An Architectural Response to the Housing Crisis

by

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ACKNOWLEDGEMENTS

I would like to acknowledge my family and friends for their support and guidance throughout my entire education. A special acknowledgement is extended to each member of my committee, Warren R. Kark, William Brown, and Charles Steger for the help and guidance from which I have learned a great deal.

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Preface

Between 1970 and 1976 general inflation and personal incomes rose at an average annual rate of 6.6%.[1] During similar periods:

Land prices rose at an average annual rate of 13.4% (1967-1974).[2]

Home maintenance rose at an average annual rate of 9.3% (1967-1974).[3]

Construction financing rose at an average annual rate of 25.4% (1970-1974).[4]

The cost of new home rose at an average annual rate of 11% (1970-1976).[5]

The cost of an existing house rose at an average annual rate of 8.9% (1970-1976).[6]

This is just a sample of the data documenting what is commonly referred to as the current housing crisis in the United States. What does it all add up to? In short, the cost of housing is rising faster than incomes with the result that in 1975 only 15% of all Americans could afford a new medium priced single family house.[7] (Compared to 70% in 1950).[8]

In recent attempts to resolve this problem many proposals have been made at all levels: H.U.D.'s project breakthrough, bankers' introduction of new mortgage terms, new products, introduction of new living styles (condominiums), and industrialized housing are only a few examples that illustrate the concern of those involved in the housing industry.

Because of the vast complexity of the housing crisis it is not likely that a solution will lie totally within one field of study, but rather a solution will evolve from a concerted effort by all involved to understand their role and respond to the opportunities within their fields.

As a central link in the building industry, the architectural profession is a potential source of major opportunities for progress within the housing crisis. Thus the objectives of this study are to identify possible opportunities within the architectural profession through which it may effectively contribute to the resolution of the housing crisis and to develop an architectural response to those opportunities.

The Problem

One of the major problems confronting the United States today regarding the housing crisis is the inability of many people who are attempting to resolve the problem to properly identify the problem. More often than not proposals resolve symptoms rather than the problem itself. The mobile home industry is a prime example. Almost anyone that has lived in a mobile home can attest to the fact that there is more to the housing crisis than just the cost of housing. Although the mobile home industry has been successful in greatly reducing the cost of housing, the general disregard of quality has removed mobile homes as a potential alternative housing type to a major portion of U. S. consumers. From this the importance of properly identifying the problem becomes apparent.

In general, many believe that the problem lies mainly in the industry, its inefficiencies, codes, unions, etc.. Others believe that consumers, their increasing demands and unwillingness to accept change, are responsible. There is no doubt that both of these play a major role in the current crisis: but I believe it is important to understand that the problem lies wholy in neither the housing industry nor its consumers but rather in the incompatibility of the two. We may then generalize the housing crisis as simply: The difference between what the U. S. consumer is demanding of the housing industry and what the housing industry is able to produce. By stating it in this manner it is emphasized that one must address both of these areas of concern in attempting to resolve any part of the housing crisis. More importantly it emphasizes the fact that we should not talk about the absolute costs of housing but rather the relative cost. Illustrating that there is a housing crisis for all economic groups rich as well as poor.

More specifically, in researching the housing industry it becomes apparent that although much of the criticism leveled at the industry has merit I believe that the factor limiting its success is not its ability but rather its lack of direction or more correctly its misdirection. Even though the building systems we use today are successful and built upon sound reasoning, they are becoming less efficient (economically) as the factors contributing to the cost of construction change.

For example, the extent to which inflation and the energy crisis have shifted a great deal of the total building cost to the time related costs of construction has not yet been manifested in the building industry as a whole.

Similarly, consumers ability to adapt or accept change is not currently the factor limiting progress but rather the lack of reasonable alternatives. There is little doubt in the minds of most consumers that the days of single family detached housing is becoming less and less an attainable reality. But unfortunately most current alternatives fall so short of expectations that they are not even seriously considered by many.

Although it is understood that these two categories do not encompass all of the factors effecting the housing crisis it is felt that they do in fact cover a great deal of the more important considerations. It is upon these two areas of thesis that this study will be built.

The Approach

Now that we have identified our two major areas of concern and their relationship it is important that the proper approach to resolving the problem is used.

It may at first be useful, in order to gain an overall understanding of the problem, to review the building process in general. (Figure 1) It becomes apparent that to adequately respond to both the variety of user needs and the site specific requirements of a project that it is necessary to allow these decisions to take place at the manipulation stage of the process. Conversely since the lower limits of a project's costs are determined to a great extent upon the selection of a construction system any desire to significantly reduce construction costs must be made prior to that decision.

This points out a major stumbling block of many proposals: proposals that produce a product at the construction system stage (mobile homes) reduce or eliminate their ability to respond to the changing requirements of different projects. Likewise proposals that depend upon their ability to respond to the users needs and the site specific requirements of a project (many architectural proposals) often use existing construction systems to implement their designs, thus greatly limiting their ability to reduce costs.

Thus what is desired is a system that responds to the cost requirements of construction without unnecessarily constraining any of the decisions that will later on allow the designer to respond to the users needs and site specific requirements of any particular proposal.

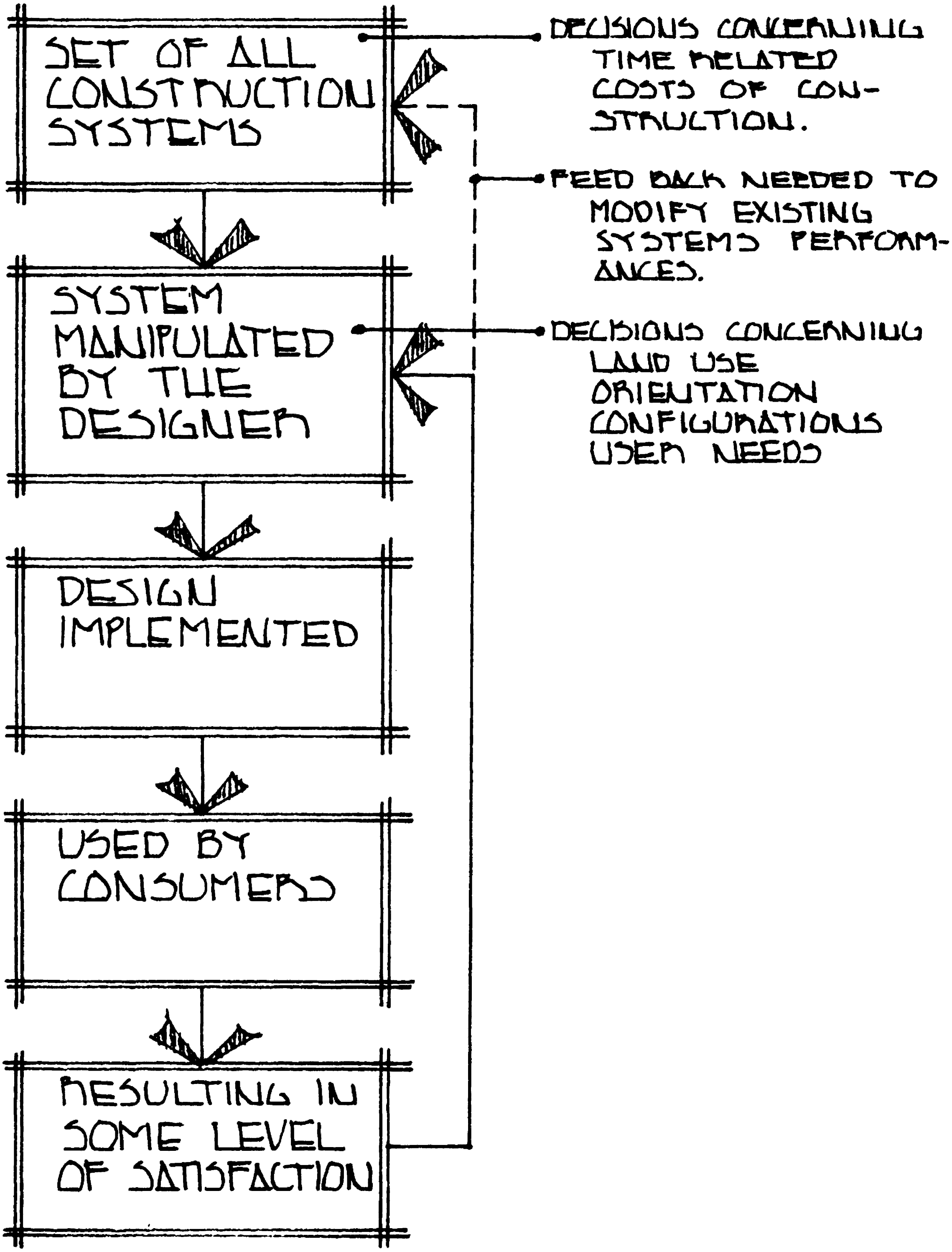


FIGURE 1 : THE BUILDING PROCESS

Objectives

In developing a construction system it is necessary to at all times retain a clear set of objectives. The overall objective of this proposal is to produce a system which will reduce the cost of housing while retaining enough flexibility so as not to unnecessarily constrain decisions which are related to the specific user or site.

The systems reduction in cost will result mainly from the use of standardization, prefabrication and close attention to facilitating efficient construction management. The use of a prefabricated standardized system of components that interfaces in a simple and consistent manner using both conventional methods and materials would best serve this purpose. It is desired that the system will facilitate the installation of all necessary services in an efficient and consistant manner.

It is necessary to generate a number of specific requirements for the systems development. To do this, it is helpful to identify the manner in which the system is to function with respect to a number of critical concerns. Those concerns are: structural capacity, design load, construction methods, and electrical, HVAC, and plumbing distribution.

Requirements

General

The construction system is to be of post and beam type construction capable of producing three story residential structures with live design loads and snow loads of 40 pounds per square foot. The use of highly industrialized components should be minimized and a reliance upon semi-skilled and unskilled labor for on-site fabrication is desired. Any off-site fabrication of components is to be kept at an appropriate level of technology as to permit local fabrication and delivery.

Electrical

Service to be delivered to individual units will consist of 120-240V, single phase 3 wire 100 amp branches. Branch circuits will be 20 amps and are to be delivered through 12-3 wire "BX" armored cable.

It is necessary for delivery of power to be possible at:

Any partition approximately 18" above finished floor for recepticals.

Any partition approximately 12"-24" below finished ceiling for wall fixtures.

Any point in a ceiling for ceiling fixtures.

HVAC

The system is to be able to accommodate forced air heating with delivery occuring at the base of exterior walls with a maximum face velocity of 600 fpm.

To estimate the maximum heating load, a calculation approximating the worst possible conditions was made assuming:

1500 SQ. FT. unit
on grade
2x4 insulated stud walls
Flat insulated roof
A wall to glass ratio of 4-1
A floor to wall ratio of .9
and a design temperature of -20 degrees

This translates into heat loss of 61,000 BTU which would require approximately 800 cubic feet of air per min.. Thus from this we find that the largest feeder duct that the system must accommodate would be approximately 81 square inches.

