

AN INDUSTRIALIZED SYSTEM FOR HOUSING

BY

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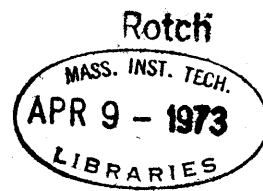
Submitted in Partial Fulfillment of the Requirements for the
Degree of MASTER OF ARCHITECTURE, ADVANCED STUDIES

At the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
January, 1973

Author.....
Department of Architecture

Certified by.....
Thesis Advisor

Accepted by.....
Chairman, Departmental Committee
On Graduate Students



January 24, 1973

Dean William Porter
School of Architecture and Planning
Massachusetts Institute of Technology

Dear Dean Porter,

In partial fulfillment of the requirements for the degree of Master of Architecture,
Advanced Studies, I hereby submit this thesis entitled:

AN INDUSTRIALIZED SYSTEM FOR HOUSING

Respectfully,

Ronald Lu

ACKNOWLEDGEMENTS

The author gratefully acknowledge the following people who assisted in the development of this thesis:

Professor Waclaw P. Zalewski Thesis Advisor
Department of Architecture, MIT

Professor Eduardo Catalano
Department of Architecture, MIT
Especially, as it was under his professional guidance that this thesis was conceived and a greater part of it developed.

Professor Imre Halasz
Department of Architecture, MIT

Professor Arthur Bernhardt
Department of Architecture, MIT

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ABSTRACT

The aim of this thesis is to develop and investigate an industrialized system for housing produced in the factory using concrete as the structural material.

The written section of this thesis provides a brief description of the system developed and establishes areas of concern and constraints within which the design proposal is made.

The design proposal is then explained by illustrations, demonstrating how modular co-ordination of basic living elements can generate many combinations called modules ready for shipping and erection. Using the sample modules and varying exterior components, the proposal illustrates the different dwelling unit plans, section variations and dwelling unit combination possible.

The final section of this thesis uses the system developed in demonstrating the application and limitation to a medium density suburban site in Medford, Massachusetts.

INTRODUCTION

For architecture, the 20th Century opened with high hopes for the use of mass production in the provision of housing.

Yet at well past mid-century, the basic structure of the American houses remains essentially unchanged.

Meanwhile, Europe, faced with a serious postwar housing problem, proceeded with considerable success to develop a number of comprehensive systems based on large concrete components in an attempt to mass produce large elements of the house. In this country, only two forms of factory-produced shelter developed: the prefabricated or so-called "manufactured house" which has many parts produced in a factory but which, because of the excessive site work still required, has not solved the technological or cost problems, and the mobile home, which is more frequently classified as a vehicle than as a house.

Recently a small group of architects, engineers, industrial designers, and manufactures, encouraged by the success of the mobile home, have begun to explore the potential of dwelling modules, or "boxes" suitable for production in factories and capable of being transported over highways, positioned on the

site by cranes and organized in various configurations. "Boxes" are being given considerable attention due in part to the publicity Moshe Safdie's habitate at Expo'67 has received.

The modular box concept is not merely a different, faster and cheaper way of constructing houses. It represents an entirely new approach. Each module is designed to meet standards of performance pre-determined on the basis of its use in a home, the length of time it can be expected to last, and its place in the total housing product.

Circulation

Circulation layouts in the United States high-density housing schemes are complicated by the fire regulation requiring two means of egress for every apartment. In Europe this has not been considered necessary, with the result that European apartments have a much more compact and flexible layout. Placed one on each side of a stairwell, European apartments generally extend from one side of the building to the other, achieving two orientations, cross-ventilation, and centralized circulation. The United States requirement usually means that a double-loaded corridor connects stairways at each end of a long building. This unfortunately results in half of the apartments with no sunlight if the building is placed north-south, and extreme morning or evening lighting for all the units if the building is placed

east-west. Furthermore, the plans are usually a string of rooms connected within the apartments by another corridor paralleling the main hall.

The attempt in this thesis is then to develop and investigate an industrialized system for housing using what present factory technology can offer to produce finished concrete three-dimensional modular units which can be transported from the factory to the construction site and stacked to produce the advantages of the European apartments (two orientation, cross ventilation and central circulation) within United States fire regulations.

AREAS OF CONCERN AND RESTRAINTS

Unit Size

- a. 14'-6" Maximum shipping width.
- b. 56'-70' Minimum to maximum shipping length.
- c. 13'-6" Maximum shipping height.

Building Conditions

- a. For high, medium and low rise density.
- b. Middle-upper middle income group.
- c. Provide apartment units with 1-6 bedrooms.
- d. Structural material to be in concrete produced and assembled in a factory.

DESCRIPTION OF SYSTEM.

The system developed is made of precast concrete floor, wall and ceiling panels which are welded together to form 'box' modular units. These modular units are completely finished in the factory save for the final utility connection which is done on site. With emphasis placed on the direct resolution of structural and mechanical needs while minimizing the restraints these systems placed on planning, the modular units are arranged to form apartments of different sizes and types. The key to the apartment arrangement is that within an apartment there is a change in floor level of a half level (about four and a half feet—which is below the average eye height of five feet). This change in level allows apartments to have views in more than one direction, cross-ventilation, and central circulation by means of an internal stair that connects the different levels in an apartment. By having a central stair, living spaces are placed on the periphery of the building for sun, light, air and view.

Structural System and Materials.

The basic element of the system is a reinforced concrete box formed by welding together precast floor, wall and ceiling panels.

Vertical loads are resisted by the wall elements of the modular box while resistance to lateral forces is obtained by the rigidity of boxes. This is increased by the addition of reinforced concrete poured between

walls of adjacent boxes.

Structural materials are of lightweight reinforced concrete.

Interior partitions are of steel studs and gypboard.

Mechanical System

HVAC are provided by fan coil units or hot water radiation with optional unit air conditioners.

Kitchen and bathroom exhaust are ducted to the roof in plumbing chase.

Final utility connection to vertical stack is connected after modules are placed.

DATA

Modular Sizes:

8'-9" x 13'-0" x 27'-6"
8'-9" x 13'-0" x 24'-6"
8'-9" x 13'-0" x 21'-6"

Apartment Units:

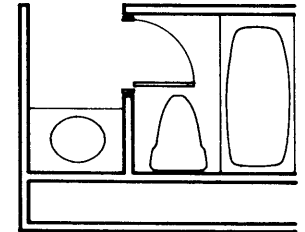
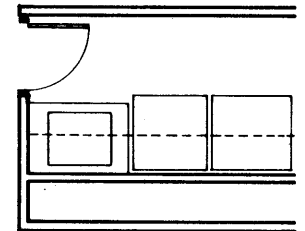
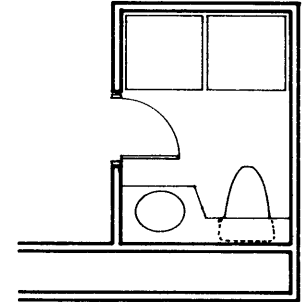
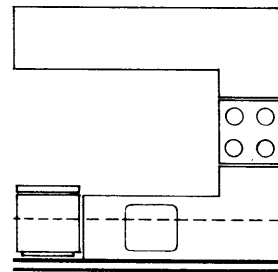
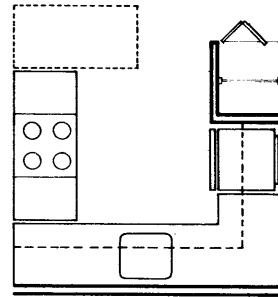
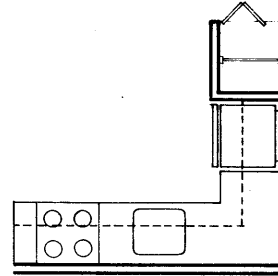
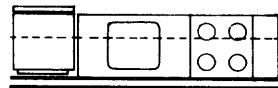
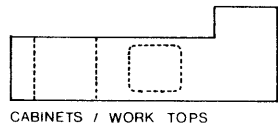
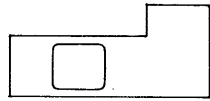
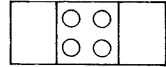
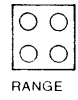
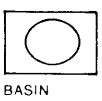
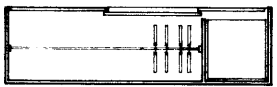
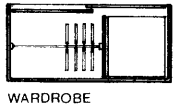
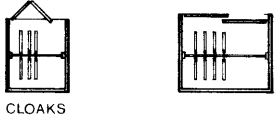
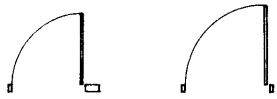
Type A (2 modular width)

Aa* 1BR UNIT 480 S.F.
Ab 1BR UNIT 603 S.F.
Ac 2BR UNIT 1053 S.F.
Ad 2BR UNIT 940 S.F.
Ae 3BR UNIT 1313 S.F.
Af 4BR UNIT 1573 S.F.
Afs 4BR UNIT

Type B (3 modular width)

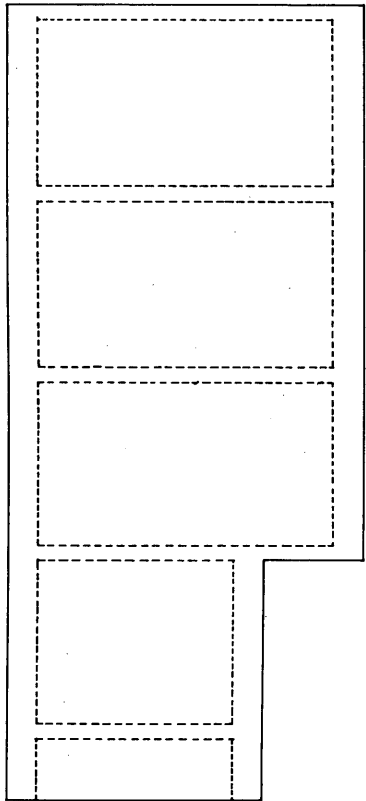
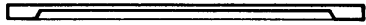
Ba 1BR UNIT 712 S.F.
Bb* 2BR UNIT 800 S.F.
Bc 3BR UNIT 1549 S.F.

2 apartment of corridor level*
7 apartments can either be above or
below corridor level
TOTAL of 9 basic apartments types

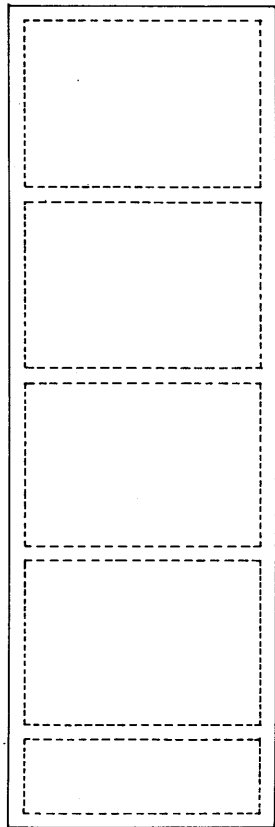
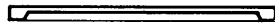


INTERIOR COMPONENTS & CONFIGURATIONS

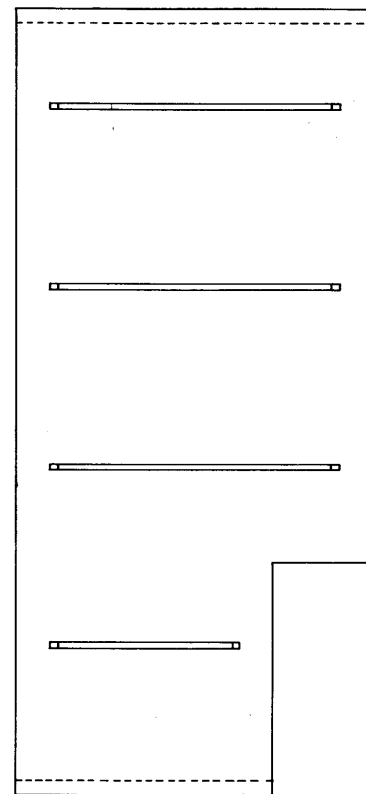
1/4" = 1' 0"



