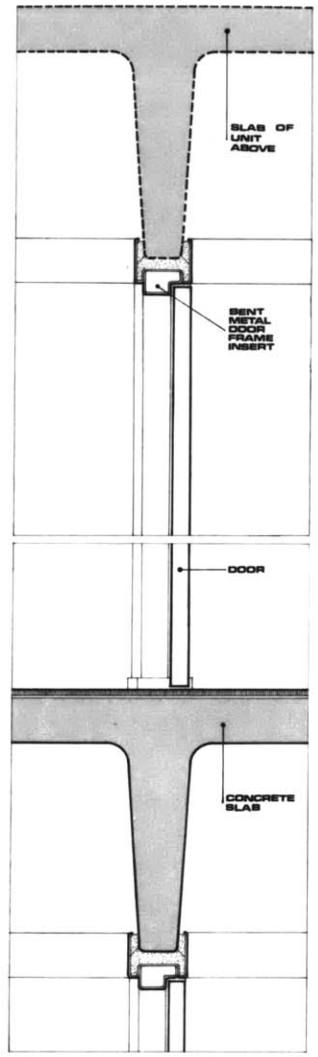

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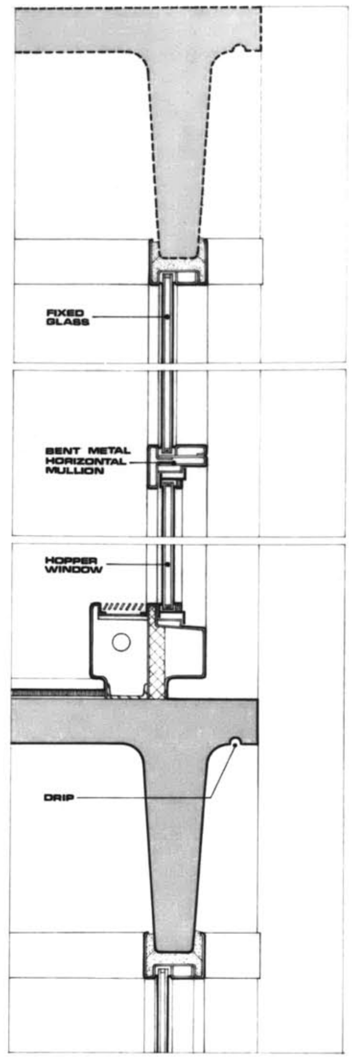

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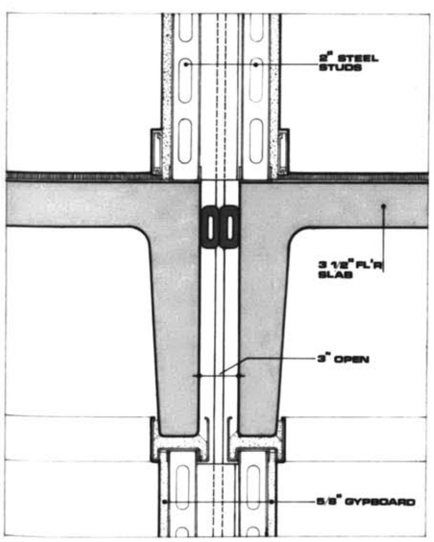

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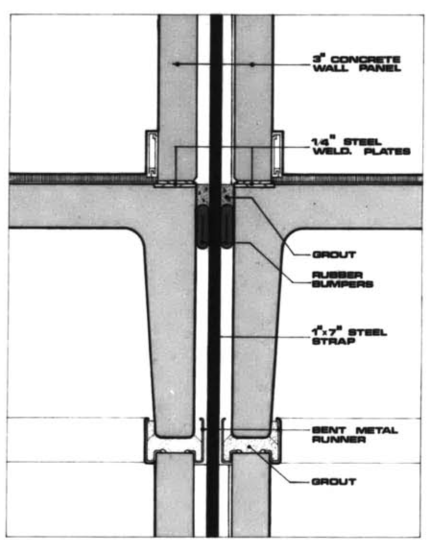

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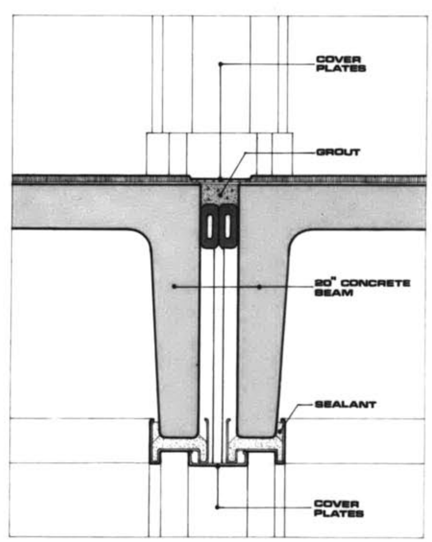
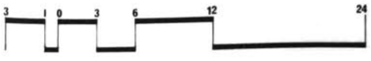