Plumbing

The plumbing demands of this scale of construction are not likely to exceed 78 fixture units per stack which would necessitate that a 4" waste stack and a 3" vent stack be easily incorporated into the system. A slope of 1/4" per foot is necessary for all horizontal waste lines and the stacking of plumbing needs is desireable.

CONSIDERATIONS

Flexibility

(The relative extent to which three dimensional decisions may be made).

One contradiction that is quickly realized in developing a construction system is that increased flexibility runs contrary to both reduced cost and standardization. That is: one would find that an extremely flexible system would result from a lack of standardization and would be relatively expensive. Thus it becomes apparent that the optimization, not the maximization, of flexibility should be the objective of this proposal.

In determining the optimal amount of flexibility two factors must be considered: factors constraining flexibility and the degree of flexibility needed.

Figure 2. Interdependent Floors:

The need to efficiently translate, to the ground, all loads created in a structure, necessitates close attention to the location of bearing members. In multistory projects this is often resolved by simply stacking bearing walls. This interdependency of floors greatly constrains spatial decisions.

Figure 3. Standardization:

The most important factor constraining flexibility in most proposals is the desire to control costs. It is important to understand that flexibility and cost are, in general, inversly proportional and that through the use of a standardized framework, this relationship may be optimized.

Figure 4. Spatial Needs:

A major concern in attempting to optimize the flexibility of a system is determining the demands that will be placed upon that system. It can be seen in developing a system for residential use, that in general, there are only three types (and scales) of spaces that need to be generated: Living, circulation/utility, and storage.

Figure 5. Diminishing Returns:

It becomes apparent that, regardless of costs, each successive increment of flexibility, within a fixed system, results in a diminishing useful return.

Figure 6. Increments of Space:

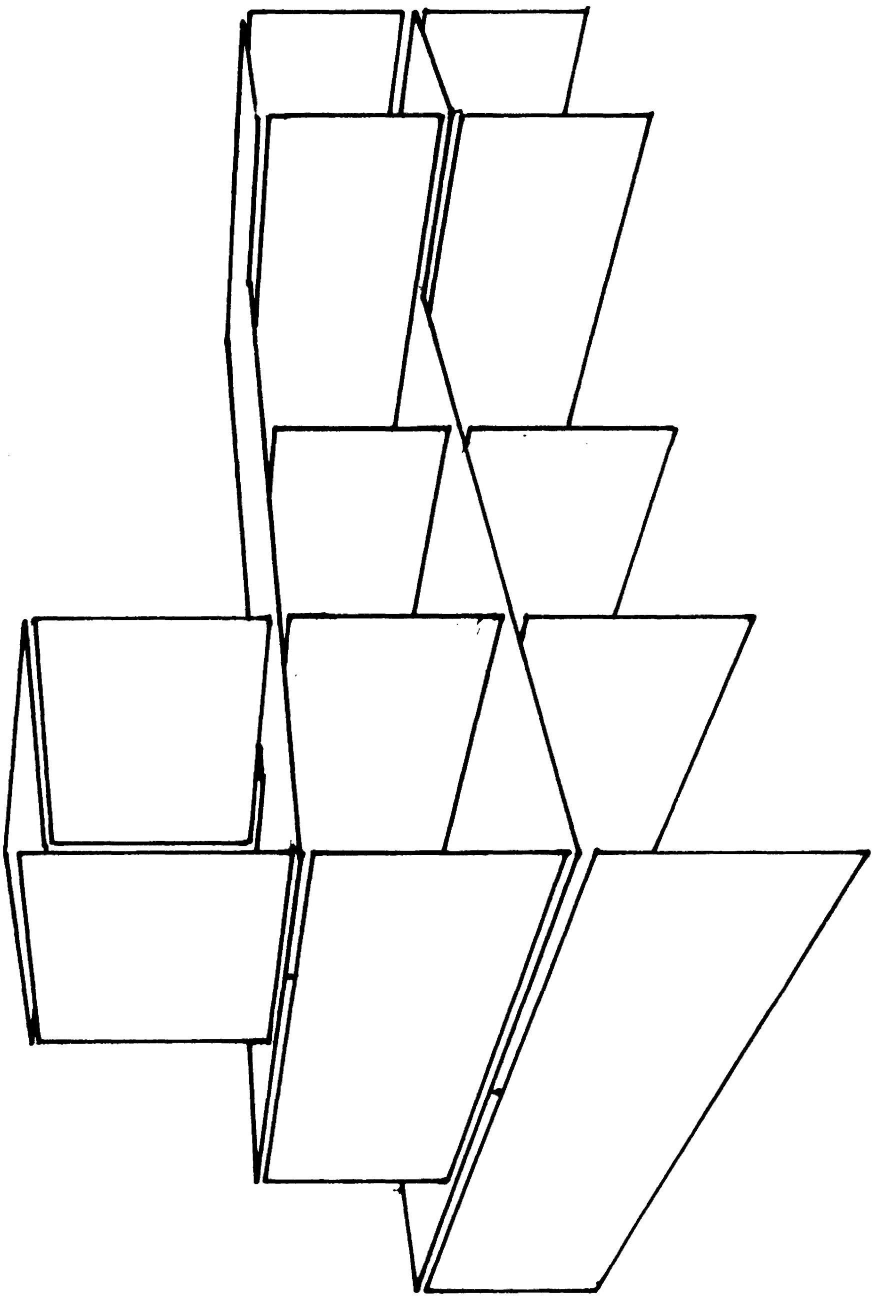


FIGURE 2 : INTERDEPENDENT FLOORS

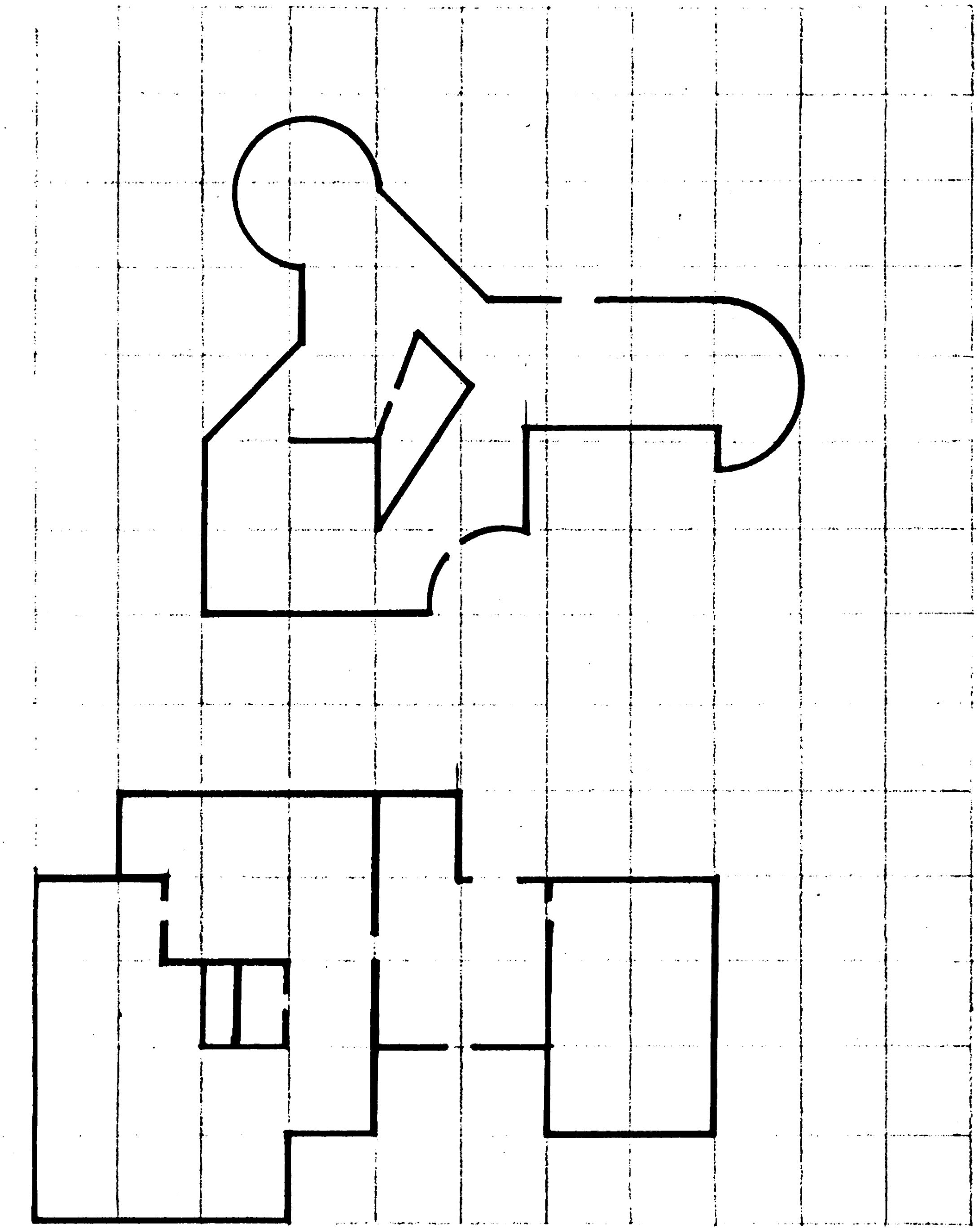
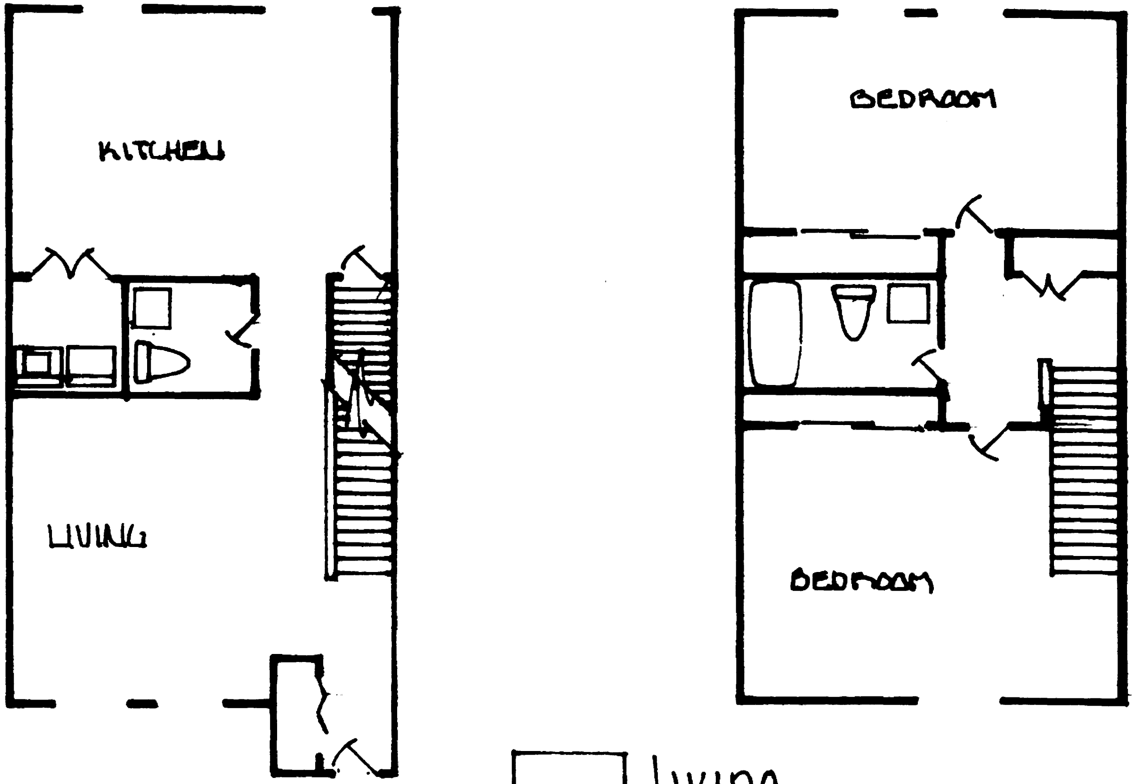