FLOOR PANEL



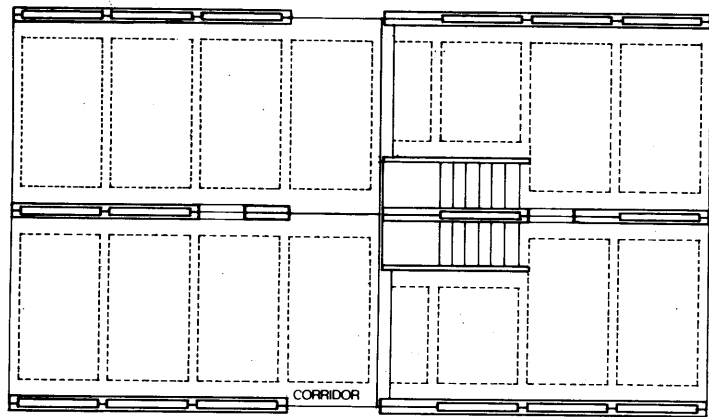
WALL PANEL



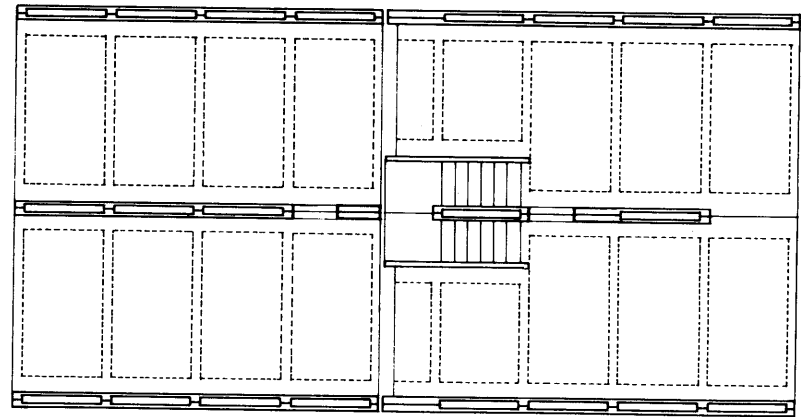
CEILING PANEL



STRUCTURAL CONCRETE COMPONENTS

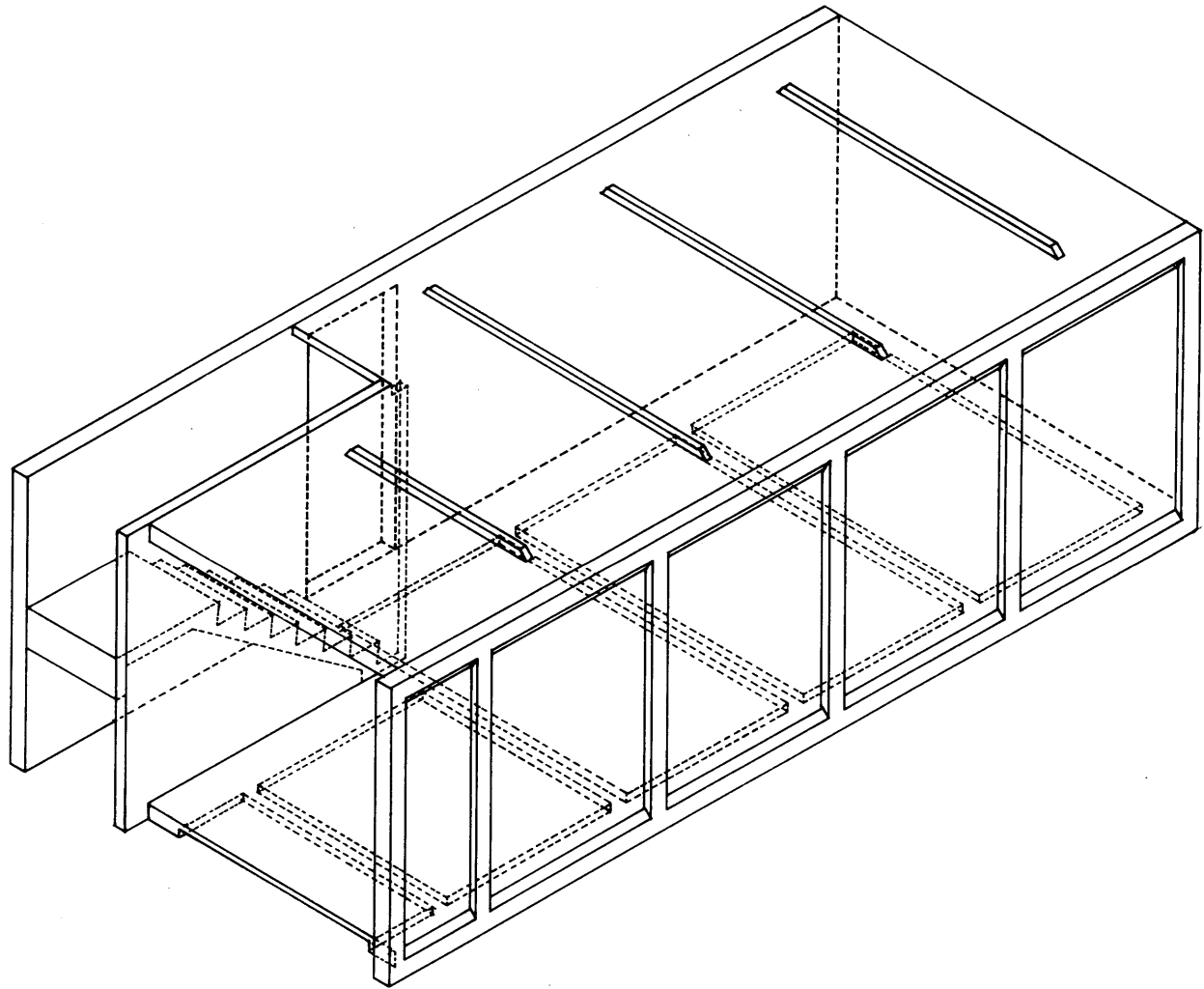


LOWER LEVEL

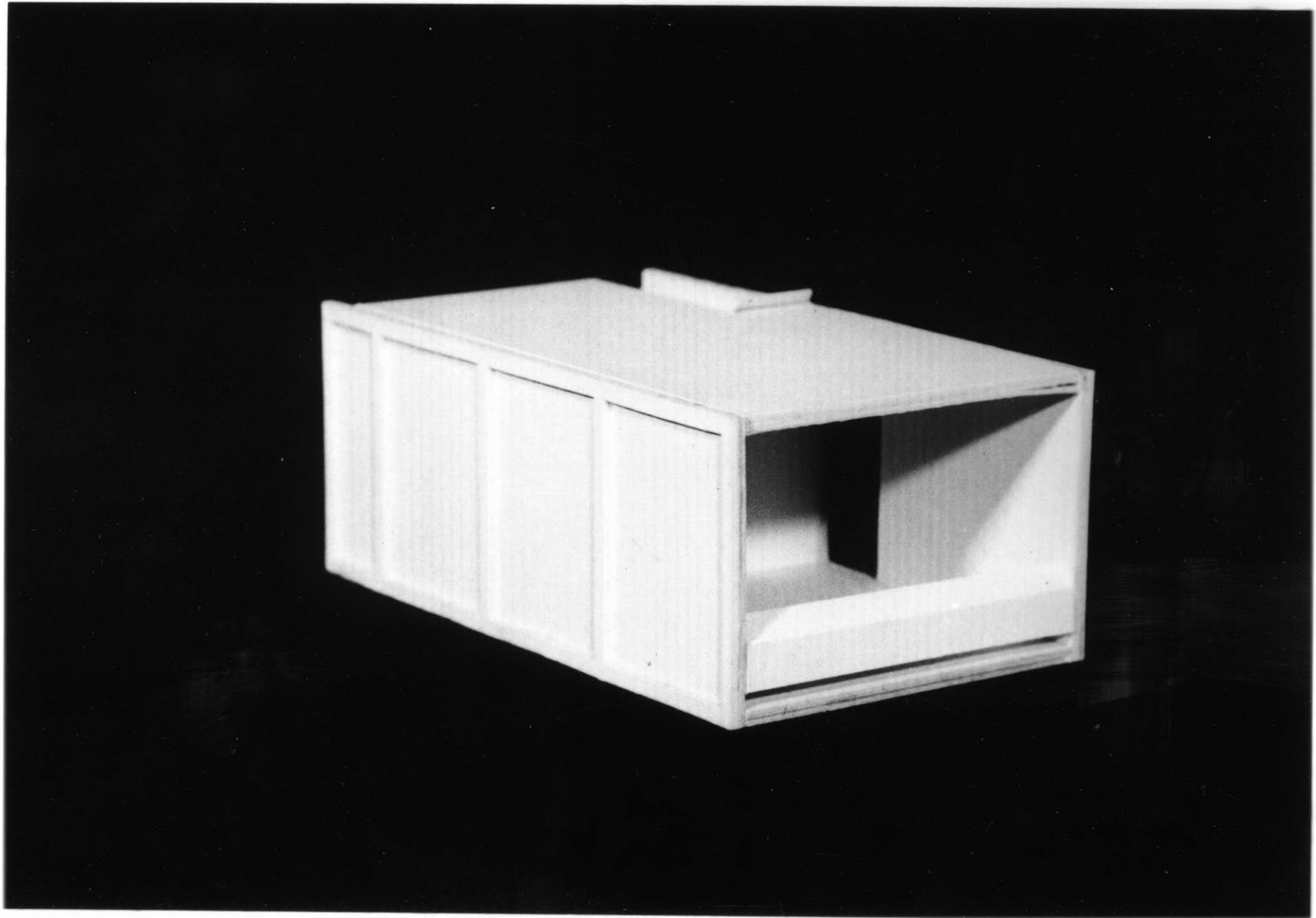


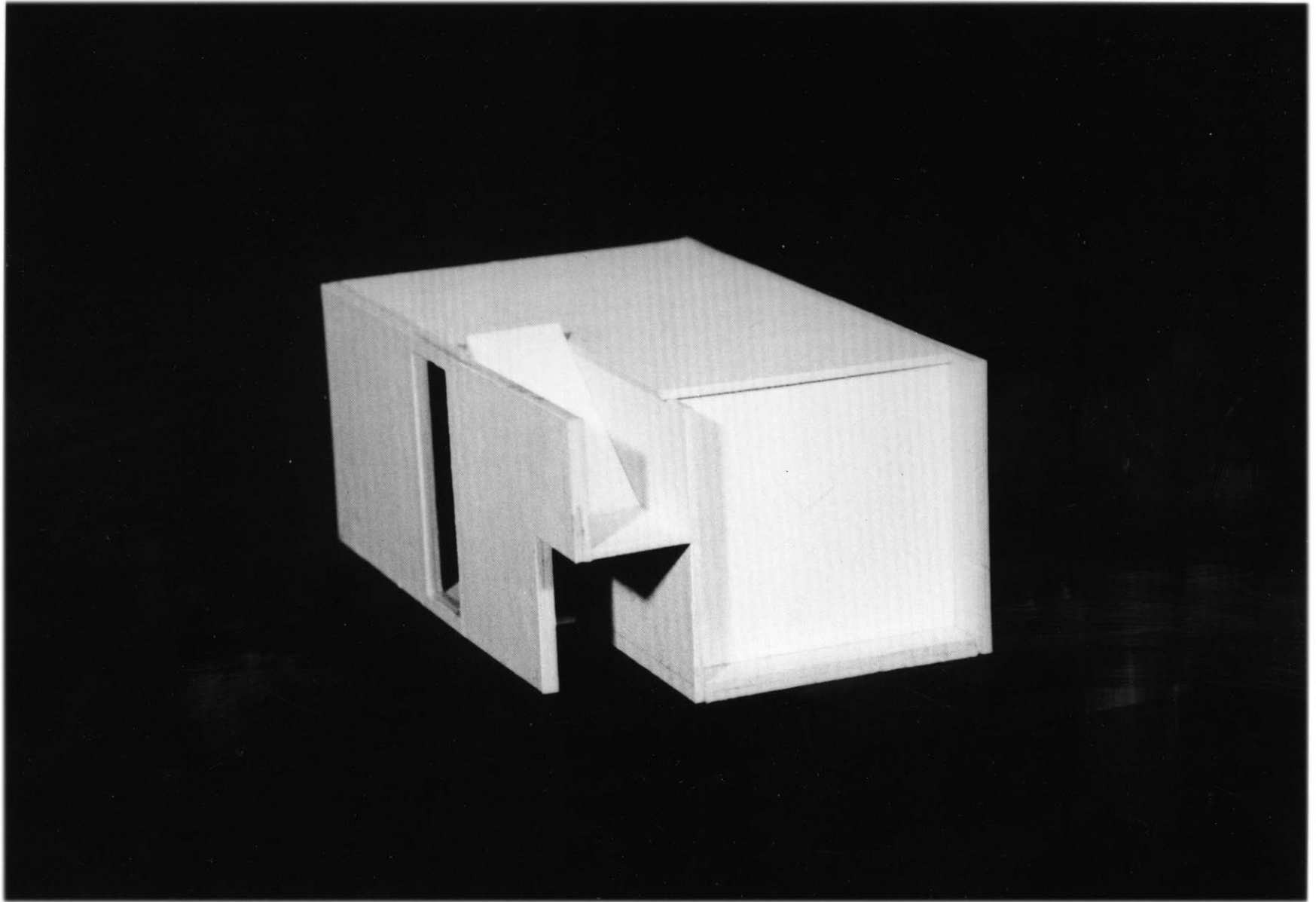
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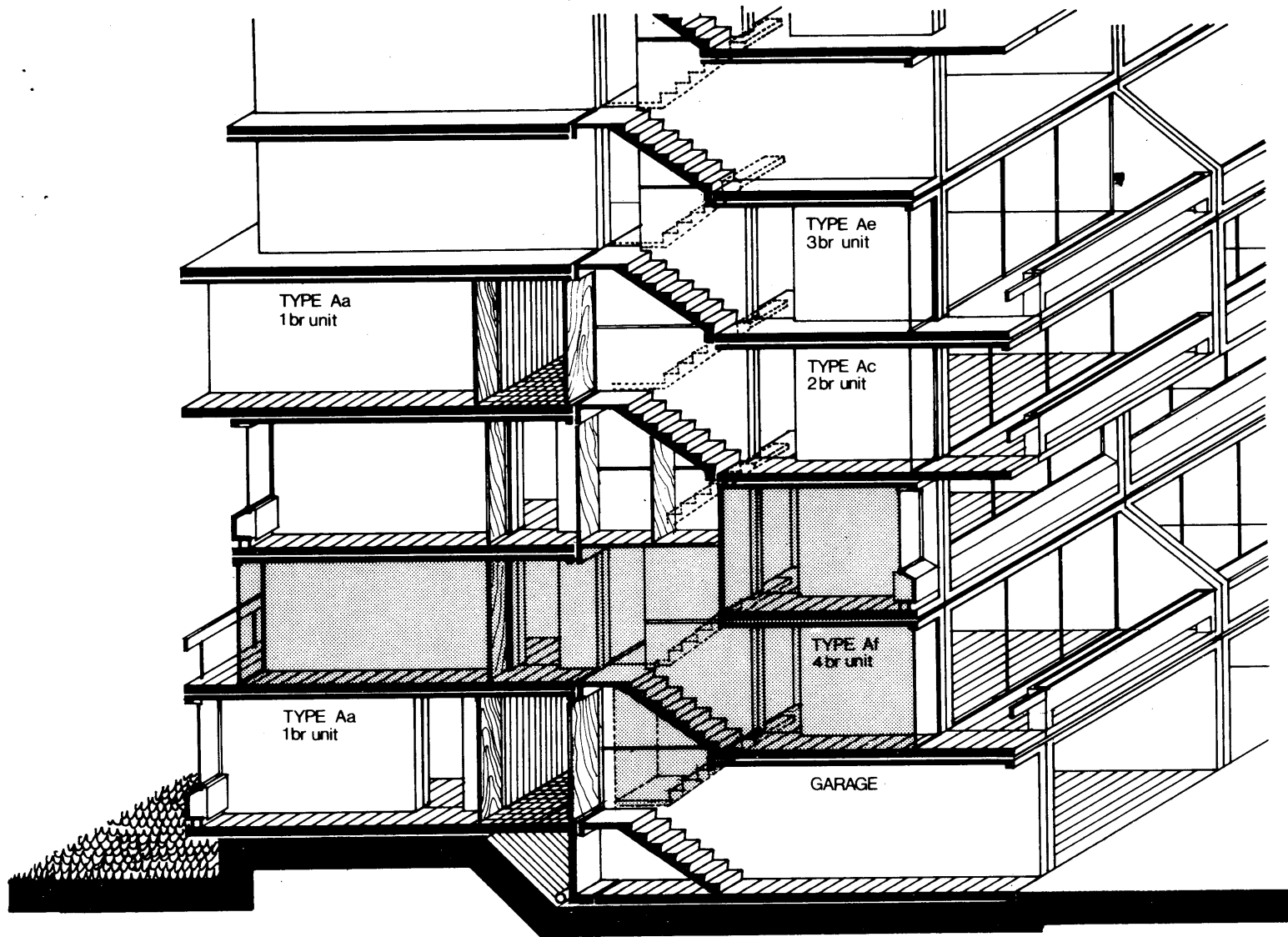
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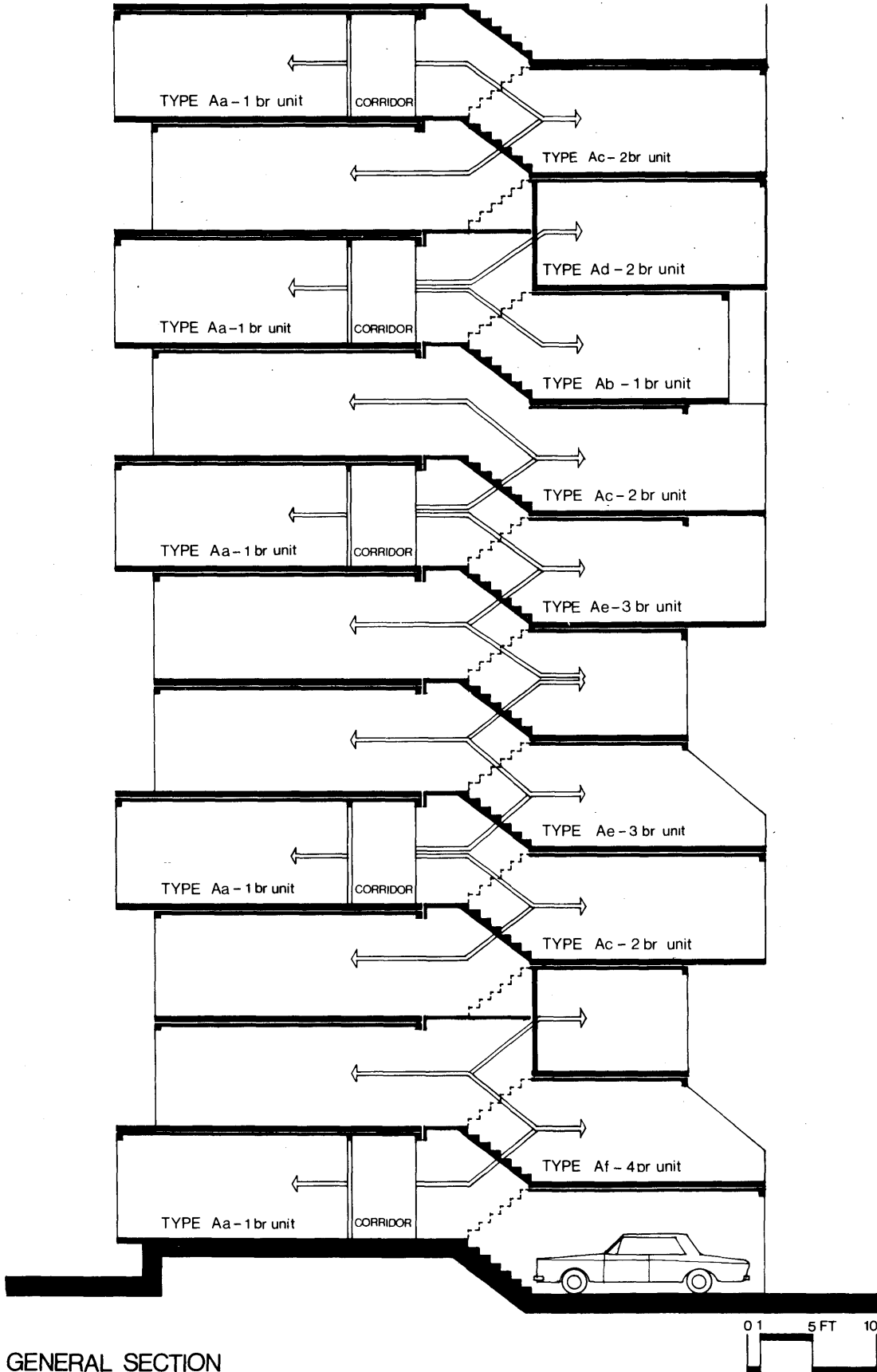
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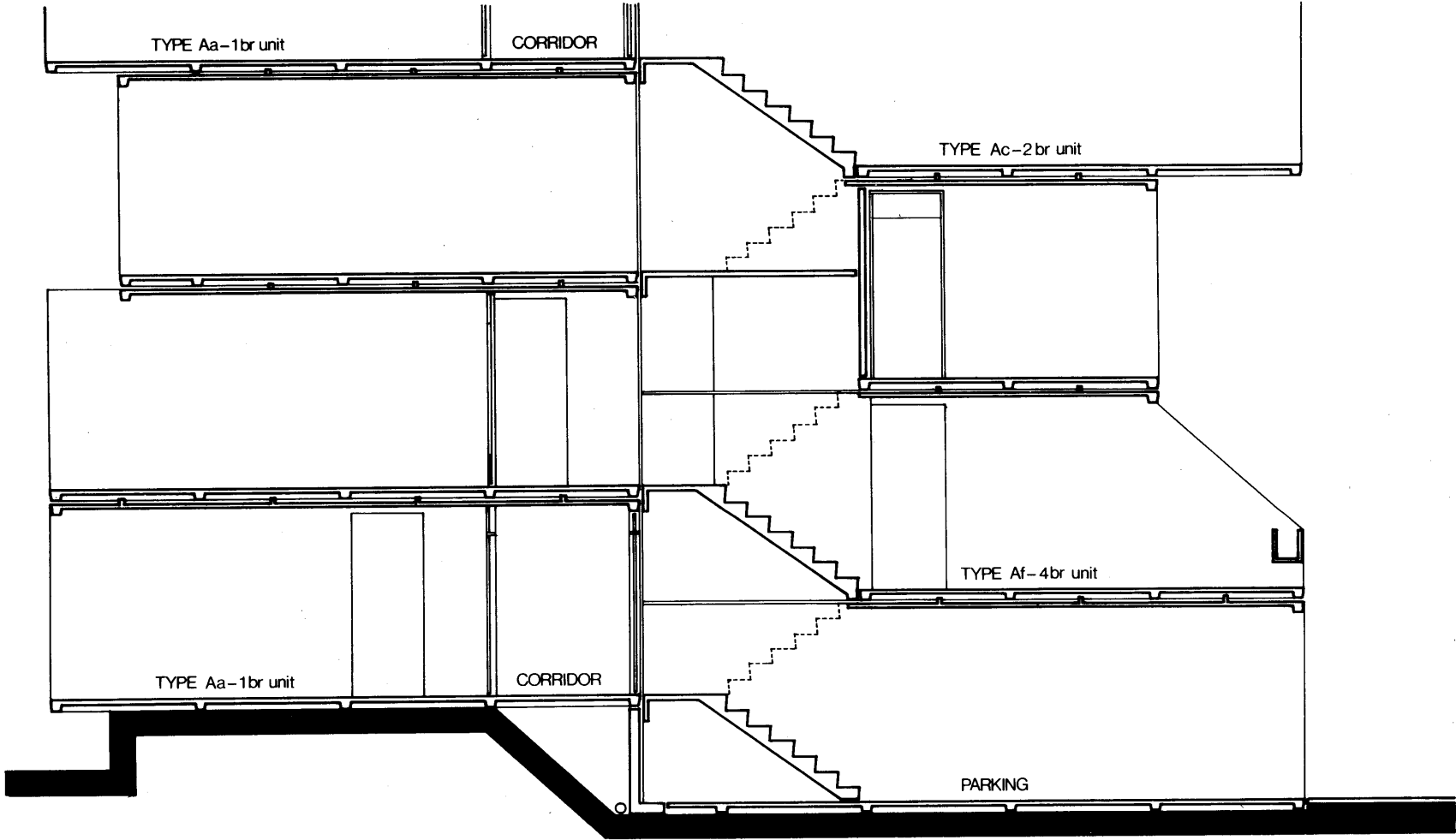




