

MODULAR and INDUSTRIALIZED HOUSING:

AN ACCEPTABLE ANSWER?

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A Thesis Presented to the
Faculty of the School of Architecture
Montana State University

In Fulfillment of the Requirements
for the
Degree of Bachelor of Architecture

presented by
Brandt D. Salo
August 1976

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ACKNOWLEDGMENTS

As the culmination of my academic career draws near I feel that it is necessary and appropriate to express my appreciation for those individuals without whose equal endeavors and dedication I could not have met with success.

Mr. David Wessel, in the capacity of my thesis advisor, was an encouraging and steadying influence whose cooperation and advice were very deeply appreciated.

My thanks and gratitude also to the faculty, past and present, for their contributions to my education; and to my classmates and friends, without who the past five years would have been many times more arduous.

A special note of thanks is due Miss Debbie Fields. She unselfishly offered to type this text and remained patient through all the changes and brought order to seeming chaos. Her efforts were deeply appreciated.

Last, but by no means least, a son's heartfelt thankyou to his parents who gladly put aside their concerns to provide me with the opportunity to obtain my choice of a college education and for their constant encouragement when times got difficult.

CONTENTS

	page
Acknowledgments	iii
Contents	iv
Introduction	1
Philosophy	2
Concept : Materials	9
Criteria and Matrix Evaluation	15
Design Interpretations	37
Conclusion	60
Bibliography	62
Appendix	64

INTRODUCTION

Initial impetus for this study arose from a middle-class dissatisfaction with the status of housing in America; the failure of the industry to evolve (ie: - submit to change) and from a feeling of professional responsibility for the living conditions millions of Americans endure because they cannot afford better.

The gap then, between available housing and affordable housing became the subject of my efforts and main thrust of my thesis, and is reflected in the title of this work - Modular and Industrialized Housing: An Acceptable Answer?

The thesis statement which follows elaborates the view point put forward in this paper:

"Housing conditions of society today and more certainly of tomorrow dictate the need for the developement of modular and industrialized building systems as a mechanism to meet man's requirement of physical shelter in an increasingly dense urban and critical environmental fabric."

PHILOSOPHY

Our current housing dilemma is a by product of socio-political values, industry obstinance and lethargy and architectural indifference.

As part of his Great Society notion, of the 1960's, the late President Lyndon Johnson saw to the establishment of several government agencies and departments (HUD, etc.) whose province it was to establish the needs of the nation and to administer the subsequent programs as the country progressed toward his ideal that every American should be adequately fed, clothed and housed.

The studies on housing which were conducted and which finally became legislation in the Housing Act of 1968, indicated that to meet such a goal as total housing would require a phenomenal annual production rate in excess of 2.5 million units per year for a period of the next ten years if both the growth rate of new demands and the attrition rate of existing substandard housing were taken into consideration.

In the nearly ten years since passage of that legislation traditional residential building has been unable to supply the demand - for the most needy and for others in the lower third of our population (a continuation of established patterns) commensurate with their income levels. Actually supply fell grossly short of demand (roughly 1 million units a year, or 40%) particularly in the early

1970's as a national inflationary trend drove construction costs up 50% or more and lending for building mortgages was discouraged by high interest rates. The resulting dilemma (as yet not a crisis) has left us with 25% of our population receiving some form of housing subsidy and nearly 40% of our annual housing starts in the mobile home field (which in the author's opinion, based on personal inspection, are of dubious quality).

National housing policy appears to have chosen to encourage continued confusion by red tape in subsidy programs instead of turning to an American strong point; her inventiveness and resourcefulness. Technology, in the form of modular and industrialized building systems, would appear to be an obvious addition, not alternative for, our traditional methods of residential construction. Why housing, of all aspects of our lifestyle, should be still resisting the advantages of a nearly limitless technology needs to be investigated.

Sociol-political

Industrialization for building was conceived primarily in Europe. It was an out growth of the destruction of two world wars. Conceived by minds like Le Corbusier and Gropius as a means of providing shelter for homeless thousands, industrialized building offered rapid production at a reasonable cost. America has never suffered that wide spread destruction. Nor have we yet suffered the

plight of limited available land as have the Japanese where conditions are so critical as to allow direct translation of design into practice. They are not theory bound or as code - restricted as we. So, as yet, people in positions of financial, political or economic power cannot, or care not too, envision the existence of a problem.

For the average American our political foundation of "individualism" has resulted in a social myopia. Beyond the obvious necessity of laws for the existence of society we go our own way pursuing assorted goals and aspirations heedless of the social costs, resenting guidance as interference. Success is measured by standards of ownership and materialism and to date the vastness of our resources, land as well as materials, has tolerated such. As resource distribution becomes more critical we must develop an awareness that our individual interests will be best served by what is best for society. In terms of housing such a realization may be that the current standard of the single-family detached home is unaffordable or that we cannot bear the social cost of having a large segment of the population inadequately housed.

This awareness of social responsibility will make the validity of industrialized housing more apparent.

Changes to the current value system are unfortunately given political designations that cast a cloud of suspicion over any ideas associated with them.

Industrial Problems

Within the building industry, also, there has been stumbling blocks to efforts to establish modular systems as an acceptable building form.

The problem arises from the manufacture of "standardized" building materials. The theory of standardization is excellently expressed by Francis Ferguson in Architecture, Cities and the Systems Approach. He defines it as follows:

"The design process which gives rise to an assemblage of standardized and correlated construction components used to form a dwelling unit, where by ad hoc construction methods are deliberately rationalized and regularized, usually in the interest of economy, speed and quality control."

The term, correlated, is important to note when one looks at an opposing viewpoint, such as is expressed by Peter Blake, chairman of education at the Boston Architectural Center. He states:

"There cannot be any true prefabrication of building components unless and until the nations building industry agrees to adhere, rigorously, to a set of dimensional and qualitative standards. ----- manufacturers ---- concentrate on clobbering the competition rather than collaborating with it. In the United States today, it is virtually impossible to assemble a building from modular components routinely available on the market without introducing innumerable special details or components that would instantly increase the cost -----"

Such a change can be accomplished only by communication and cooperation between the various manufacturers as a result of the new social awareness spoken of earlier. The debate lies in the likelihood of such ever happening.

A possible alternative exists in the establishment of an independent industry (necessarily with governmental assistance because of the implied scale) which researches, develops and produces all its components and can thereby remain aware of the level of standardization it must maintain in subsequent developments.

The financial aspects of such an industry requires a massive market - the potential for which exists in the area of low cost housing. Hand in hand with this goes the requirement for a large distribution network such as entailed in the automobile industry, with independent arrangements for warehousing and financing. One can envision buying a house complete with dealer prep' and destination charges.

In the final analysis it would be the quality of the product available which would determine whether the necessary arrangements for such an industry were ever made. Down that road lies years of legislation, attitude - adjustment, communication and cooperation.

More immediate endeavors in the modular and industrilized field have met with staunch resistance from the building and trade unions who deem such an

idea as a threat to their livelihoods. As I have proposed, industrialized building systems will represent an addition to the building industry to fill the housing gap that exists in the low income area where conventional housing cannot be economically provided. It is not a total replacement of the present system nor should it be.

Obstinace to accept industrialized systems for the purpose envisioned in this paper represents a dog in the manger attitude by the labor unions. Many instances of union harassment and vandalism are documented concerning use of prefabricated components. Often times the units are broken down and reassembled by the affected trade before they agree to install them.

Such delays are extremely costly in a system where speed of assembly is an important criteria.

Architectural Indifference

Another difficulty with industrialized and modular building systems stems from the architectural profession itself, in that many feel that the commodity of architectural design is not for the "masses". Hans Hollein in Modern Movements in Architecture by Charles Jencks, states:

"Architecture is not the satisfaction of the needs of the mediocre, is not an environment for the petty happiness of the masses - - - architecture is an affair of the elite."

Albeit such elitism has its necessary place in the developement and forwarding of the cause of architecture the exposure of the masses to architecture carries a valid counterpoint. With small exception few architects before their professional training were elite in either upbringing or backgrounds, from which we consciously or unconsciously draw many of our values and viewpoints when making architectural decisions. By raising the level of architectural awareness of the masses by exposure to a good architectural environment, such as one composed of industrialized or modular systems could be, all future architects would have a richer heritage from which to operate; beginning a cycle which benefits architecture and the elitists in turn. Architecture has the unique position of being able to be both art and a tool to serve mankind.

In a nation such as ours, where a great wealth of technology and fabrication skills exist, it is unfortunate we cannot recognize and utilize the same to assure that all Americans have the opportunity for quality housing.

CONCEPT

Material Considerations:

To establish a working knowledge of previous and continuing efforts in the modular and industrialized building field requires the investigation of the inherent advantages and disadvantages of the available types of building materials.

From such a basis further evaluation and classification of building systems can be made with the research contributing to a matrix analysis of the topic from which one can then draw relevant design inferences.

At the present state of our technology there exist four main categories of building materials which can, in their pure applications, be easily differentiated. These are 1) concrete, 2) wood, 3) plastic and 4) steel.

In further work specific examples will be analyzed and although admittedly the material groups above are used often times in various combinations and rarely are totally homogenous the examples will be classified according to their predominant material.

Concrete:

As a building material concrete has several distinct advantages that can be applied to modular and industrialized building systems.

Depending on amount of forming required concrete offers relatively low costs and because of its initial fluid state can be formed into numerous types of

panels, components or cells.

Factory production allows for repetitive steps and processes which contributes to lower costs through increased output and use of a semi-skilled labor force.

Concrete is an exceedingly durable material and for high - density building situations, as are many proposals involving modular and industrialized building systems, it offers inherent fire proofing. In addition concrete offers design flexibility from its ability to perform as both the structure and the means of enclosure for a building system.

As a building system concrete has some distinct disadvantages stemming mainly from its weight and the economics of equipping a plant of sufficient size to accommodate the production of the various system elements.

Concrete systems necessitate the use of a wide variety of heavy equipment in all stages of manufacture right on through erection. In addition concrete requires a large yard space for stockpiling elements while they undergo the curing process. In a region such as Montana the process should be enclosed if year round production is desired and such is almost mandatory to justify the initial capital investment. Weight causes difficulties in transportation of panels or pre-assembled modules.

By itself concrete lacks any inherent insulative quality.

Technology in constantly improving the strength to weight ratio of concrete through pre-stressing as well its insulative capacity.

Wood:

Currently wood is the dominant residential building material in the United States. In our ecology and resource conscious age, wood has the advantage of being a renewable resource if managed properly.

Through years of use and developement the value of wood as a structural material has been recognized. Despite sharply rising costs lumber can still be considered a low cost material in comparison to the others we are analyzing and when considered jointly with its workability and high strength to weight ratio it is even more valuable.

In applications where a single solid member is inadequate or unavailable technology has supplied the glue-laminated member.

Ease of factory production is enhanced by the methods with which wooden members can be fastened - such as pneumatic nailers, heat and pressure sensitive glues and joinery.

Equipment investments are much less than those entailed with concrete

systems but are still several times more than that borne by a typical residential contractor.

Technology has come a long way in development of compounds for use as wood preservatives but deterioration caused by insects and the elements as well as its susceptibility to fire still remain the principle disadvantages of wood.

Plastic:

Only relatively recently did plastics enter onto the building scene; taking the form of laminates and pre-formed building components (ie. - bathtubs, sinks, piping etc.)

Plastics consist of several generic types and can be extruded, cast and molded taking on an infinite number of shapes in an infinite range of colors.

Used in combination plastics can suffice as structure, insulating material and interior appointments as well as jointing compounds and electrical hardware.

Slight changes in the chemical structuring of a plastic can customize it to a particular need and as a whole they are generally a light weight material.

As an oil derivative in this age of fear for the exhaustion of that fossil fuel plastics command a high price which would make the cost of an all plastic dwelling quite high and in all likelihood prohibitive to all but the very wealthy.

Technology promises plastics as by-products of coal processing but as yet they are in the preliminary stages of development.

In a society such as ours where the demand for housing is so great and where plastics is indicated as having potential as a possible material solution we seem to be suffering from a confusion in priorities. Tremendous quantities are used annually to supply us with all manner of disposable containers when glass (although breakable) would suffice.

For plastics to have overcome traditional biases and the stigma of "it's only plastic" to then be relegated to such mundane applications when more socially relevant uses go wanting tells a sad tale of our social consciousness.

Steel:

It could be said that with metals lies our greatest wealth of technology and experience; ranging from the production of standardized structural forms to the modular and industrialized production of the automobile.

Metals, in particular steel, have a capacity not unlike that of plastics for tremendous physical variety through the addition or deletion of chemicals in the forming process. This enables the final product to be tailored to a specific use.

Also forming can occur at almost any point of the material's creation

because of the variety of methods available. As a fluid it can be cast or extruded while as a solid, dependent on physical dimensions, it can be bent, rolled, pressed, forged or stamped.

A variety of applicable joining methods increases the flexibility of the material. Metals can be fastened by adhesives, welding or mechanical means.

The relative ease with which metals can take finishes of other metals, paint and plastics aids in the production of a durable material. Combine this with metal relative resistance to fire (extreme heat will weaken structural members) and precision of manufacture and one has an excellent building material.

Metals present difficulties with respect to thermal and acoustic insulation and have a greater expansion/contraction factor than does either concrete or wood. When combined with other materials this can cause jointing difficulties.

Metal fabrication entails a large investment in specialized tools and machinery and to be economically feasible would require continuous production with a receptive and massive market - not unlike what is enjoyed by automobile manufacturers today.

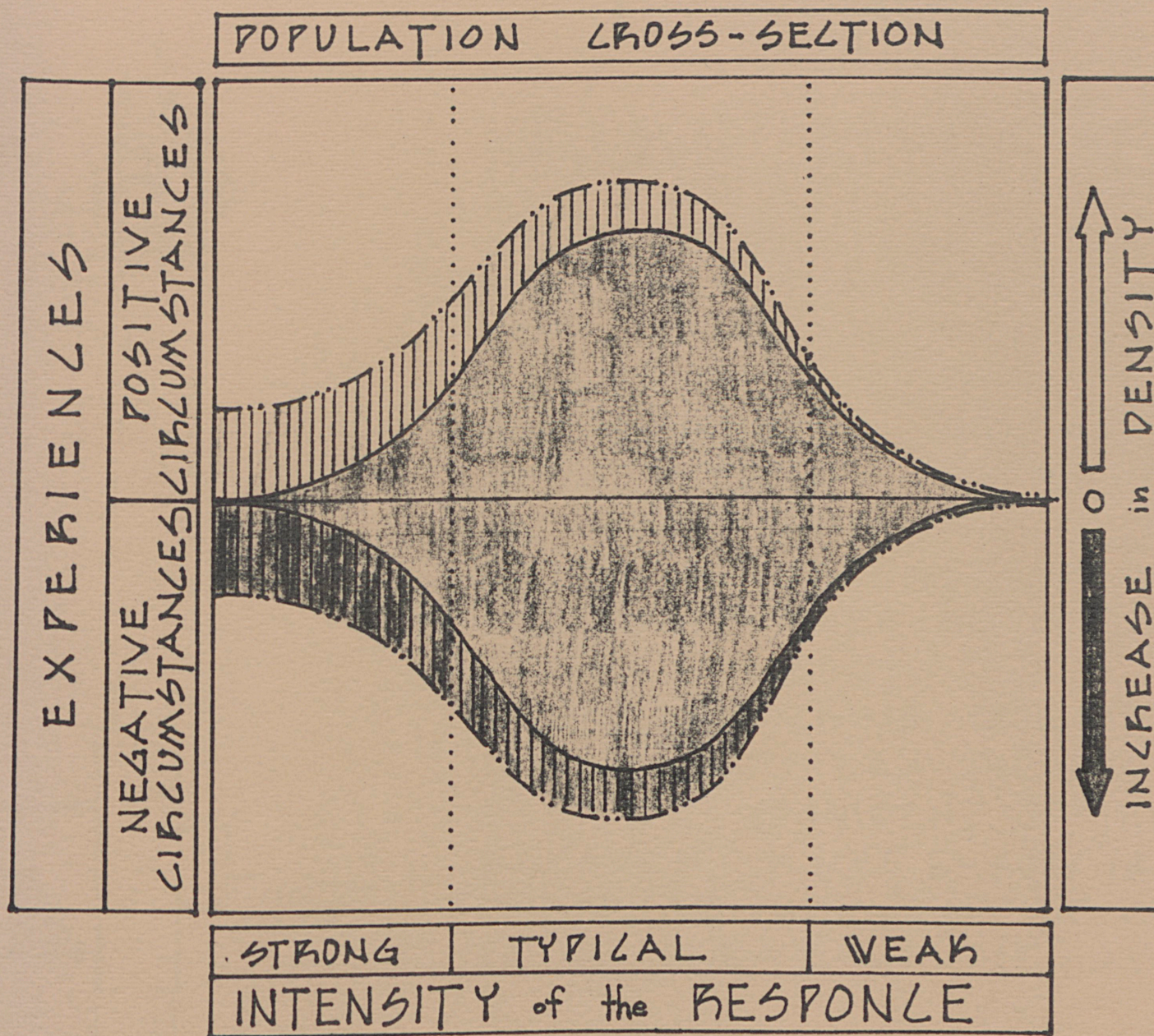
Criteria

The concept of using modular and industrialized building as a solution to the shortages found through conventional methods of housing has implied an evaluation of the four major material groups against how well they perform in the role of systems building. Materials for systems building can be classified also according to their manufactured configuration, such as panels, frames or cells.