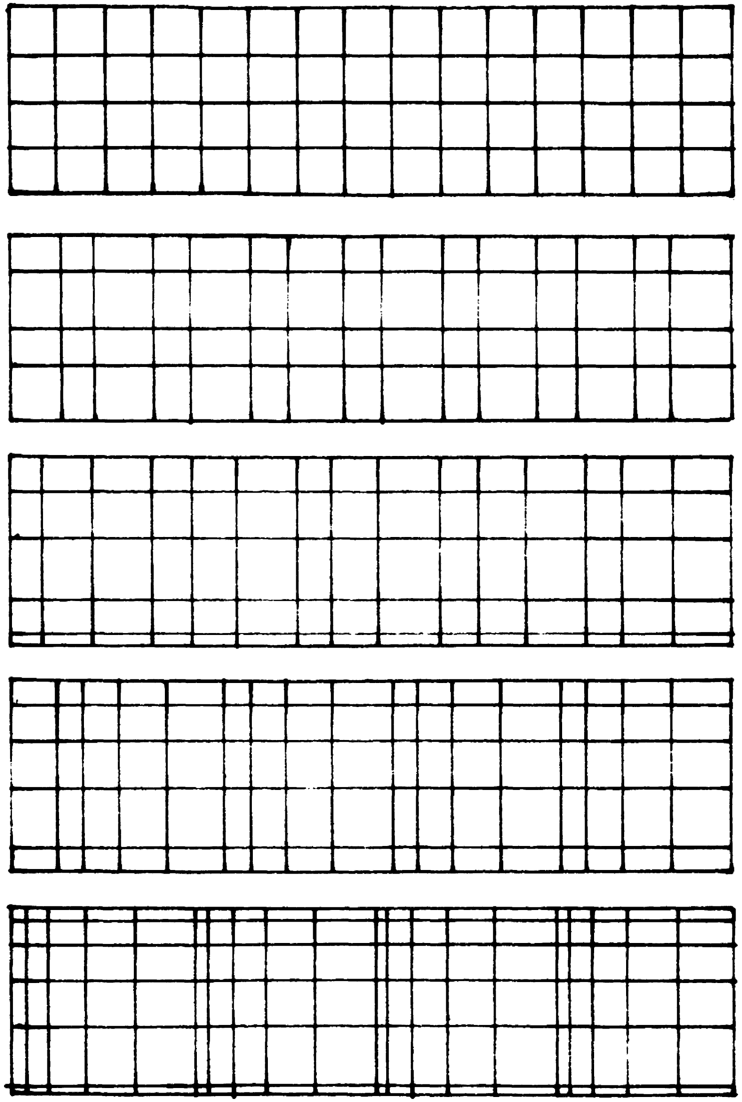
FIGURE 3 : STANDARDIZATION

FIGURE 4 : SPATIAL NEEDS



☐ living
☐ circulation/utility
☐ storage.

FIGURE 5: DIMINISHING RETURNS



COMPONENTS	1
AREAS	1
RATIO	1:1

COMPONENTS	2
AREAS	3
RATIO	1:4

COMPONENTS	3
AREAS	6
RATIO	1:16

COMPONENTS	4
AREAS	10
RATIO	1:64

COMPONENTS	5
AREA	15
RATIO	1:256

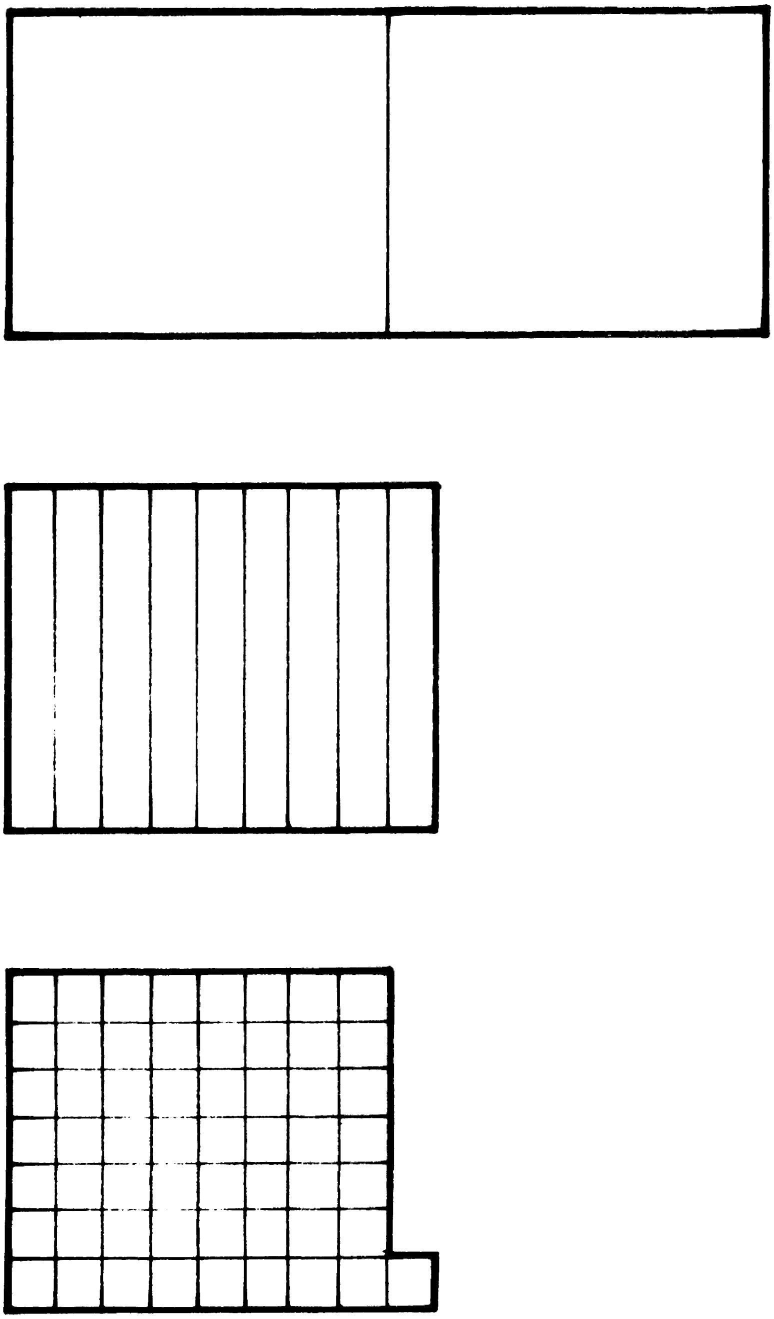


FIGURE 6 : INCREMENTS OF SPACE

It is important to determine the increment of flexibility that is needed and which may be substantially preceived. Again, the optimization, not the maximization, of this increment is desired.

Structures

There are a number of characteristics inherant in post and beam construction that should be considered during both the design and construction phases of the building process. The following illustrate a few such considerations.

Figure 7. Lateral Support:

The problems concerning lateral support encountered when using post and beam construction result mainly from the fact that all of the components used are relatively one dimensional. The introduction of a rigid two dimensional component would resolve this problem. If these components can be used during construction the need for temporary bracing may be minimized.

Figure 8. Plumb:

The use of rigid two dimensional components is also necessary to insure that the vertical posts in post and beam construction remain plumb. Again, if these components can be involved in early construction, the need for temporary bracing may be reduced.