3. SIDE OPENING

UNIT DETAILS

SCHEME A



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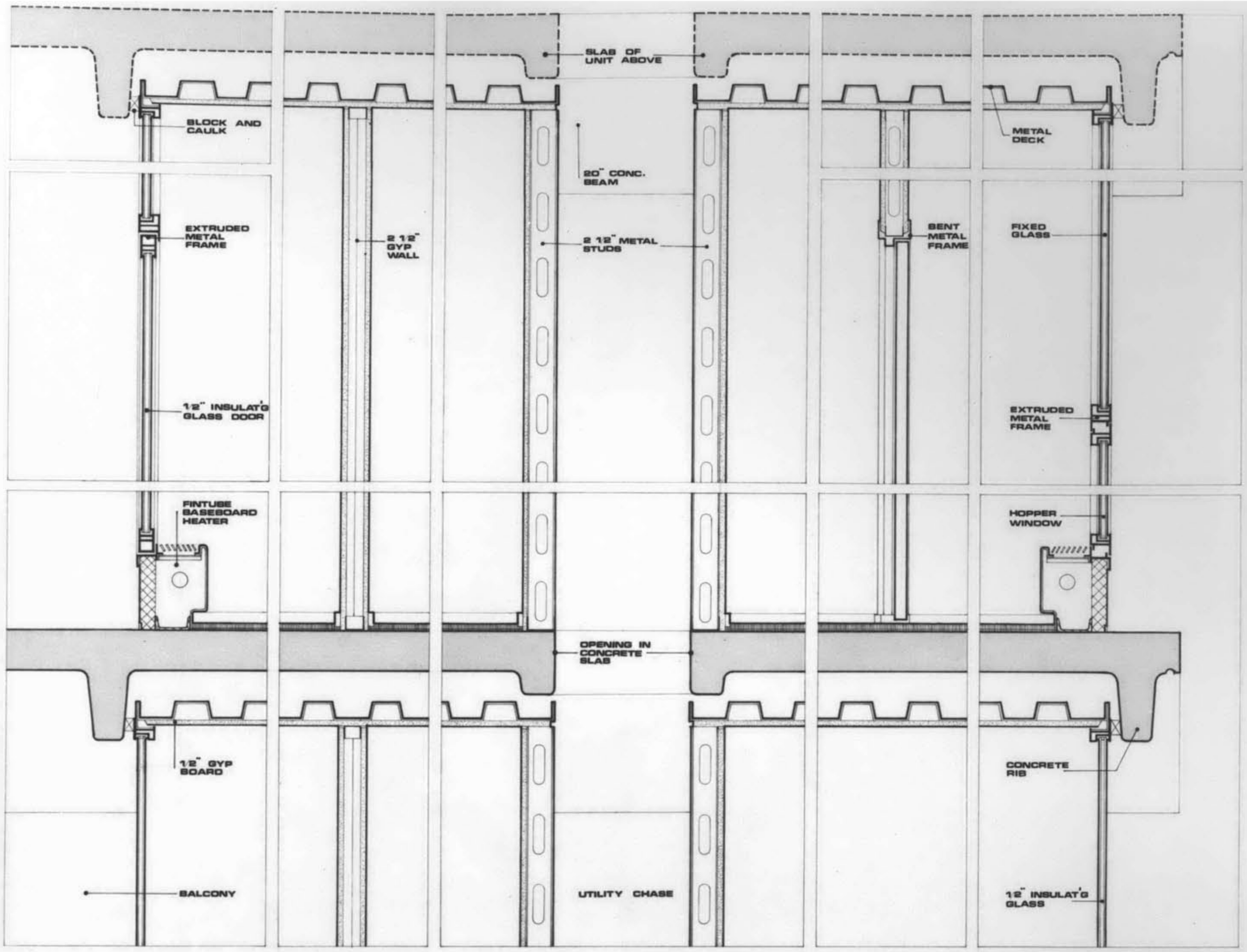
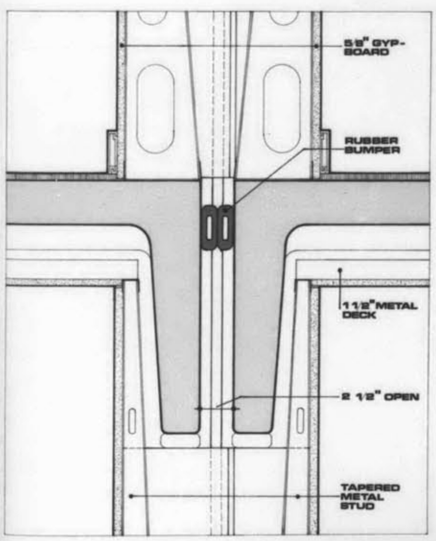


4. END WALL **5. PARTITION** **6. DOOR** **7. END WALL**



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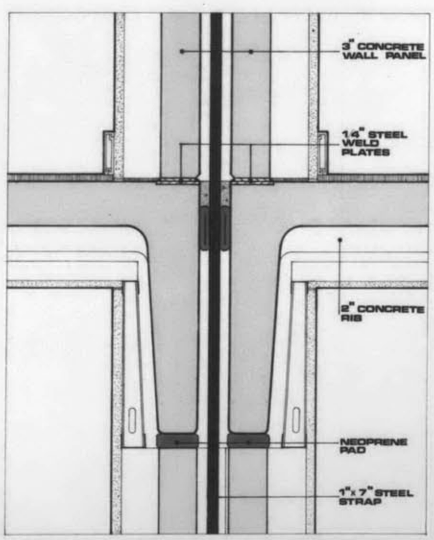

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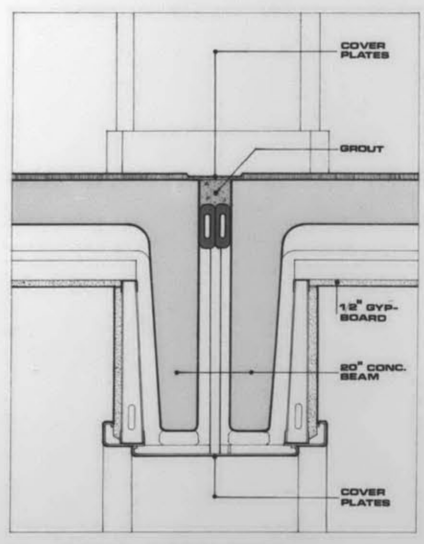
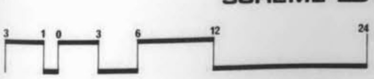


3. SIDE OPENING

UNIT DETAILS

SCHEME B



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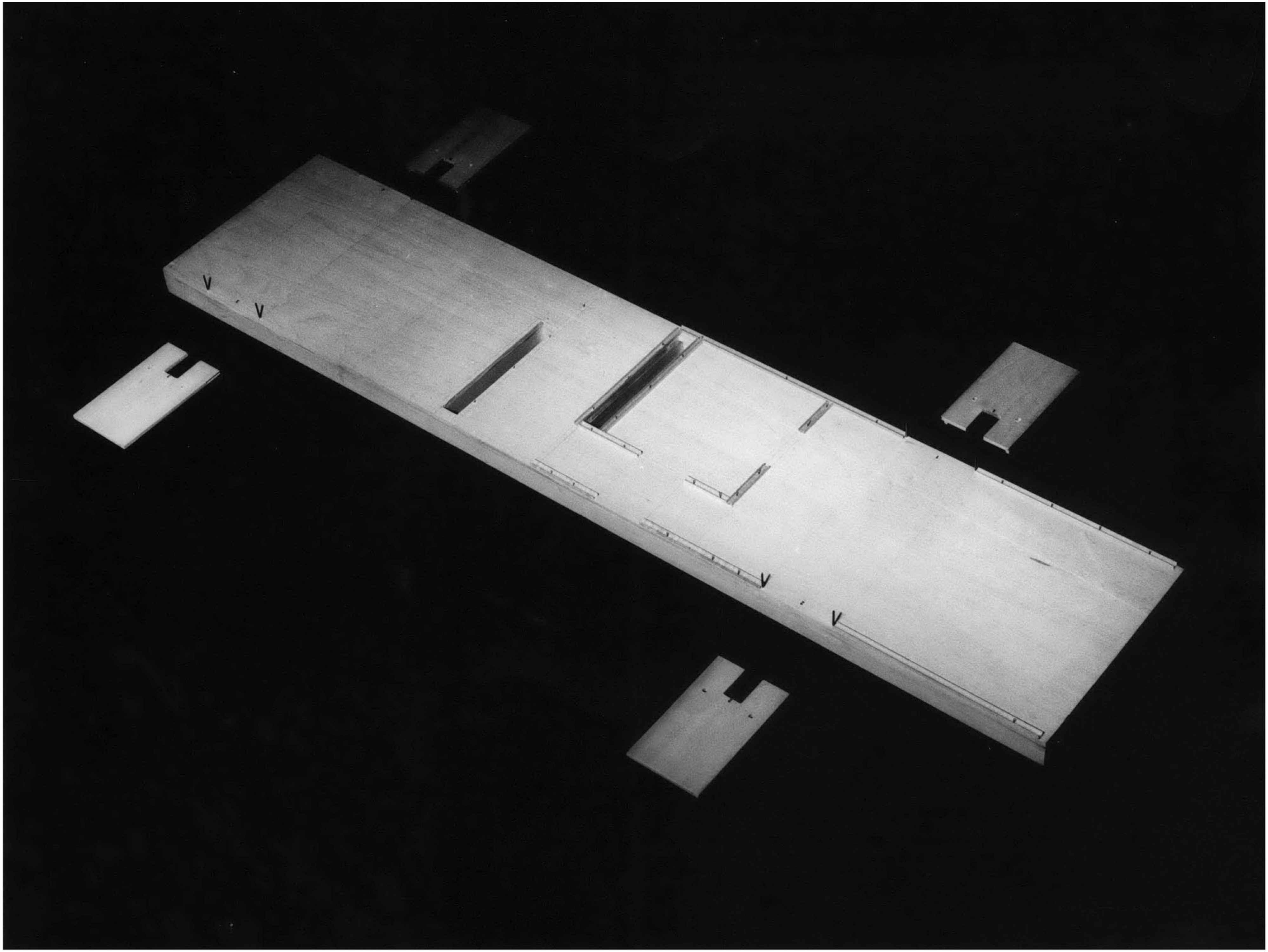