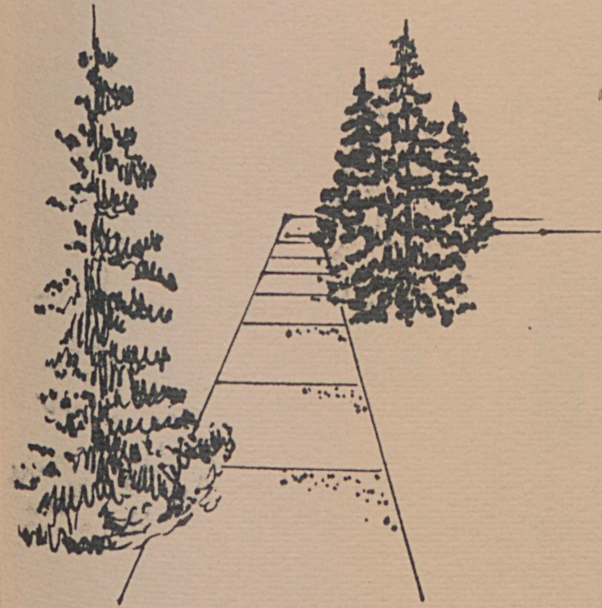
Insight must be gained relative to the sociological and economical ramifications of such a housing system.

Several factors and considerations deemed to be pertinent to the sociological and economical effects of a modular and industrialized housing system are presented in the following pages with illustrative sketches, as well as commentary on those which may not suffice as self-explanatory.

These "criteria" represent a compilation of factors of concern to the author with respect to an attempt to come to grips with what constitutes the balance that must be struck between sociological (humanistic) and economic (technological) inputs into any housing system.

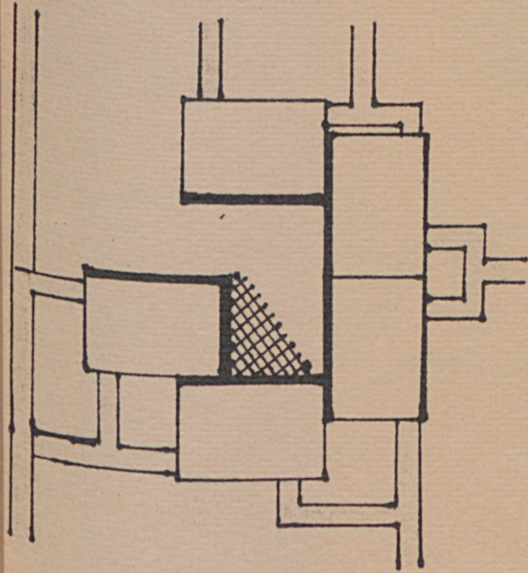


DENSITY acts as an AMPLIFIER

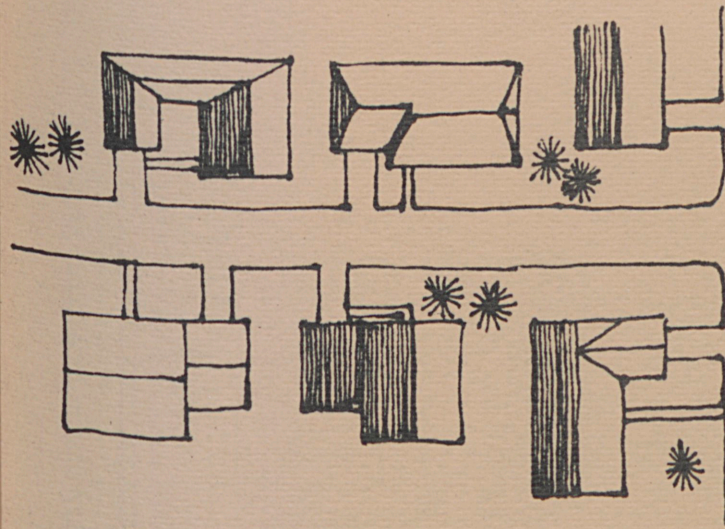


CRIME by DESIGN

LANDSCAPING IS AN IMPORTANT FEATURE OF A HOUSING PROJECT BUT NOT AT THE SACRIFICE OF THE RESIDENTS SECURITY. HEDGES AND CONCEALING FOLIAGE SHOULD BE SET BACK FROM WALKS TO AID IN ELIMINATING THE POSSIBILITY OF ATTACKS. APPROPRIATE LIGHTING SHOULD BE CONSIDERED.



WHEN CONSIDERING BUILDING SITING WITHIN A COMPLEX THE DESIGNER MUST BE AWARE OF THE FUTURE RESIDENTS NEED FOR PRIVACY BUT NOT TO THE POINT OF CREATING BLIND AREAS IN THE LAYOUT.

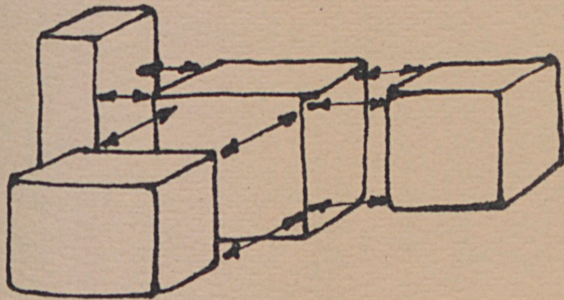
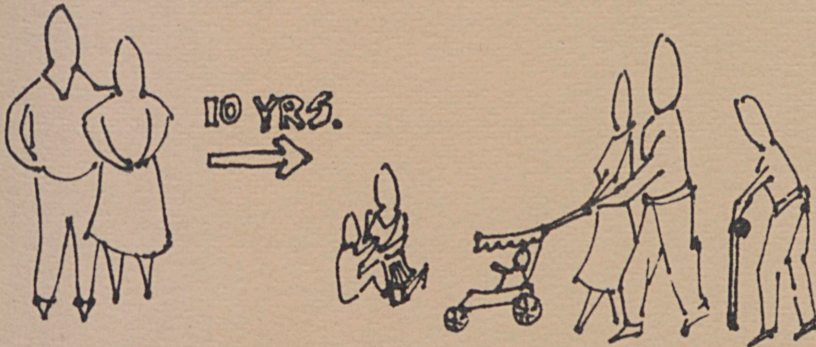


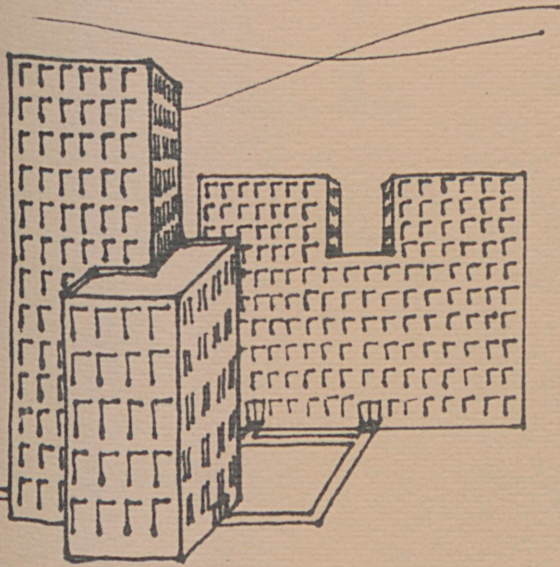
SELECTIVITY -

IN ORDER TO SATISFY THE NEEDS OF THE BUYER THERE MUST BE AN OVERSUPPLY OF HOUSING ON THE MARKET TO ALLOW FOR CHOICE. WHEN A HOUSE NO LONGER FILLS THE USER'S NEEDS HE MOVES - NOT ALWAYS BECAUSE OR WHEN HE WANTS TOO. THIS MOBILITY DESTROYS NEIGHBORHOODS AND CREATES HOUSING PRESSURE ELSEWHERE.

ADAPTABILITY -

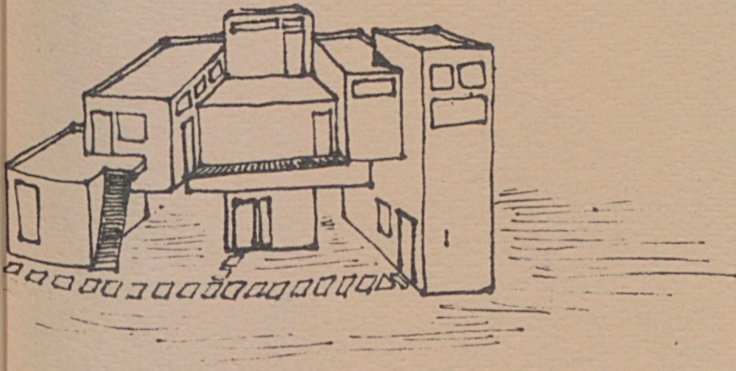
AS THE FAMILY GROWS AND ITS NEEDS CHANGE THROUGH TIME SO SHOULD THEIR HOME GROW IN RESPONSE TO THOSE NEEDS, PROVIDING A CONTINUITY OF TIME AND SPACE AND FOSTERING A NEIGHBORHOOD STABILITY.





HIGH-RISE -

LIVING IN A VERTICAL FASHION SAVES LAND BUT AT THE EXPENSE OF DISASSOCIATING PEOPLE FROM IT BECAUSE OF LACK OF ACCESS AND DISTANCE. INTERACTION IS LESSENERED THROUGH IMPERSONAL MEANS OF CIRCULATION - (IE. - ELEVATORS)



LOW-RISE -

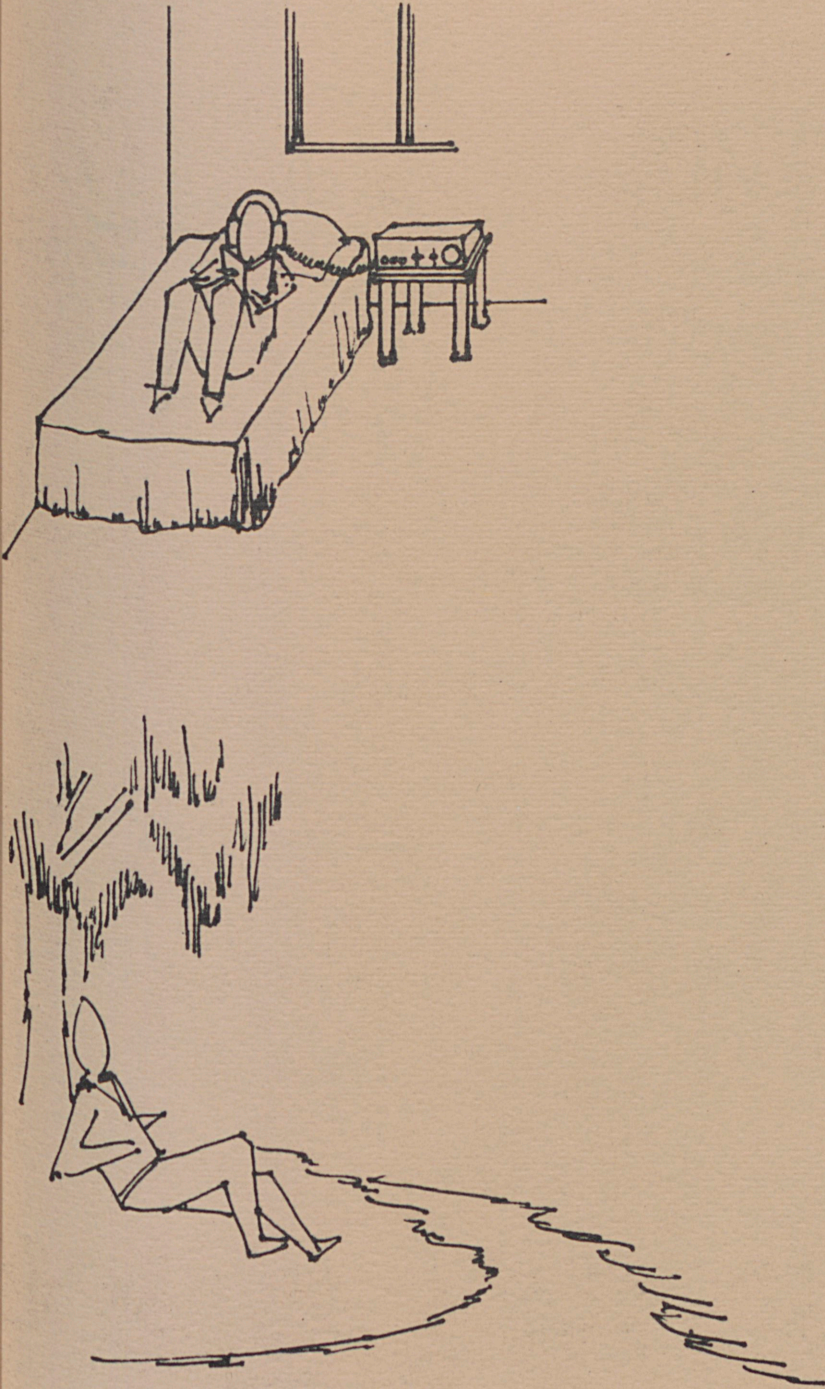
A WALK-UP FORMAT ENCOURAGES INTERACTION THROUGH CIRCULATION AND WHILE IT USES MORE LAND FOR THE BUILDINGS IT PERMITS BETTER HUMAN UTILIZATION OF THAT WHICH REMAINS, BY EASIER AND MORE DIRECT ACCESS.

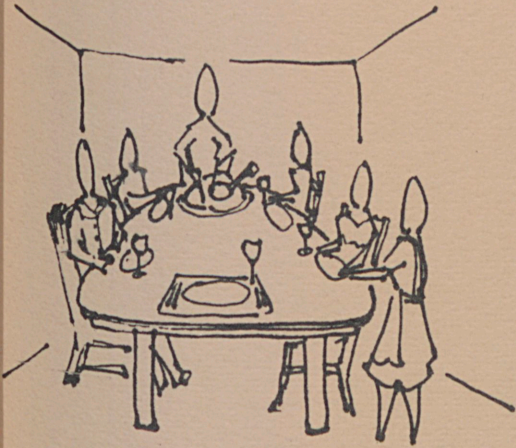
PRIVACY —

IS THE MOST FINITE OF SPACIAL CONTEXTS, INFERRED FROM SOMMER'S PERSONAL SPACE, AS A FUNCTION OF THE RELATIONSHIP BETWEEN THE PARTIES INVOLVED AND THE SPACE.