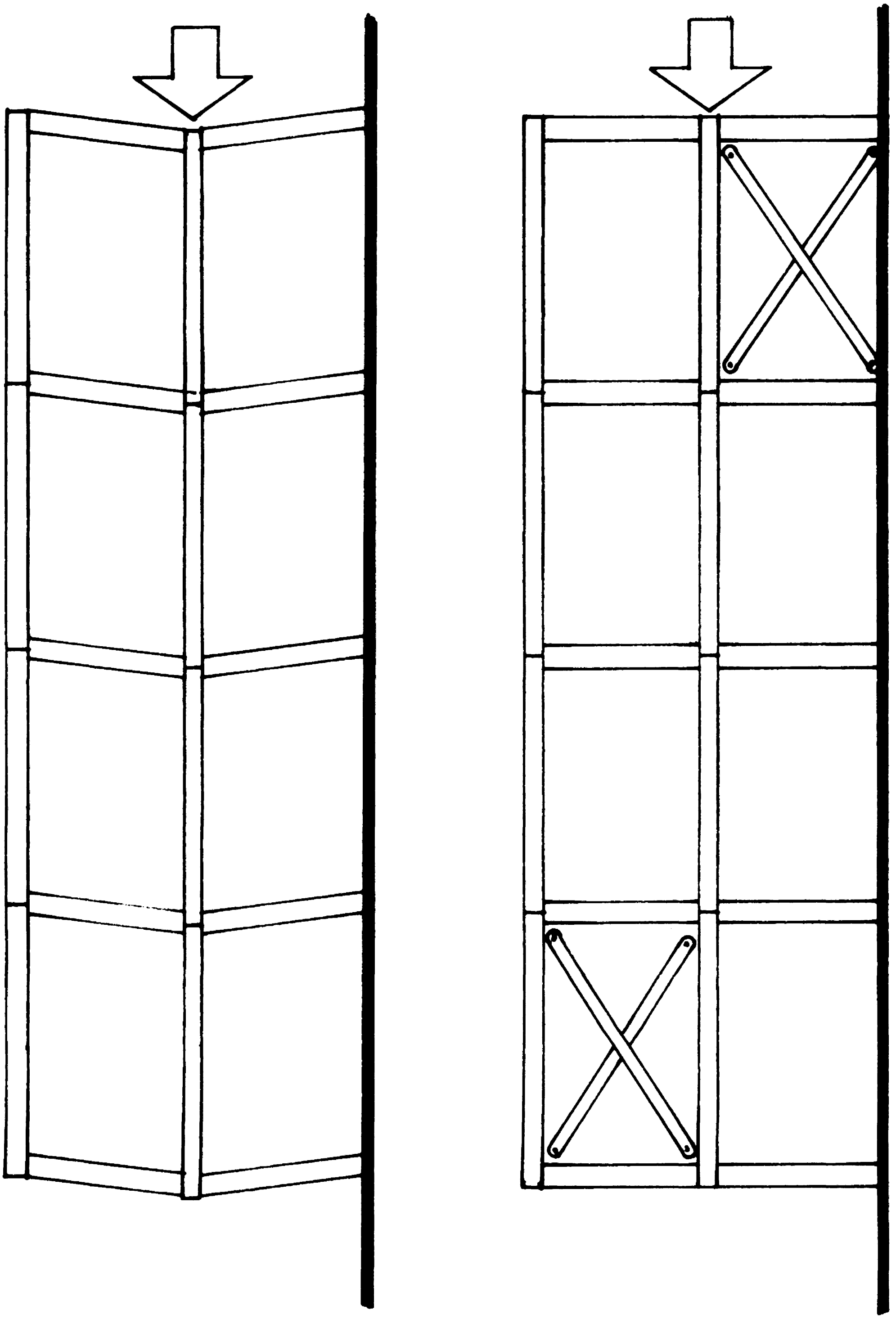


FIGURE 7 : LATERAL SUPPORT

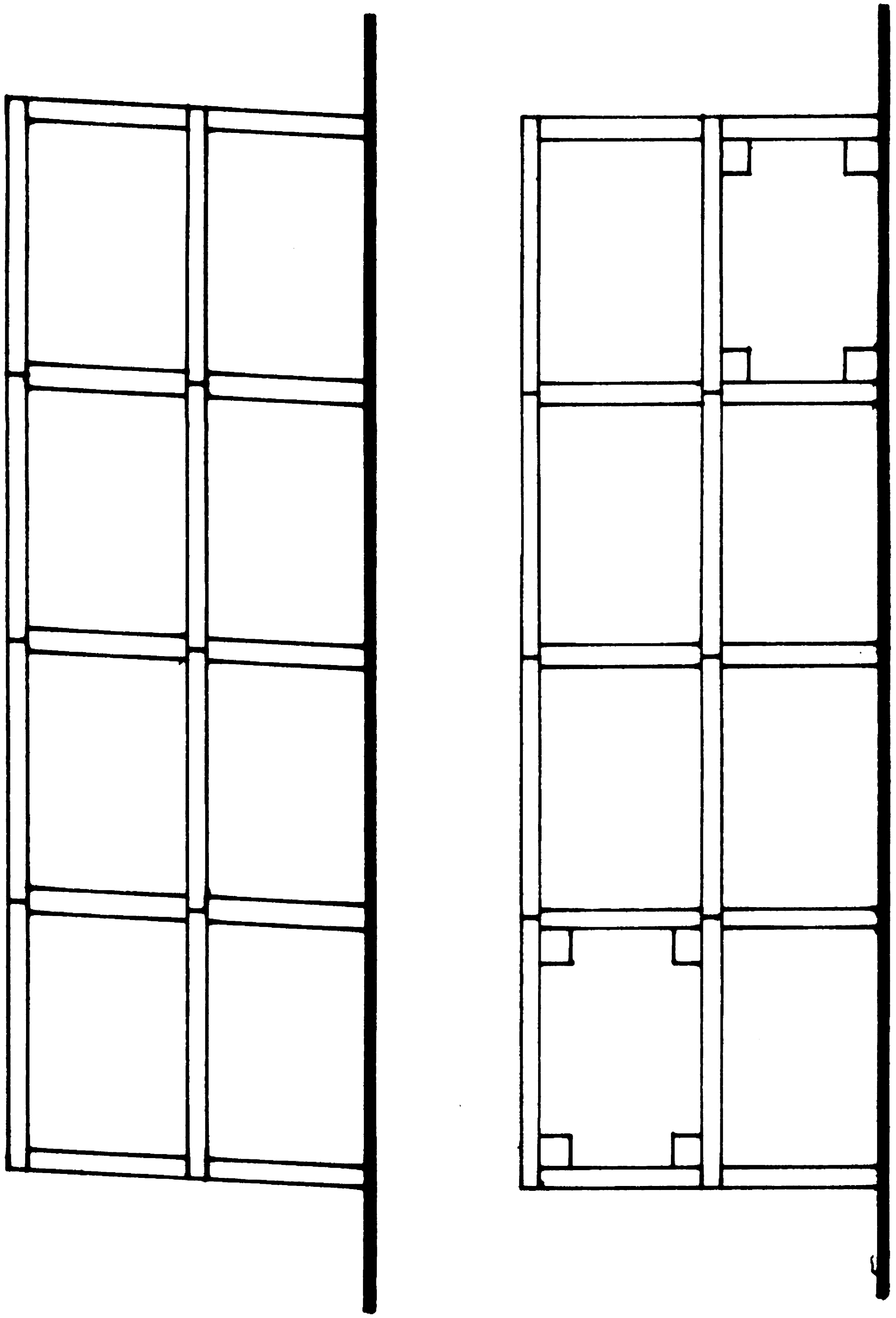


FIGURE 8 : CONTROLING THE PLUMB OF A BUILDING.

Figure 9. Vertical Tolerances:

To insure that the horizontal members of post and beam construction are level, it is necessary to control the tolerances of the vertical components. The tolerances necessary will depend on the number of components involved: thus it is desireable to minimize the number of components that comprise the vertical dimension of a building.

Figure 10. Excentric Loads:

The loading calculations for post and beam construction are somewhat different than most other structural systems. In transfering loads horizontally, through the use of beams, to columns, as opposed to carring loads vertically as in most bearing systems, the connection between the beam and the column in many instances produces excentric loads which reduces the structural capacity of the column. In calculating allowable loads for excentrically loaded columns it is necessary to calculate a bending factor for the column.

bending factor = area/section modulas

For wood columns:

Size	Section Modulas	Area	Bending Factor
4x4	7.94	13.14	1.65
4x6	19.11	20.39	1.066