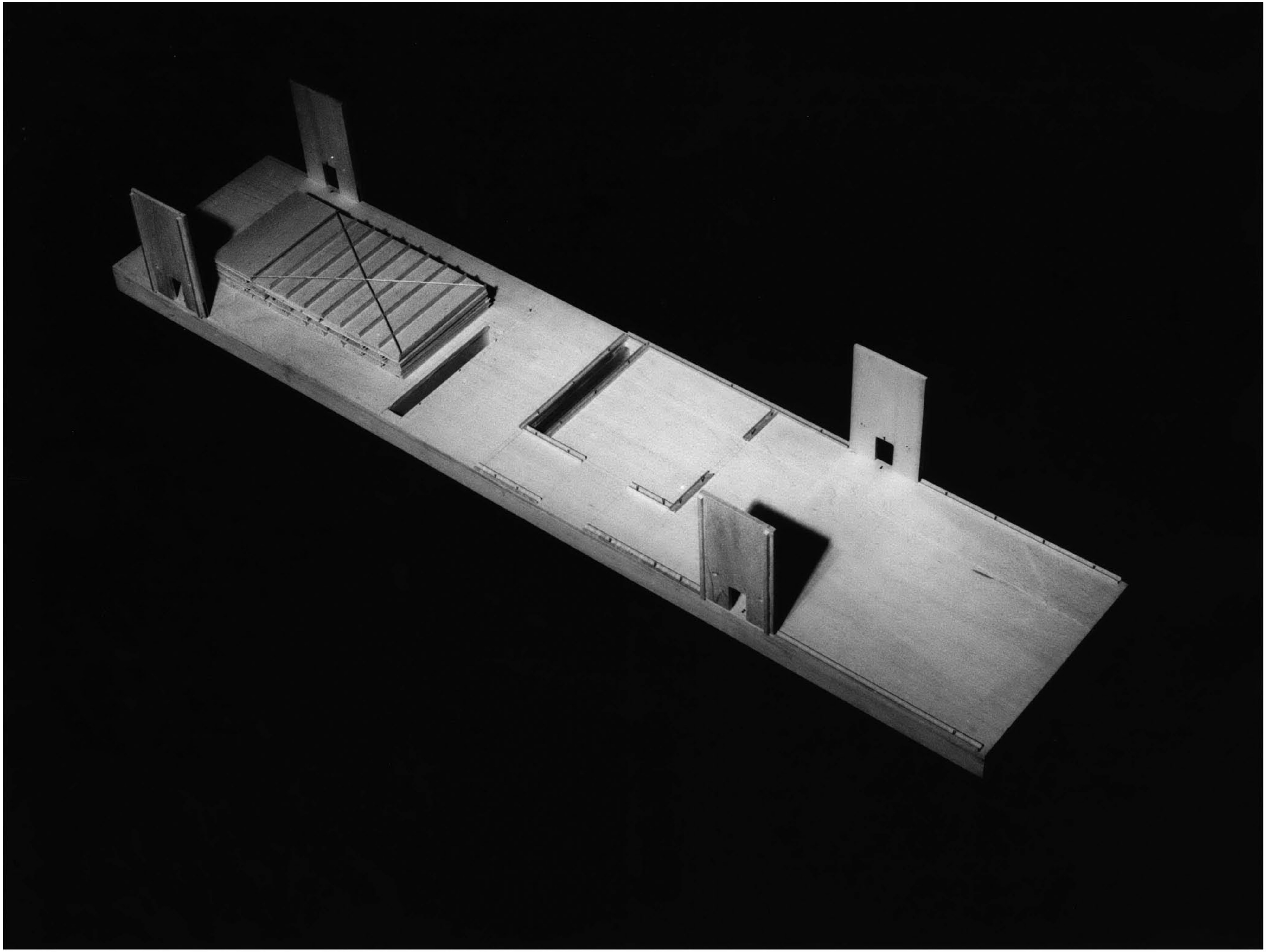

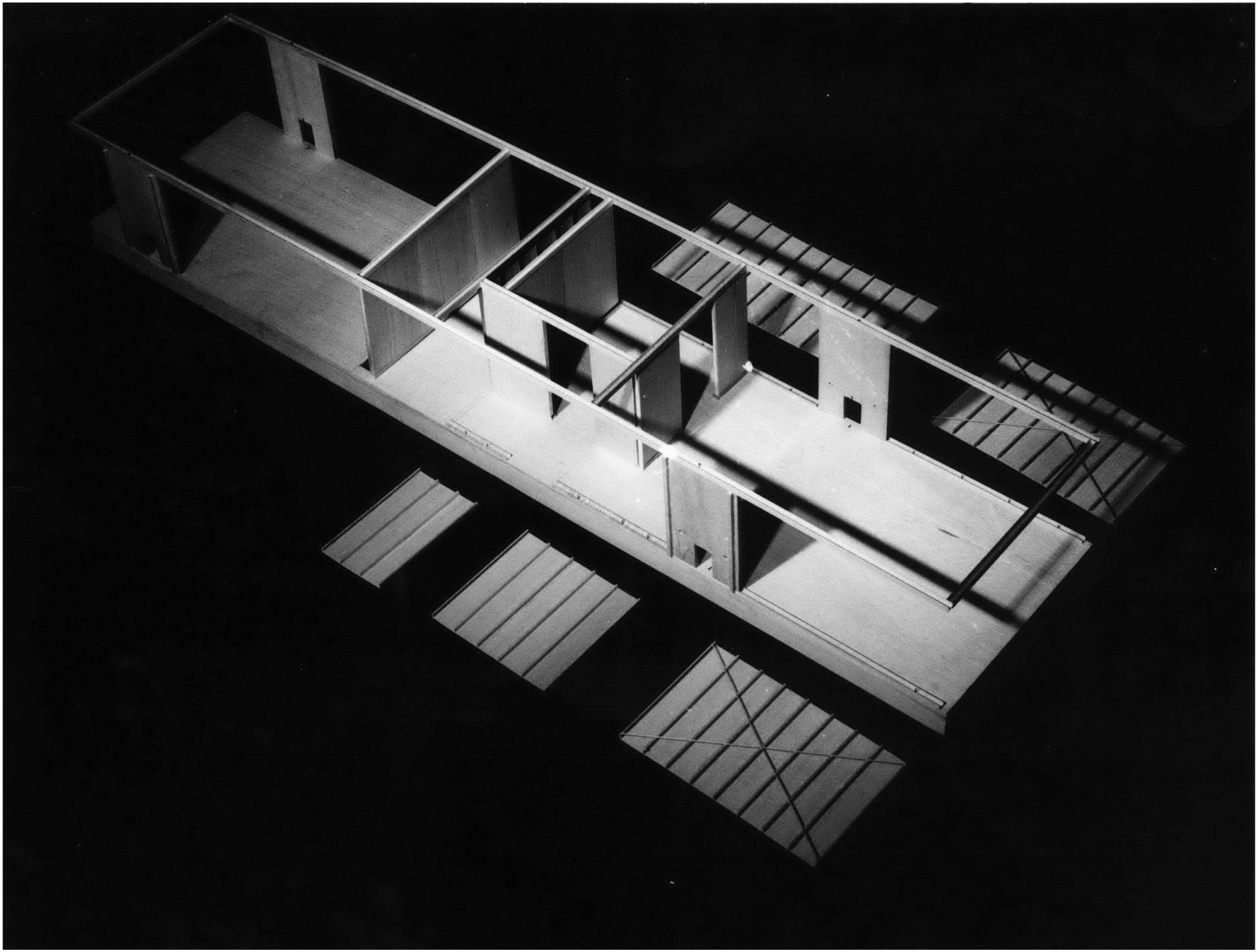

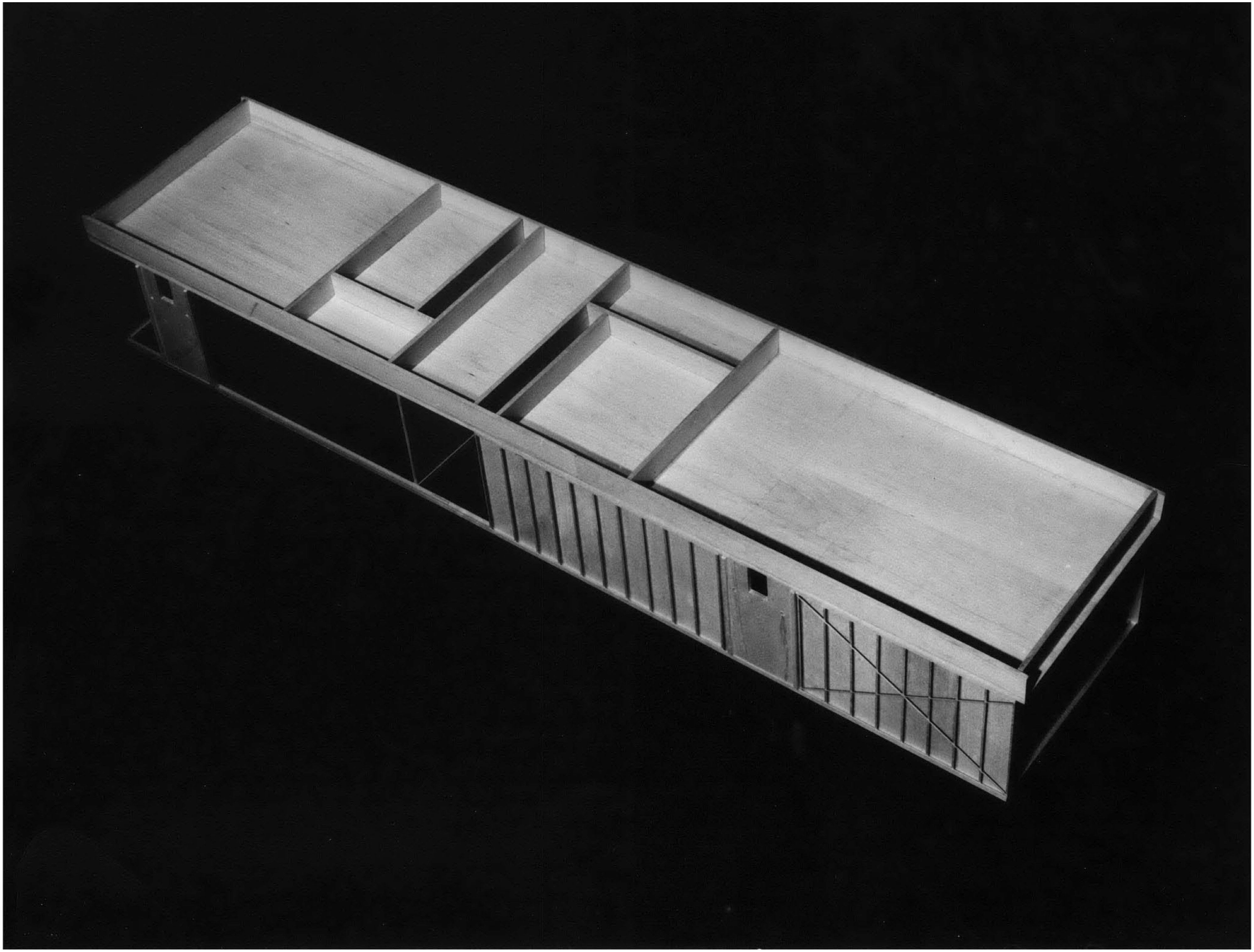