THE RESPIRE OF SOLITUDE/PRIVACY IN THE BUILT OR PHYSICAL ENVIRONMENT IS NECESSARY TO THE MAINTENANCE OF THE "SPIRIT" WHICH DISTINGUISHES MANKIND.

IT IS A DIRECT HUMAN-SPACIAL RESPONSE WHICH WHEN THE HUMAN ORGANISM IS IN THIS MODE IS LEAST TOLERANT OF OTHER HUMAN PARTICIPATION AND INTERACTION.



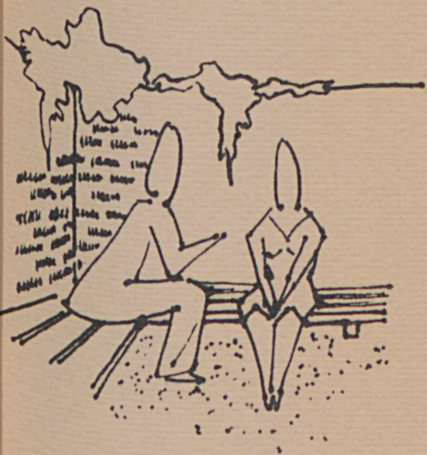


INTIMACY -

BEARS A CONNOTATION OF HUMAN INTERACTION AT A PAIR TO SMALL GROUP SCALE IN CONJUNCTION WITH A SPACIAL CONTEXT OF INFORMALITY.

THIS MODE OF INTERACTION MAYBE FURTHER ENHANCED BY THE GENDER OF THE PARTIES INVOLVED AND BY THE EMOTIONAL BONDS BETWEEN THEM - AS IS THE CASE WITH LOVERS OR MEMBERS OF A FAMILY.

AN INTIMATE SPACE SHOULD COMPLEMENT THE WARMTH AND EMOTION OF THE PARTICIPANTS.



PERSONALIZATION —

OF A SPACE IS IMPARTED BY THE STRUCTURING OF IT TO MEET THE NEEDS OF THE USER OR USERS — TAKING INTO ACCOUNT FACTORS SUCH AS CIRCULATION, ROOM ARRANGEMENT AND TYPE OF INTERACTION TO BE ENCOURAGED.

TASTES AND PREFERENCES IN THE FURNISHINGS AID PERSONALIZATION OF A SPACE AT A COSMETIC LEVEL.

IDENTITY —

WITH A SPACE OCCURS WHEN THE USER IS "COMFORTABLE" IN A SPACE AND CAN RECOGNIZE THAT IT FULFILLS HIS NEEDS — MORE SO WHEN THE USER HAS HAD INPUT INTO ITS DESIGN OR PHYSICAL CREATION.

VARIETY and VITALITY -

AS REQUIREMENTS FOR A DYNAMIC AND CHANGING BUILT ENVIRONMENT-ALSO REFLECTING QUALITIES PROMOTING THE "SPIRITUAL" GROWTH OF MAN, THE ELEMENTS OF VARIETY AND VITALITY CAN BEST BE ACCOMMODATED IN A MODULAR SYSTEM - TO WHICH ALTERATIONS OR ADDITIONS CAN BE MORE READILY MADE THAN TO A MORE CONVENTIONAL CONSTRUCTION SYSTEM.

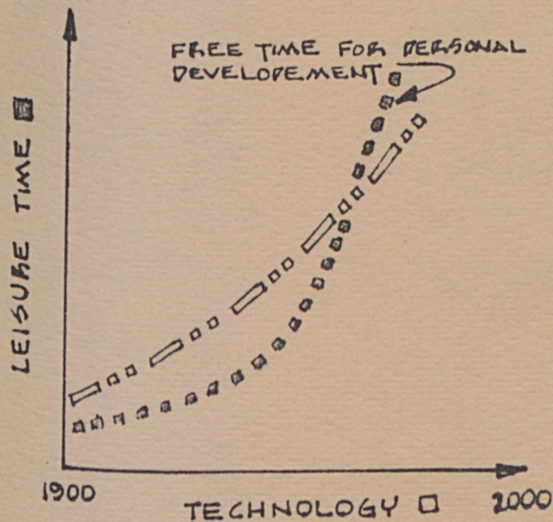
SUCH MODIFICATIONS AND CHANGE CREATE VISUAL AND SENSORY INPUT TO STIMULATE THE WAY IN WE SEE AND DEFINE SPACE. THIS NEW PERCEPTUAL AWARENESS IN TURN ENCOURAGES FURTHER ENVIRONMENTAL EXPERIMENTATION AT THE PERSONAL AND CULTURAL LEVEL.



LIFE-SUSTAINING -

SUCH CONDITIONS IN THE BUILT ENVIRONMENT REPRESENT THE FULFILLMENT OF MAN'S MOST RUDIMENTARY NEED FOR SHELTER - A PHYSICAL COMMODITY, WHILE DISCOUNTING HIS MORE REFINED PSYCHOLOGICAL NEEDS.

LIFE-ENRICHING -



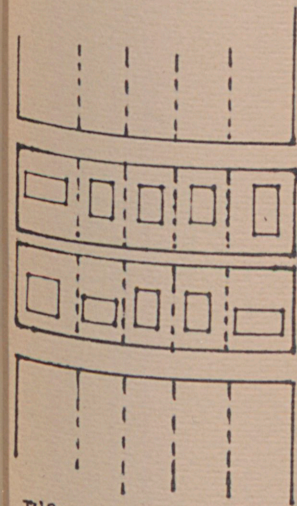
SUCH AN ENVIRONMENT ALLOWS MAN THE FULFILLMENT OF HIS INNER DESIRES, IT PROVIDES THE MEANS FOR PERSONAL DEVELOPEMENT BY INTER-RELATIONSHIPS AND PROMOTING THE "THINKING" PROCESSES BECAUSE OF THE HIGH DEGREE TO WHICH THE BASER PHYSICAL NEEDS HAVE BEEN SATISFIED. A CREATIVE AND STIMULATING ENVIRONMENT ENCOURAGES INHABITANT CREATIVITY AND CONCERN.

LAND -

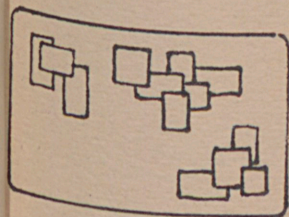
REALESTATE IS MAJOR CONCERN IN ANY PROJECT. BECAUSE OF DESIGN CONTINUITY INVOLVED IN MODULAR PROJECTS HIGHER DENSITIES CAN BE ACHIEVED BY CLUSTERING UNITS TOGETHER THEN COULD BE BY CONVENTIONAL SINGLE-FAMILY DWELLINGS.

THROUGH SUCH A METHOD LAND CAN BE CONSERVED IN LARGER AREAS AND USED FOR RECREATION WITHIN THE COMPLEX OR KEPT AS OPEN SPACE.

BUILDINGS OF A VERTICAL FORMAT CONSERVE LAND BUT SHOULD NOT BE SO TALL AS TO DISSOCIATE THE POTENTIAL USER FROM THE USABLE SURPLUS.



TYPICAL CITY BLOCK



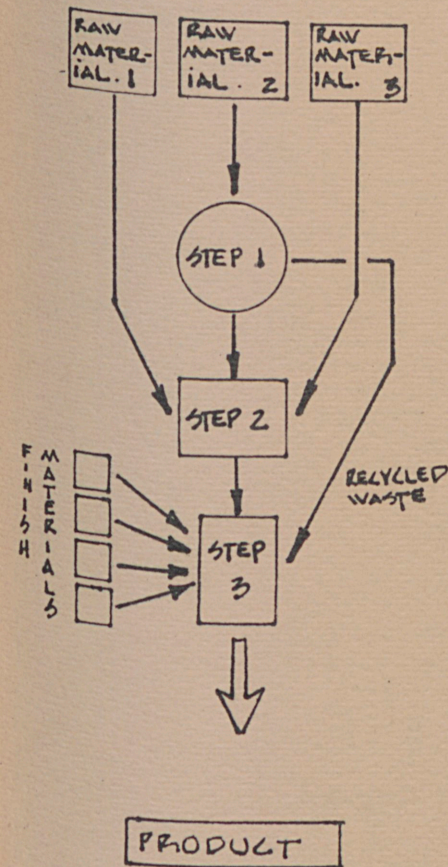
LAND CONSERVING USE

MATERIAL -

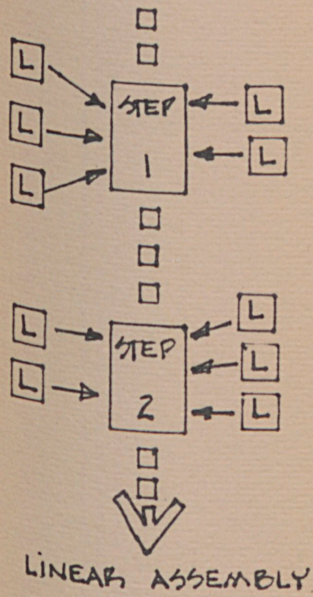
INDUSTRIAL PROCESSES CHARACTERIZE THE OPTIMIZATION OF STOCK AND UNAVOIDABLE WASTES OFTEN BECOME BY-PRODUCTS.

BECAUSE OF REPETITION IN MANUFACTURING, MATERIALS CAN BE ORDERED BY BULK LOTS FOR THE RELATIVE ECONOMY OF SUCH A PROCESS.

OF CONCERN ALSO IS THE USE TO WHICH THE MATERIAL IS PUT AND THE EFFICIENCY OF ITS PERFORMANCE UNDER THOSE CONDITIONS.



LABOR -



INDUSTRIALIZED BUILDING PROCESSES DO NOT GENERALLY REQUIRE SKILLED CRAFT LABOR AND ARE PAID LOWER WAGES. TASK PATTERNING INCREASES PRODUCTION SPEED AND OUTPUT. BETTER MANAGEMENT OF SYSTEMS AND OF PROCEDURES PLUS EQUIPMENT SPECIALIZATION ALL TENDS TO FORCE PRODUCTION PRICES DOWN

UNIONIZED LABOR IS A MAJOR STUMBLING BLOCK TO ADOPTING MODULAR SYSTEMS WHICH UTILIZE PRE-FABRICATED PLUMBING COMPONENTS AND OTHER SIMILAR ITEMS. WHILE NEED FOR HOUSING OUTSTRIPS SUPPLIES LABOR ORGANIZATIONS COMPLAIN OF WORK THEY'D MISS BUT WHICH THEY CAN'T REALISTICALLY CONSTRUCT.



FLEXIBILITY —

CAN A SPECIFIC MATERIAL SUPPLY
ALL THE BASIC REQUIREMENTS OF A
MODULAR SYSTEM — SUCH AS:

WALLS — ARE THEY BEARING OR INFILL?

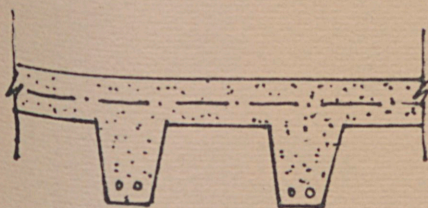
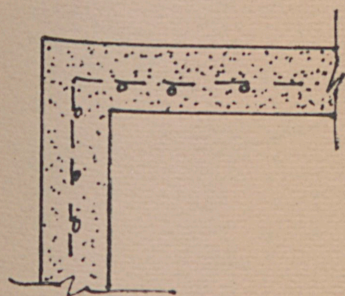
FLOORS — CAN THEY SPAN SUFFICIENTLY?

CEILINGS — CAN THEY SPAN AND SUPPORT
ANOTHER UNIT ABOVE?

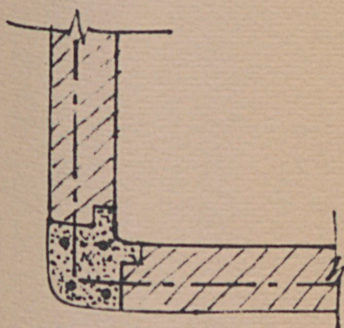
CAN IT BE USED AT CORNERS AS WELL AS
AT CONSTRUCTION JOINTS?

DOES IT HAVE INHERENT DESIGN FLEXIBIL-
ITY OR DOES IT HAVE SPECIAL CHARAC-
TERISTICS WHICH LIMIT ITS PERFORMANCE?

CEILING



FLOOR



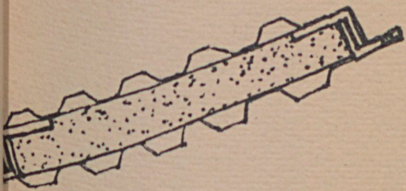
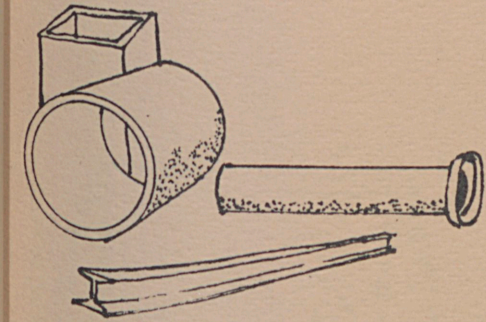
CORNER

FABRICATION -

CAN THE MATERIAL BE EASILY MADE INTO THE FORMS REQUIRED BY THE DESIGN OR ARE ANY RESTRICTIONS ON THE FORM DUE TO CHARACTERISTICS OF THE MATERIAL?

ARE JOINTS IN THE MATERIAL SUBJECT TO EVEN OR UNEVEN EXPANSION - IS THE MATERIAL HOMOGENOUS?

IS FORMING AN EXPENSIVE PROCESS AND DO THE SHAPES LEND THEMSELVES TO FACTORY PRODUCTION?

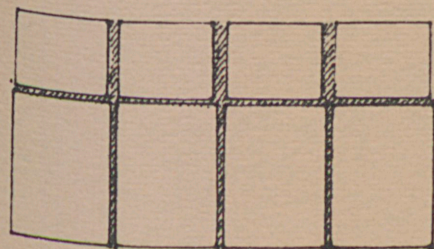
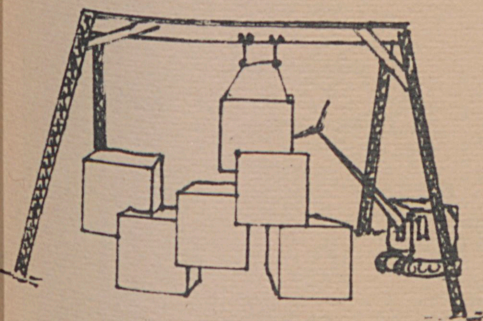


COMPOSITE SYSTEM

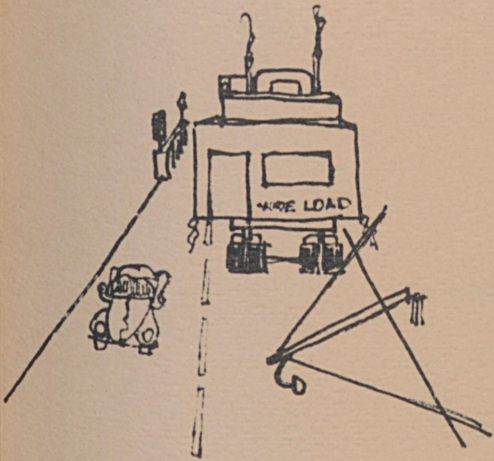
CONSTRUCTION -

IS THE ERECTION OF THE STRUCTURE POSSIBLE WITH TYPICAL METHODS OR DOES IT REQUIRE SPECIAL MEANS?

DOES THE CONSTRUCTION REQUIRE NUMEROUS PIECES AND JOINTS OR A FEW LARGE SECTIONS? WILL IT REQUIRE MORE HOURS OF LABOR THAN IS REASONABLE.