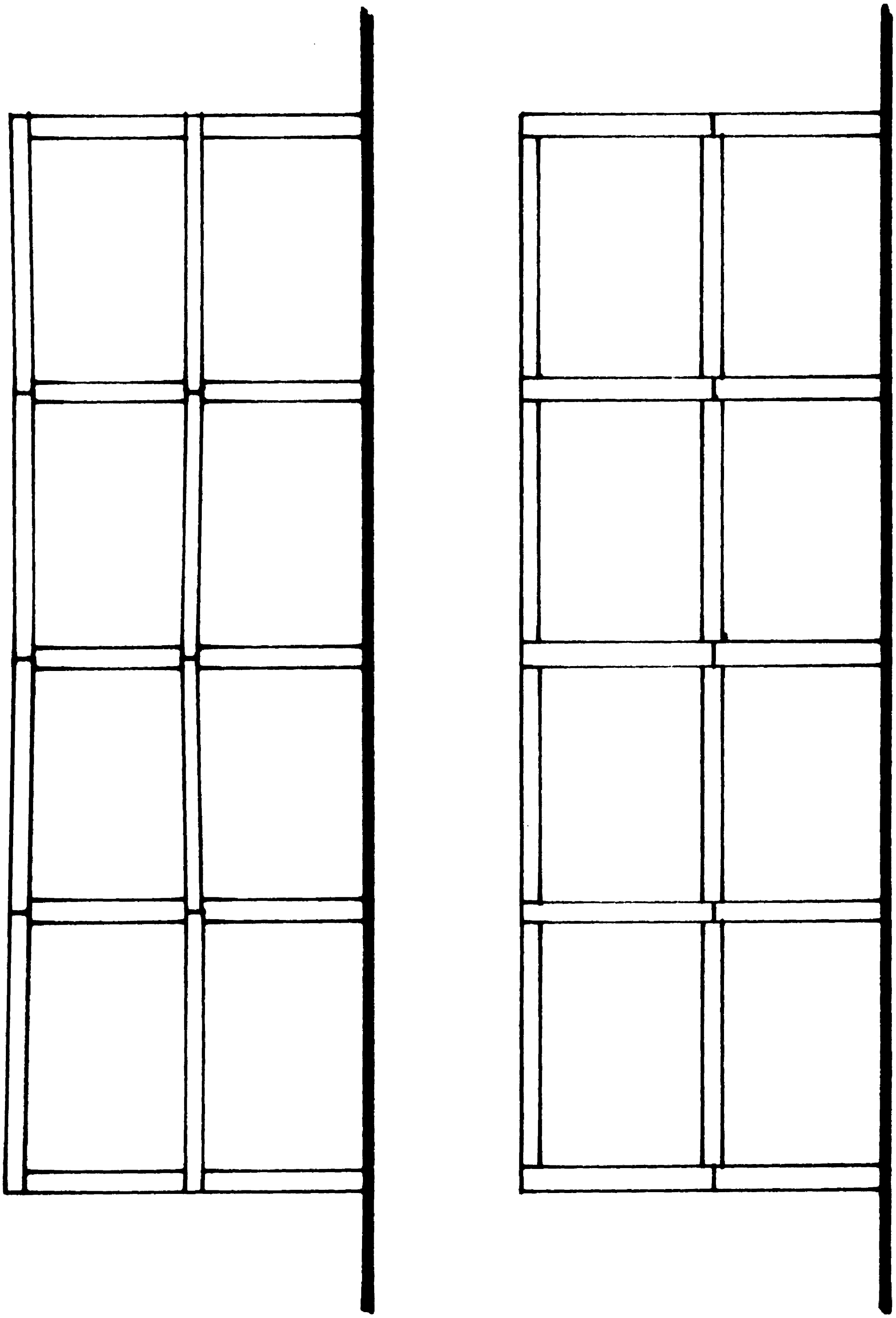


FIGURE 9 : VERTICAL TOLERANCES

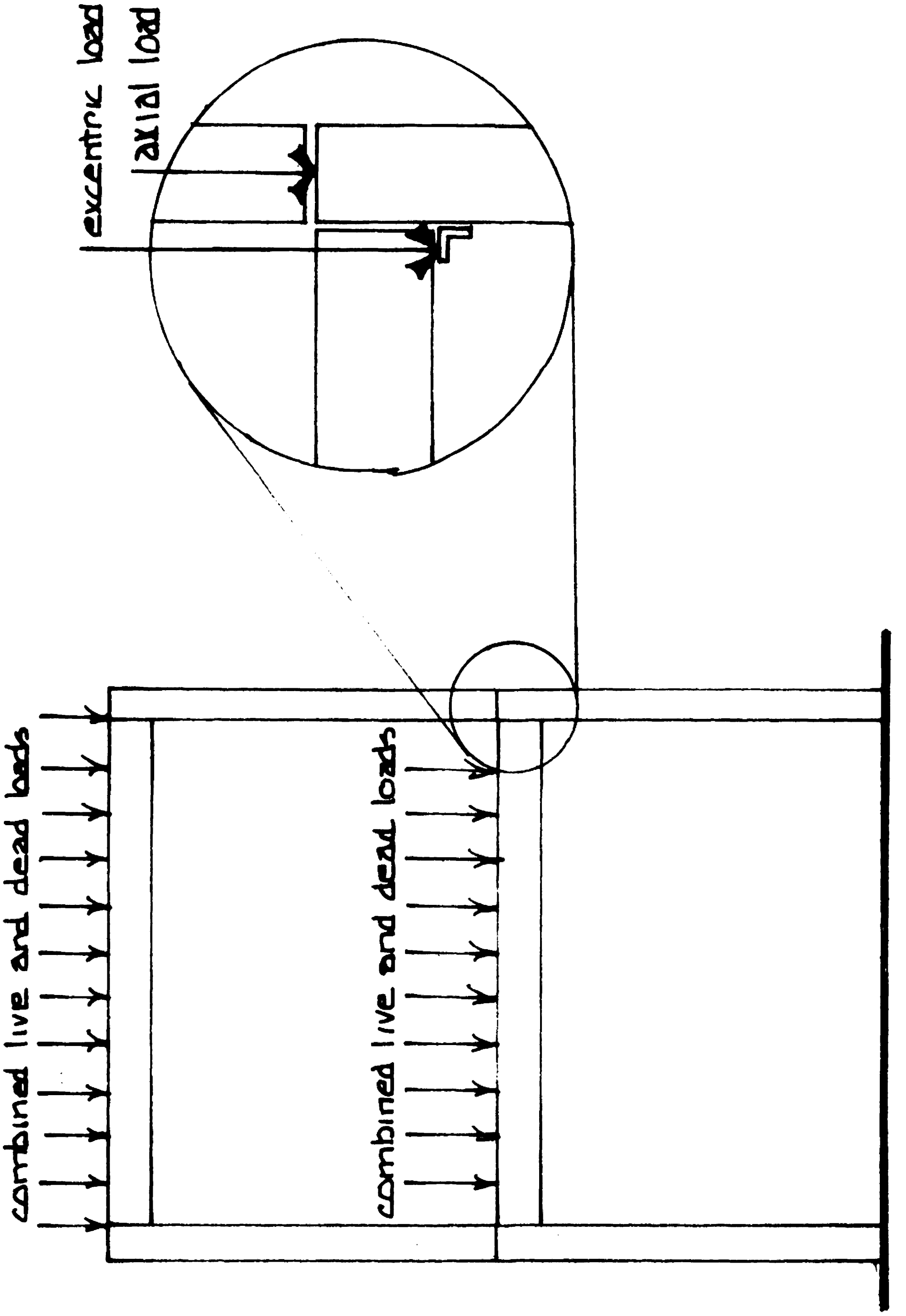


FIGURE 10 : EXCENTRIC AND AXIAL LOADS

6x6	27.73	30.25	1.09

Thus, as may be seen above, when using a 4x4 column the allowable load is reduced by 39% when the load is transferred to the column in such a way as to produce an excentric as opposed to an axial load.

Lateral Support in Columns:

Another consideration necessary in making load calculations in post and beam construction is the lateral support of a column. As the proportion between a column's height and its smallest cross sectional dimension increases the allowable load decreases. Causing allowable loads to be limited due to buckling rather than direct stress calculations.

This contingency may be calculated using the following formula:

$$P/A = .30\ E/(L/D)^2$$

Where: P = Allowable Load

A = Column's cross sectional area.

E = Modulas of elasticity.

L = Column's unsupported vertical length inches.

D = Column's smallest dimension inches.

Using this formula we may illustrate the dramatic effect the unsupported length of a column has on its allowable load.

Column Size	Unsupported Length	Allowable load
4x4	8 Feet	9221 Pounds
4x4	9 Feet	7153 Pounds
4x4	10 Feet	5902 Pounds
4x4	11 Feet	4877 Pounds

Components

In developing a standard panelized system a number of problems inherant in panelized systems must be resolved.

Figure 11. Components in plan:

In locating panels along a standard planning grid it becomes apparent that since the panels are three dimensional special consideration must be given to the way in which the panels interface.

Figure 12. Components in Section:

It also becomes apparent that considerable attention must be paid to the interface between vertical and horizontal components to insure simple and consistant construction. This will reduce both the number of components as well as the way in which they interface.

Figure 13. Three Dimensional Decisions:

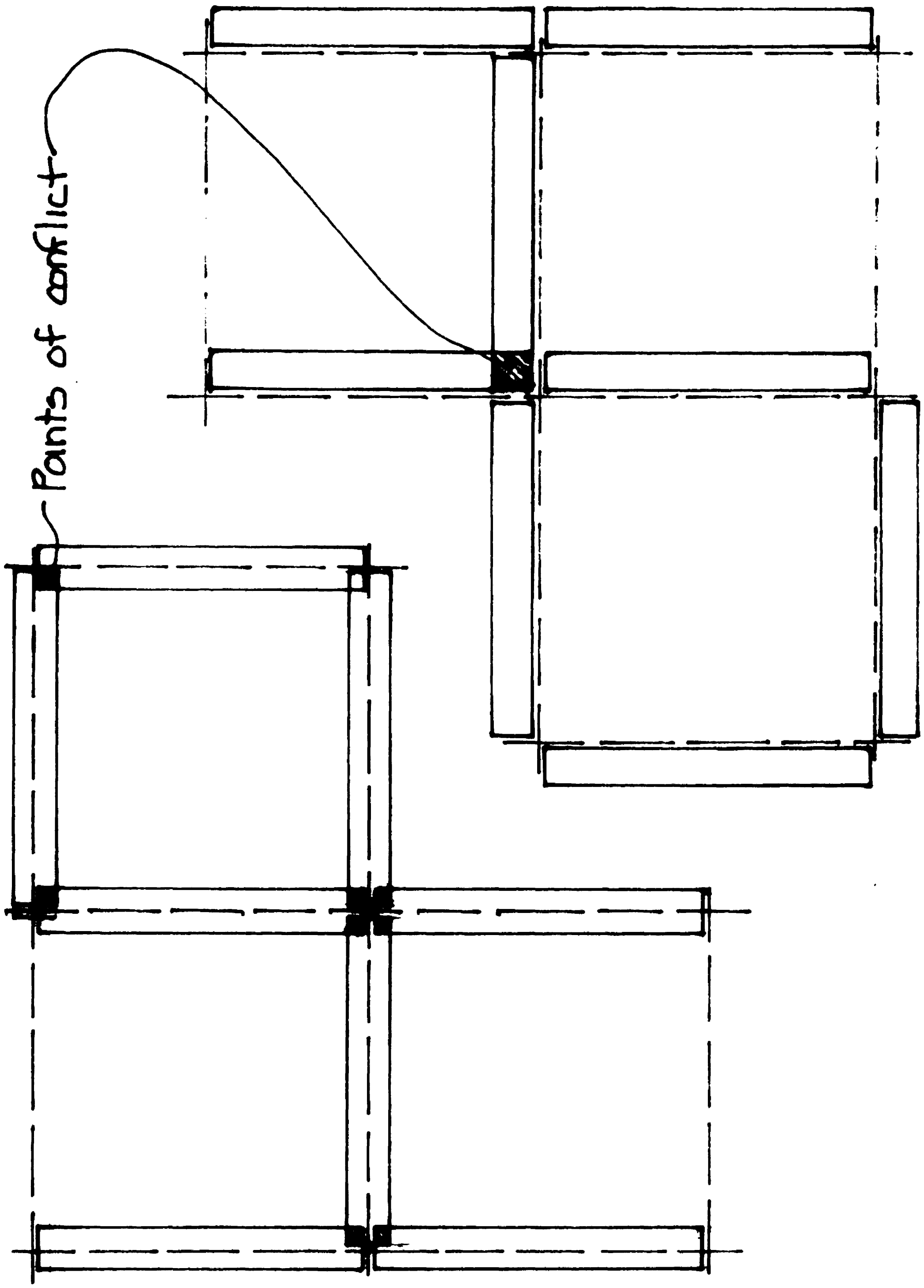
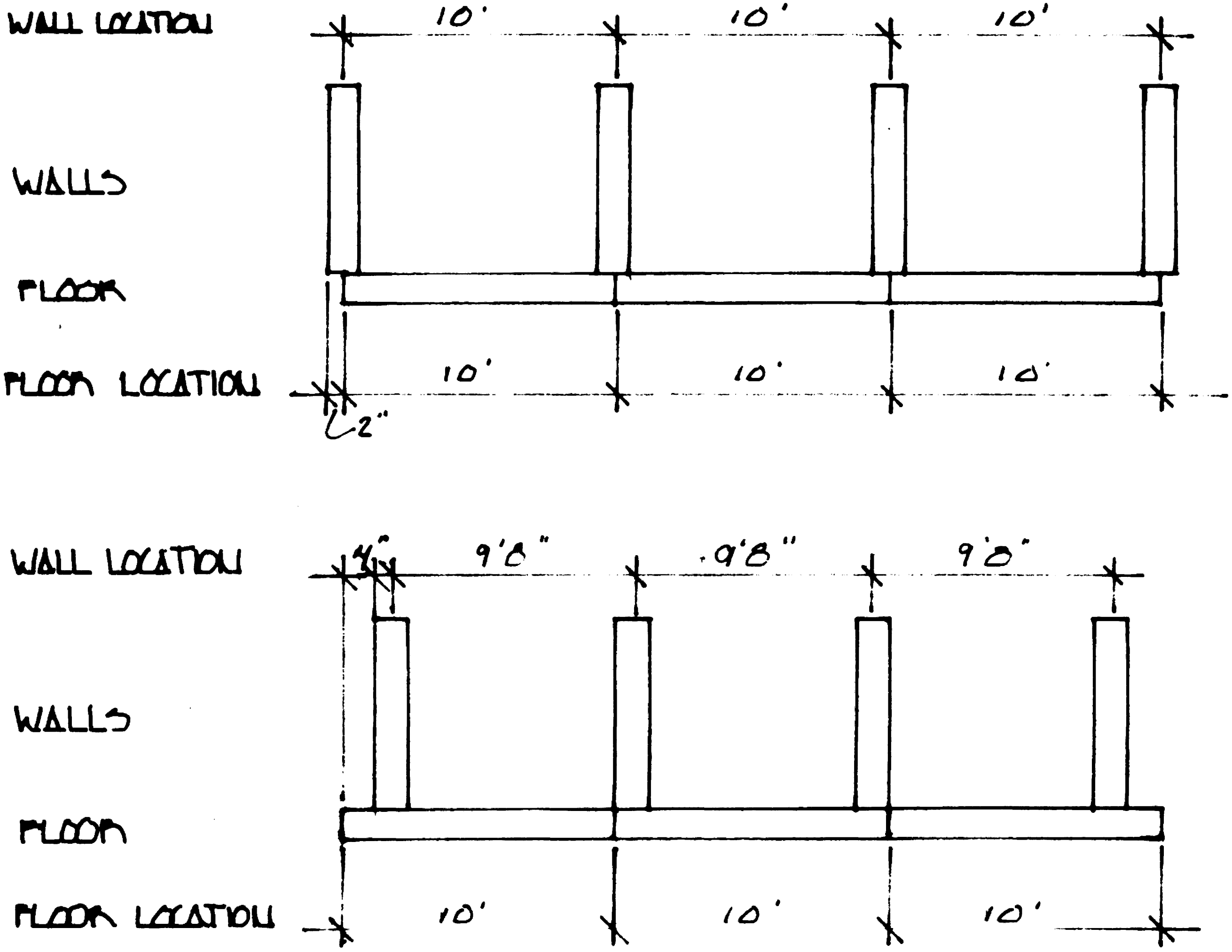