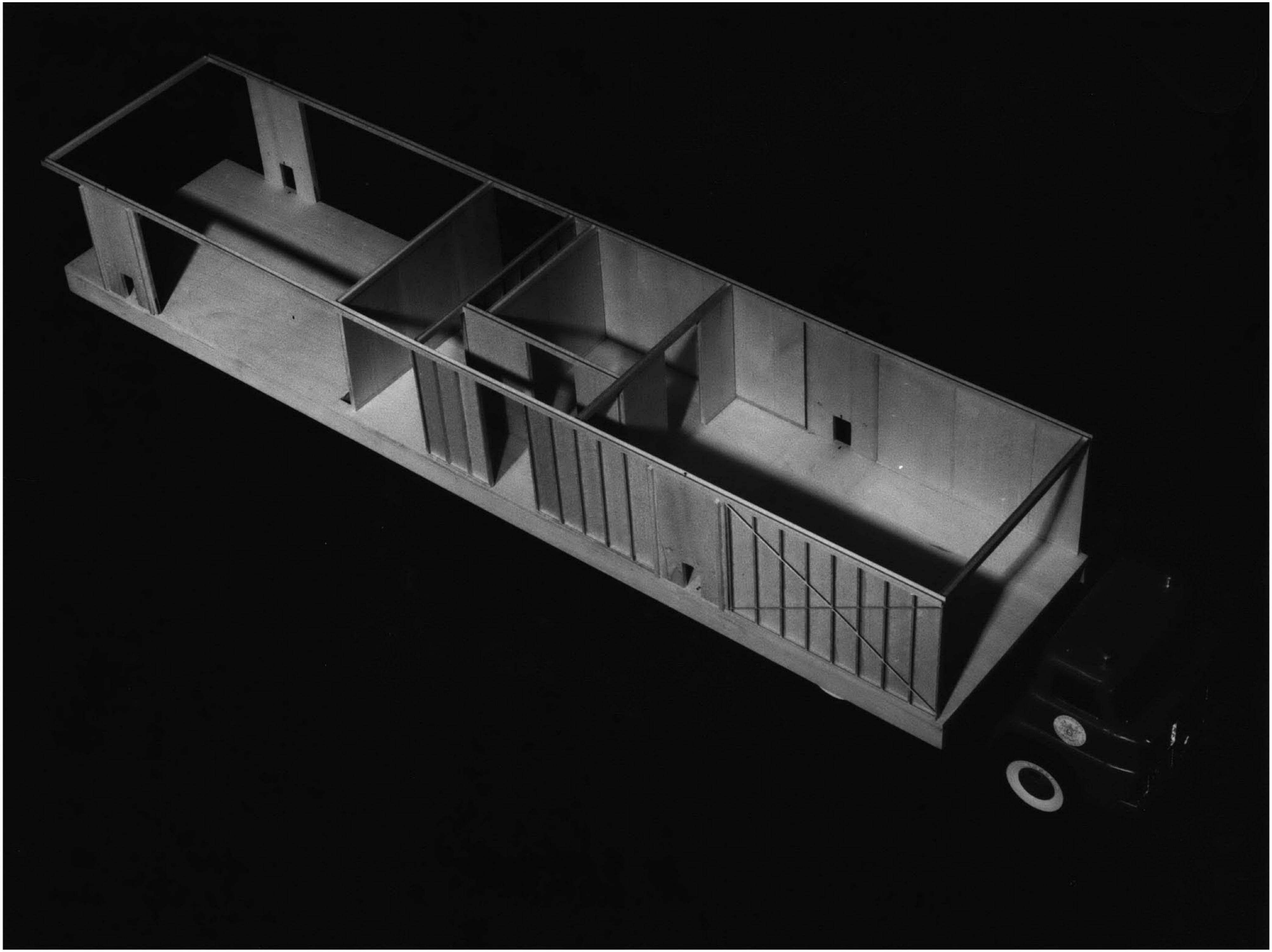

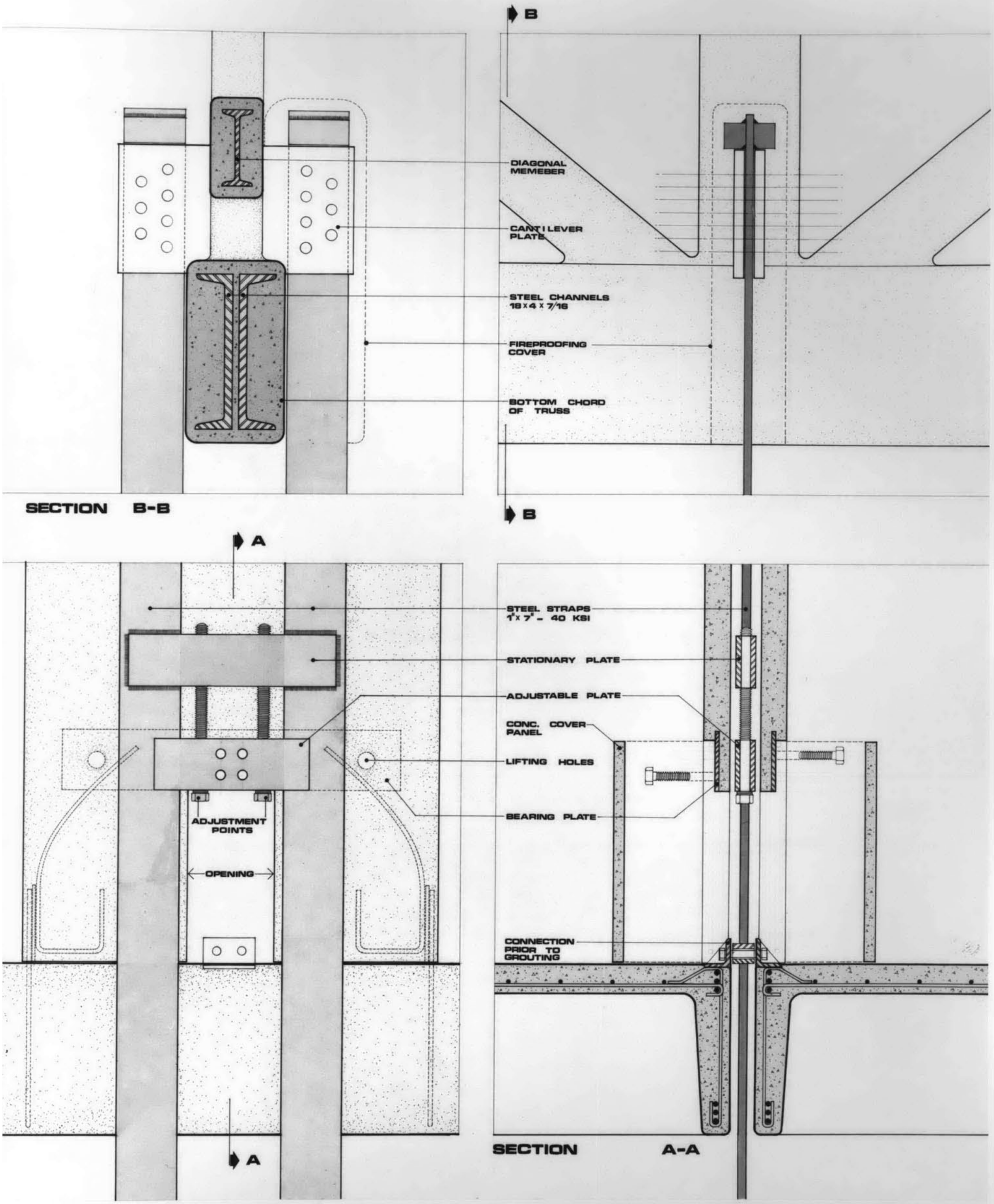

SUSPENSION DETAILS