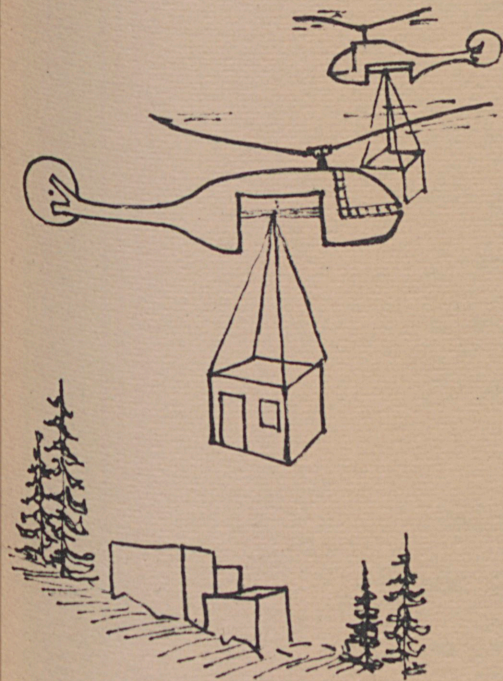
PANEL SYSTEM



TRANSPORT -

ARE THE UNITS OR SYSTEMS EASILY TRANSPORTABLE (MOST COMMON CARRIER IS TRUCKS WITH WIDTH LIMIT OF 12' SET BY REGULATORY COMMISSIONS)

LESS ACCESSIBLE SITE UTILIZE SKY CRANE'S. RAILROADS ALSO COMMON.



If, after establishing the above criteria, one were to oppose them to examples from the material/configuration pairings it becomes relatively easy to construct a matrix. A matrix enables you to have your information in a visual, correlated and concise format. (see following page.)

This is the means of evaluation that I chose. The entries, in terms of materials, were divided into the four major classifications which were, in turn, divided into alphabetized examples of the manufactured configuration. An entry of PLS (short for plastic) frame A would correlate then to a visual documentation of the system coded PFA - P for plastic; F for frame; and A for the first example.

Visual entries in the matrix carry a dual value. The circular forms are indicative of how well a particular example performed with respect to the social and economic criteria (magnitude only) while the shading within the circle is indicative of that particular criteria's value from the standpoint of design. In such a fashion are the criteria "ranked" which more easily enables one to make future design inferences.

This is what has been done in the design portion of the matrix. By assigning a numerical value of 1, 2, or 3 too both the circles and too the shading and then cross-multiplying them together each entry acquires input into the design process when summed left to left to right with the remaining entries for each

PERFORMANCE

- 3 GOOD
2 AVERAGE
1 POOR

HIGH
AVERAGE
LOW

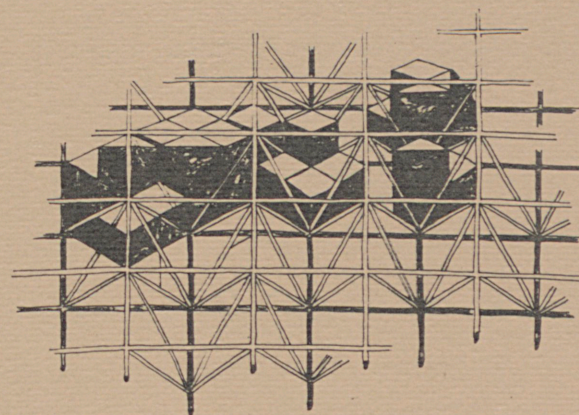
DESIGN VALUE

SOCIOLOGICAL

ECONOMICAL

5 6000			HIGH		SOCIOLOGICAL												ECONOMICAL											
2 AVERAGE			AVERAGE		FUNCTIONAL CONDITIONS				INTERACTION MODES				SELF-ACTUALIZATION				USE OF RESOURCES			MATERIALS			TECHNOLOGY					
1 7000			LOW		DENSITY / RELATIVITY	DESIGN / FORM	SELECTIVITY / AFFABILITY	HIGH-RISE / LOW-RISE	PRIVACY	INTIMACY	SOCIALITY	PUBLICLY	PERSONAL / IDENTITY	VARIETY / VITALITY	LIFE-ADAPTING / BE-ENJOYING	LAND	MATERIAL	LABOR	FLEXIBILITY	FABRICATION	CONSTRUCTION	FEASIBILITY	FUNCTIONALITY	LIFE-CYCLE COST	TRANSFORM	SAFETY		
DESIGN VALUE																												
CONCRETE	panel	A	●			○	•	●								●	•	•	●	●	●	○		●				
		B	●	●	•	○	●	●	•	●	•	•	•	•		●	•	•	●	●	•	○	○	●	•	●		
		C	●	●	●	○	●	●	●	●	●	●	●	•	●	●		●	•	•	●	●	•	○	○	●	•	●
	frame	A	●	●	•	○	●	●	●	●	●	●	●	•	•	●		●	•	•	●	●	•	○	○	●	•	●
		B	●	●	•	○	•	●	•	●				•	•	•		●	•	•	●	●	•	○	○	●	•	●
		C	●	●	•	○	●	●	●	●	●	●	●	•	•	●		●	•	•	●	●	•	○	○	●	•	●
		D	●	●	•	○	●	●	●	●	●	●	●	•	•	●		●	•	•	●	●	•	○	○	●	•	●
		E	●	●	•	○	●	●	●	●	●	●	●	•	•	●		●	•	•	●	●	•	○	○	●	•	●
	cell	A	●	●	•	○	●	●	●	●	•	•	•	•		•	●	●	●	●	●	•	○	○	●	•	●	
		B	●		•	○	●	●						•	•	•		•	●	●	●	●	•	○	○	●	•	●
	STEEL	frame	A	●		●	○	●						●	●	●		•	•	•	●		●	○	○	●	•	●
			A	●	●	●	○	●		•	•	•	•	•	•		●	•	•	●	●	•	○	○	●	•	●	
cell		B	●	●	●	○	●	●					●	●	●		•	●	•	●	●	•	○	○	●	•	●	
		C	●	●	●	○	●	●	●					●	●	●		●	•	•	●	●	•	○	○	●	•	●
		A	●	●	•	○	●	•			•	•	•	•		●	•	•	●	●	•	○	○	●	•	●		
cell		B	●	●	•	○	●	•	•	•	•	•	•	•		●	•	•	●	●	•	○	○	●	•	●		
		C	●	●	•	○	●	•	●	●	•	•	•	•		●	•	•	●	●	•	○	○	●	•	●		
		C	●	●	•	○	●	•	●	●	•	•	•	•		●	•	•	●	●	•	○	○	●	•	●		

DESIGN				
MATRIX EVALUATION				
SNA + BEST DESIGN VALUES	TOTAL + RANK + CATEGORY	TOP SYSTEM IN CATEGORY	TOTAL RANK SUMMATION	INTEGRATED RANK
54	6.75			
72	6.0			
90	7.5			
90	7.5			
07	7.25			
66	5.5			
90	7.5			
93	7.75	7.75	140	6.36
70	6.5			
07	7.25	7.25	152	6.0
72	6.54			
07	7.91	7.91	112	6.58
93	7.75			
93	7.75			
69	6.9			
102	8.5	8.5	137	6.85
102	8.5	8.5	142	6.76
75	6.25			
75	6.25			
04	7.0			



POSSIBLE SOLUTION

fig. 1

material example. (At this point I limited myself to a summation of those entries which correlate to the criteria of highest design value; of which there are 12). Each entry, then, has a value of from 1 to 9 with the maximum for any material example being 9 times 12 or 108; the product of the number of criteria and the maximum individual entry input.

Correspondingly, the lowest obtainable summation would be 12, where each entry for the 12 criteria were 1.

The second column of the design portion of the matrix is a division of each respective summation by 12 (the number of most desirable criteria). The resultant figure is a pure number indicative of the ability of that material/configuration pair to perform as a system building component, relative to others of the same material and different configuration or of a different material but same configuration.

At this point I again limited my considerations; in this case, to the highest ranking material/configuration pairing within each of the four major material classes. (see illustrations - Appendix A) These selections constitute the third column in the design portion of the matrix. Due to the equality of SFB and SFC at this point a check of the total matrix was required. Calculated for the best system in each class it would provide a cross check on which was the optimum

performer. Of a possible maximum of 159 for the total matrix (108 for criteria of highest design value, 42 for those of average value and 9 for those of the lowest value) the material/configuration pairing of SFC ranked highest with a 142. The slight variance seen in the last column of the design portion results from SFB being evaluated on 20 of 22 criteria where as SFC is evaluated on 21 of 22 criteria which causes the seeming less desirability of SFC.

Regardless of the slight statistical fluxuation the pairings of SFB and SFC, they are indicated by a substantial margin to be the most likely material and system configurations to utilize for a modular and industrialized housing form.

The sketch in figure 1 envisions a possible steel frame solution where the frame functions as the structure for a cellular living unit.

Developement for an actual design solution as the next stage of my thesis will determine the value of this matrix analysis as an indicator of valid design approaches.

Design:

With the matrix results giving the indication of the appropriateness of a steel frame system as a possible design solution I felt it would be advantageous to commit myself to a thorough analysis of steel from the design viewpoint; to see if the matrix would be verified.

The most opportune point of departure seemed to be a variation of the system sketched on the matrix, that of a space frame.

In regard to the space frame (see figure 1 on page 40) system I wanted to achieve an identity, visually, between the frame portion of the system and the cellular living units. This autonomy I hoped would provide some practical benefits. By utilizing a large diameter steel pipe (roughly 2') as the struts one could anticipate using their interior, essentially, as mechanical chases. The living units then could be combined freely within the utility structure or moved when desired.

Recognizing the positioning of the struts led me to rotate the living units to a 45° angle to the rectangular portions of the space frame; the units then were supported diagonally. This rotation maintained the structural separation by allowing the struts to pass planar to the building surfaces not penetrate the volume. In addition it provided for a larger living unit format because now

the side of the cubicle was aligned as the hypotenuse of the triangle formed by diagonally bisecting a square within the horizontal grid of the space frame. This meant that for a span of roughly 18' for the structural members one could achieve a living cube with dimensions of 25' on a side. The height could be adjusted by a variation in the angle of the struts to about 20', comparable with two floors and interior structural depth.

It was at this point where the flaws in such a system began to be evident.

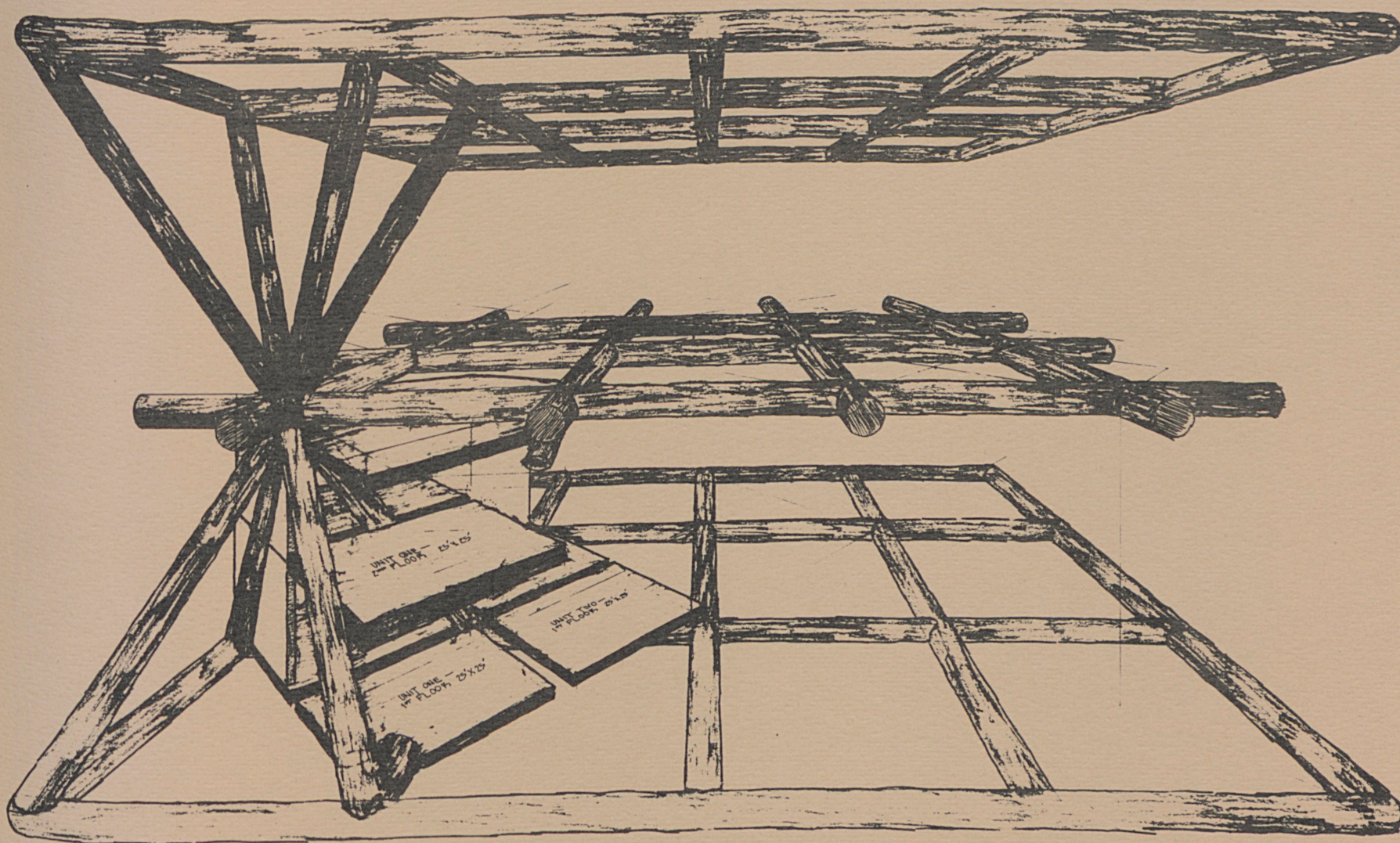
Because the units were so large and because of the diagonal bearing upon the structural frame the cellular units would require sufficient structure to both span the distances and resist the racking caused by the diagonal supports. In addition the unit walls must be structured with sufficient bearing capacity to carry the second floor of the unit. If this were done then the units could stand by themselves without an external structure which thereby made the space frame an expensive method of supplying utilities.

Also previously it had been tacitly accepted that the space frame connections, comprised of twelve members each 2' in any diameter, could be joined in some fashion which did not exceed 2' in any dimension. If it did so it would intrude into the space reserved for the living units. Such an assumption about size

began to seem irrational.

In addition the mobility within the system, for which I had hoped, was only superficial. The functioning of a space frame is dependent upon a three dimensional structural continuity which implied that the living cells must have a strut passing down all four sides as well as the rectangular frames oriented diagonally on top and bottom. This structural integrity effectively precluded any real hope for mobility.

The system could possibly be forced to work but other approaches, more direct, should be investigated.



SPACE FRAME SYSTEM

Still believing it necessary to make a visual distinction between frame and enclosure I re-evaluated my ideas and decided to attempt the same pipe column - utility chase concept in a rectangular frame application (see page 43). This, I hoped, would make the structural frame more responsible for actually carrying the loads.

With the design of the structure including the bearing flanges one could no longer hope to position a cellular unit within it; it seemed that some form of panel system was in order.

The short comings of this attempt were soon all too obvious. Although the bearing of the panels onto the structure was more efficient than with the cells each panel (floor and ceiling) required its own structure to make the span. Each panel required an structural member on both sides for dimensional stability in placement which lead to unnecessary duplicity of materials.

The wall panels had to be load bearing to support the intermediate floor unless another pipe member were added which would have severely over structured the project and disrupted the visual continuity; and if the walls were structural then, again, the frame work proved unnecessary and too expensive for what it provided.