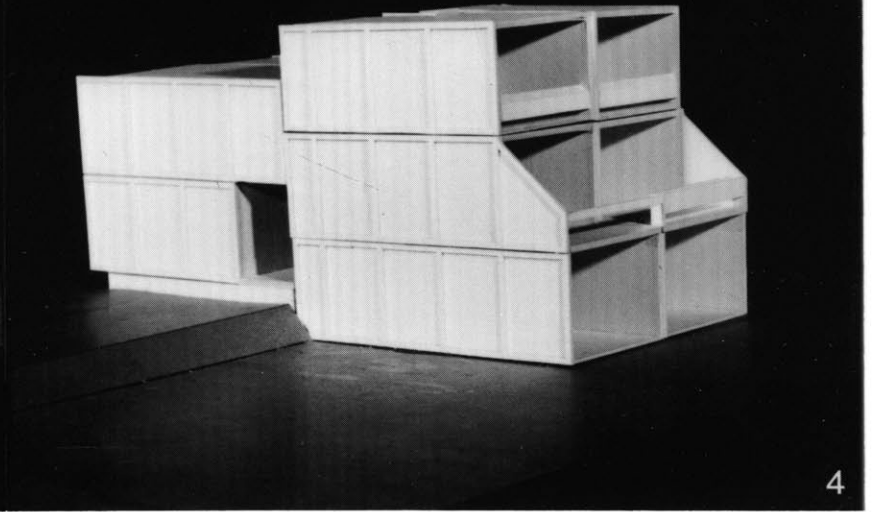
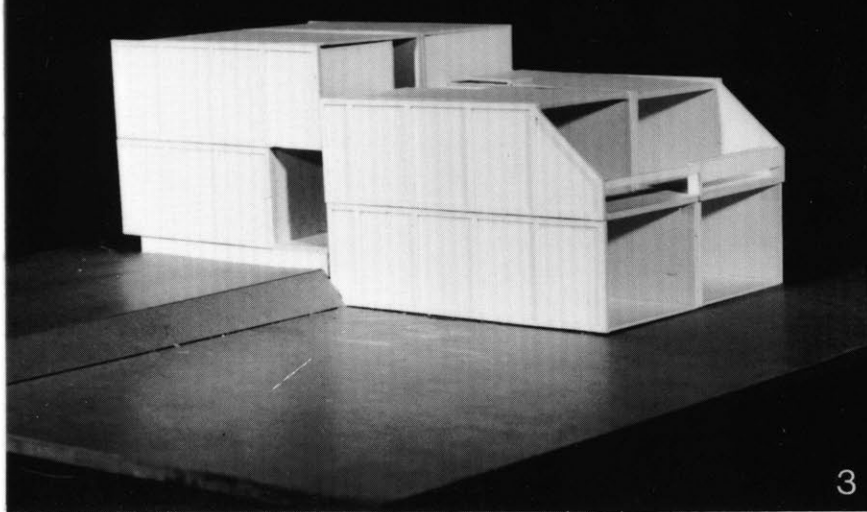
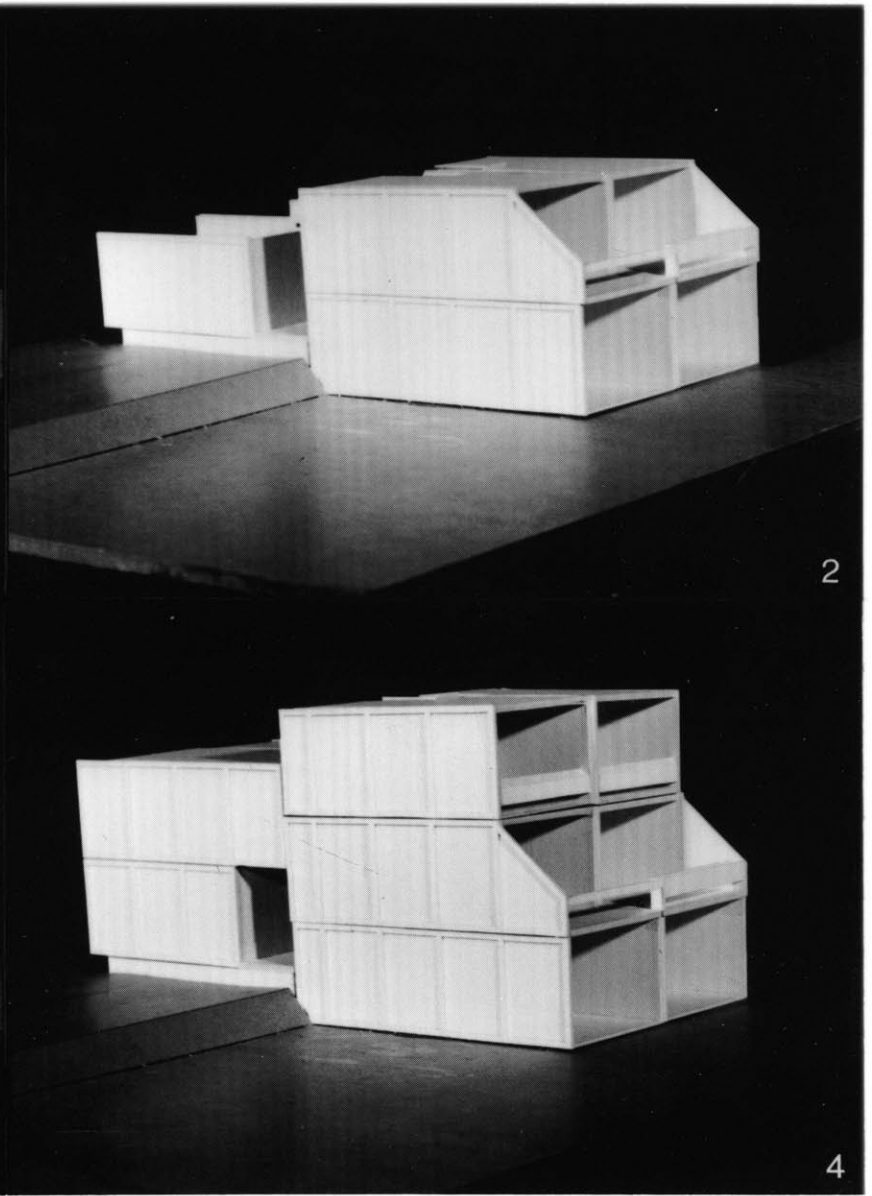
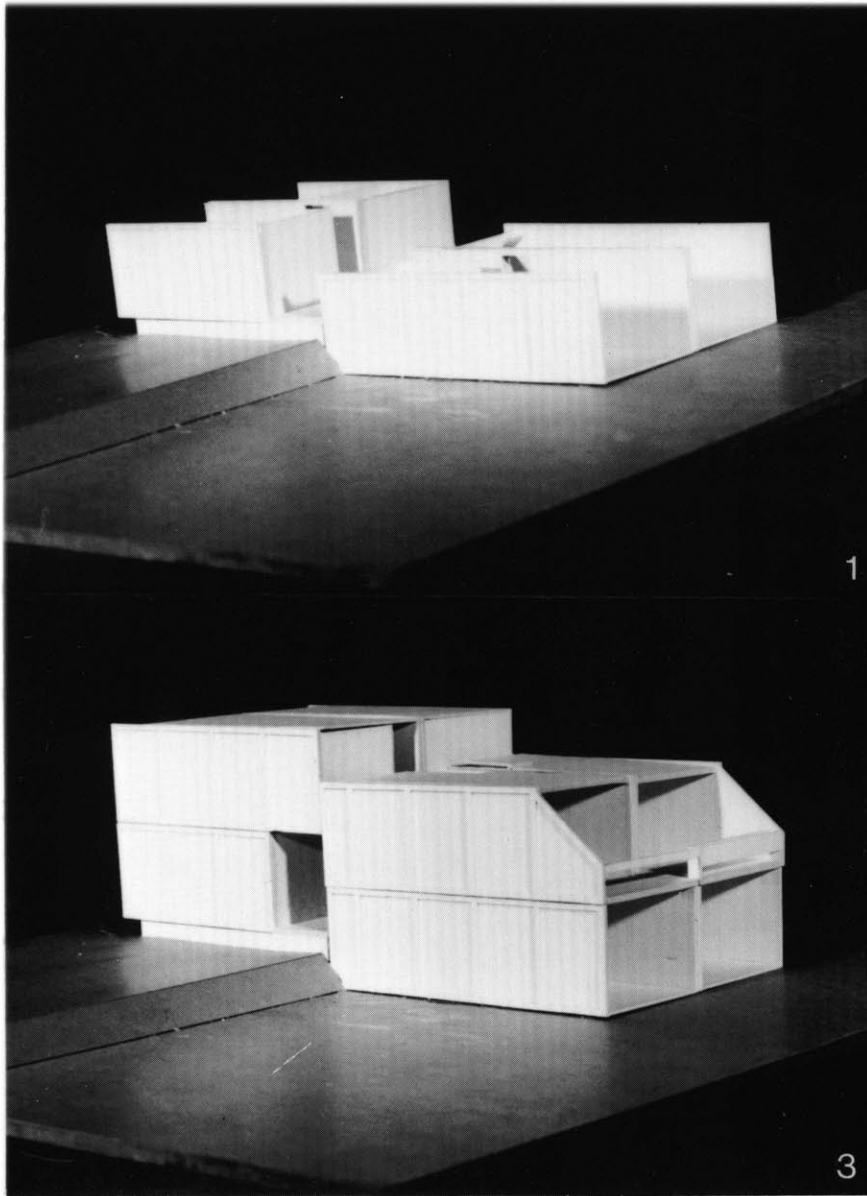
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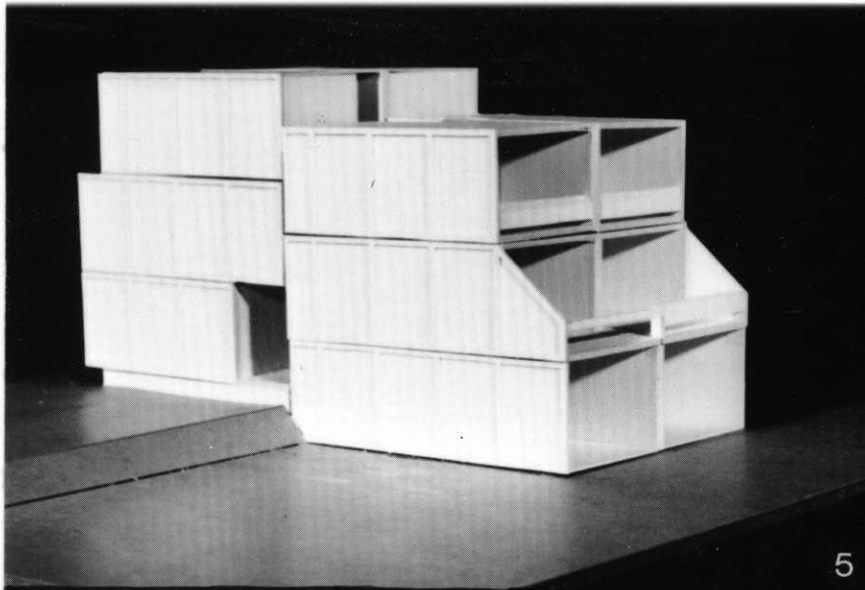
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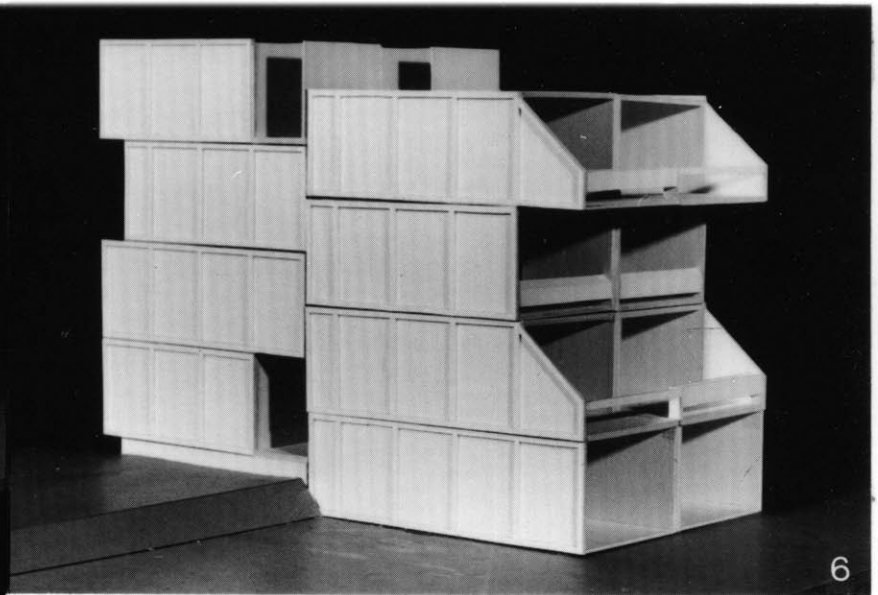
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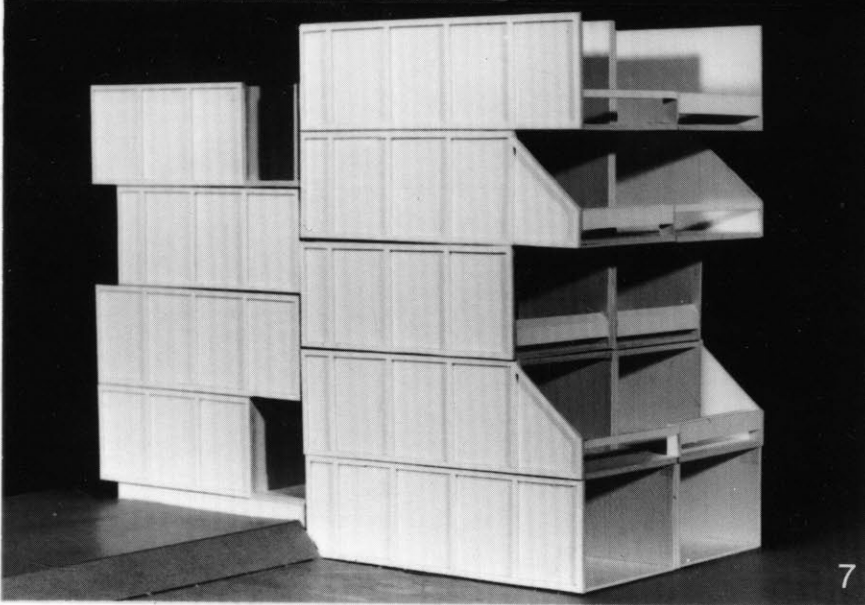
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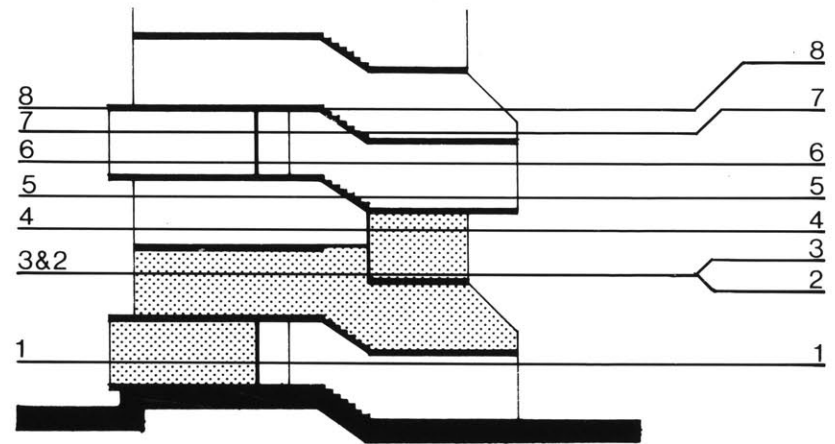
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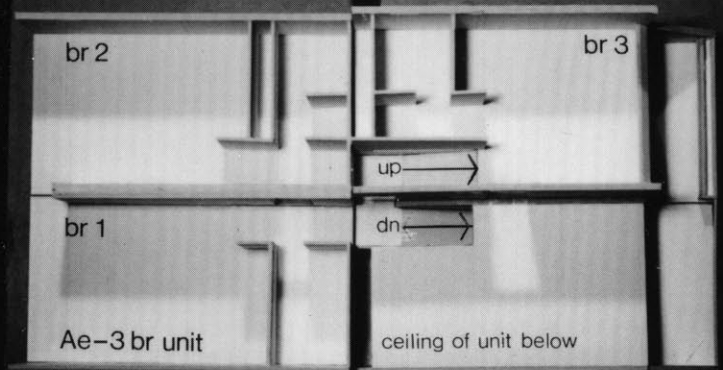
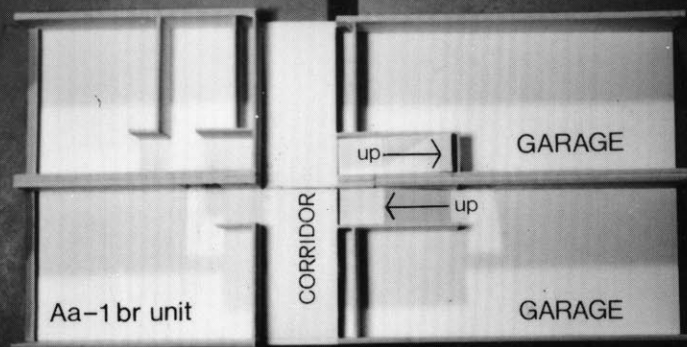
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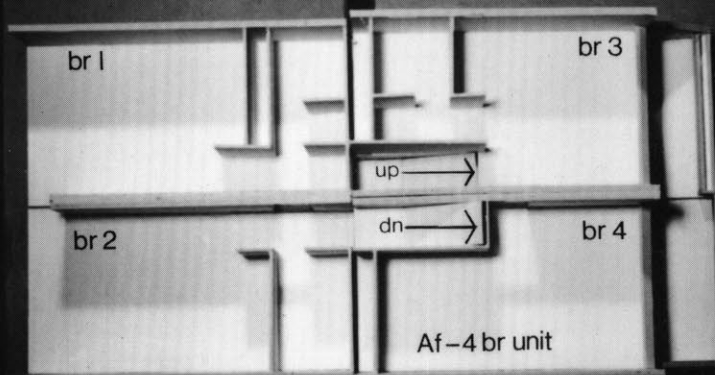


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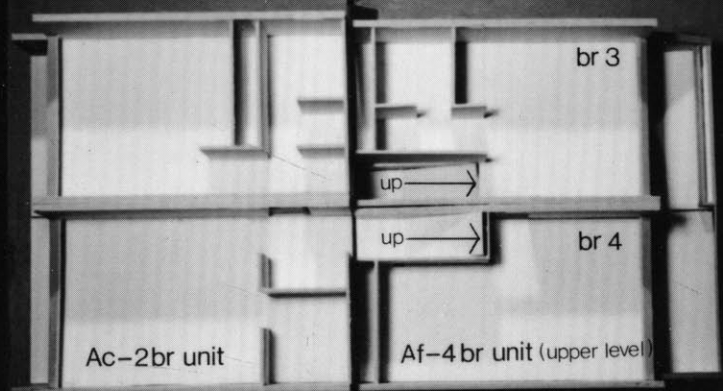


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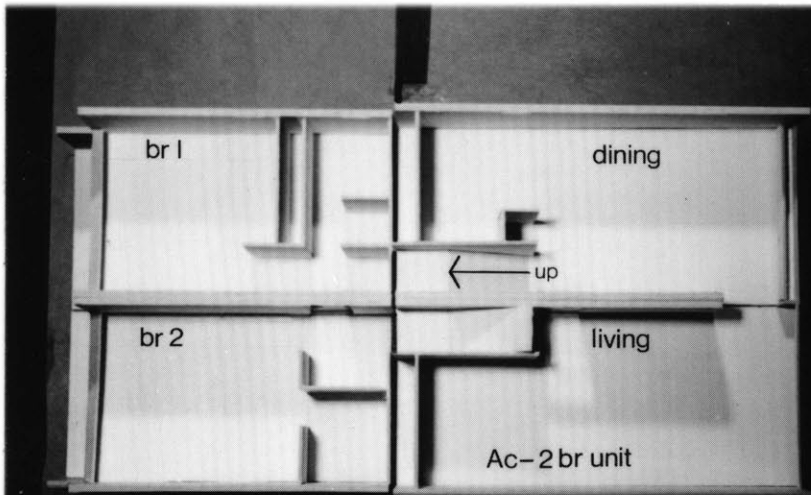
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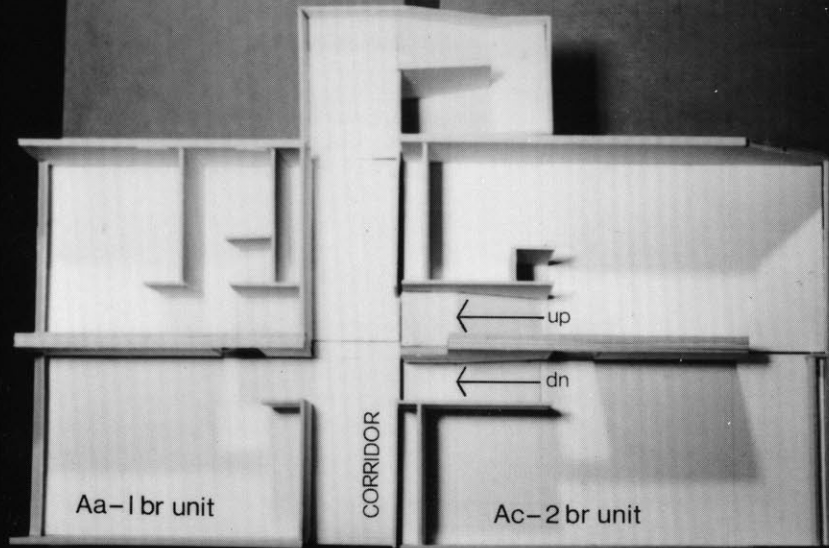
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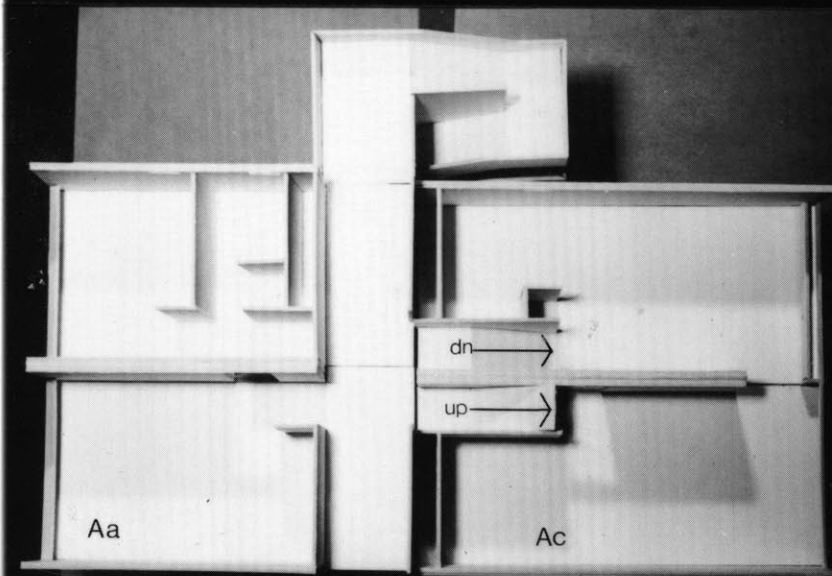
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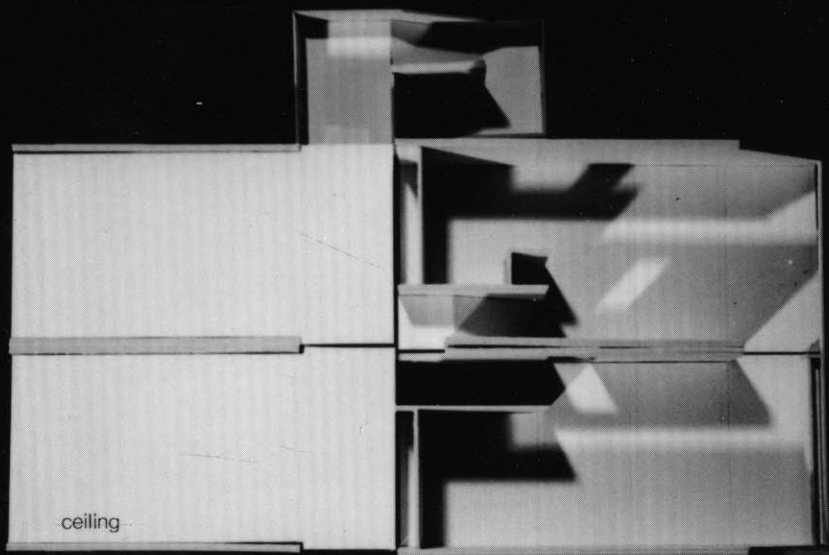
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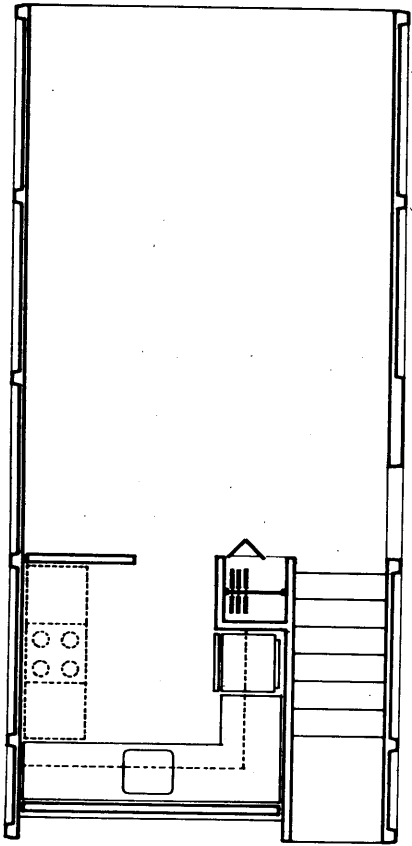
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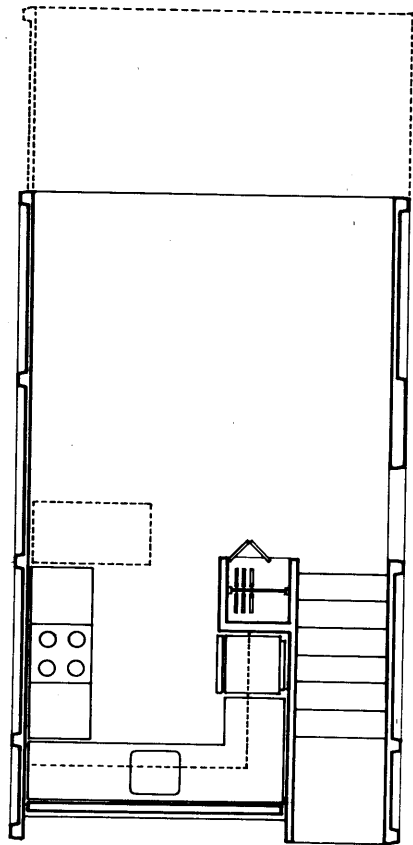
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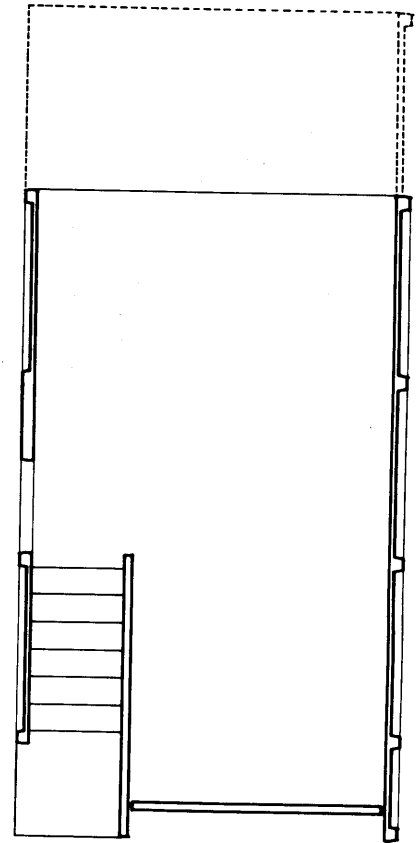
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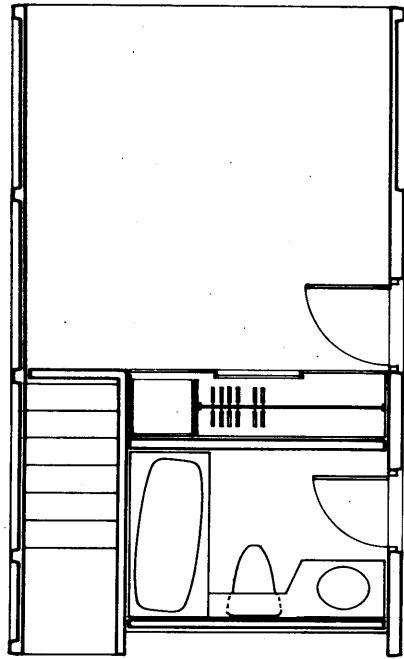