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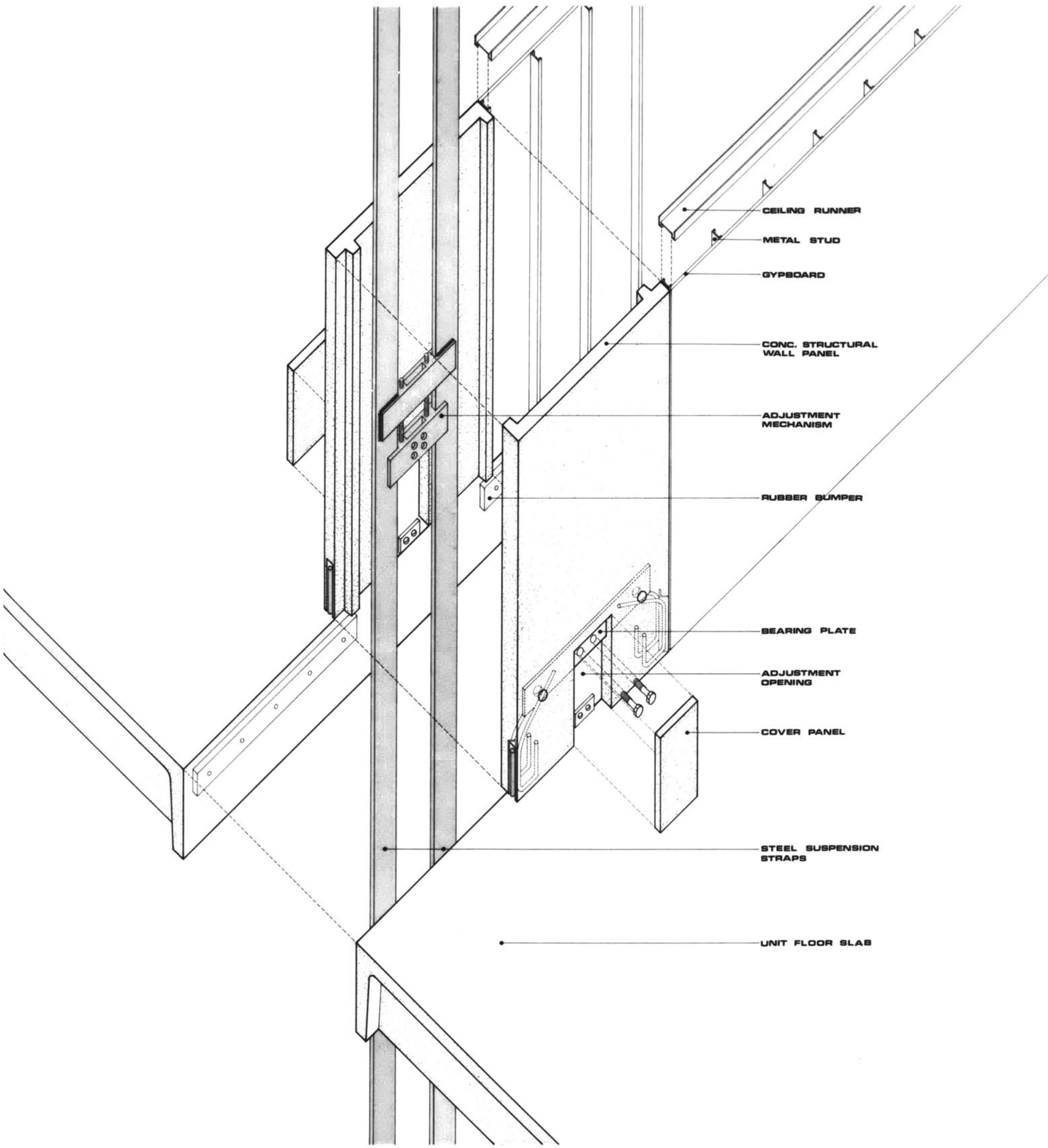

UNIT SUSPENSION DETAIL