FIGURE 11 : COMPONENTS IN PLAN

FIGURE 12 : COMPONENTS IN SECTION



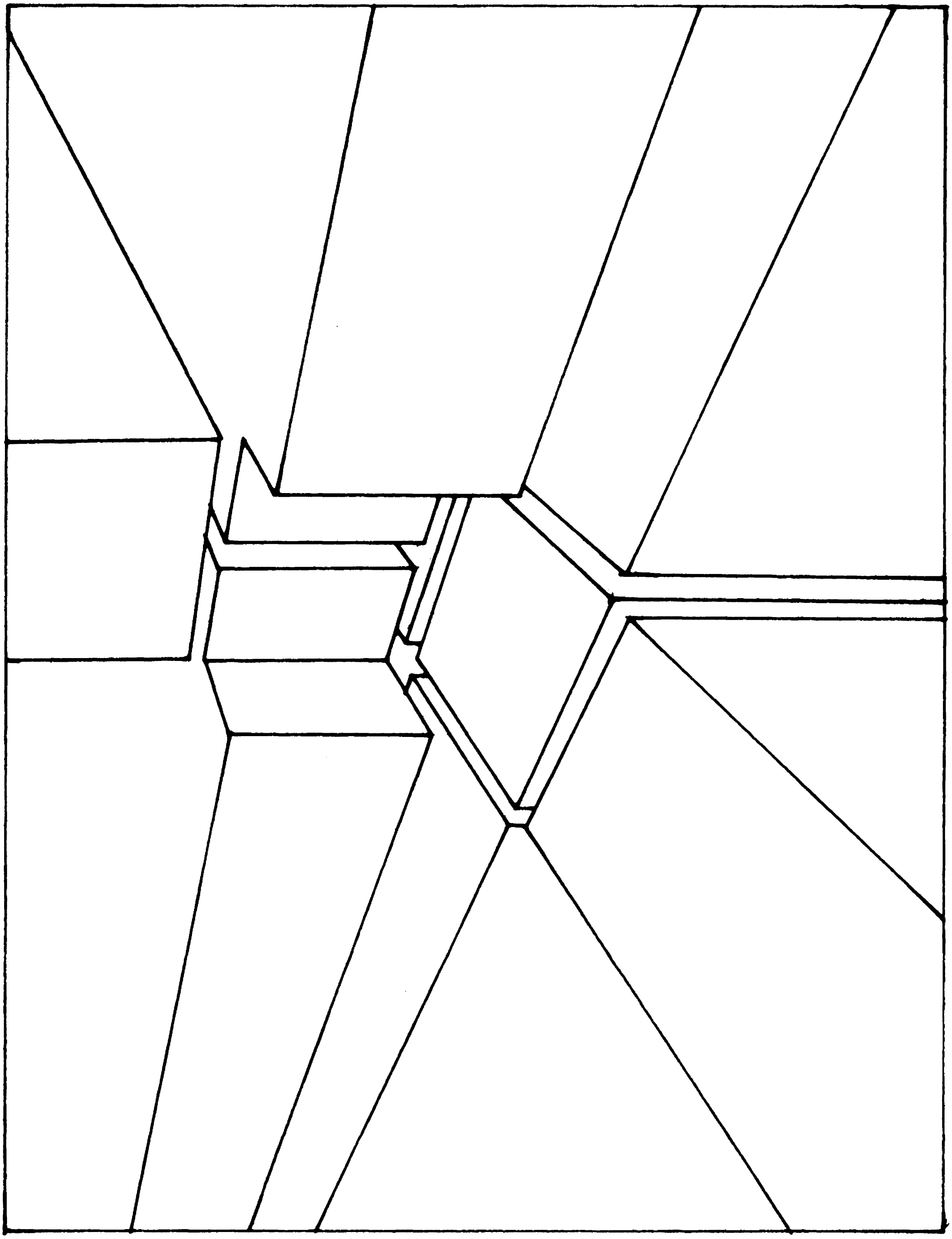


FIGURE 15 : THREE DIMENSIONAL DECISIONS

It is very important in designing a standard panelized system that the designer not dwell too long in only two dimensions but that three dimensional considerations be investigated early in the design process.

Figure 14. Integrating Structure:

Serious consideration must also be given to the, manner in which, and the implications of, the integration of structural elements into the panelized system. This will, of course, be effected by the size of the structural components.

Figure 15. Tolerance Control:

Since, in general, the cost of a product will increase as the tolerances of that product increase it is desireable to attain only the degree of tolerance necessary to achieve the desired quality. One way to decrease the level of tolerances is to reduce the number of points at which components interface.

Figure 16. Securing Components:

There are three reasons for securing components: structural integraty, insuring permanence of location, and for quality.