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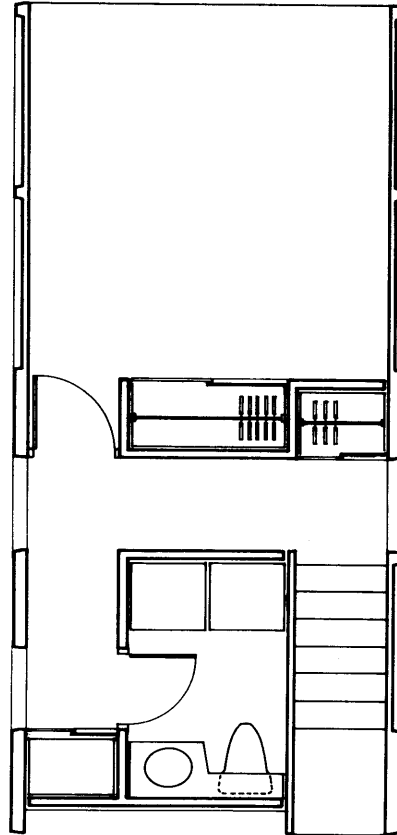


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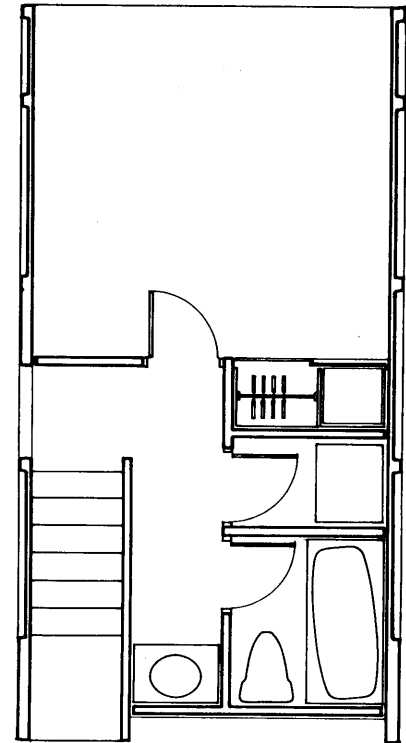
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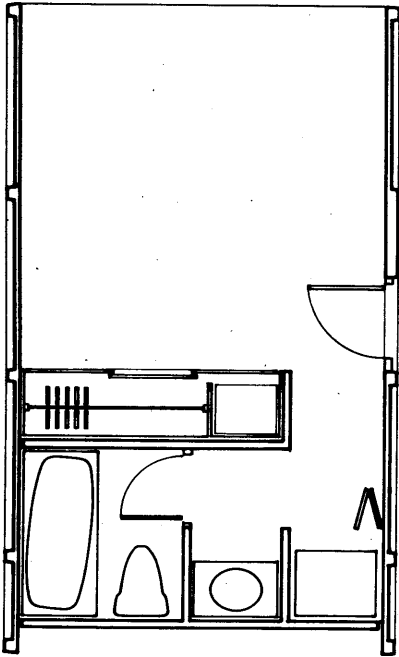
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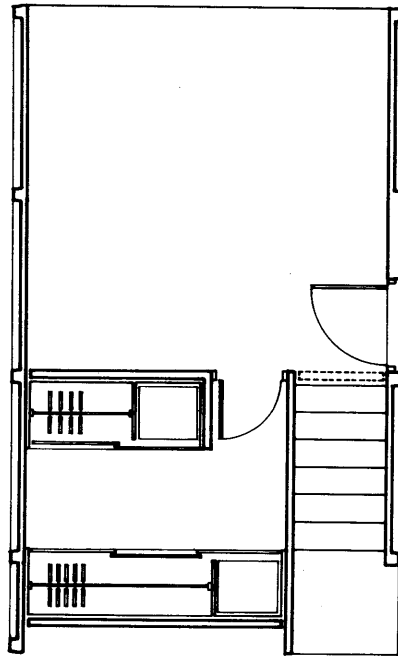
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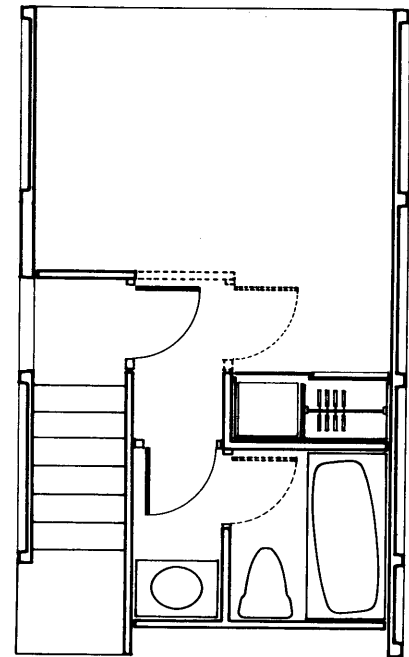
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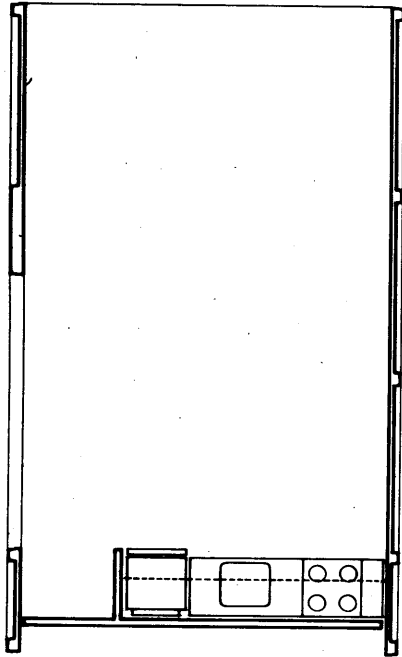
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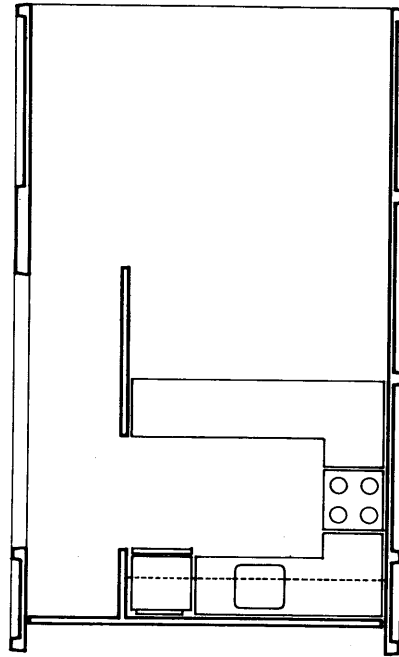
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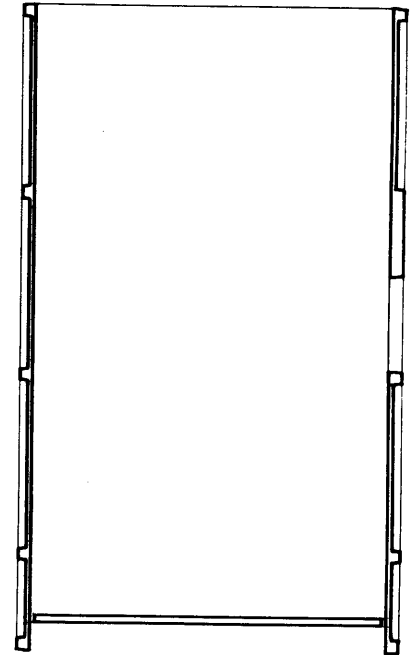
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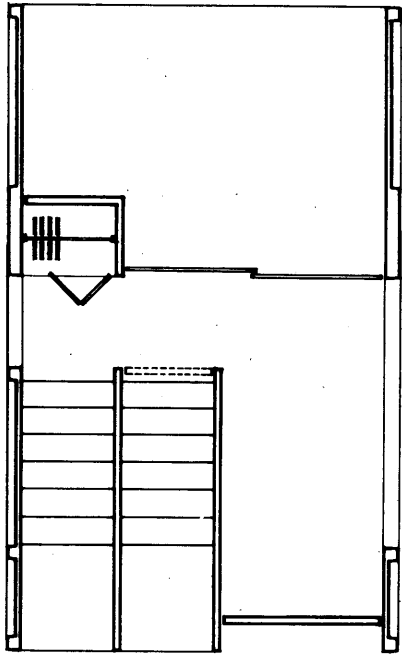
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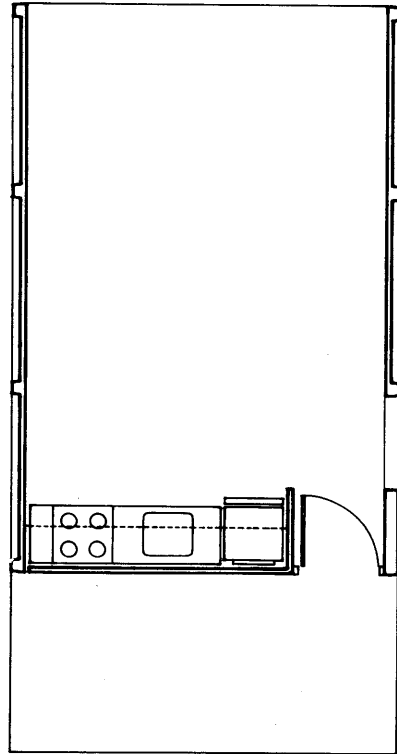
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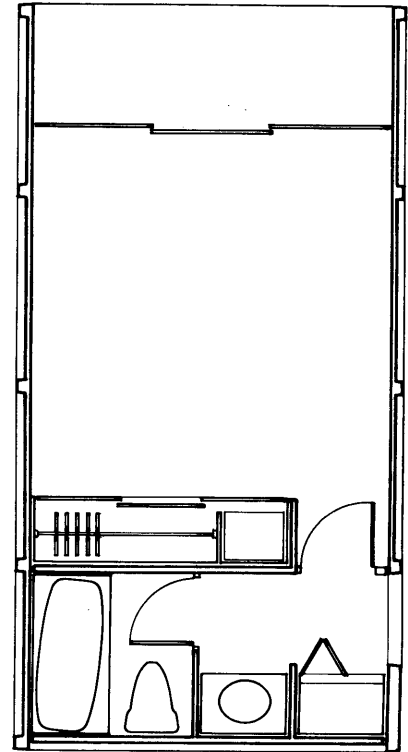
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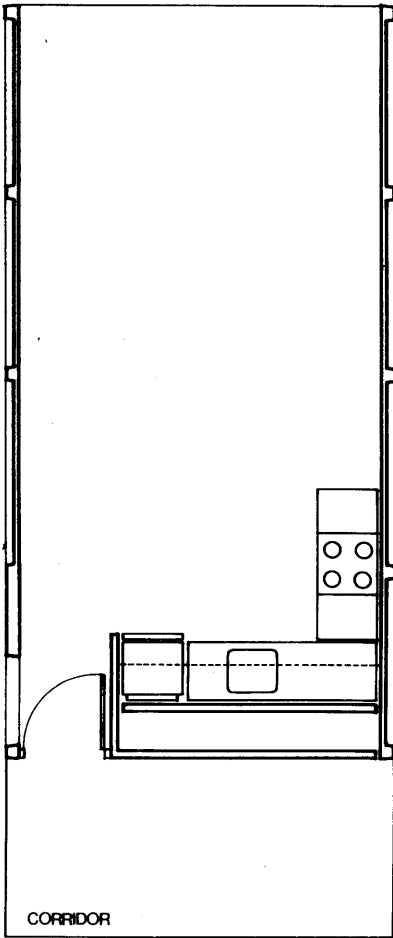
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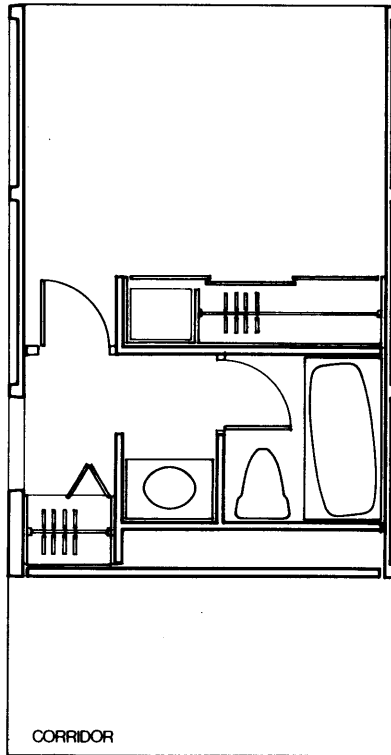
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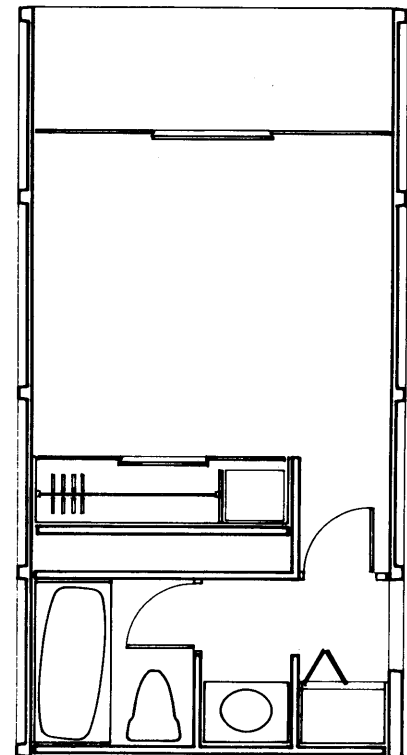
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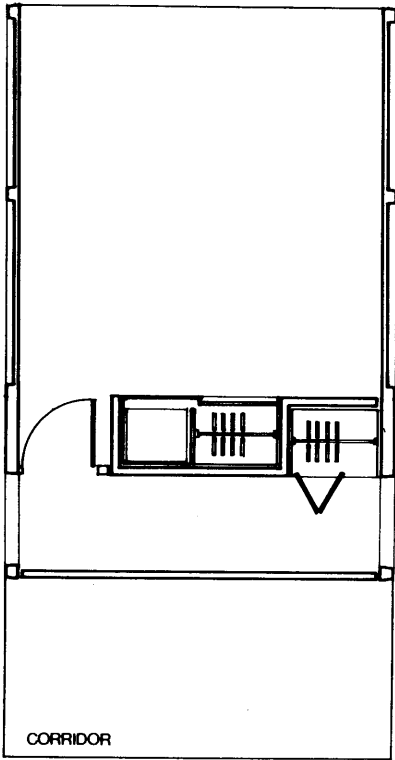
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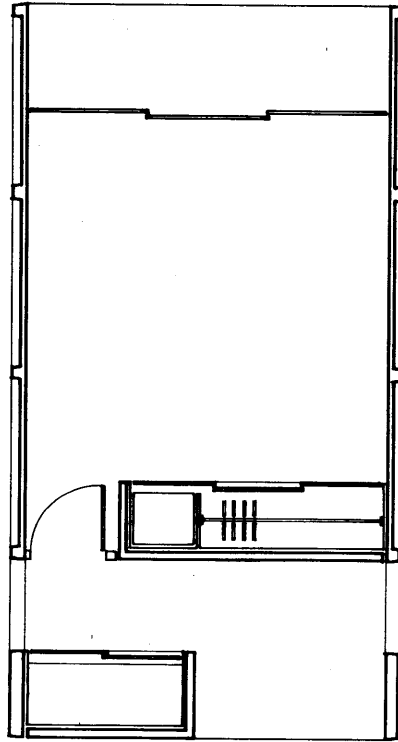
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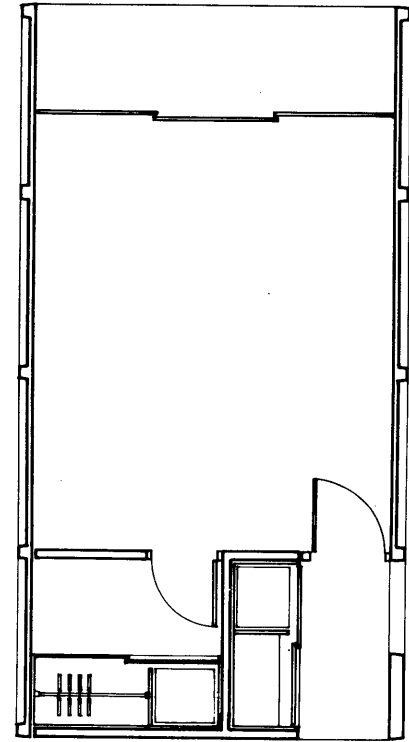
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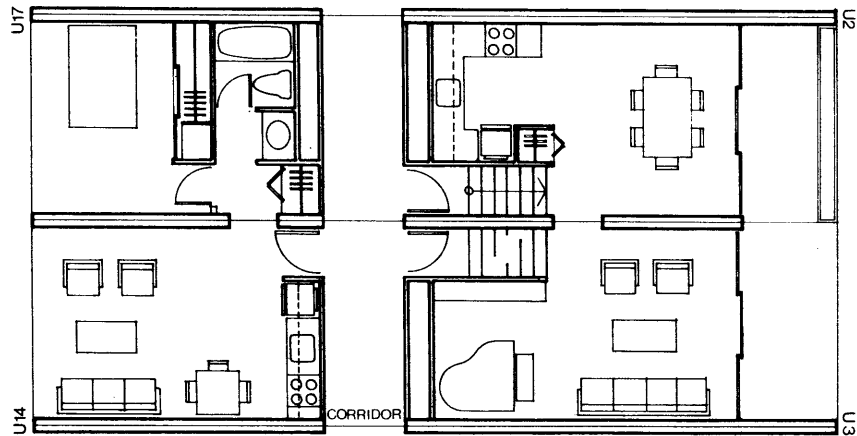
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U20 BT

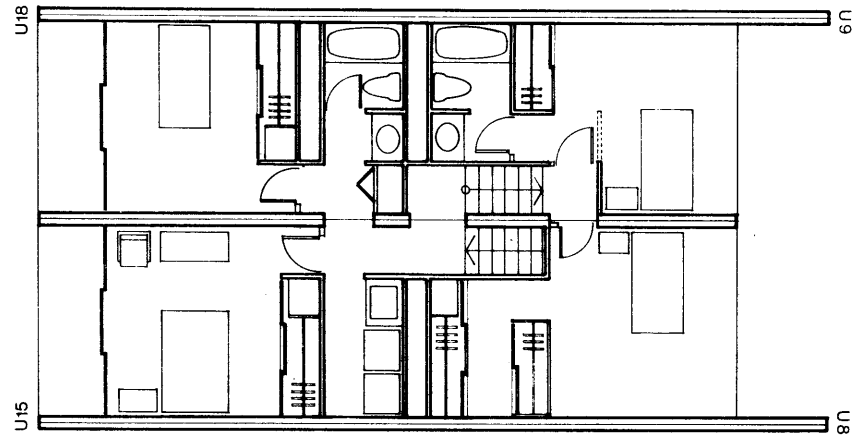


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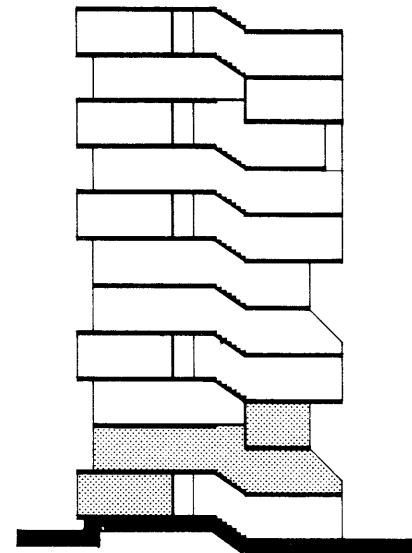
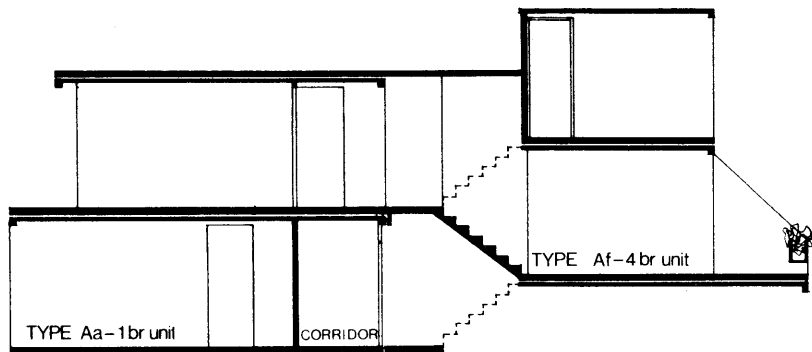


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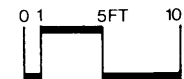
TYPE Af - 4 br unit



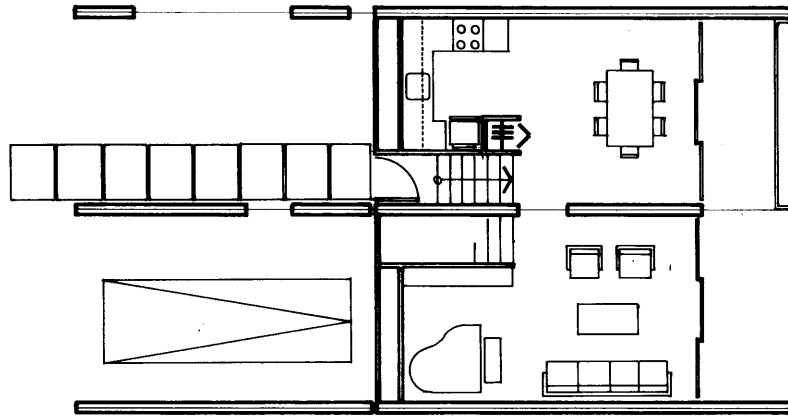
TYPE Af - 4 br unit (over)