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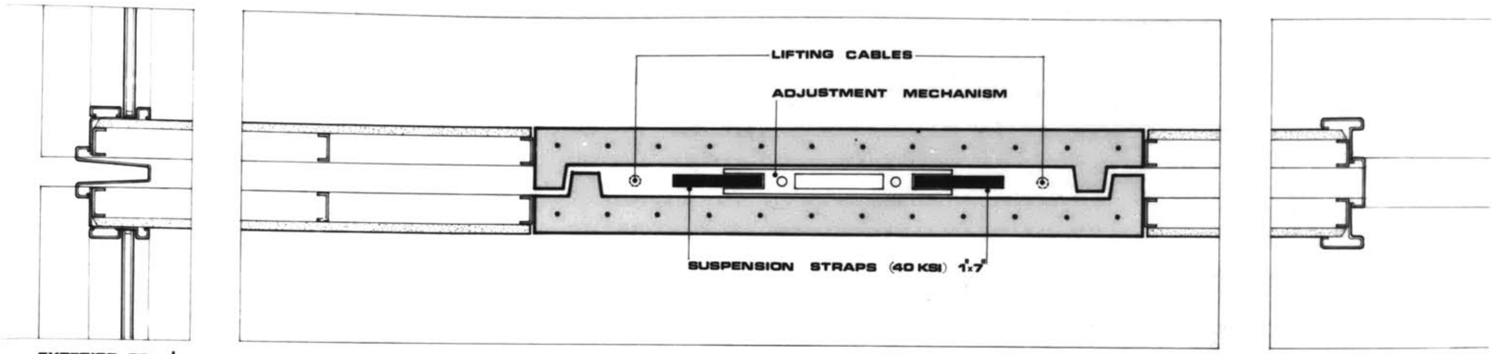
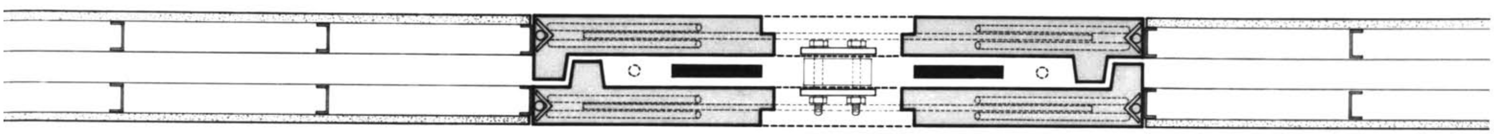