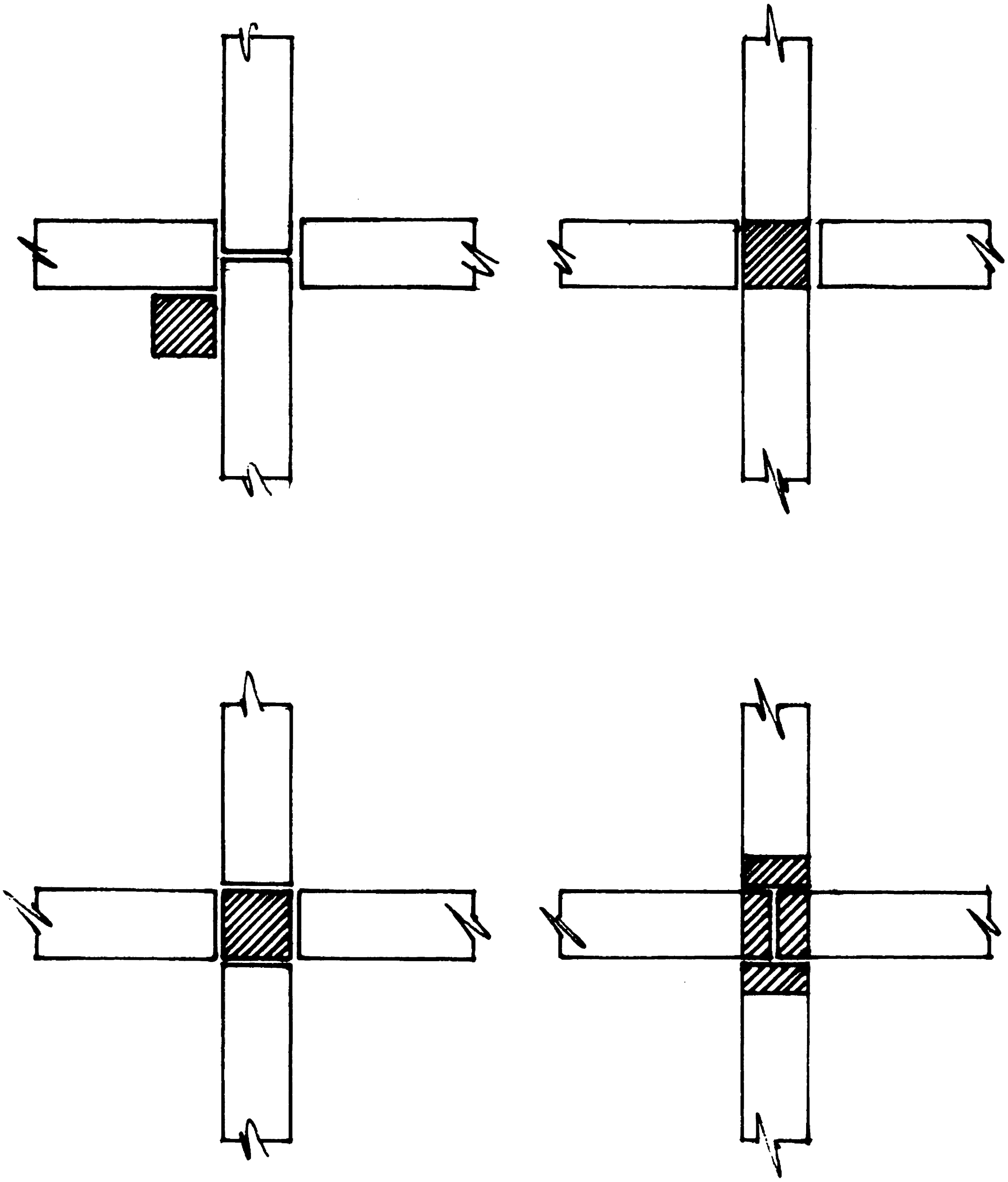


FIGURE 14 : INTEGRATING STRUCTURE

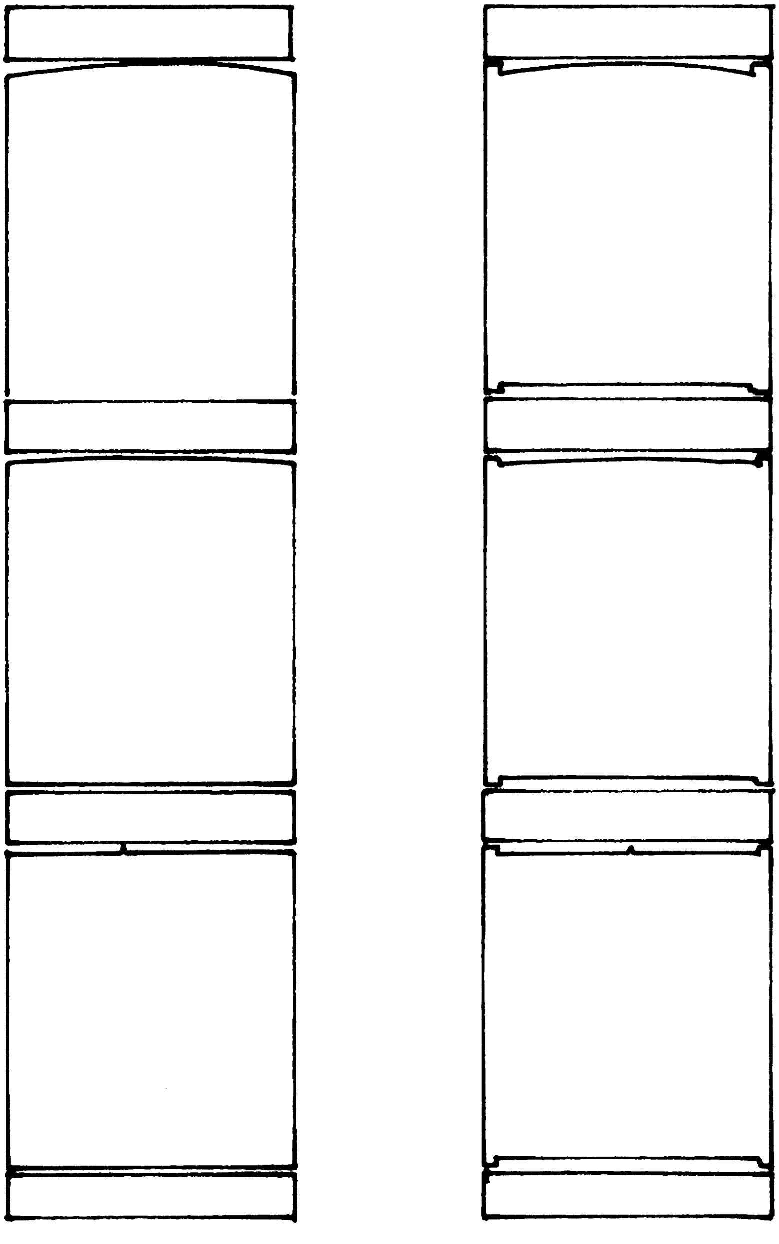


FIGURE 1.5 : TOLERANCE CONTROL

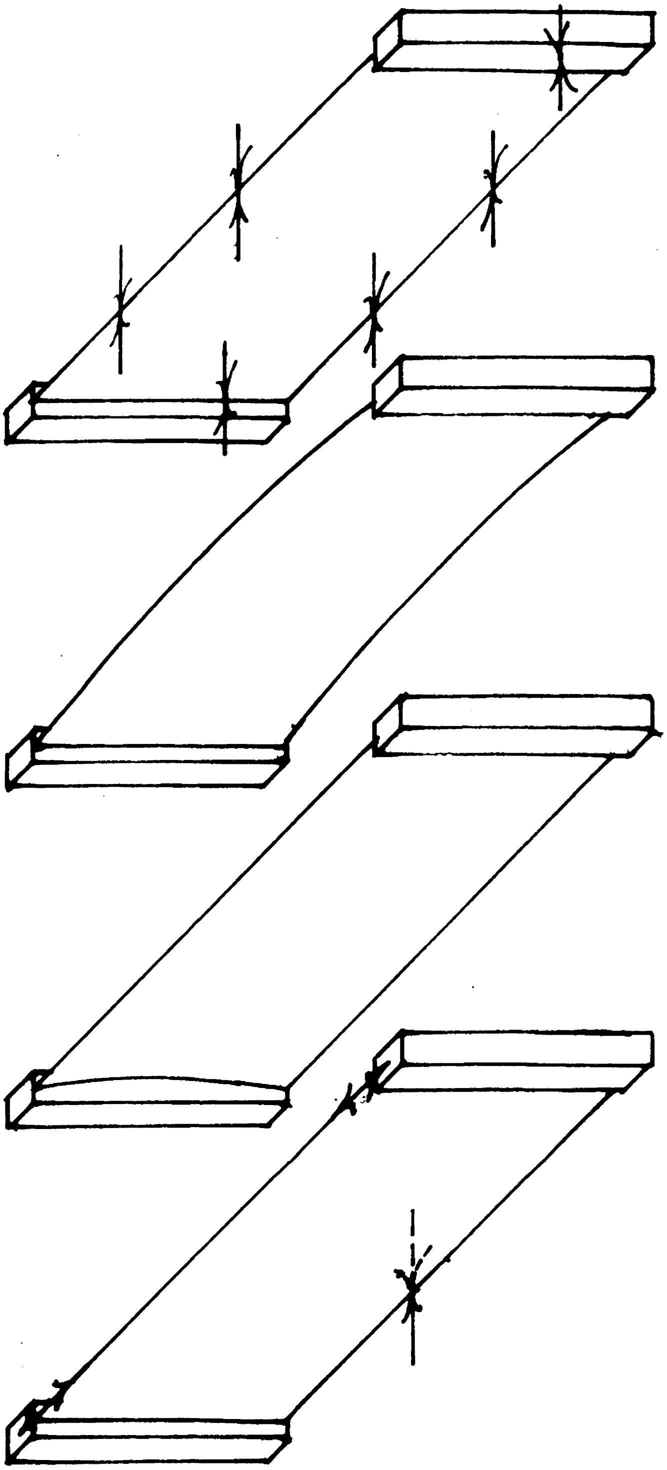


FIGURE 16 : SECURING COMPONENTS

A System

Components

Figure 17. Components:

At this level of development there are nine distinct sizes of component parts to the system. Three wall, three floor, two beams, and one column component.

As was indicated earlier, it is our desire to incorporate the structural columns of this system into the space defined by the intersection of the structural walls. Let us investigate the constraints this places on the systems size if we choose to use wood columns.

Using a combined live and dead load of 53 /Sq. ft. and an unsupprted length of 87" the allowable axial load on a 4'x4' column would be:

$$\text{Allowable axial load} = \frac{(.30)(E)(A)}{(L/D)^2}$$

$$= \frac{(.30)(1.760.000)(13.14)}{(87/3.625)^2}$$

$$= 12.045$$

Thus 4"x4" wood column will support an axial load of 12.045 or 12,045/53 = 227 sq. ft. of living space.

Figure 18. Connection Detail:

The use of clips, to control any lateral movement of the wall components, is simple and requires a minimum degree of tolerances.

Figure 19. Construction:

These nine components may then be used within the systems bounds to form a variety of spaces. The next consideration is in determining the exact manner in which the components interface.

Figure 20. Connection Detail:

The need for consistantly interfacing wall components and the ability to control their lateral movement to ensure quality are two very important considerations.

Figure 21. Connection Detail:

Where a nonstructural wall component intersects a structural component it is not possible to use the same type clip as above since the structural component has already been drywalled. Instead, a surface mounted clip may be used.