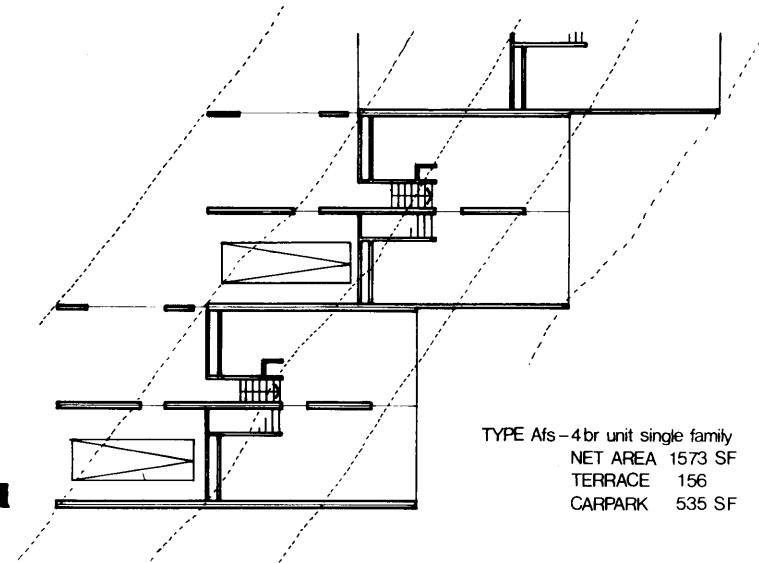
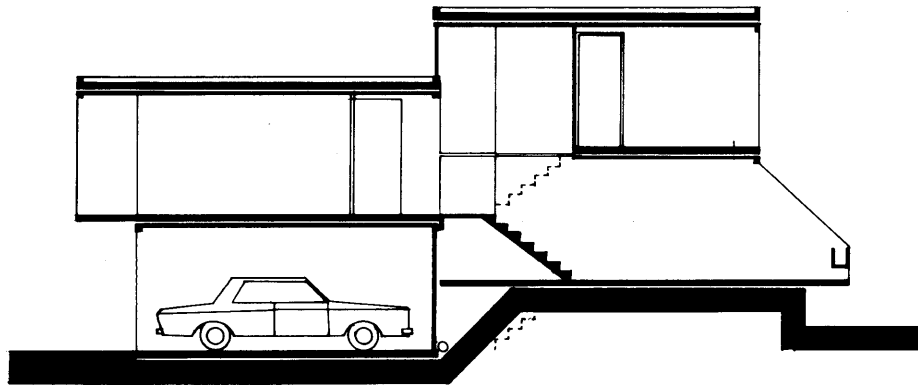
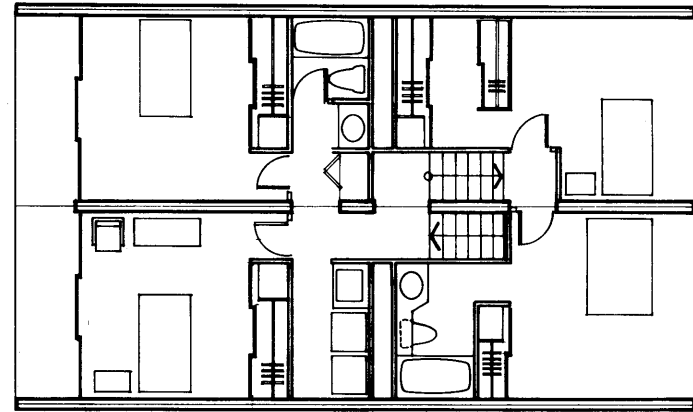
TYPE Aa - 1br unit	
NET AREA	480 SF
TYPE Af - 4br unit	
NET AREA	1573
TERRACE	156
GROSS AREA	1729 SF



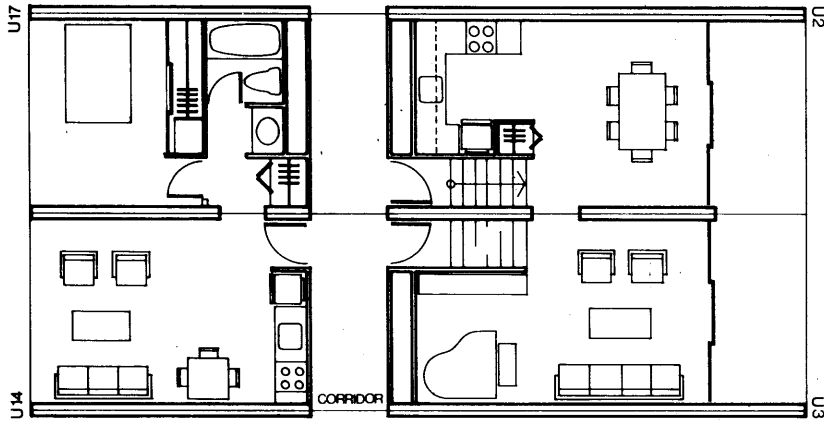
APARTMENT PLANS and SECTIONS



TYPE Afs - 4br unit single family attach

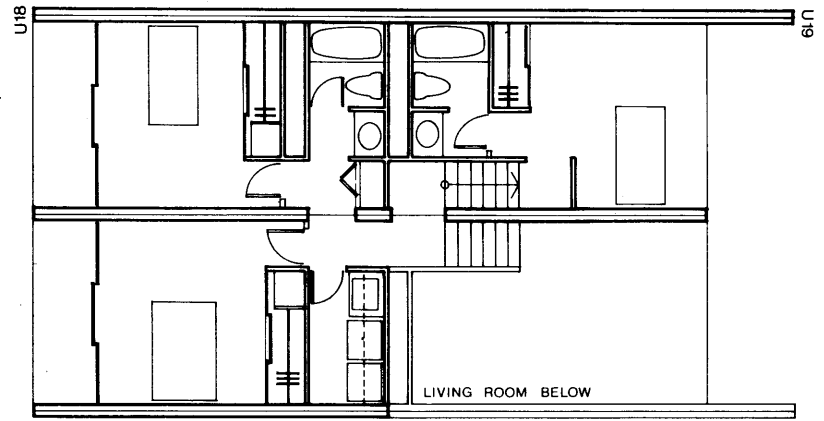


TYPE Afs - 4br unit single family
 NET AREA 1573 SF
 TERRACE 156
 CARPARK 535 SF

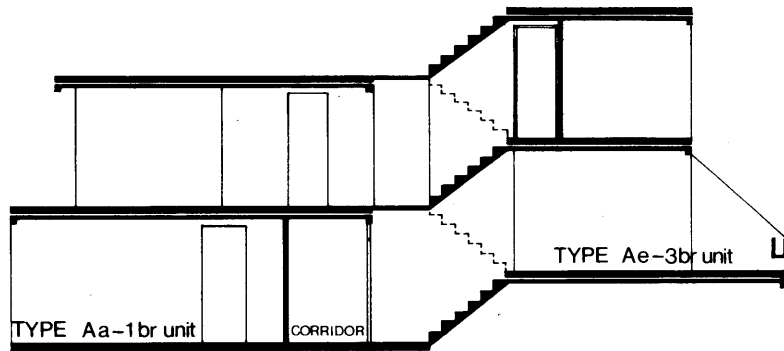


TYPE Aa-1 br unit

TYPE Ae-3 br unit



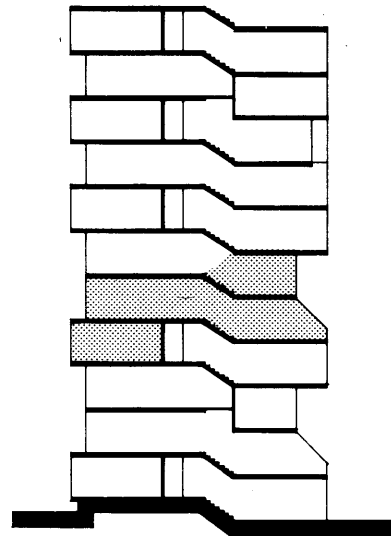
TYPE Ae-3 br unit (over)



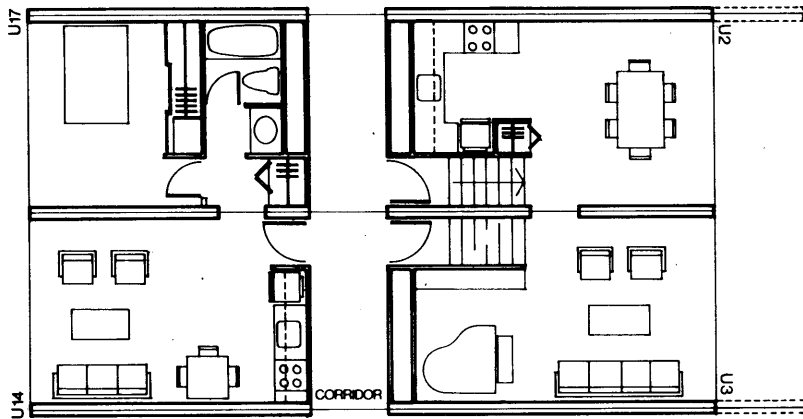
TYPE Aa-1 br unit

CORRIDOR

TYPE Ae-3 br unit

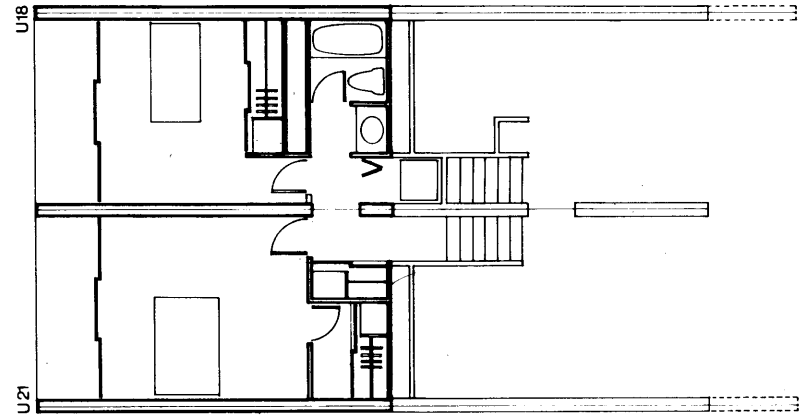


TYPE Aa-1 br unit		
NET AREA	480 SF	
TYPE Ae-3 br unit		
NET AREA	1313	
TERRACE	156	
GROSS AREA	1469 SF	

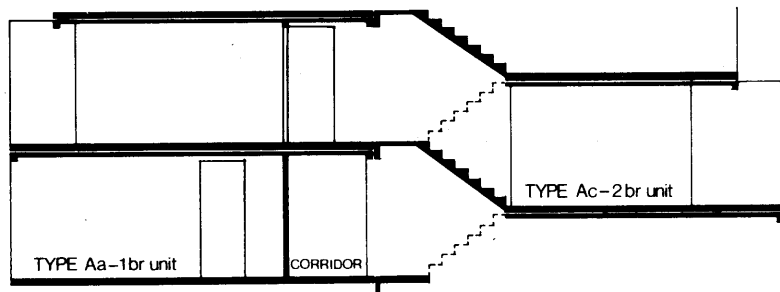


TYPE Aa-1br unit

TYPE Ac-2br unit



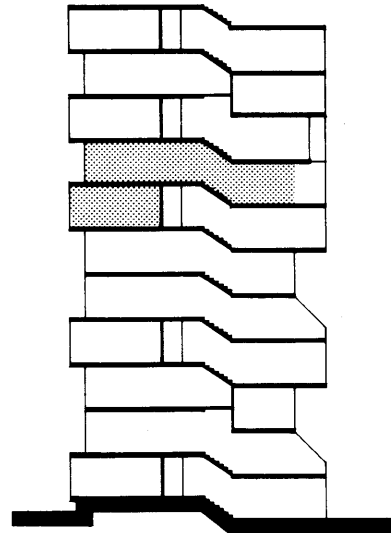
TYPE Ac-2br unit (over)



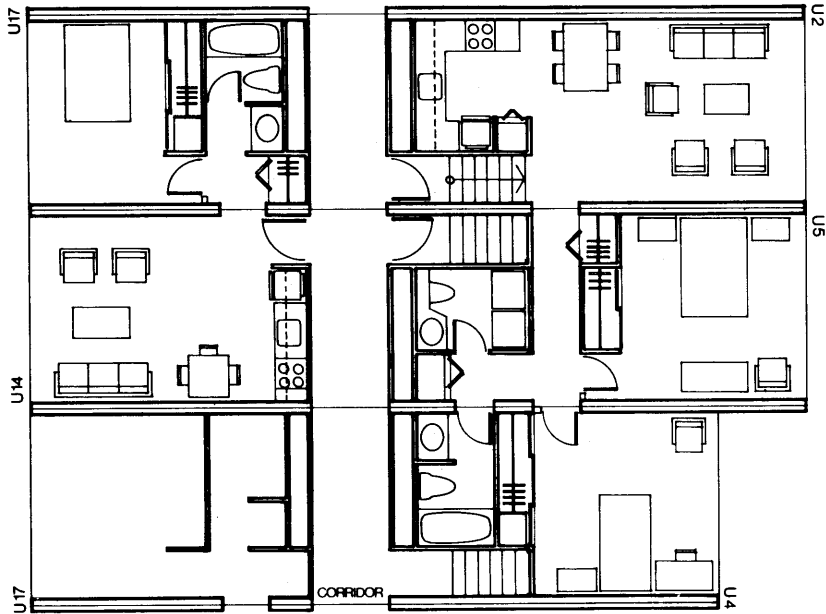
TYPE Aa-1br unit

CORRIDOR

TYPE Ac-2br unit

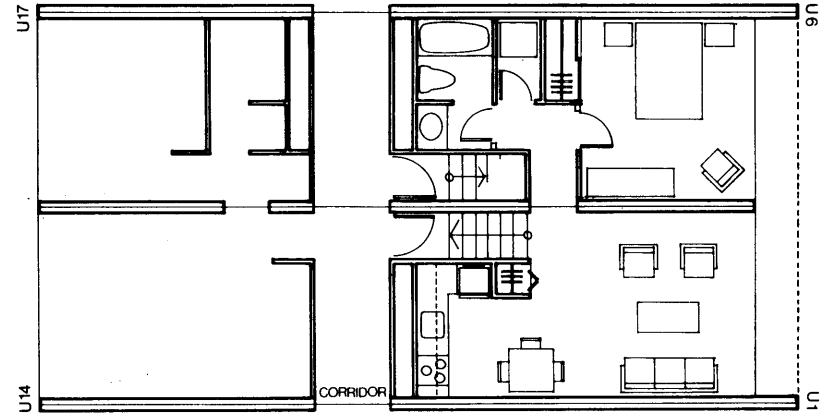


TYPE Aa-	1br unit	
	NET AREA	480 SF
TYPE Ac-	2br unit	
	NET AREA	1053
	TERRACE	156
	GROSS AREA	1206 SF

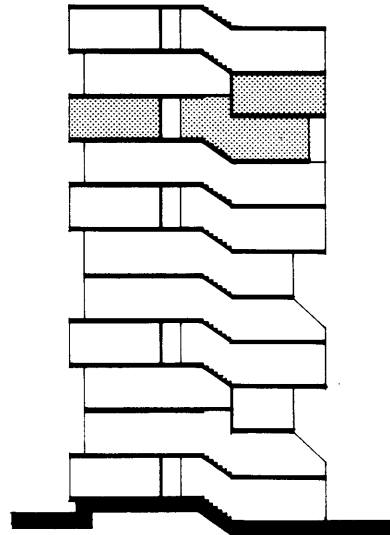
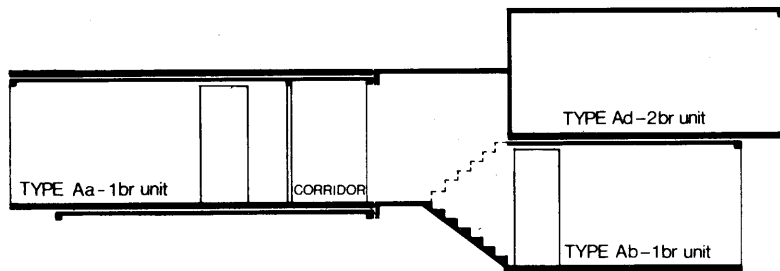


TYPE Aa-1br unit

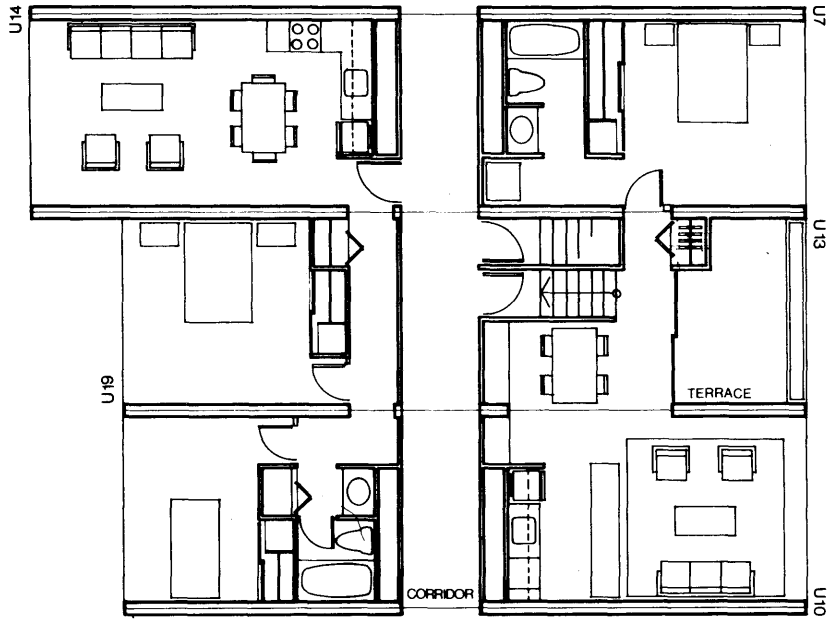
TYPE Ad - 2 br unit



TYPE Ab - 1 br unit

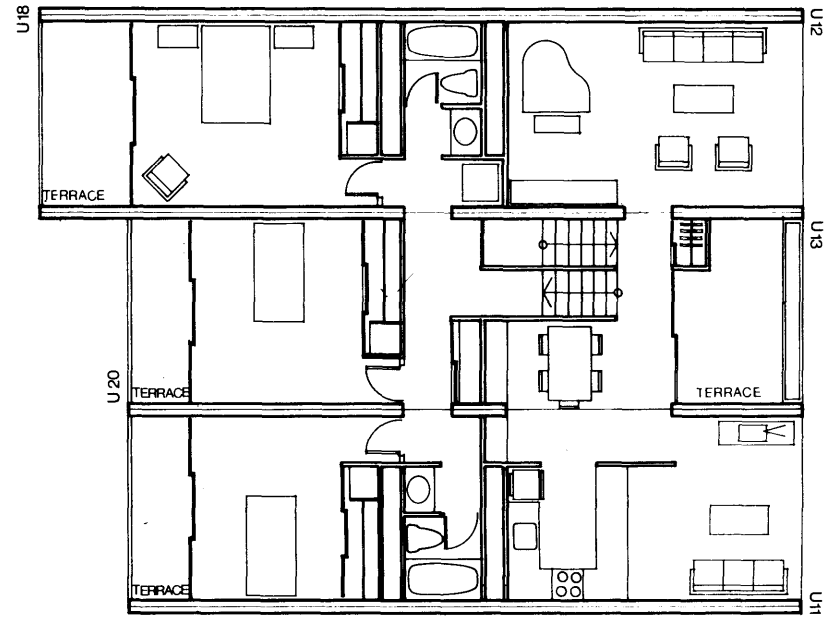


- TYPE Aa - 1br unit
NET AREA 480 SF
- TYPE Ab - 1br unit
NET AREA 603 SF
- TYPE Ad - 2br unit
NET AREA 940 SF

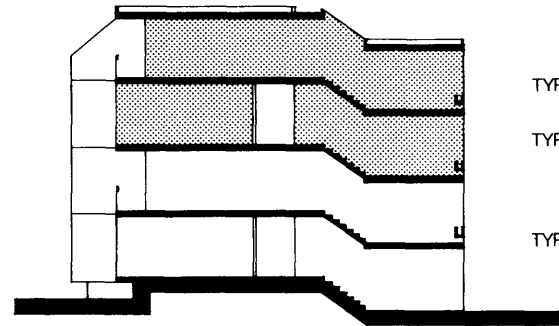
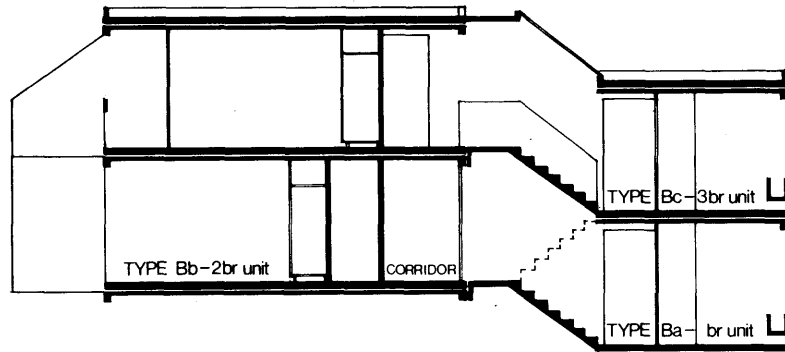