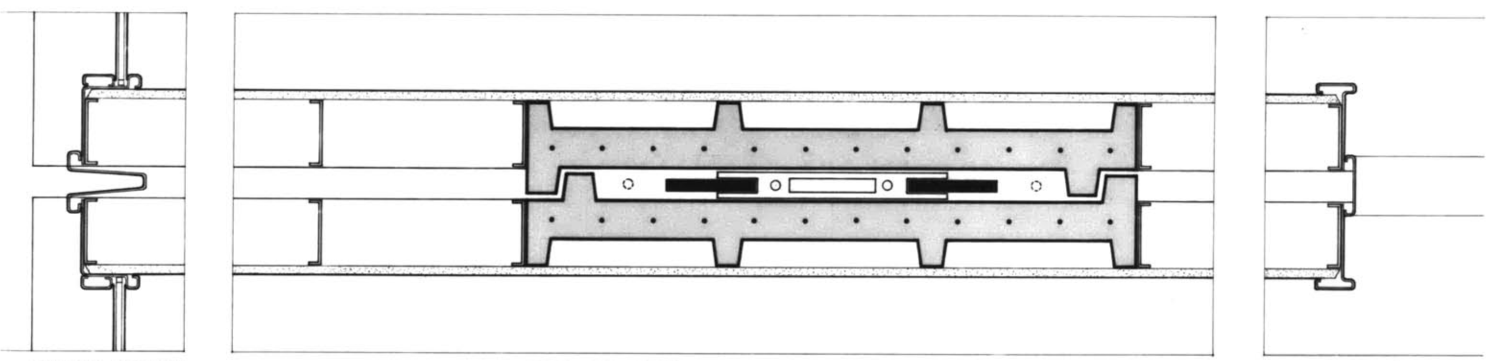
EXTERIOR OPEN'G — CONC. STRUCTURAL WALL PANEL — INTERIOR OPENING

SCHEME – A



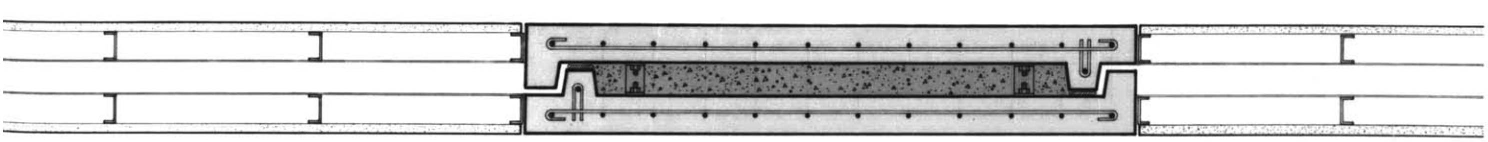
CONC. WALL PANEL AT ADJUSTMENT OPENING

SCHEME – A



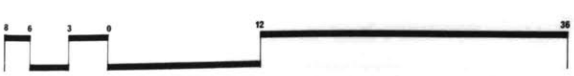
EXTERIOR OPEN'G — CONC. STRUCTURAL WALL PANEL — INTERIOR OPEN'G

SCHEME – B



SCHEME – A STACKING

PLAN – WALL SECTION



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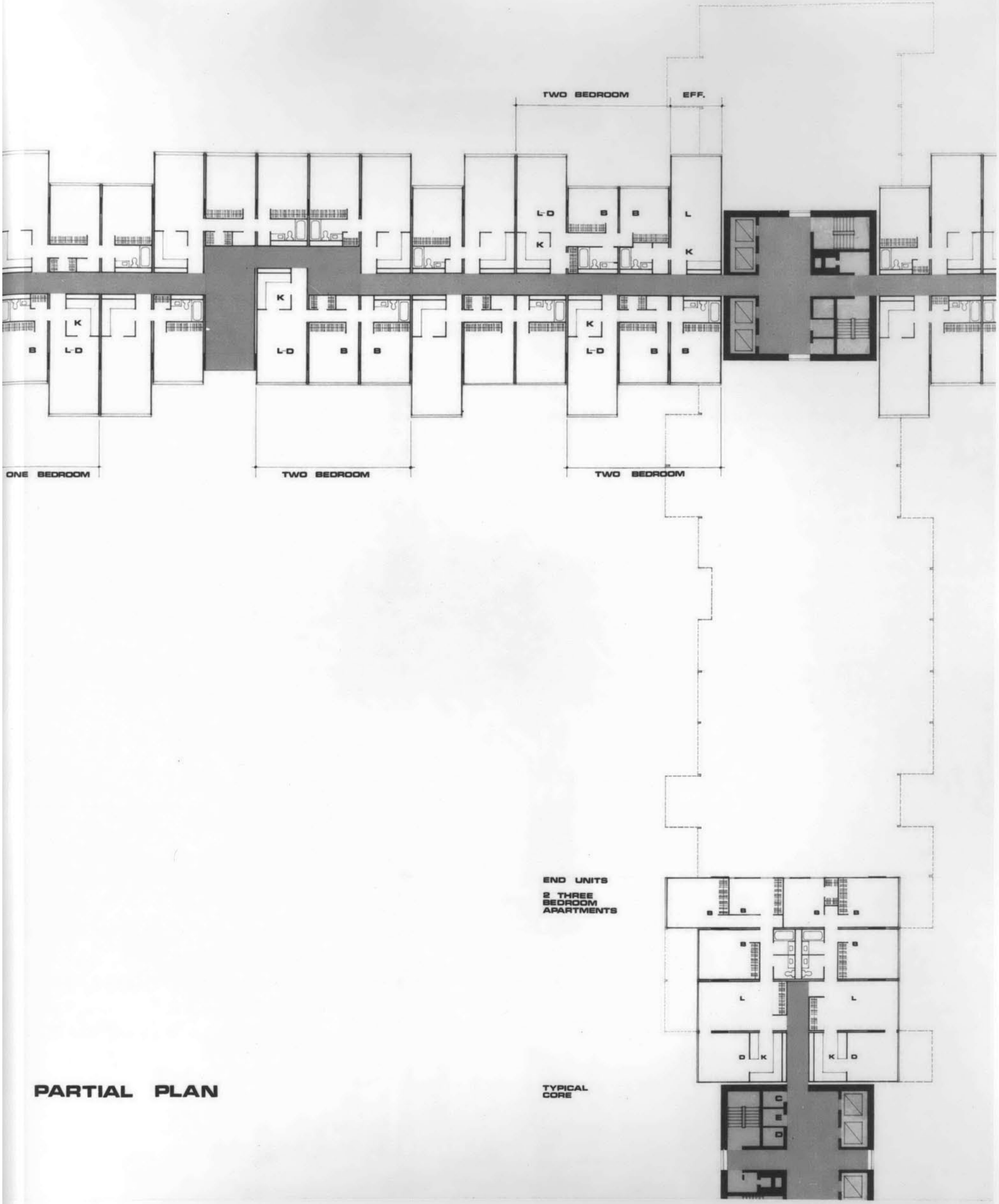