Another difficulty arose in the joining of the panels, primarily in the

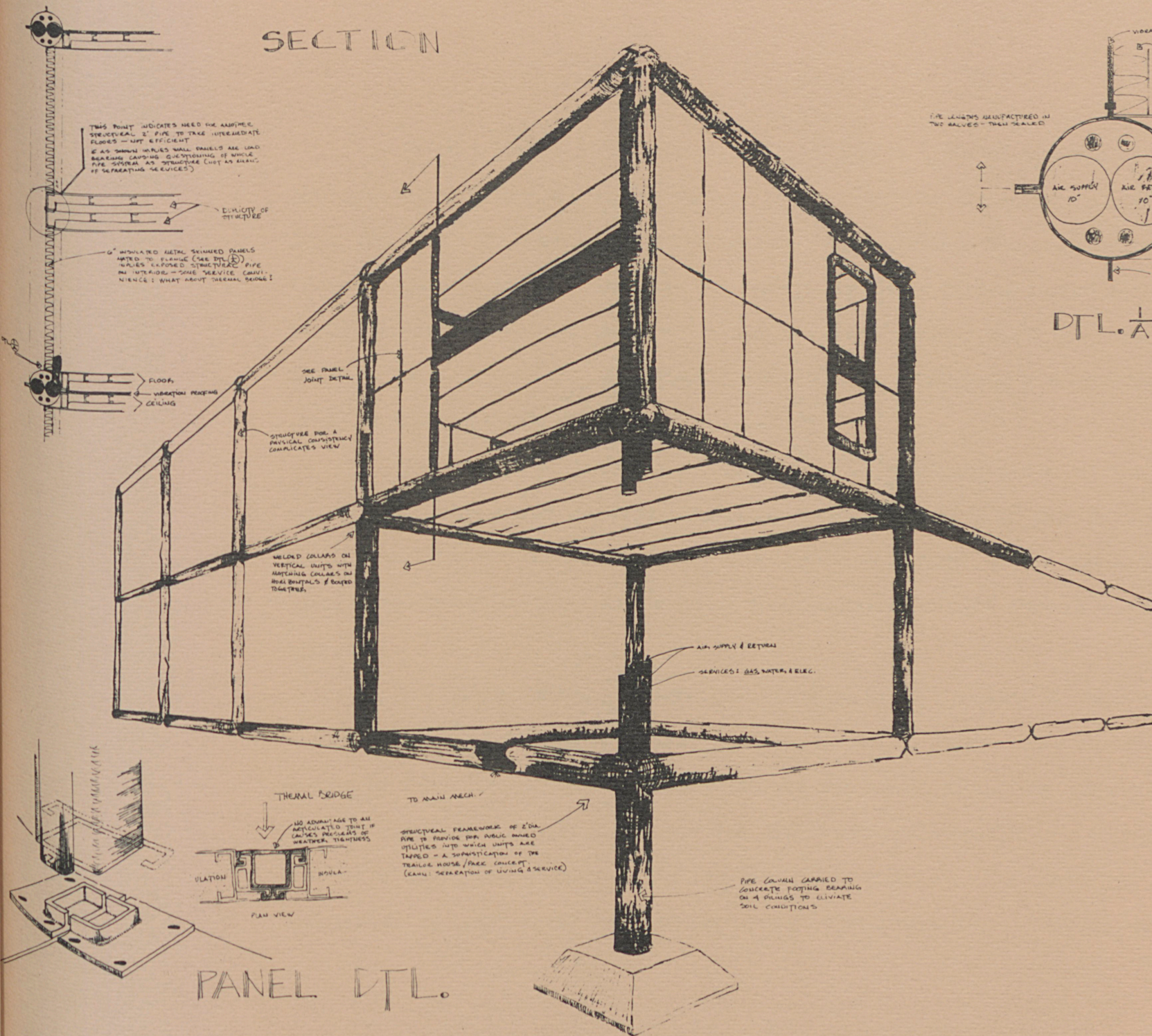
walls. That was - how to make a simple connection that would be weather tight.

Several approaches were tried with the result being either too gimmicky or allowing a thermal bridge or too much infiltration.

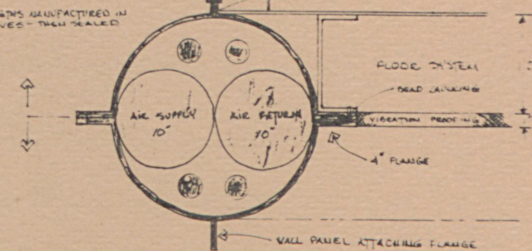
The main factor which caused me to discard this system was the severe material duplicity evident between two units side by side (no party walls were possible) and also between the floor of one unit and the roof below as dictated by the frame structural system. Such inefficient use of materials needed to be re-evaluated.

SECTION

43



PIPE LENGTHS MANUFACTURED IN TWO HALVES - THEN SEALED



DTL. 1/A

PANEL DTL.

At this point, in the interest of efficiency, I ceased to consider the autonomy between frame and living space. It appeared that all solutions needed their own structure regardless of the massive frame. Perhaps the connotation of "frame" should be more in line with the members necessary for the structuring of the panels. So my next endeavors became a study of panels which were weather-tight at their connections, structural, would work on a module and which would avoid as much duplicity as possible.

The results of designs utilizing panels which lapped either at the sides or top and bottom and those which utilized a tongue and groove to provide the weather ability were always the same. They became encumbered at the connection by gimmicks necessary to make them function, they lacked a straight forward uncomplicated approach.

The panels, also, presented a difficulty in that because of their thickness an attempt at setting up a module pattern seemed to always leave you off the module by the thickness of one panel which was the result of turning corners. With an elaborate joint at the corner the difficulty could possibly be solved, but not without some gimmicry. The problem is intensified in the context of modular and industrialized building when one of the conditions is that you work

with a limited number of components of set dimensions. The problem becomes one of how to create a building perimeter, with all its designed projections and indentations which dimensionally works out to your controlling module (which in turn must be of a sufficient size to accommodate the interior functions). I had been attempting to get my panel system to work out on whole feet with maximum exterior dimensions between 10' and 12'.

I had finally arrived at a module 13' square, of which 12' on each side (when exposed to the exterior) would be composed of systems panels. The remaining 1' would be divide into two 6" square corner posts used to eliminate the discrepancy caused by the panel thickness, which was also 6".

As the modules were linked together a lengthwise axis would be determined and the floor/ceiling panels would be oriented perpendicular to it. I felt that common floor/ceiling panels would elminate part of the material duplicity which seemed to plague my attempt. Walls, I justified, needed to be double for sound as their materials were not a sound resistant (dense) as those used in the floors.

This approach was devastated when I realized a fatal oversight on my part. My criteria of flexibility, adaptability and an unspoken one of mobility were being negated. By depending on continuous bearing with common floor/ceiling

panels one could not effect design changes to lower floors (if the design was multifloored as I was considering) and moving a unit meant someone was left with no ceiling or no floor, just walls, and if a lower unit was removed the upper stories couldn't exist.

Certain aspects of this design had come together very well and I was hesitant to abolish it. Therefore it required an intensive re-evaluation, which brought me, finally, to the design which was the product of my thesis presentation.

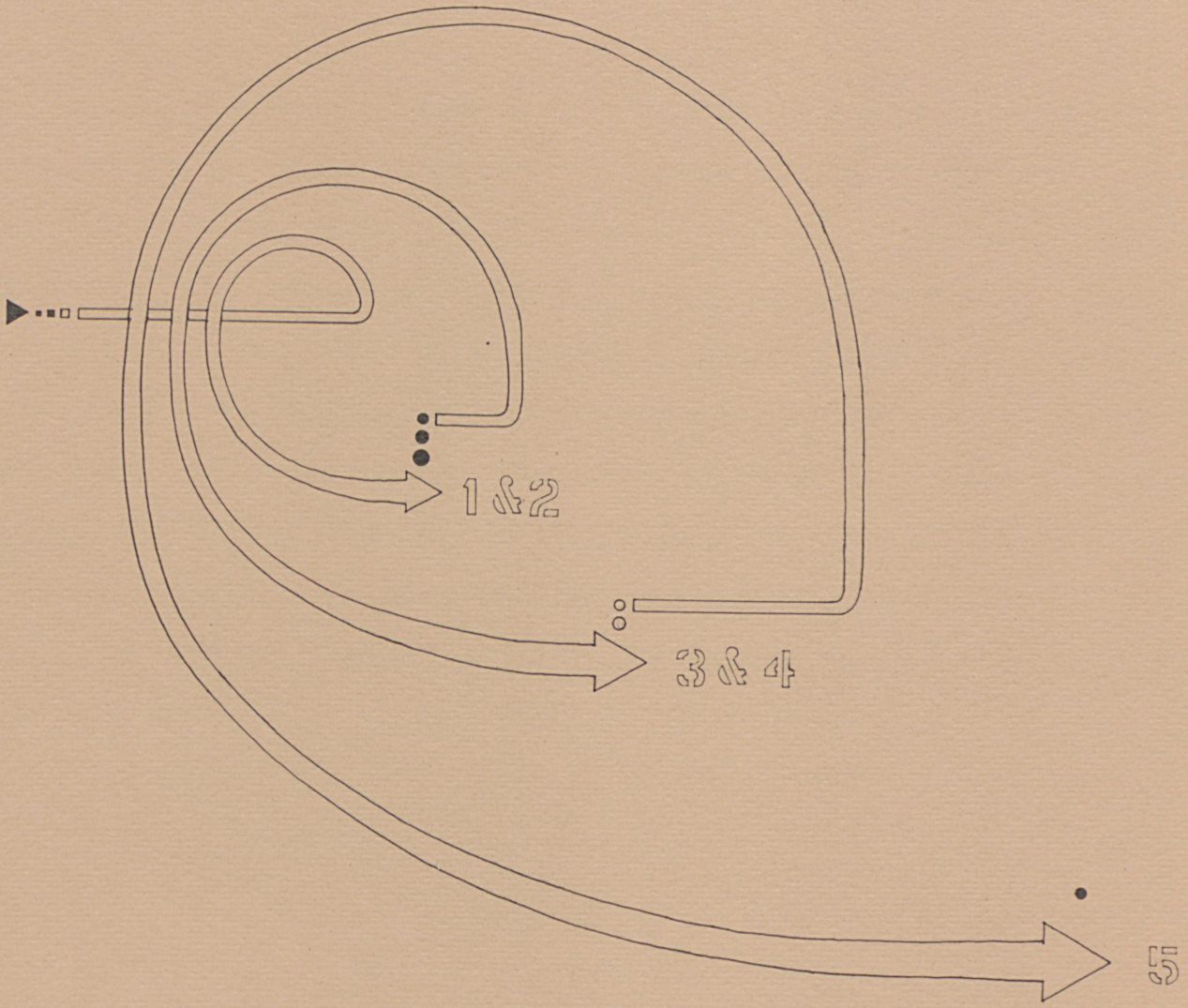
One can see how my thoughts and design attempts were integrated through the necessary re-evaluations which occurred in the diagram which follows. Each circular track represents new territory and ideas explored. These are evaluated at the arrowheads, with problem areas symbolized by the dot pattern indicating a slight regression. The tightness of the next track to the first indicates an integration and re-evaluation of initial material before the track flairs off into new areas of thinking. The cycle can repeat itself indefinitely until all obstacles are removed or a solution is reached commensurate with required level of design. I was into the fifth cycle when it became necessary for me to curtail the development of the design and begin presentation.

THESIS STATEMENT

1 & 2: REPRESENTS TETRAHEDRAL SPACE FRAME & RECTANGULAR FRAME STUDIES USING HOLLOW STRUCTURAL PIPES TO HOUSE THE SERVICES IN DEPENDENTLY OF LIVING UNIT.

3 & 4: REPRESENTS TONGUE-GROOVE PANEL SYSTEM & CUT-JOINTED PANEL OF STEEL WITH LAPPED INTERLOCKING STRUCTURAL CONNECTIONS - BOTH WITH PANELS ACTING AS BEARING MEMBERS.

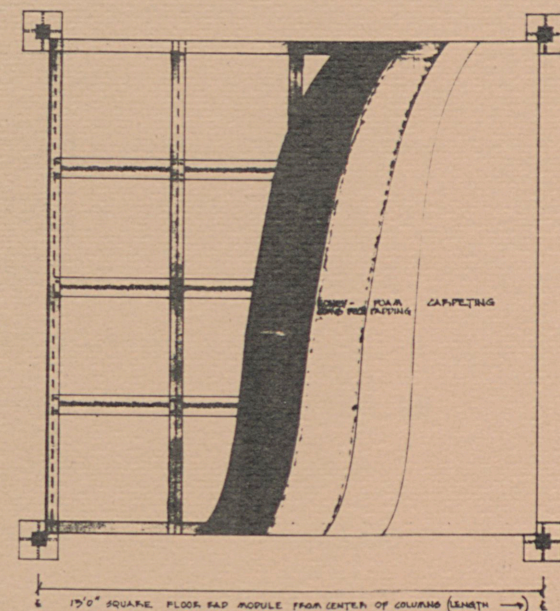
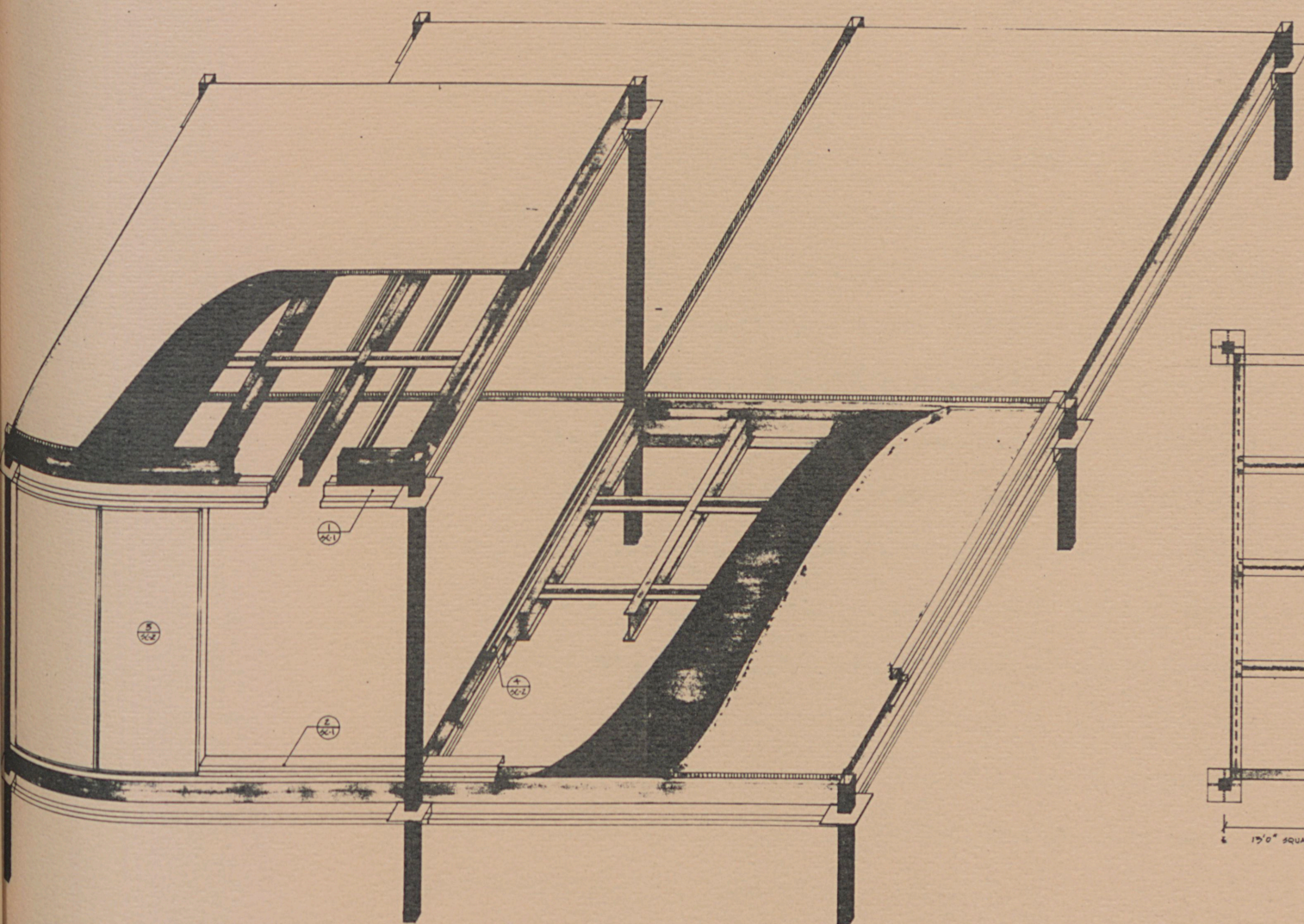
5: REPRESENTS PRESENTATION SCHEME - OF NON-DEPENDENT FLOOR PLANS WITH EXTERIOR WALLS MADE OF INFILL PANELS & INTERIOR PARTITIONS OF A MODIFIED WALL PANEL.