TYPE Bb - 2 br unit

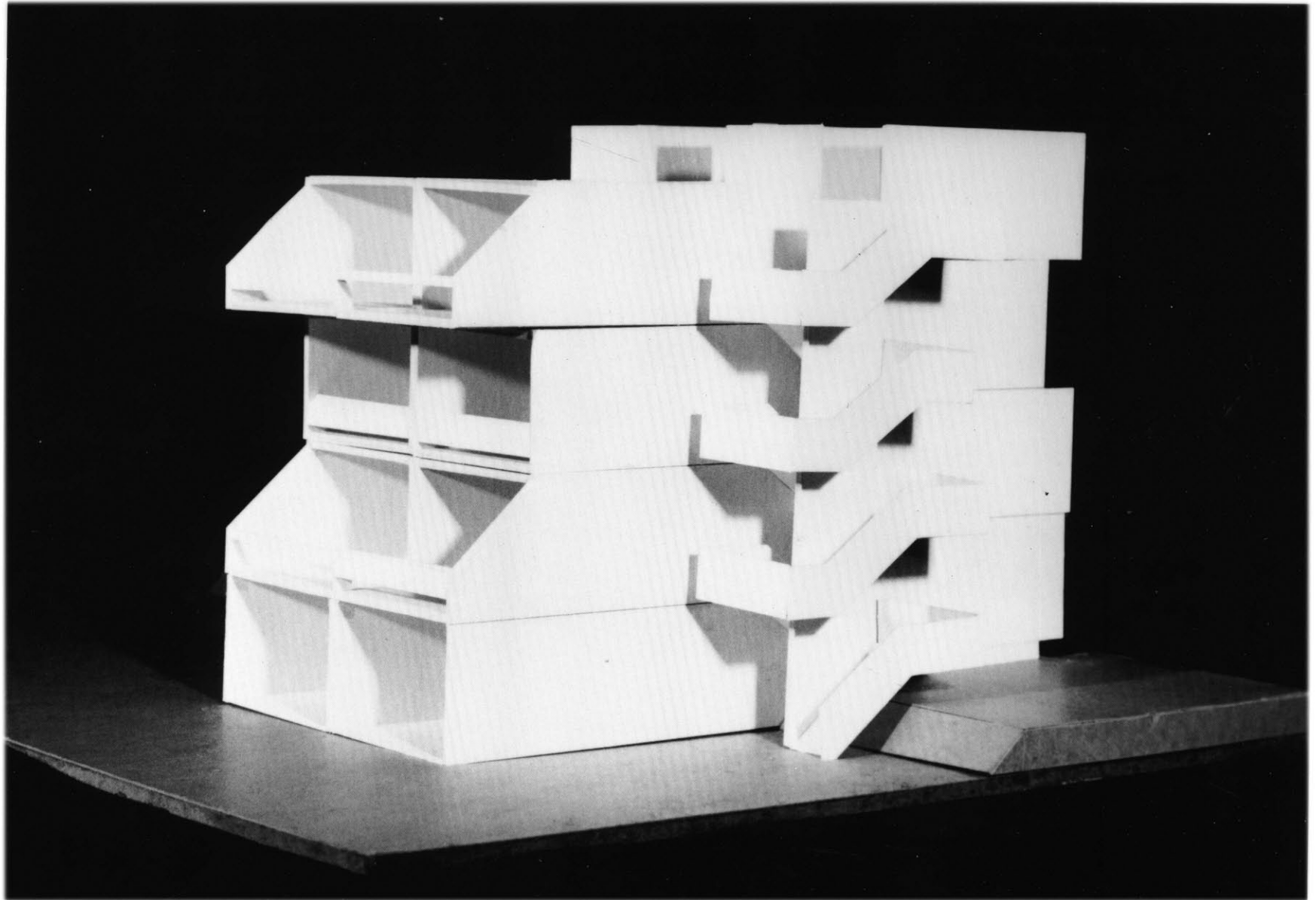
TYPE Ba - 1 br unit

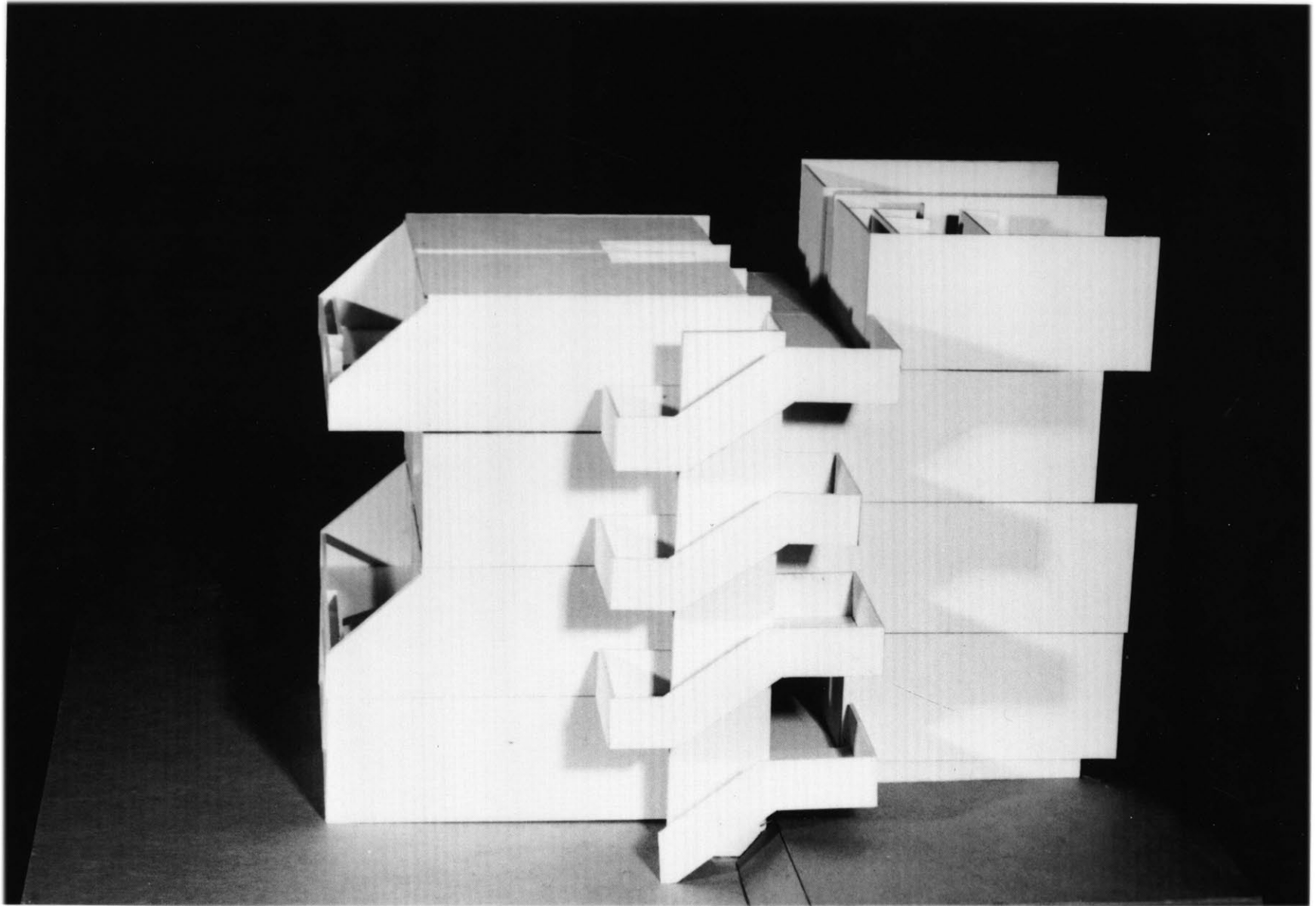


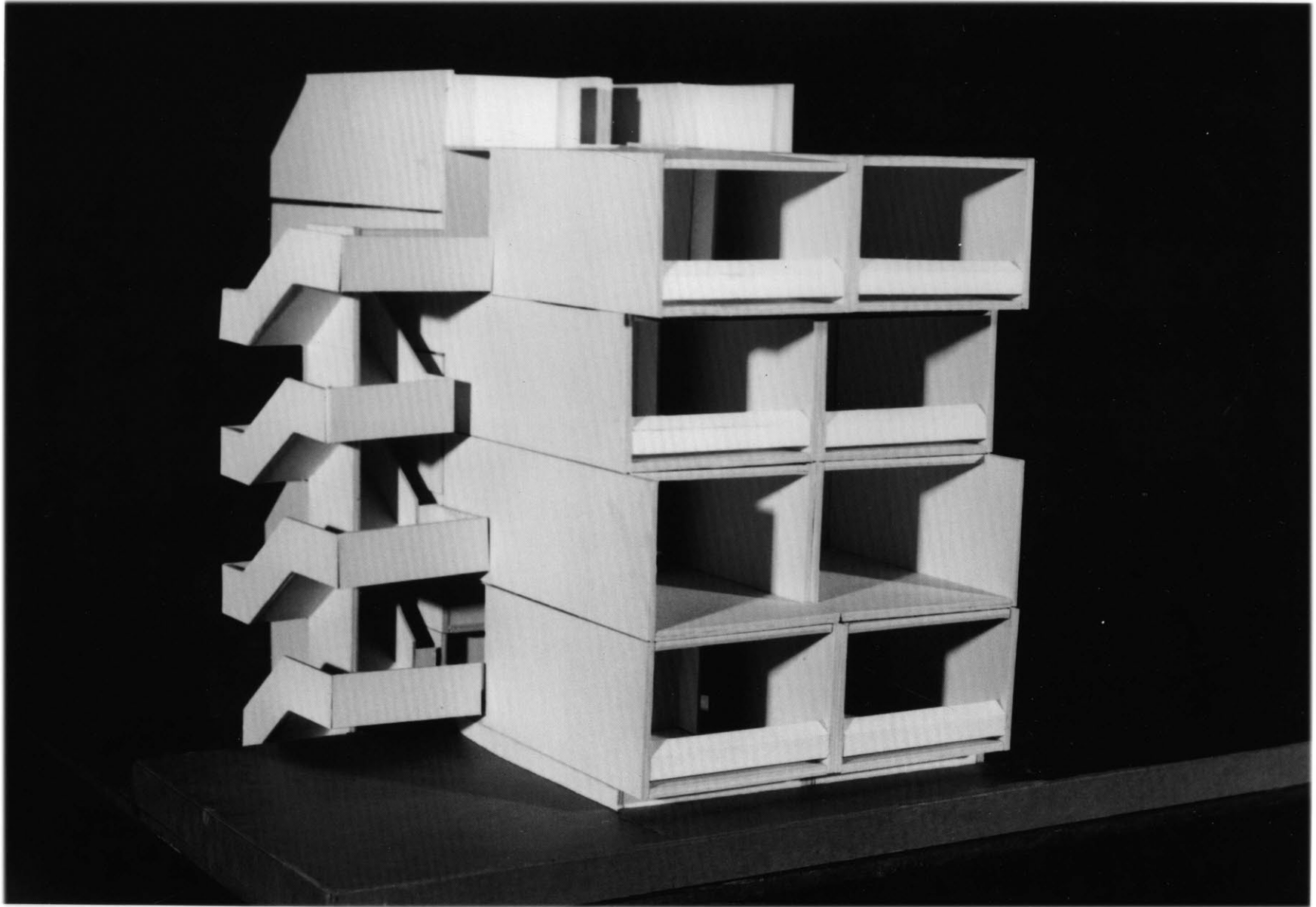
TYPE Bc - 3 br unit

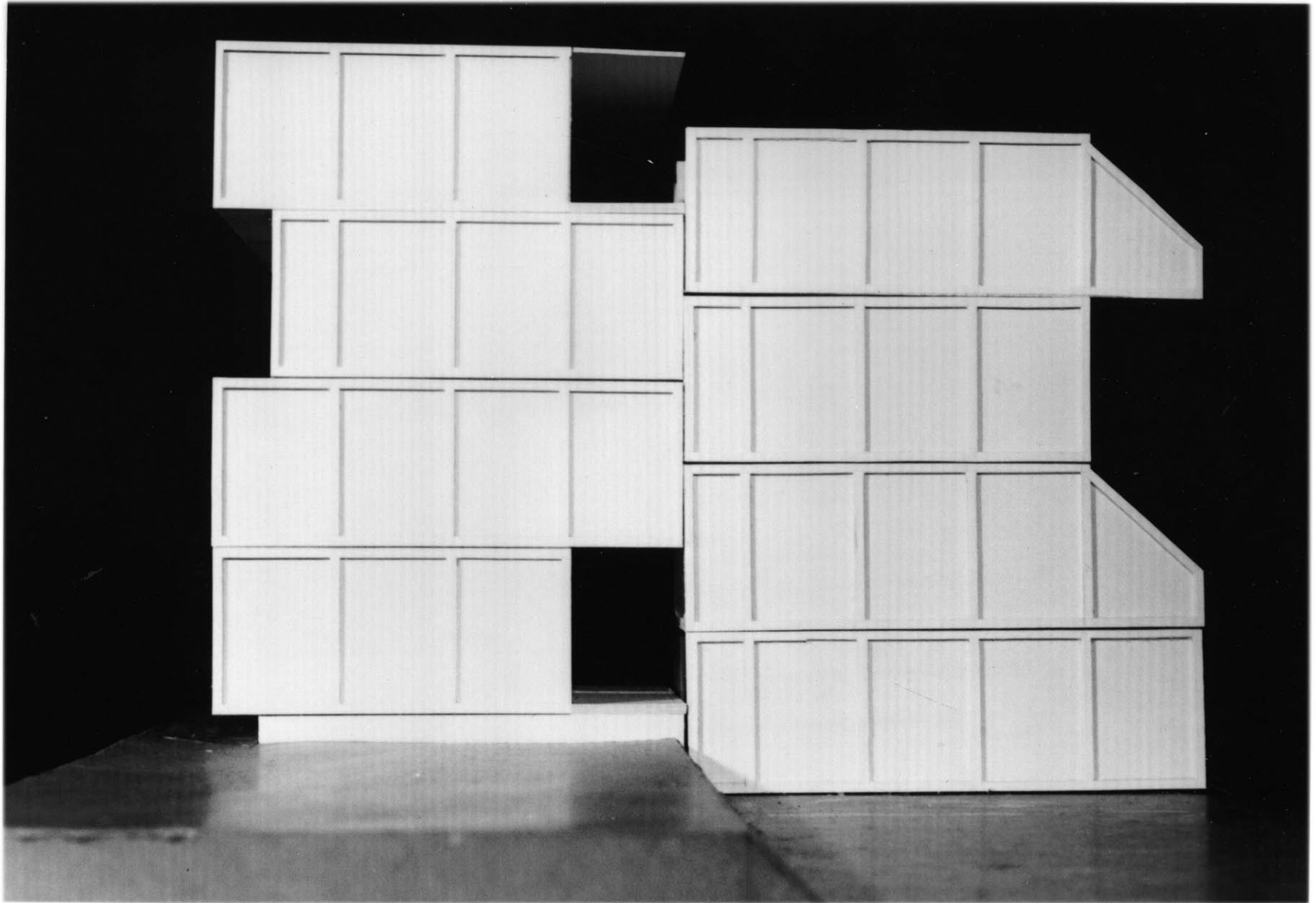


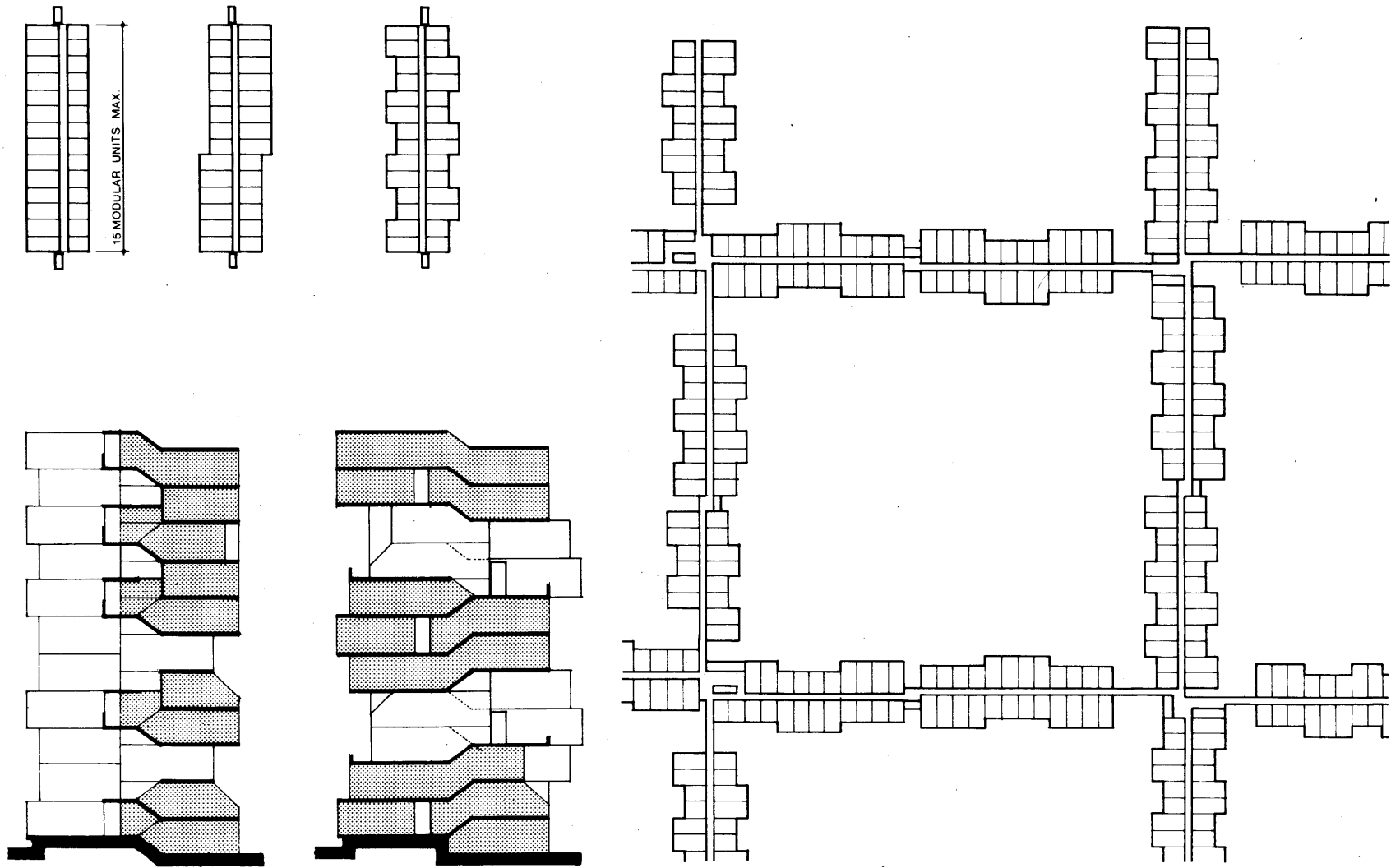
TYPE Bb-2br unit		
NET AREA	800	SF
TYPE Ba- 1br unit		
NET AREA	712	
TERRACE	04	
GROSS AREA	816	SF
TYPE Bc - 3 br unit		
NET AREA	1549	
TERRACE	286	
GROSS AREA	835	SF



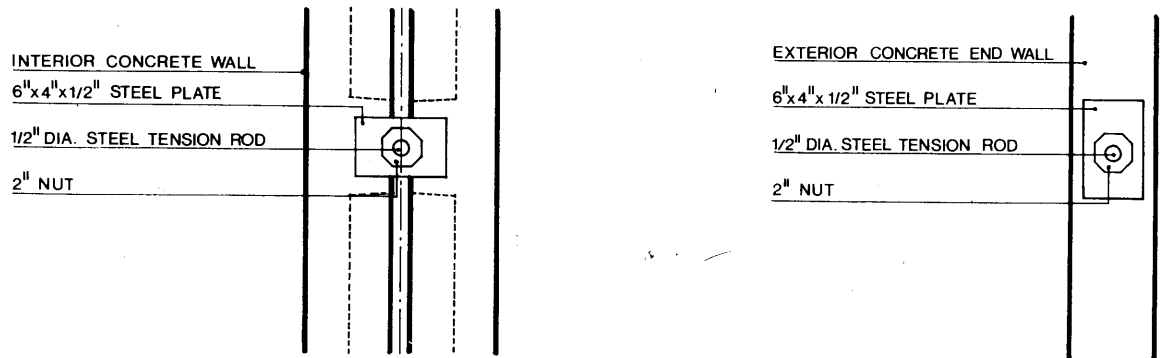






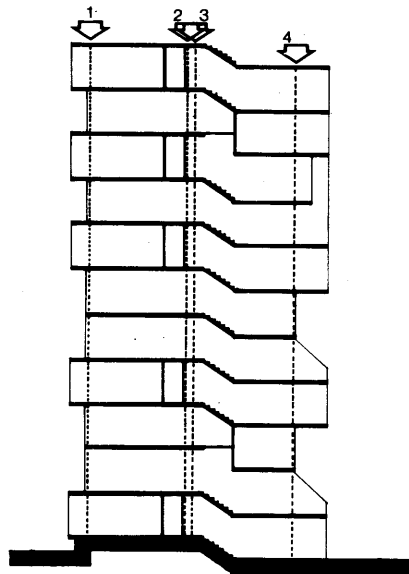


BASIC PLAN and SECTION CONFIGURATIONS



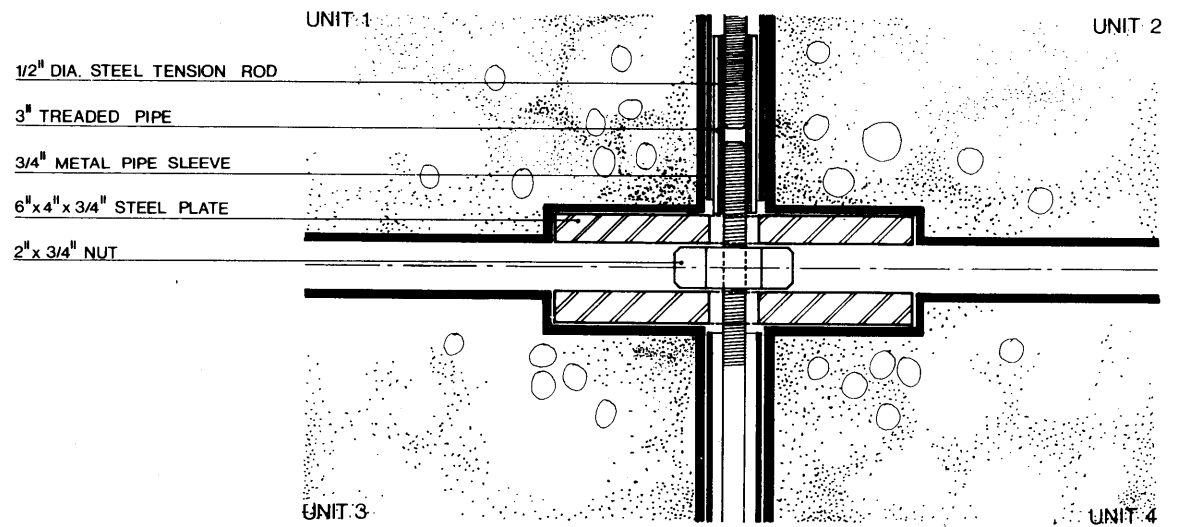
PLAN OF INTERIOR WALLS 1 1/2" = 1' 0"