PARTIAL PLAN

HIGH DENSITY COMMUNITY

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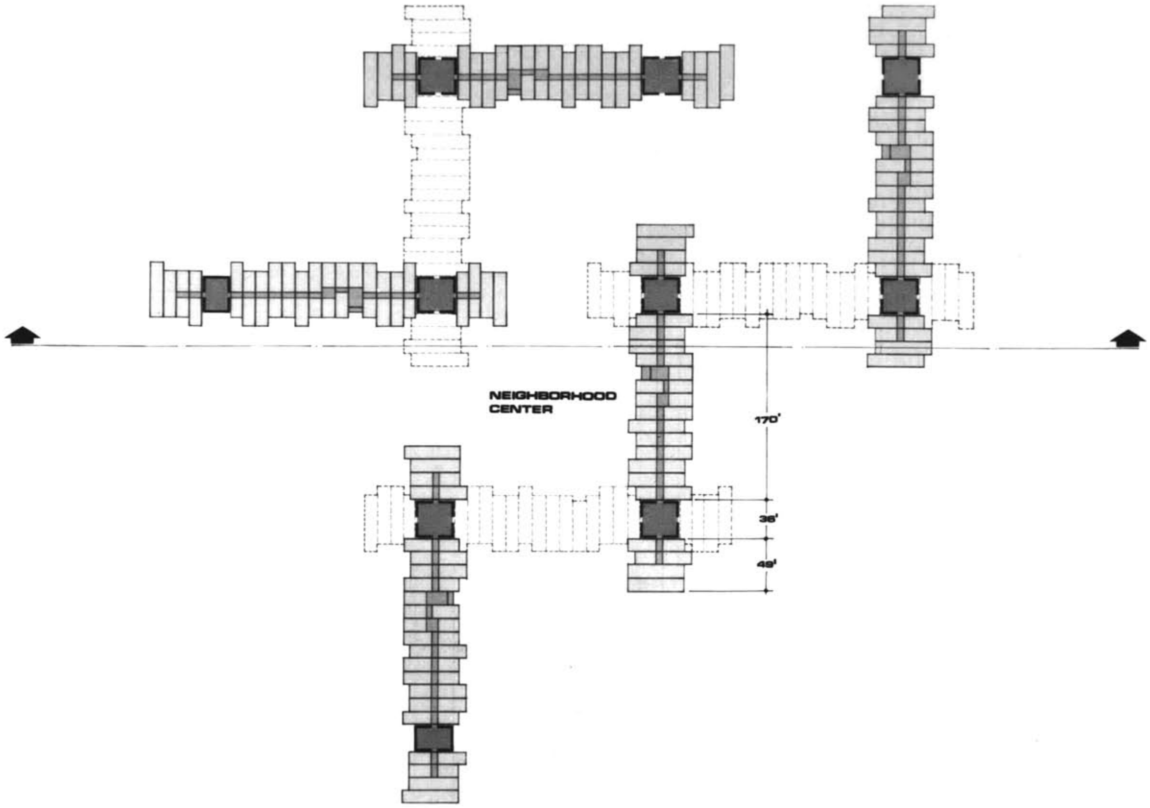
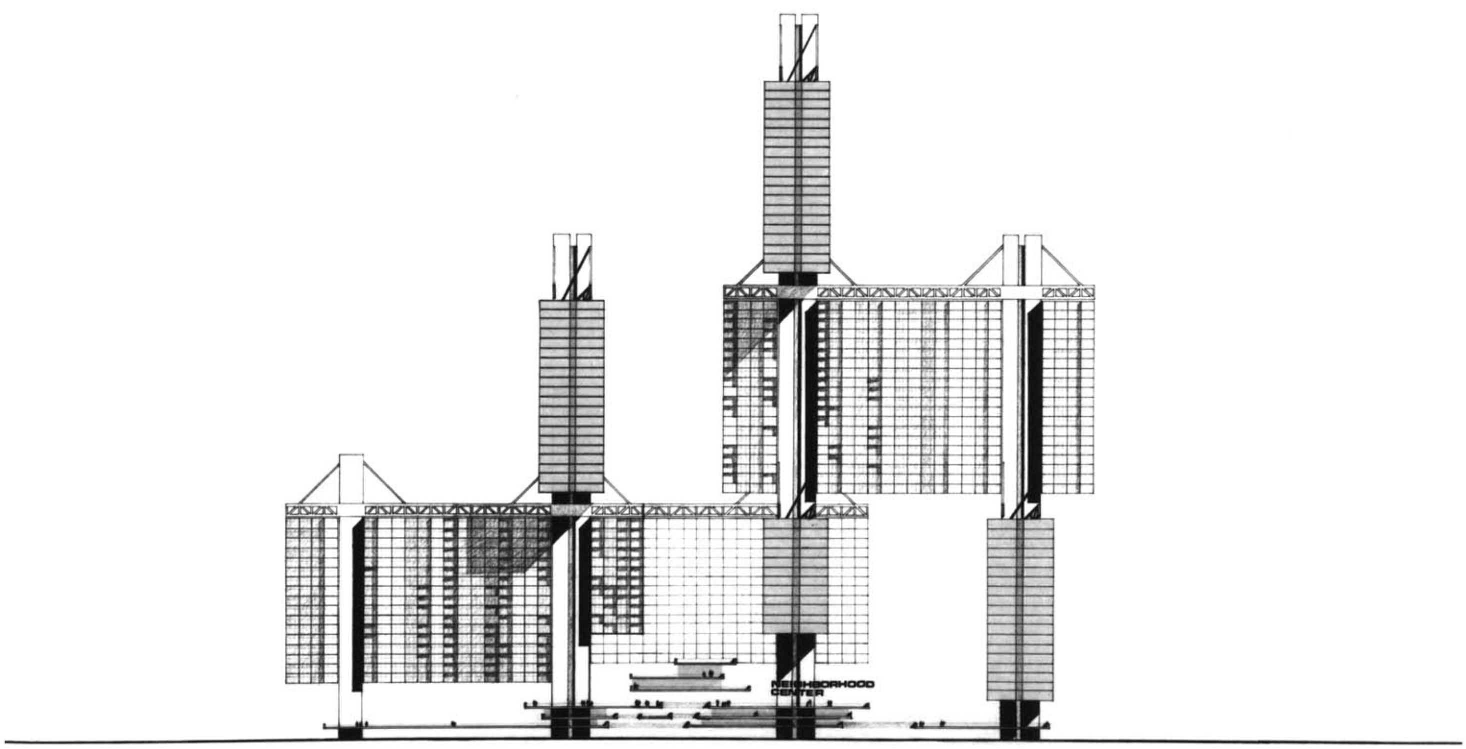


SCHEMATIC PLAN



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