THOUGHT PROCESS

The final re-evaluation which I underwent preparatory to the developement of my presentation design indicated several things. To avoid floor/ceiling duplicity there must be a common floor/ceiling system but not dependent on there being a unit below. This implied a slab of sorts and a means of supporting it. Then each living unit would be dependent on only a quantity of infill wall panels. If the means of vertical support were continuous steel members and decking then there would be a reinstitution of the concept I had originally expoused - that of separating the structure from the living space (see page 49). Then flexibility, adaptability and mobility were a function of this separation.

If all the diverse elements could be brought together the system would work.



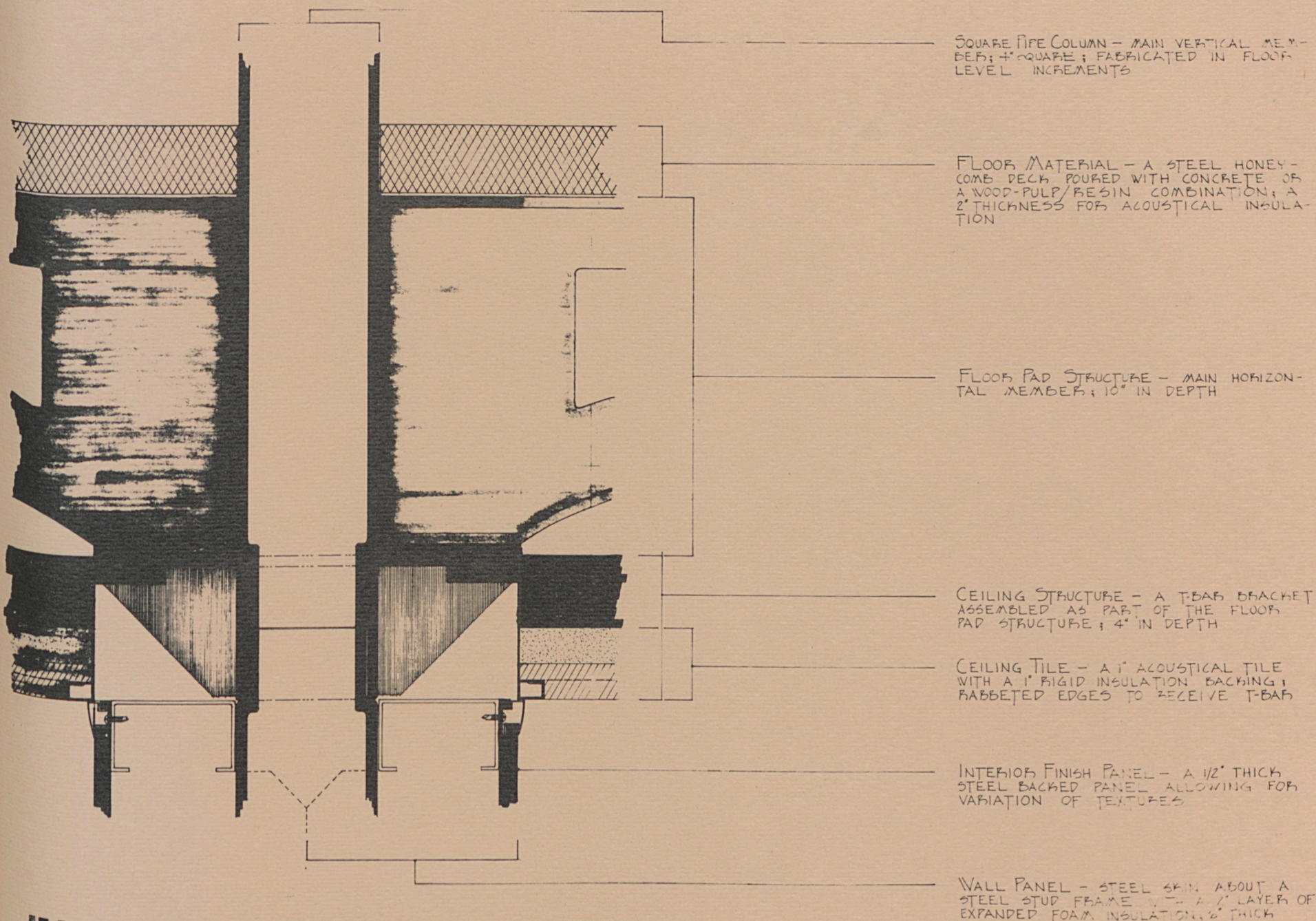
STRUCTURAL ISOMETRIC

PLAN

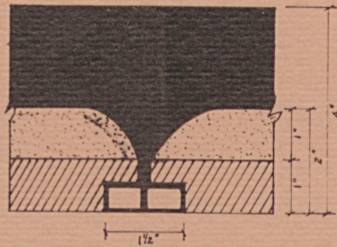
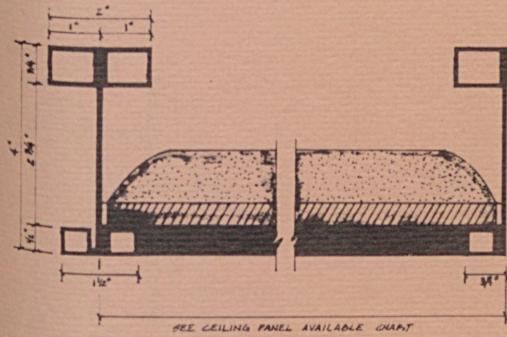
The system became a repeating one of independent 4" steel columns and 16" deep floor/ceiling pads to which the panels were affixed based on a module, center to center dimension between the columns, of 13". The 16" depth of the floor pad included a 2" sound-proof floor decking on a 10" structural frame below which projected a 4" T-bar ceiling system. (See floor-ceiling system, page 51)

The real advantage to a modular and industrialized system of housing is in providing variety through the use of a minimum quantity of repetitive components. The system I was developing consisted of 1 type of column and bearing sleeve, 16 configurations for exterior wall panels (with heat and electrical service and variable interior surfaces), 2 types a panel mating plates, a corner closure, 2 plate corner connectors, a floor pad unit composed as state above, a floor filler strip, 9 sizes of ceiling panels, 3 widths and heights of interior partitions, 6 sizes of windows, 2 configurations of doors, an angle to fasten interior partitions into perimeter wall and an exterior insulated filler. (See system components 1-4 pages 52 to 55) A relatively small total of 52 major components which when combined give as much variety and choice to the prospective owner as do most conventional housing methods. (See floor plans - page 56)

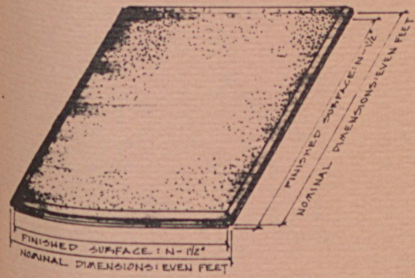
The panels (which have beveled edges) are simply butted together with a



FLOOR-CEILING SYSTEM



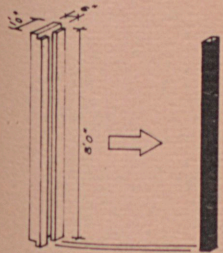
1
X2
SUSPENDED CEILING (T-BAR) SYSTEM SECTIONS
SCALE: 1"=1'



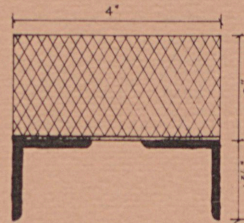
TYPICAL CEILING PANEL

	1	2	3	4
1				
2	●	●		
3	●	●	●	
4	●	●	●	●

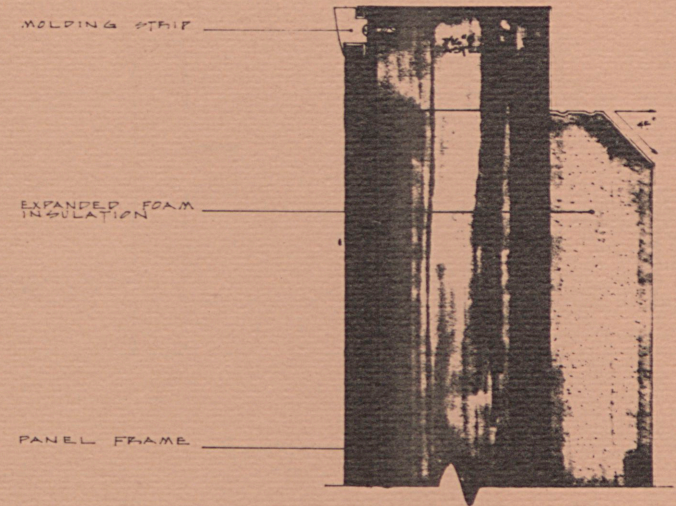
CEILING PANEL CHART-
NOMINAL DIMENSIONS (N)



2
X2
WALL CONTINUITY PANEL
SCALE: 1/2"=1'

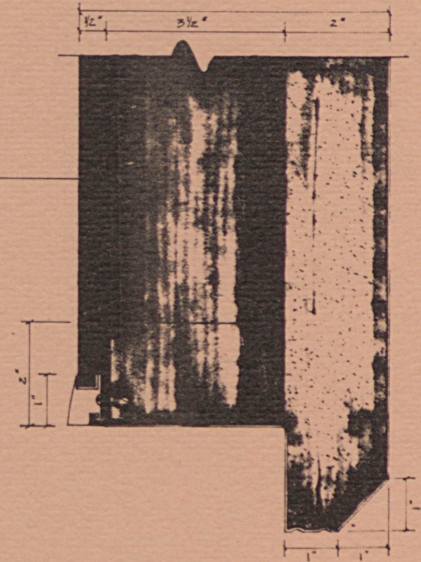


4
X2
FLOOR FILLER
SCALE: 1"=1'



PANEL FRAME

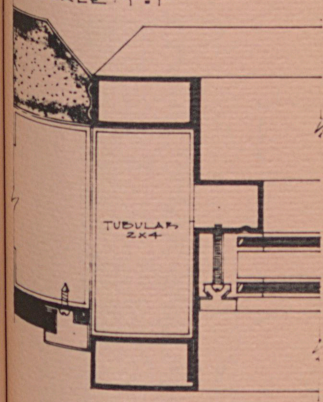
INTERIOR
FINISH PANEL



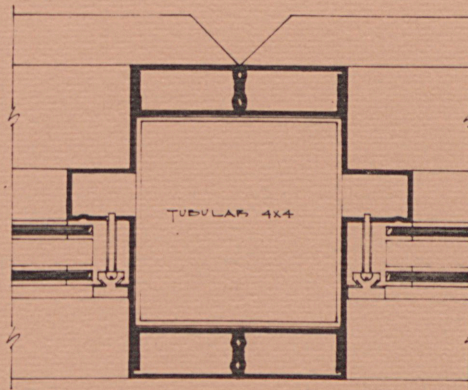
3
X2
TYPICAL WALL PANEL SECTION
SCALE: 1"=1'

SYSTEM COMPONENTS 2

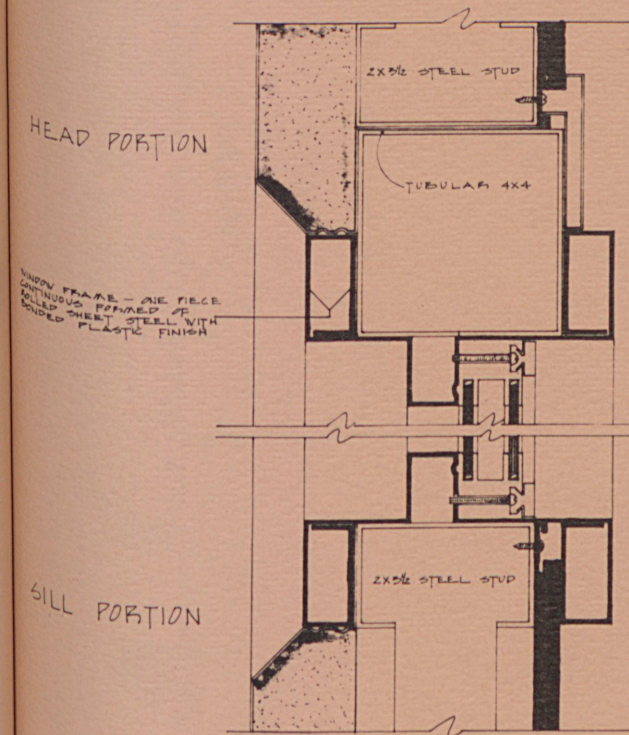
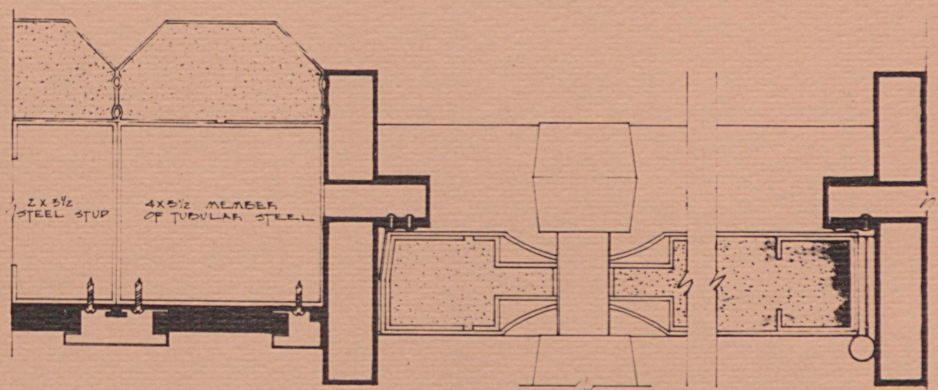
1 WINDOW JAMB DET.
SCALE: 1"=1'



2 CENTER MULLION DET.
SCALE: 1"=1'



4 DOOR JAMB DET.
SCALE: 1"=1'

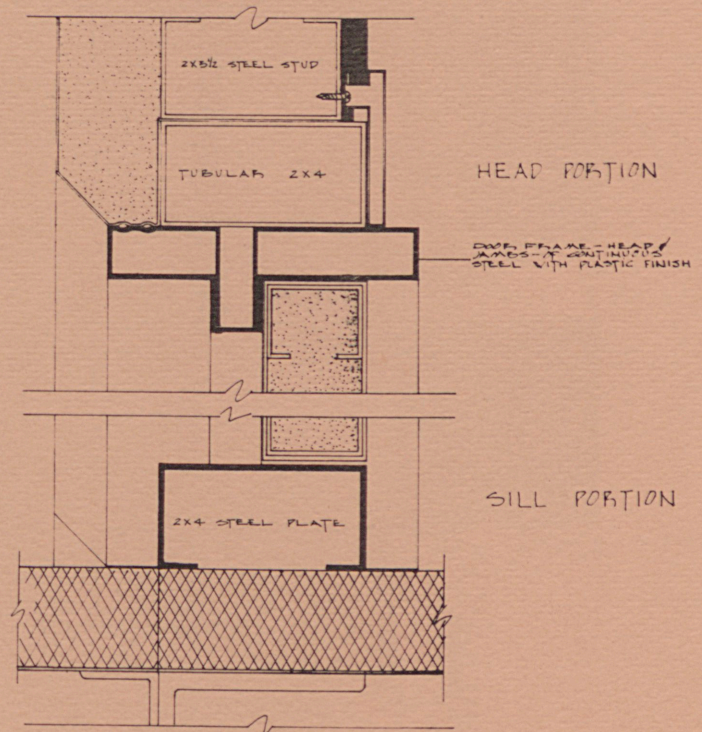


WIDTH	
HEIGHT	3'
4'	IN PLACE OF THE 5' x 4' PANELS ONLY
5'	