PLAN OF EXTERIOR WALL

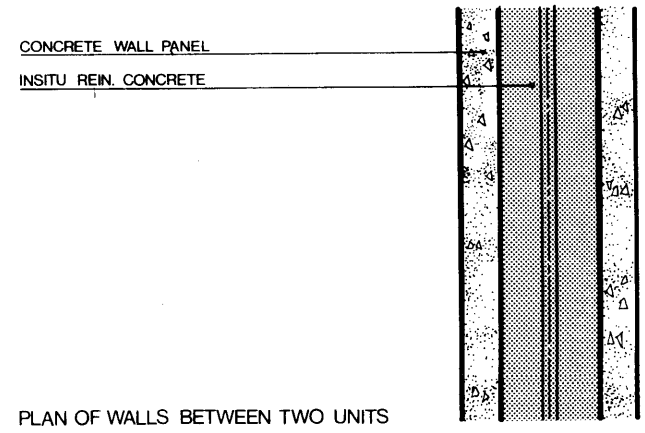
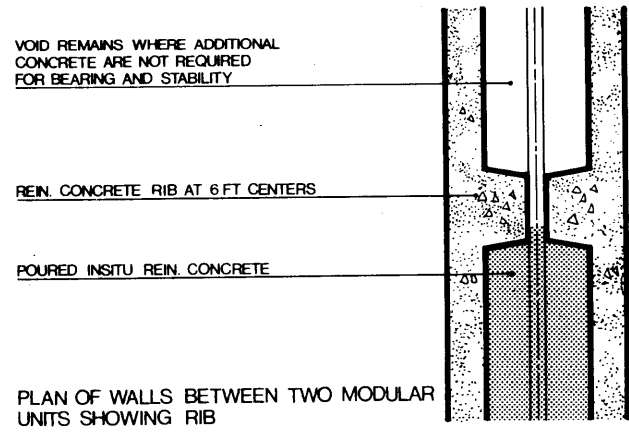
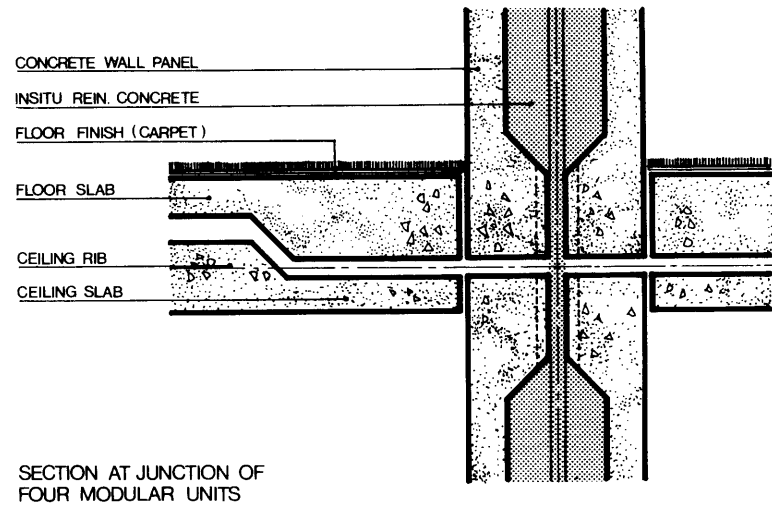
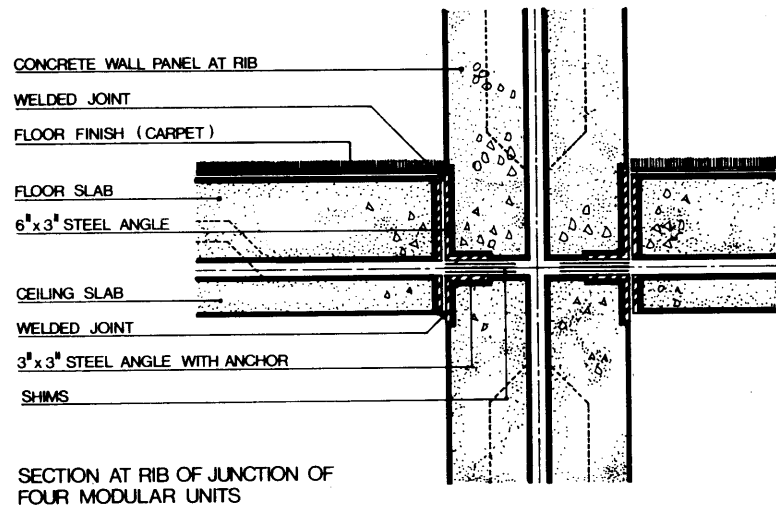


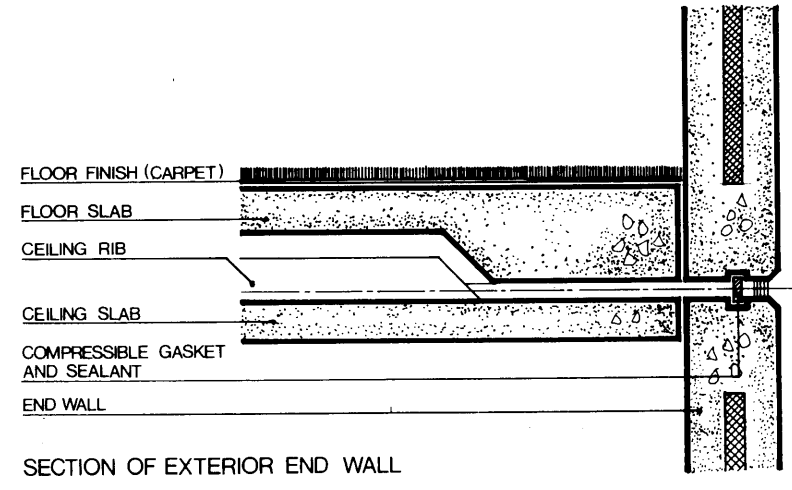
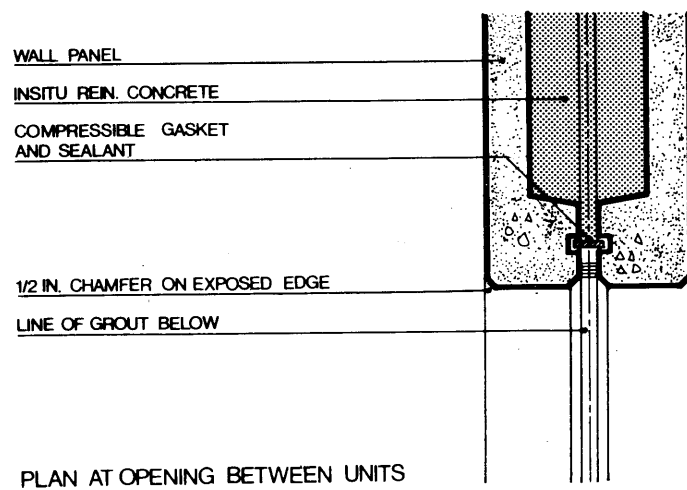
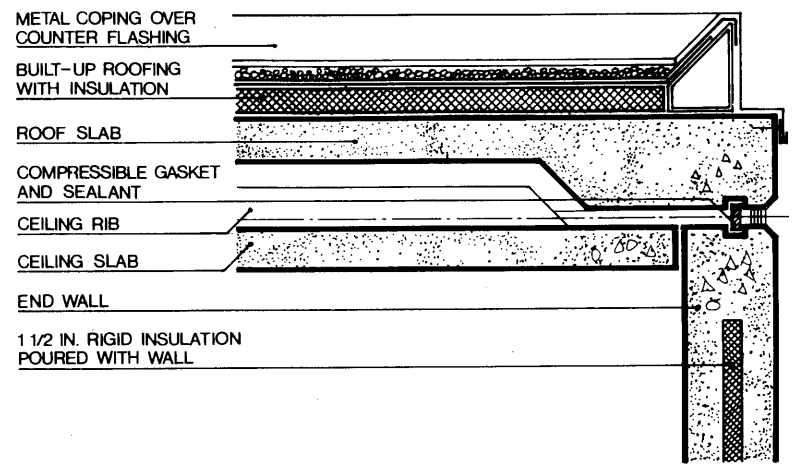
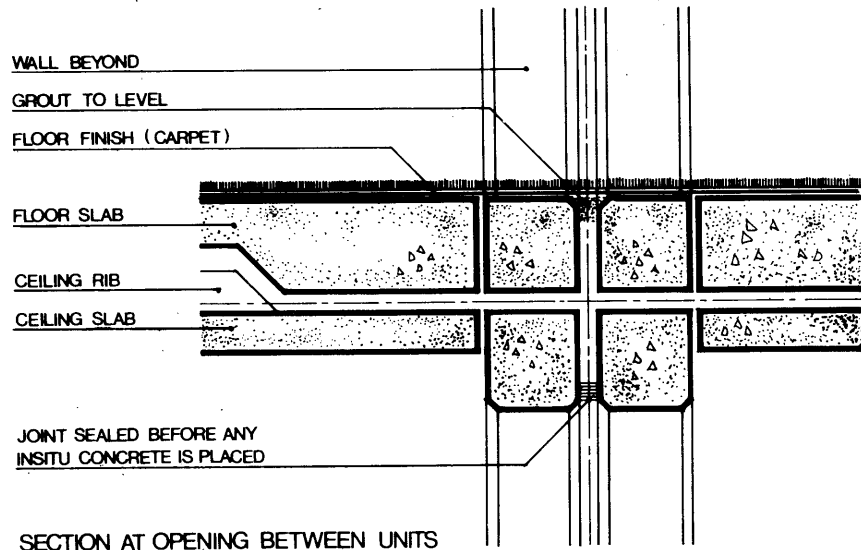
POSITIONS OF VERTICAL CONNECTING RODS

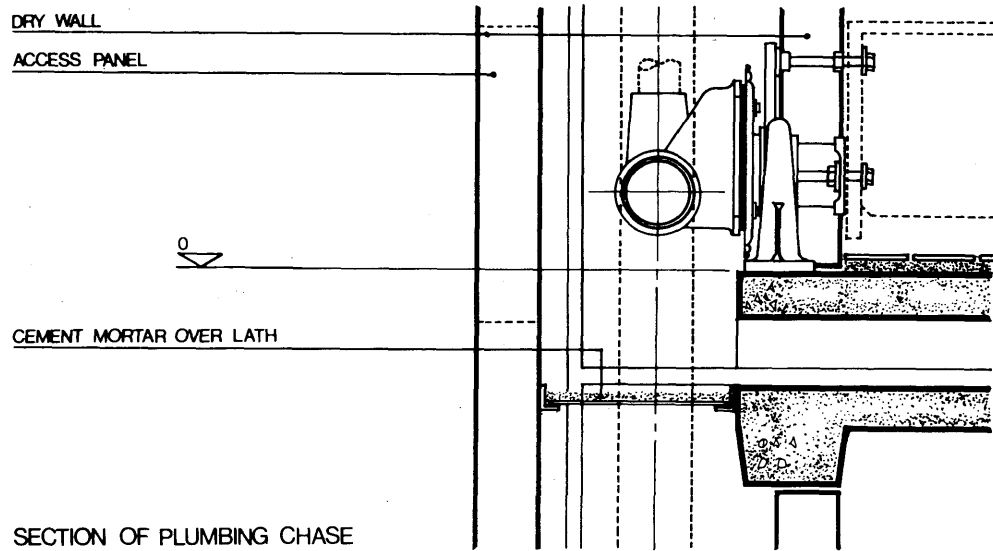
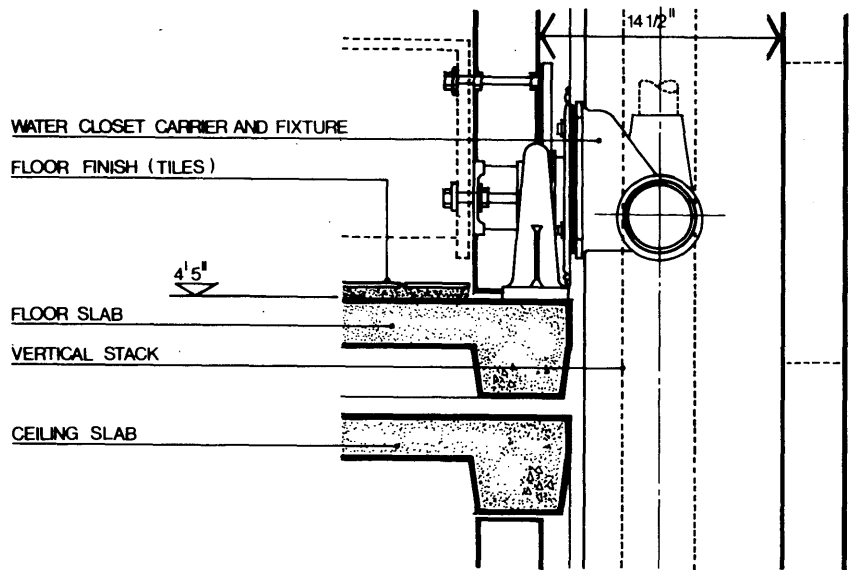
CONSTRUCTION DETAILS



DETAIL OF POST-STRESSED CONNECTING RODS BETWEEN 4 MODULAR UNITS







CASE STUDY

The aim of the case study is to illustrate the application and limitation of the system developed to a five acre medium density suburban site in Medford, Massachusetts.

Requirements

- a. Density, 48 dwelling units per acre, equals 240 units for the site.
- b. Car ratio 1-1.25 per dwelling unit. Covered and on grade parking.
- c. Dwelling units to be of 1-4 bedrooms, with higher ratios of 1 and 2 bedroom units than others.

Description of site

The site is bounded on three sides by roads. On the South by the primary road Mystic Valley Parkway. On the West by Winthrop Street and the North by High Street. Most of the pedestrian traffic occurs along High Street which leads to the shopping district to the East and a high school to the West.

The site is graded with the higher level on High Street and slopes away to the South. On the Southern end of the site, there is a small natural waterway which passes through the site.

Concept

The concept in site planning is to produce an identity to the community of this development. This is

achieved by a pedestrian way linking the pedestrian traffic on High Street to the recreational area at the bottom of the site. This pedestrian way provides the main circulation to the apartments and is identified by it.

To encourage life and activity along the pedestrian way, the scale of the spaces are kept low by the use of low rise walk-up apartments which defines the open spaces. Pedestrian movements, play areas for children in close proximity to their home and apartments which overlook the pedestrian way helps to create life and activity to the main pedestrian path. Vehicles which are segregated from the main pedestrian path are limited to the East and West periphery of the site.

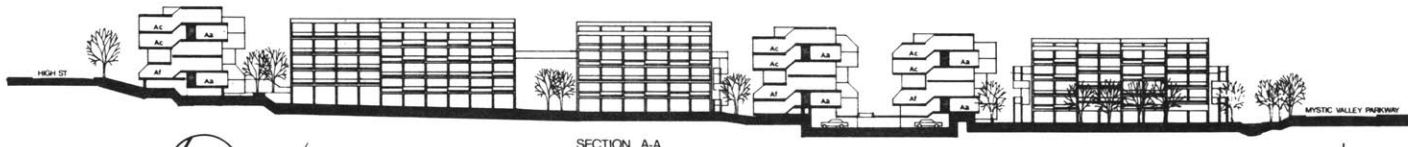
DATA OF CASE STUDY

	4BR. UNIT	3BR. UNIT	2BR. UNIT			1BR. UNIT		UNITS PER
	TYPE Af	TYPE Ae	TYPE Ac	TYPE Ad	TYPE Bb	TYPE Aa	TYPE Ab	BLOCK
BLOCK A	4	-	8	-	-	8	-	20
B	-	8	4	-	-	8	6	26
C	3	-	6	-	2	-	1	12
D	-	6	3	-	4	-	-	13
E	-	10	5	2	4	4	4	29
F	5	-	10	4	4	10	-	33
G	4	-	8	-	4	6	8	30
H	4	-	8	-	-	8	2	22
J	-	6	3	-	-	10	4	23
K	-	12	6	-	6	-	-	24
L	-	8	4	-	-	8	-	20
			65	6	24	62	25	252
	20	50	95			87		
	8%	19.8%	37.7%			34.5%		

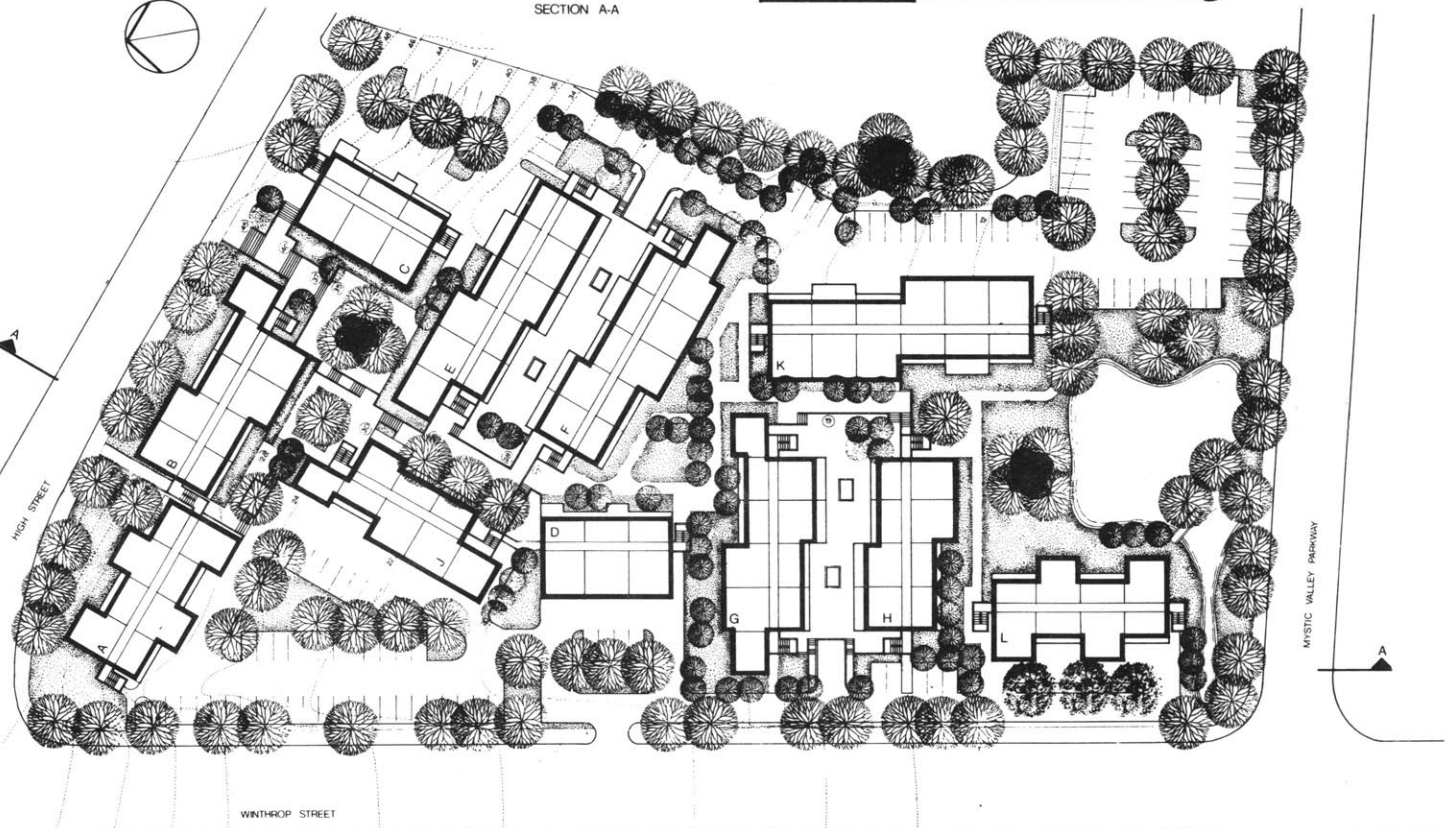
Total number of dwelling units equals 252
 Density is 50.4 DU/acre

Car parking on grade 127
 Under cover 90
 Total number of cars 217

Building site coverage 58,000 s.f. = 28%
 Covered car park 3,090 s.f.
 Total site coverage 61,090 s.f. = 29%

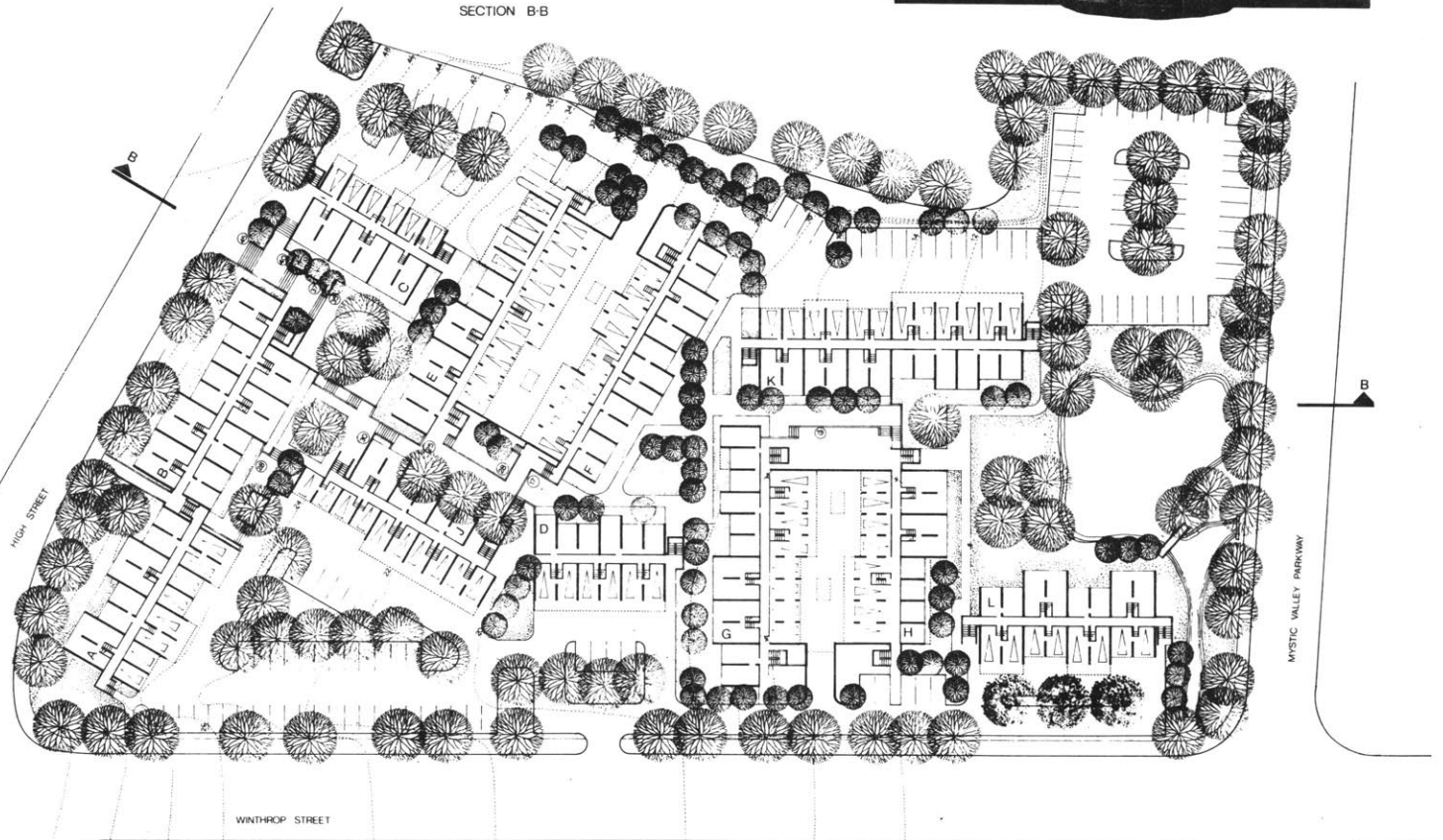


SECTION A-A



SITE PLAN

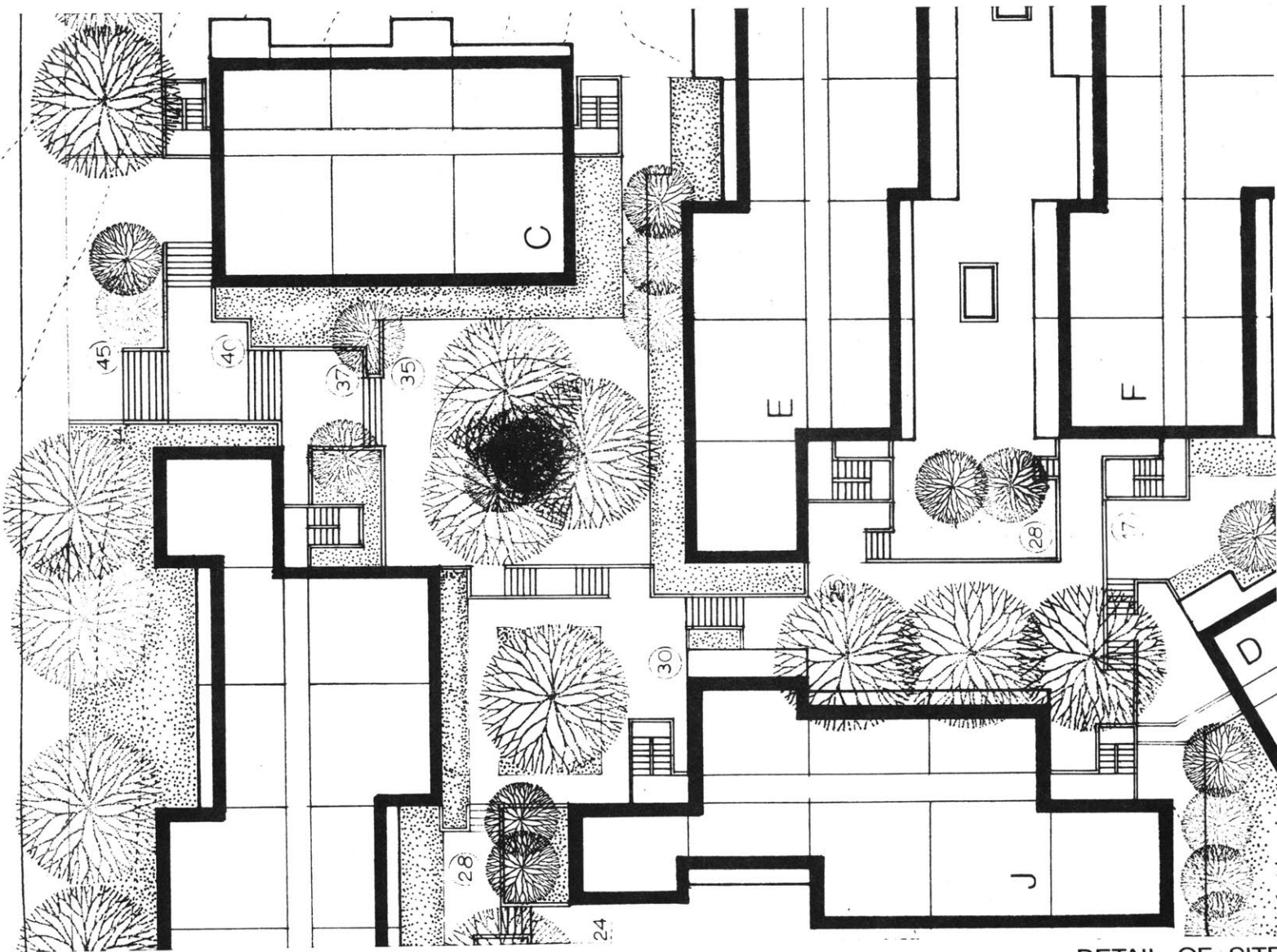
MASTER OF ARCHITECTURE THESIS
M. I. T. JANUARY 1973 RONALD LU
0 10 20 100 FT



SITE PLAN AT CAR PARK LEVEL

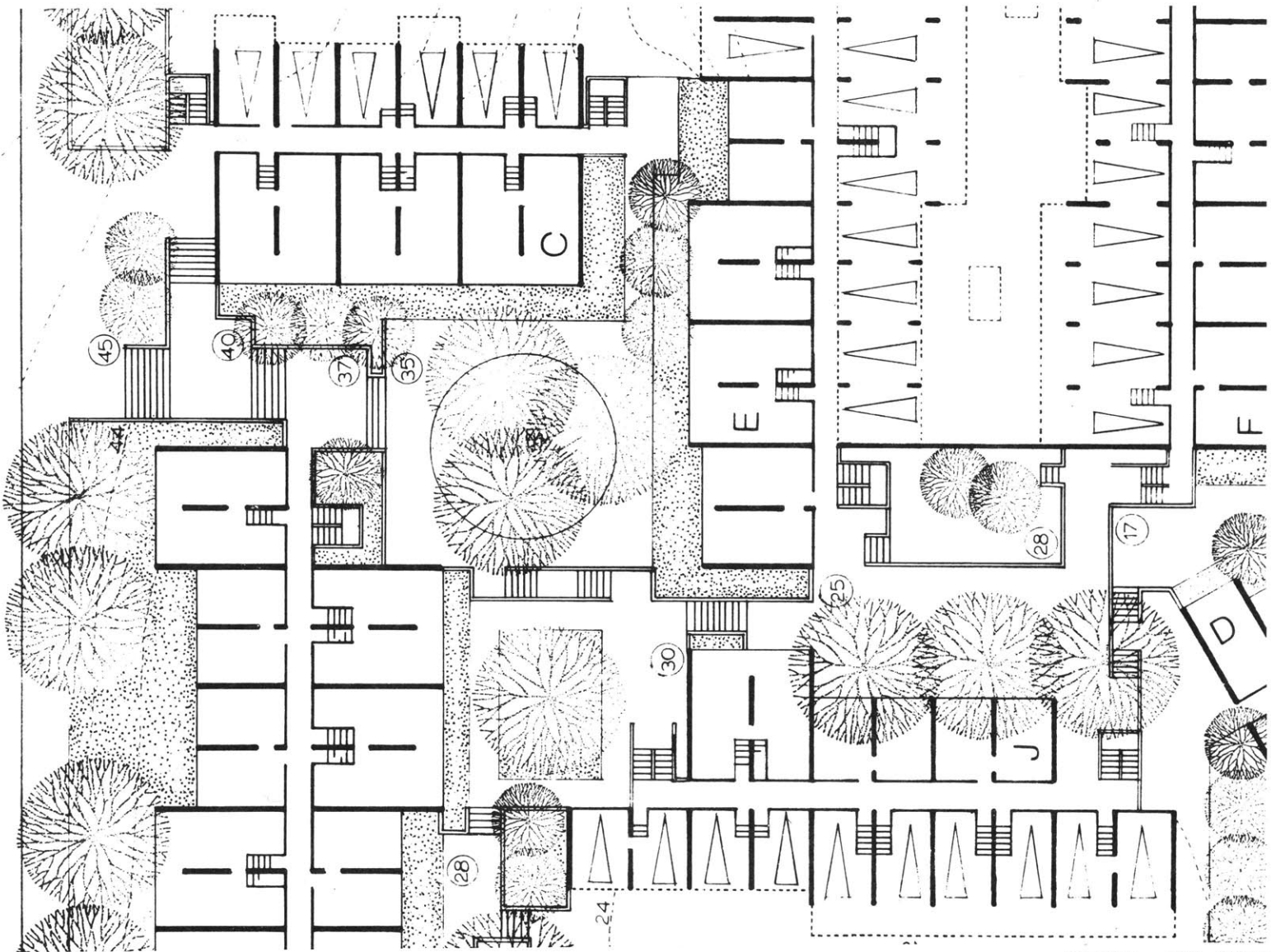
MASTER OF ARCHITECTURE THESIS
 M I T JANUARY 1973 RONALD LU

0 15 30 60
 FEET

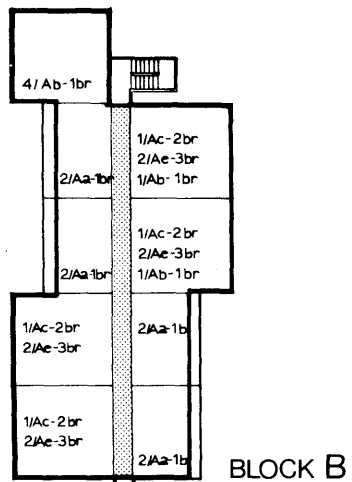


DETAIL OF SITE

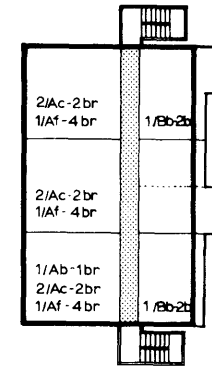
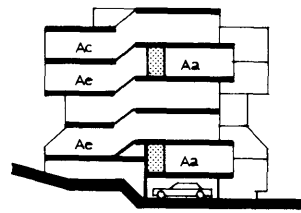
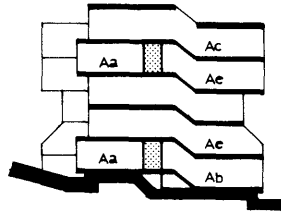
HIGH ST



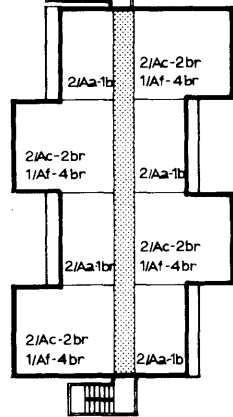
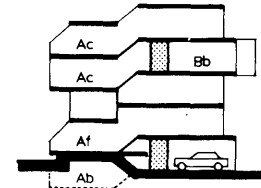
DETAIL OF SITE



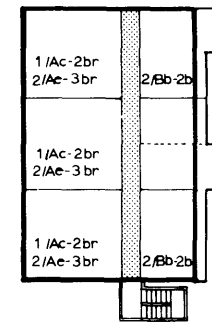
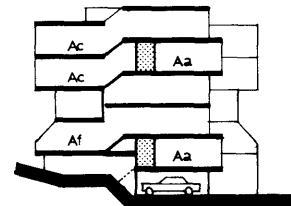
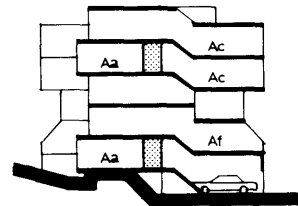
BLOCK B



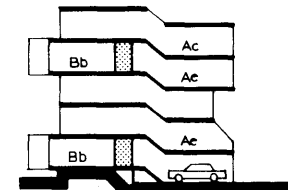
BLOCK C



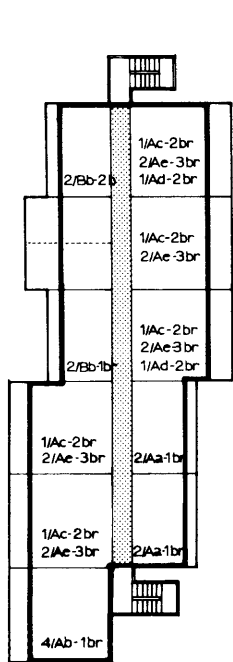
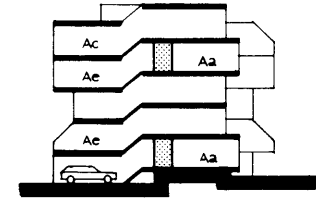
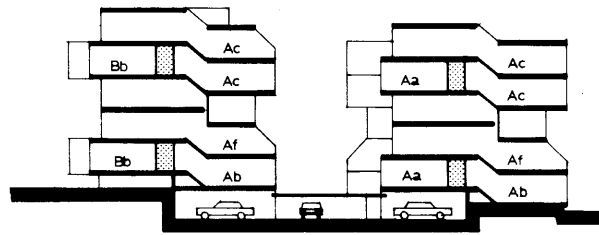
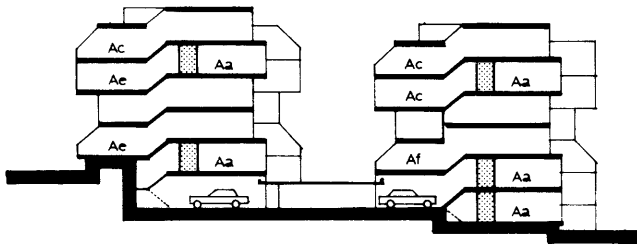
BLOCK A



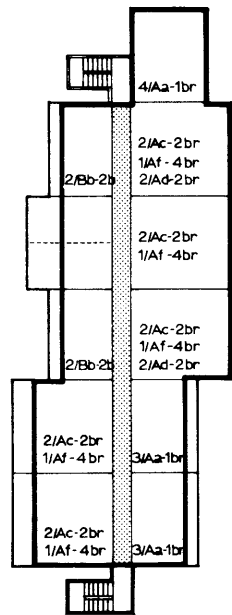
BLOCK D



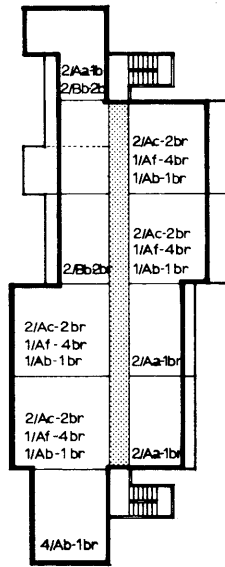
BUILDING KEY TO SITE PLAN



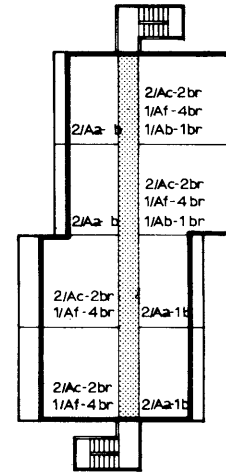
BLOCK E



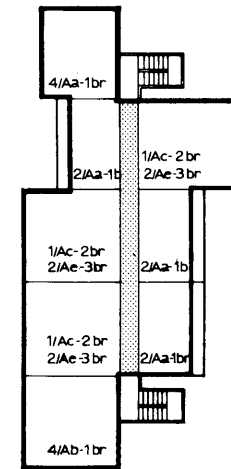
BLOCK F



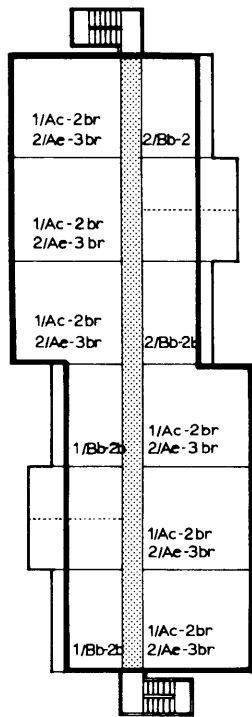
BLOCK G



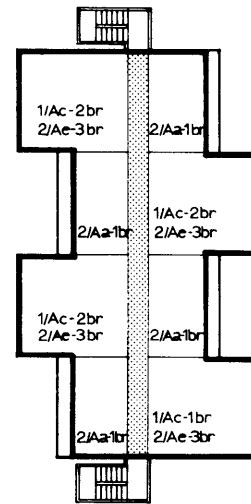
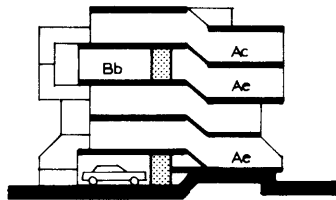
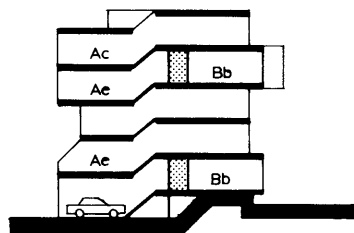
BLOCK H



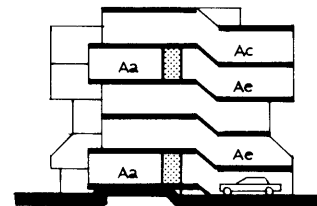
BLOCK J



BLOCK K



BLOCK L



CONCLUSION AND RECOMMENDATION

The advantages of the housing proposal developed are:

1. Greater separation of living (active) spaces from sleeping (passive) spaces by a buffer of stair and utility spaces.
2. Reduction in corridors and hence increase elevator efficiency. (the exact amount depends on the type of apartments used—the further the corridors are apart, the more efficient the system becomes.)
3. Ease of access to junctions of plumbing fixtures for connection and inspection.
4. The possible corporation of multi-level car parking spaces at the lower level within the building.
5. Allows within the constraints of walk-up apartments with no elevator, an extra apartment above the third floor level, hence increasing density.

Being a linear system determined by the position and direction of the corridor, the building can only be displaced forward or backward if a transition area e.g. elevator lobby is introduced to connect the corridors, or if the apartments on the same level as the corridor is eliminated to form a gallery for circulation. The elimination of apartments would decrease efficiency and density, and would perhaps only be suitable for low rise or single attach family housing (see housing type Afs)

The site plan demonstrates that the system adapts to a low gradient (approx. 1:10) which extends along its length but requires major earth adjustments when placed perpendicular to the gradient.

It also demonstrate the increase in density that can be achieved. The target density of 240 units was exceeded by 12 units with a small site coverage of 29%, leaving more open spaces for community recreational and social use.

Mass production of industrialized housing is efficient and can have considerable reduction in cost, but it seems inevitable that land economics and other practical necessities will force upon us greater concentration of individuals and families in the future. The suburbs will eventually spread, and begin to rise in density. High-rise and megastructures seems equally inevitable for central cities. But we only know little about the effects of density on people. The degree of gregariousness, appropriate in order to develop a genuine sense of community in relation to the amount of privacy needed is imperfectly understood.

What is obviously needed then, are a variety of demonstrations which further explore some of the technological and economic advantages of the system approach, but with a concern for the potential hazards to human, social and cultural values.

Despite these hazards, all of the research, statistics, concepts, proposals, and arguments are academic unless they are ultimately translated and transformed into demonstrable and final effective "hardware" (i.e., houses).

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1. Cornell University, "The New Building Block", Ithaca, New York: Cornell Press, 1969.
2. M.I.T. 1971 Department of Architecture Master' Class with Professor Eduardo Catalano, "Housing Systems: Seven Studies for Factory Produced Concrete and Steel Modular Units", Limited published master's thesis, M.I.T.
3. Safdie, Moshe, Beyond Habitat, Cambridge, Massachusetts, M.I.T. Press, 1970.
4. Dietz and Cutler, Industrialized Building Systems for Housing, M.I.T. Special Summer Session 1969 & 1970. Cambridge, Massachusetts, M.I.T. Press, 1971.
5. H.U.D., Operation Breakthrough, Washington D.C.U.S. Government Printing Office, 1970.