WINDOW AVAILABILITY CHART

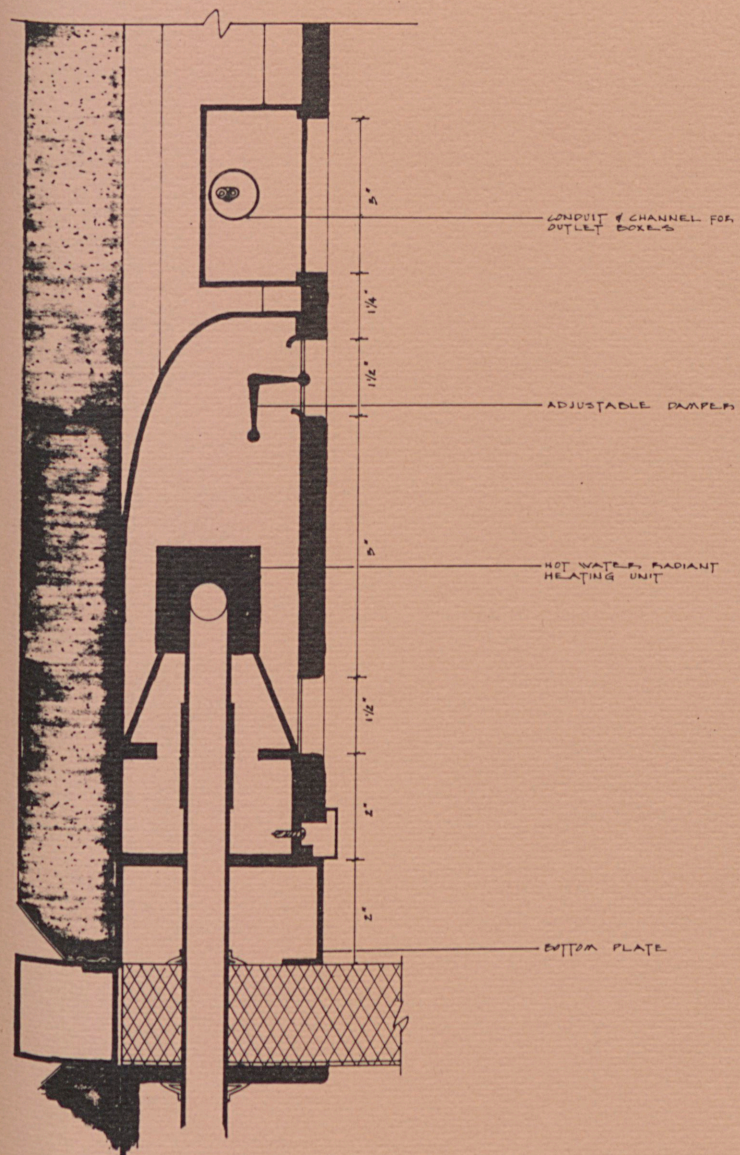
WIDTH	
HEIGHT	7'
5'	FRAME ONLY TO FIT A 5' OPENING
7'	FRAME & FILLER PANELS TO FIT A 4' OPENING

DOOR AVAILABILITY CHART



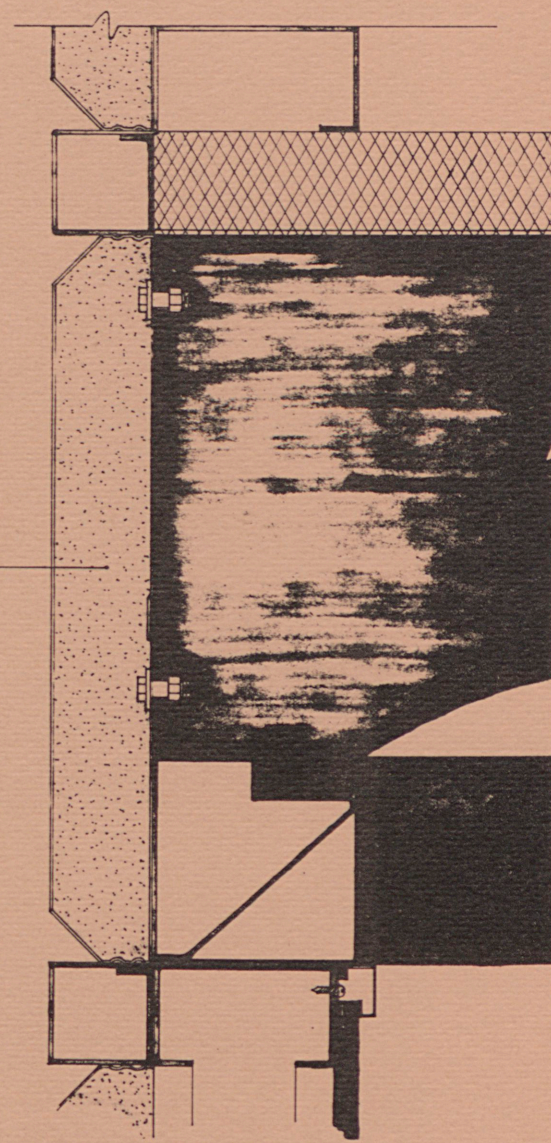
5 EXTERIOR DOOR SECTION
SCALE: 1"=1'

3 TYPICAL WINDOW SECTION
SCALE: 1"=1'



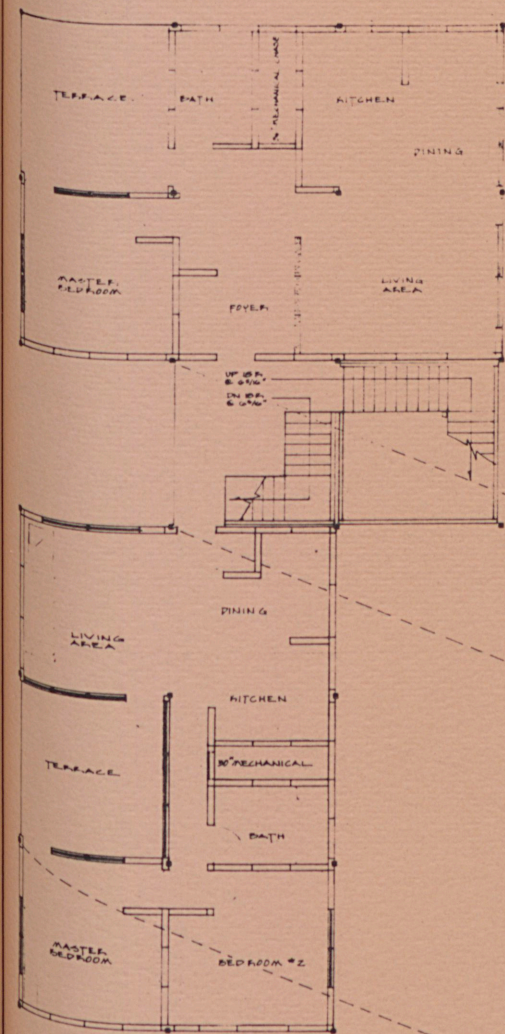
(1)
24 RADIANT PANELS & ELECTRIC SERVICE
SCALE: 1" = 1"

INSULATED-2" FILLER PANEL

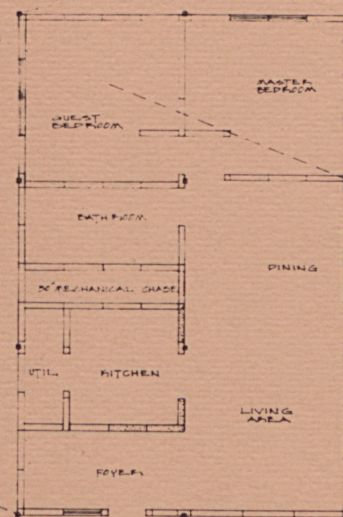


(2)
24 INSULATED FILLER PANEL
SCALE: 1" = 1"

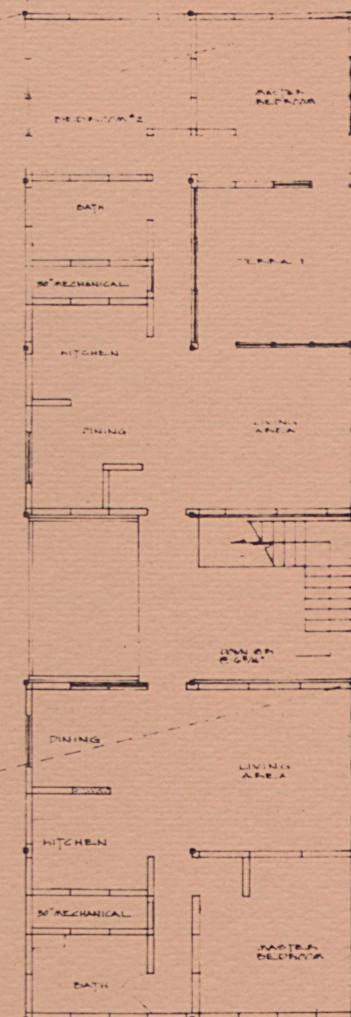
SYSTEM COMPONENTS 4



SECOND FLOOR
SCALE: 1/4" = 10"



FIRST FLOOR
SCALE: 1/4" = 10"



THIRD FLOOR
SCALE: 1/4" = 10"

FLOOR PLANS

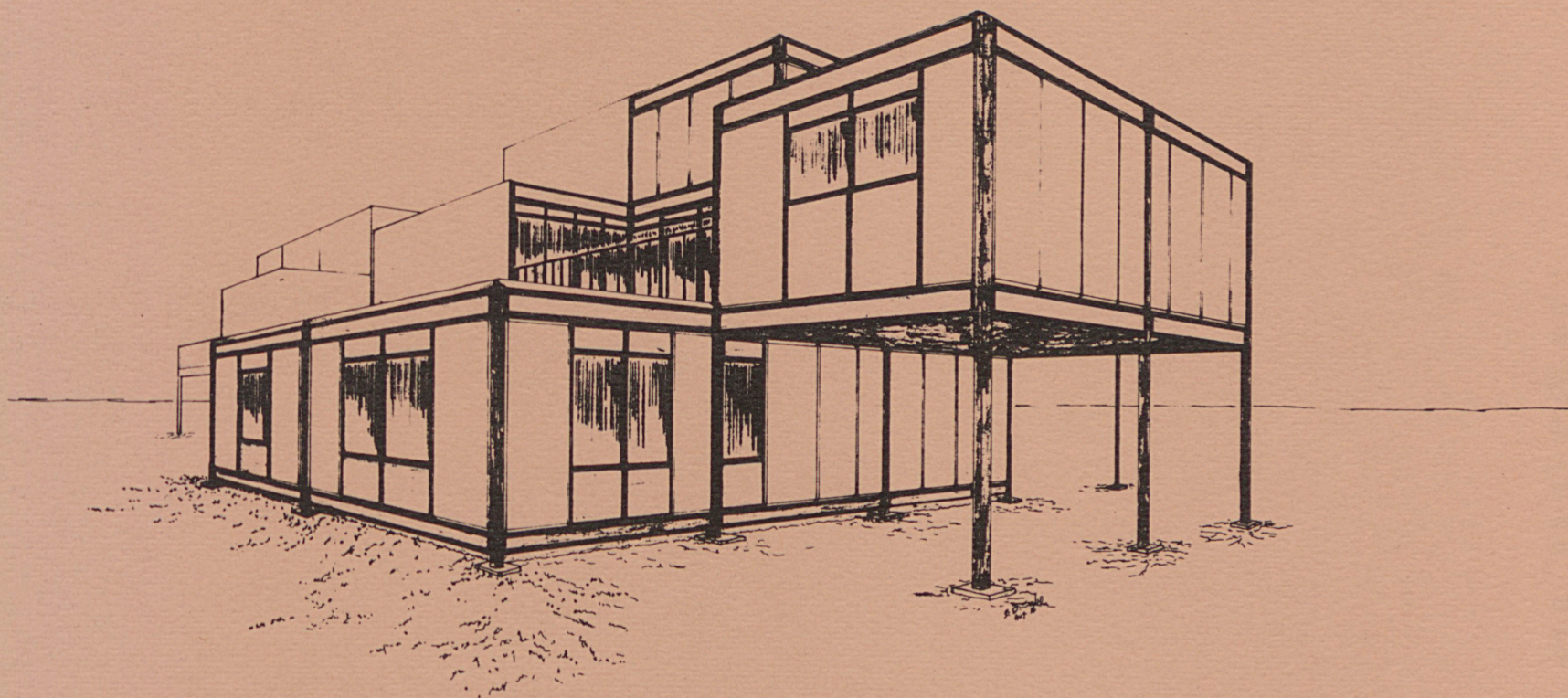
seal provided by a double strip of non-hardening caulking or possibly a compressible rubber gasket at the interface. Attachment to the upper and lower plates as well as adjacent panels is completed while the interior finish panel is off and consists of a series of self-drilling, self-tapping fasteners. The panels are placed from the interior.

Connections for those panels having integral radiant heating units (primarily under windows) are also made while surface panel is removed. Piping is run in the floor cavity until reaching the vertical chase. Electric service is brought through the floor cavity and, by either a riser or drop conduit, into the service channel found in each panel. Lighting is by conventional fixtures; either recessed or surface mounted and either fluorescent or incandescent.

As the six-plex drawn on the floor plans and shown also in perspective (see page 59) begins to indicate, this system of panels and pads establishes a clarity of line and form. When combined with the projection or recession of the facades and the interplay of solid and void which would occur more intricately in a larger developement for circulation, as it does here to small degree, the system would have great visual impact.

The exterior color scheme is bold. The long horizontal filler panels as

well as those immediately above and below the windows would be in bright accent tones against the neutral color (creme) of the remaining panels. The extent of a unit would be known by the extent of the accent color on adjacent modules and by the spacial separation.



PERSPECTIVE

CONCLUSION

Having reached the culmination of this project and realizing at the same time that one is never really finished I find myself wondering what effects that unknown sixth cycle in my thought processes would bring to this subject.

Through a quarter of research and a quarter of design I have found the subject of modular and industrialized building as an addition to traditional means of housing an interesting and complex project. Now in retrospect, judging my own solution and those which I have studied and being aware of the technology available in the United States today, I can honestly answer the question which I posed for myself. Yes - modular and industrialized housing is an acceptable answer to our housing shortage today. It will aid in eliviating that shortage for tomorrow.

It is not meant to satisfy every one. No one proceedure should, but for those who cannot afford traditional housing their need for shelter can be met with the low-cost of modular - industrialized home.

My exploration has just scratched the surface of design possibilities. The system which I designed is extremely basic and straight forward. As the concept of industrialized housing gains strength as it must of necessity and as more and more architects contribute their expertise to the cause tremendous progress will be made in the field.

The path which modular and industrialized building will follow in the future is dependent upon the attitudes toward it which we begin forming today.

As Ferguson states, in Architecture, Cities and the Systems Approach:

"Social, economic and political phenomena are ---
the determinants of form ---.

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APPENDIX

The following pages include the illustrations of the five foremost examples of modular and industrialized systems which I evaluated when I established my matrix. They include one each from concrete, wood, plastic and two from steel. They are coded to correspond to the matrix designations as well as the listing below.

Because it would be financially prohibitive the remaining 15 systems which I analysed to arrive at the matrix have been eliminated.

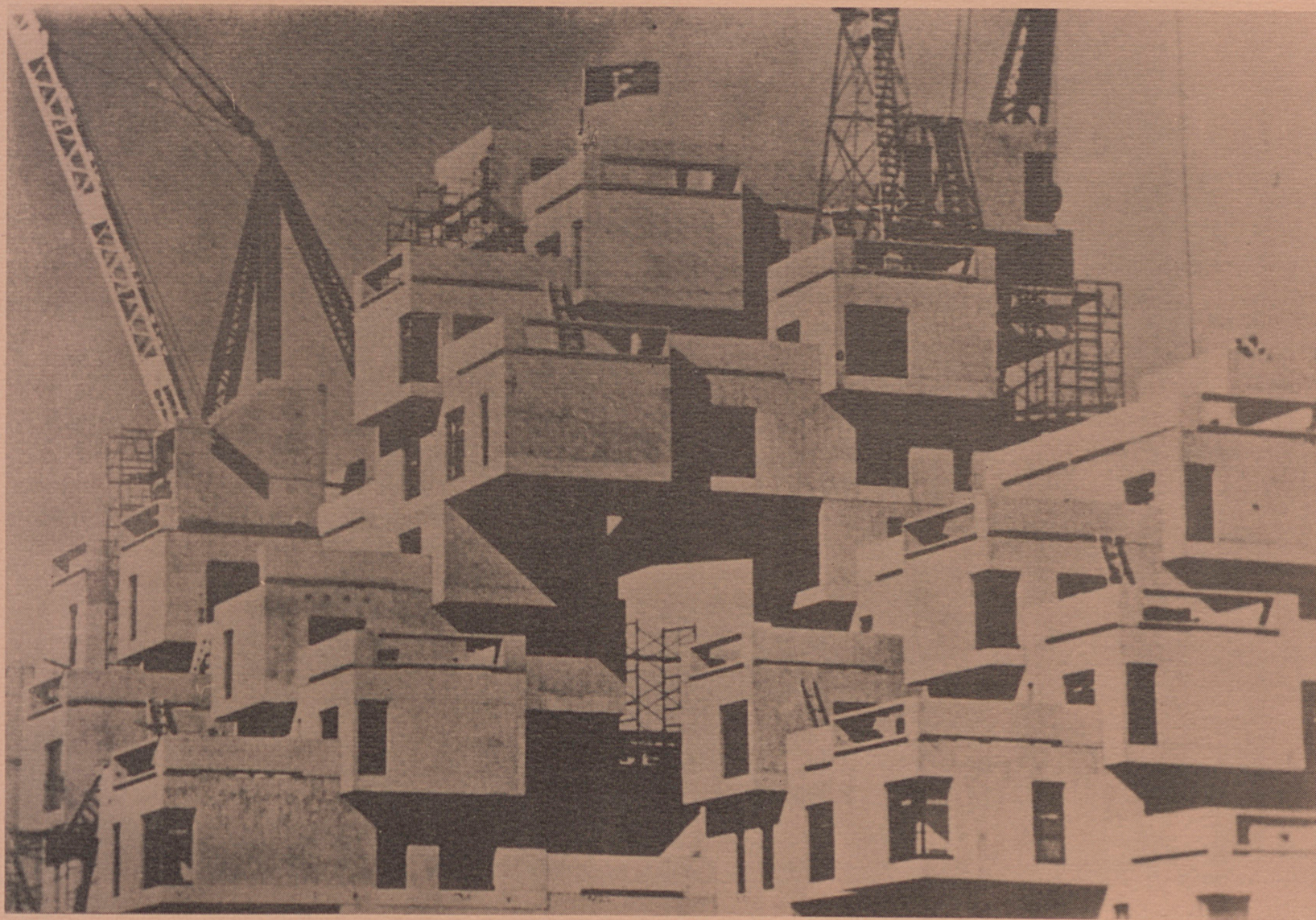
CCD. Habitat by Moshe Safdie from The New Building Block, page 178.

WCA. Mobilehome technology by Paul Rudolph in Charlottesville, N.C.

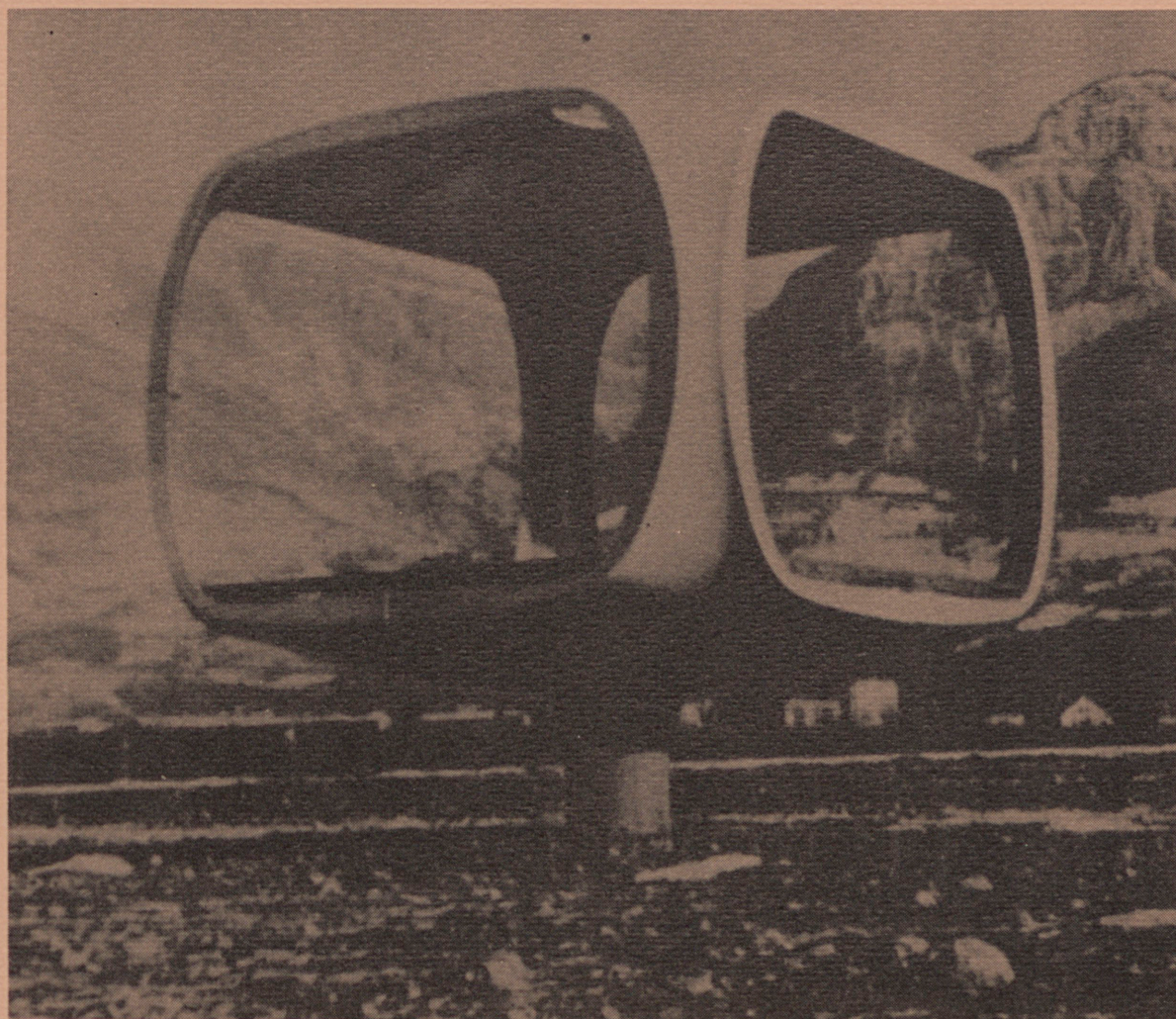
PFA. Designer unknown.

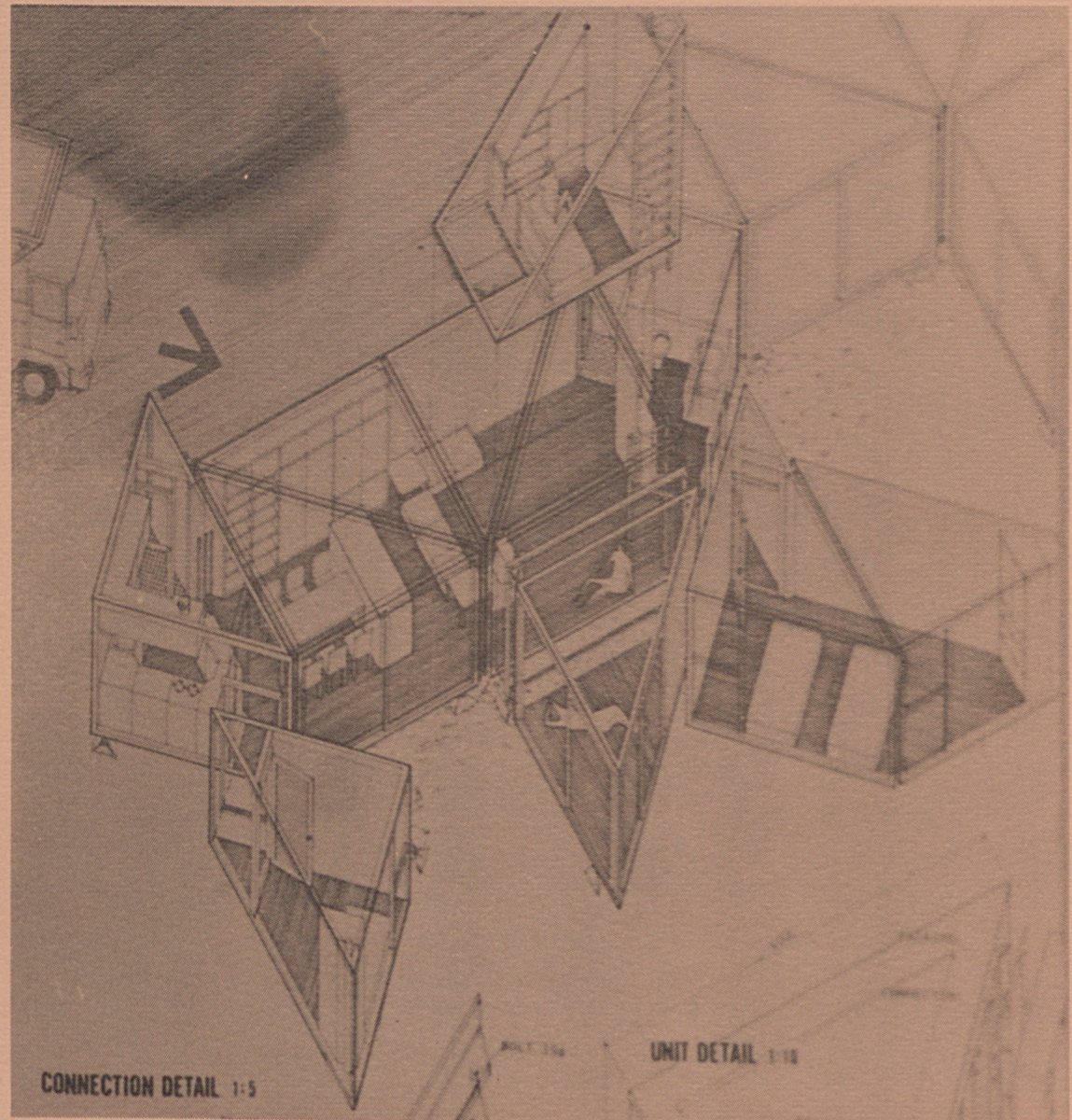
SFB. Competition design from Misawa International Prefabricated Housing Design Competition, 1972.

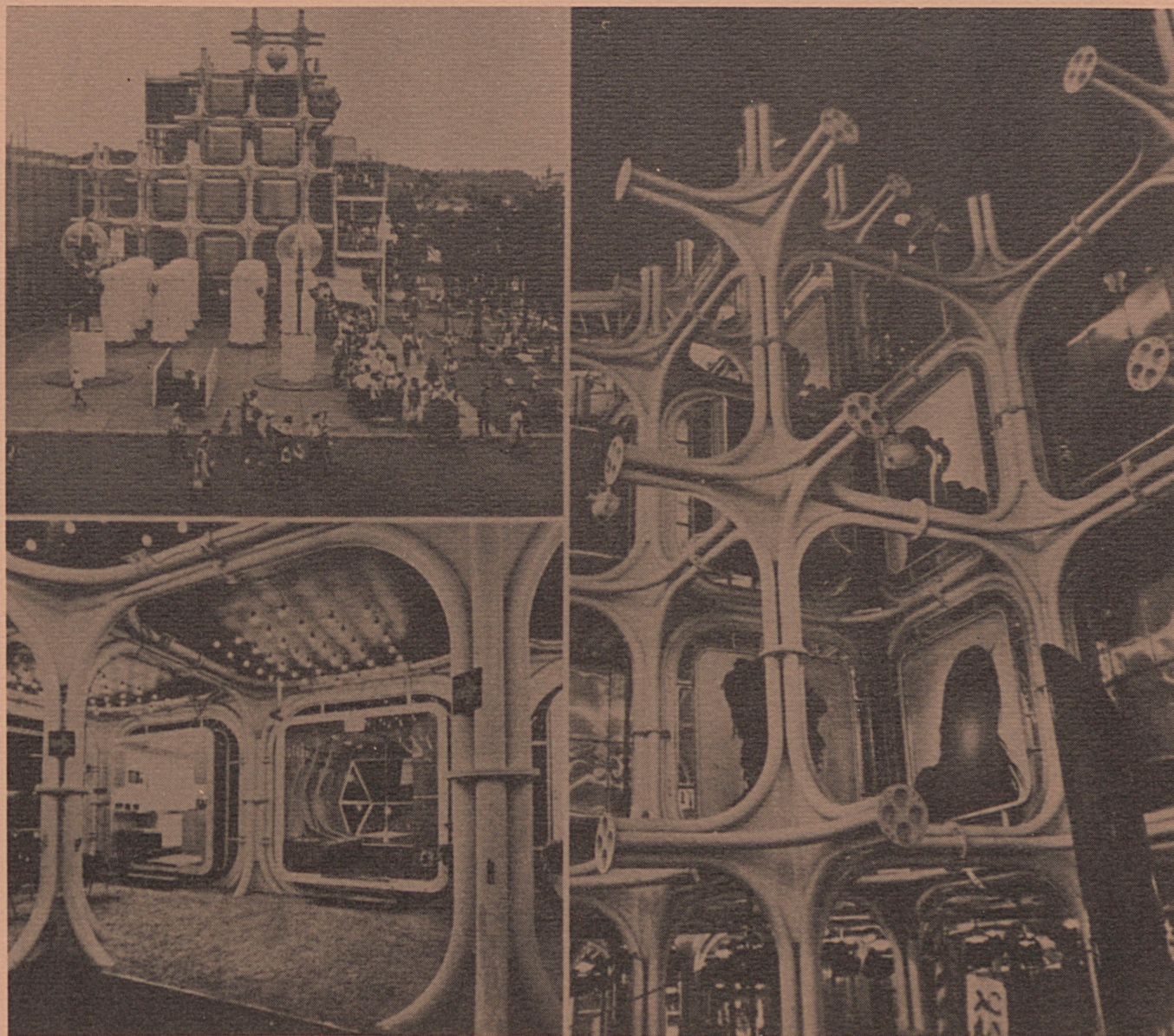
SFC. Capsules by Kurokawa from Architectural Record.











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