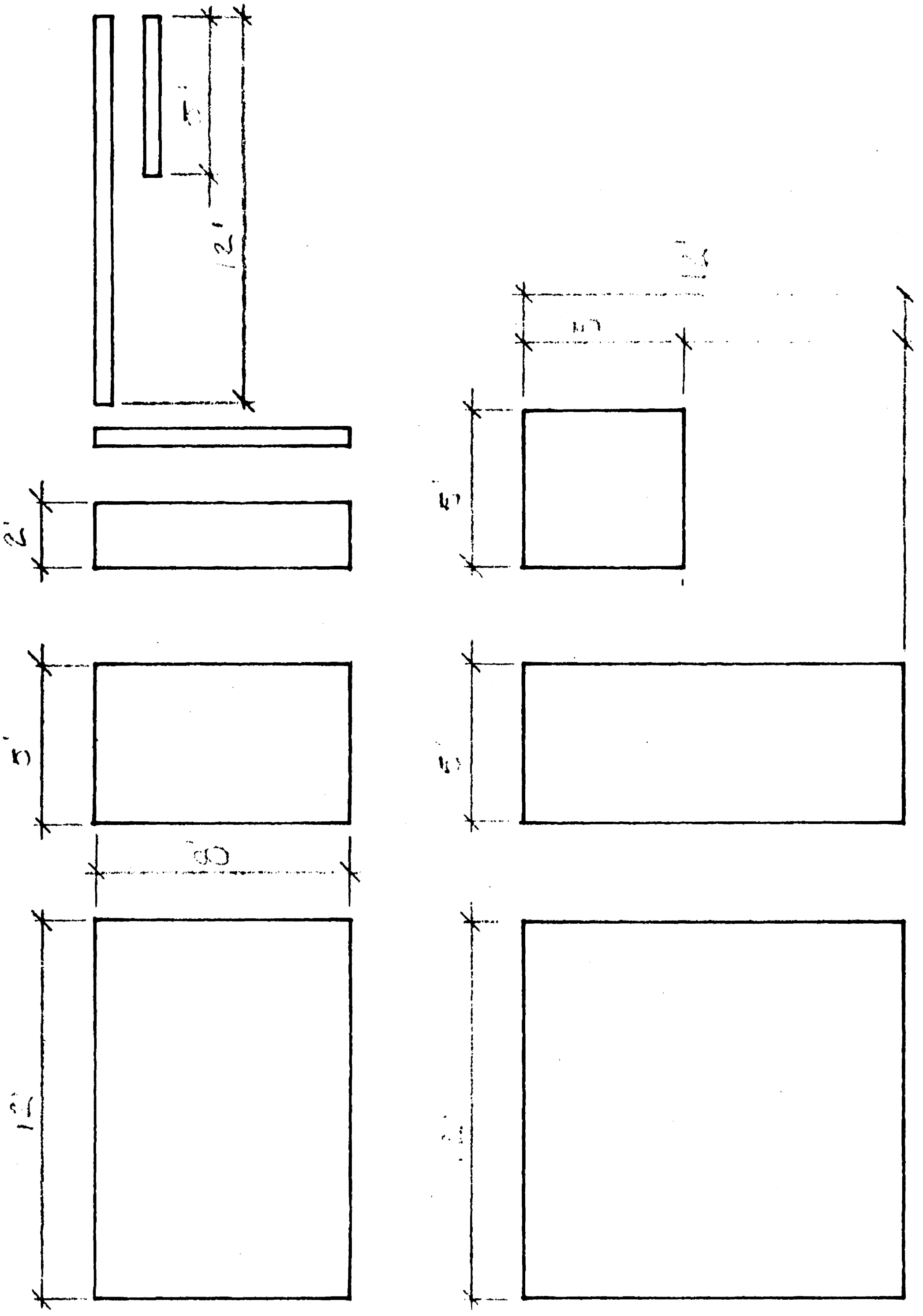


FIGURE 17 : COMPONENTS

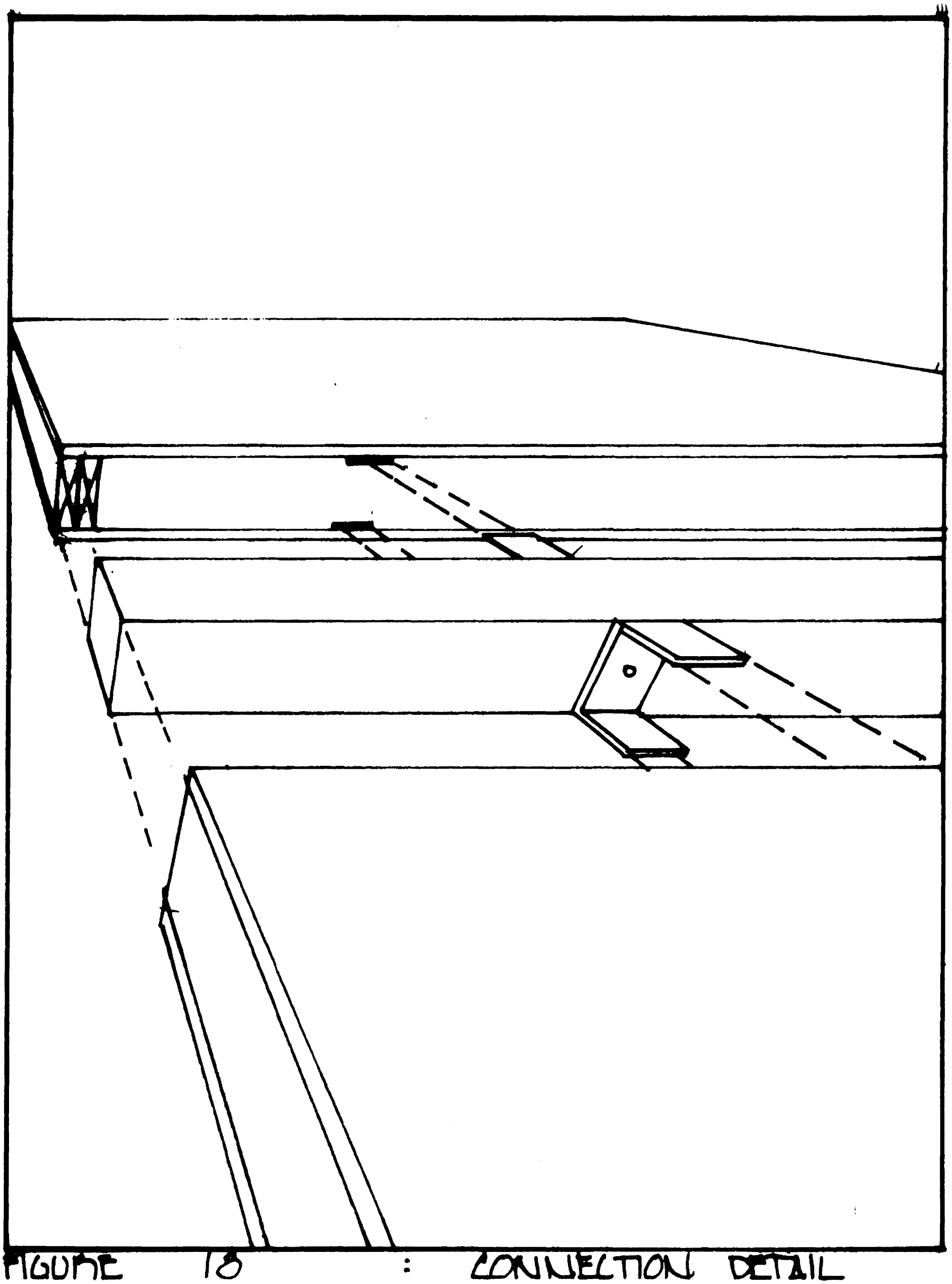


FIGURE 18 : CONNECTION DETAIL

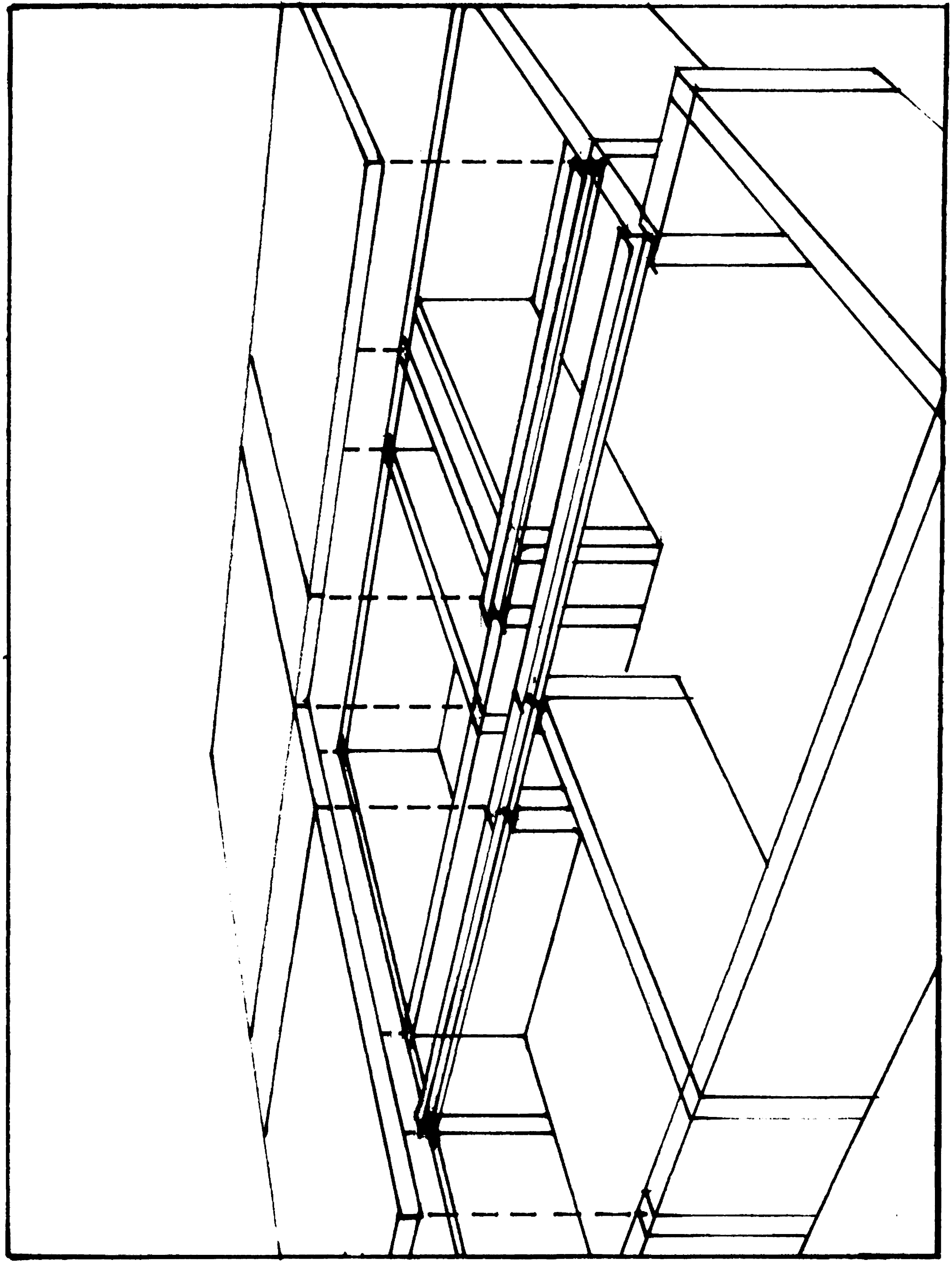


FIGURE 19 : CONSTRUCTION

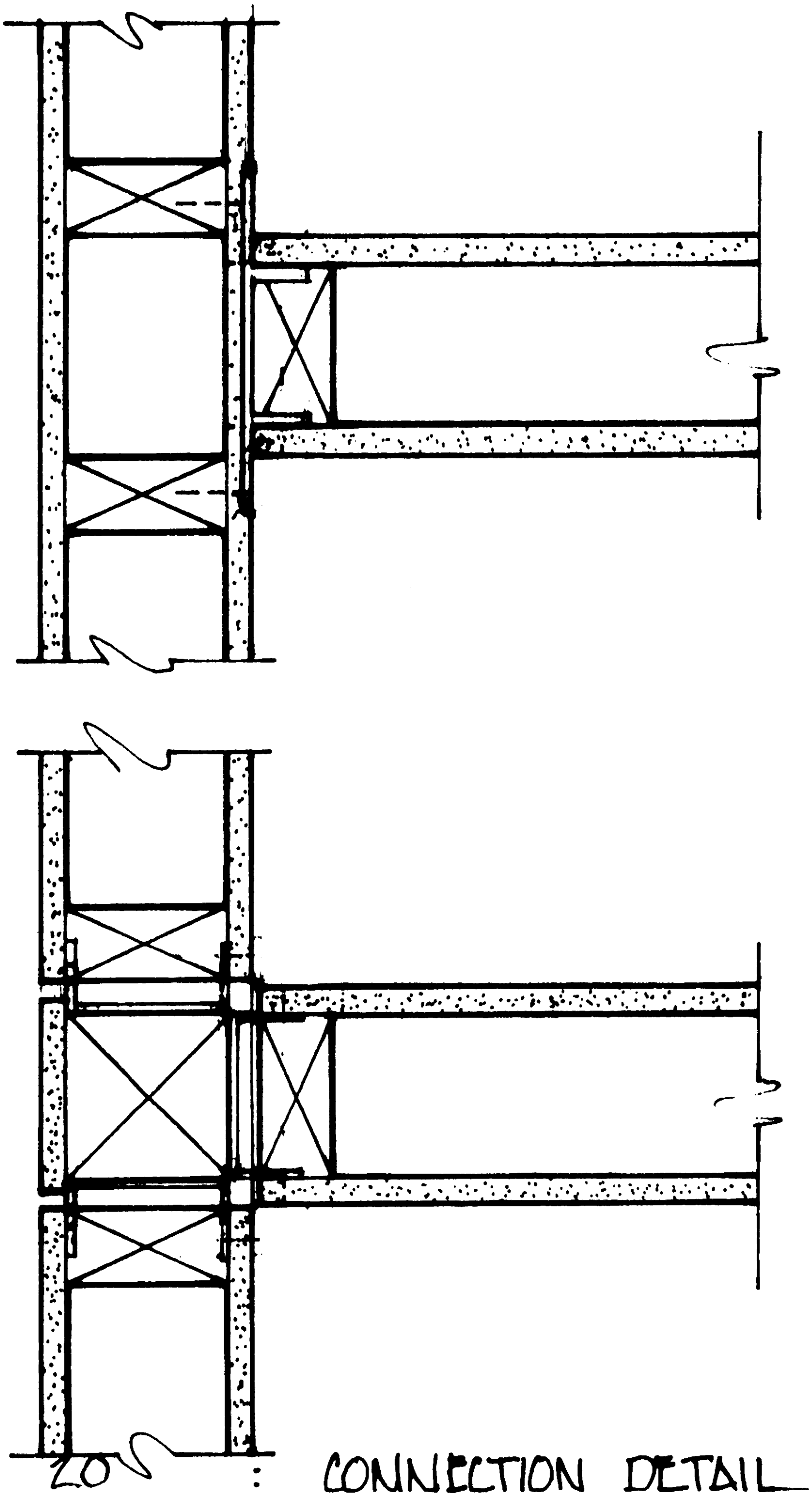
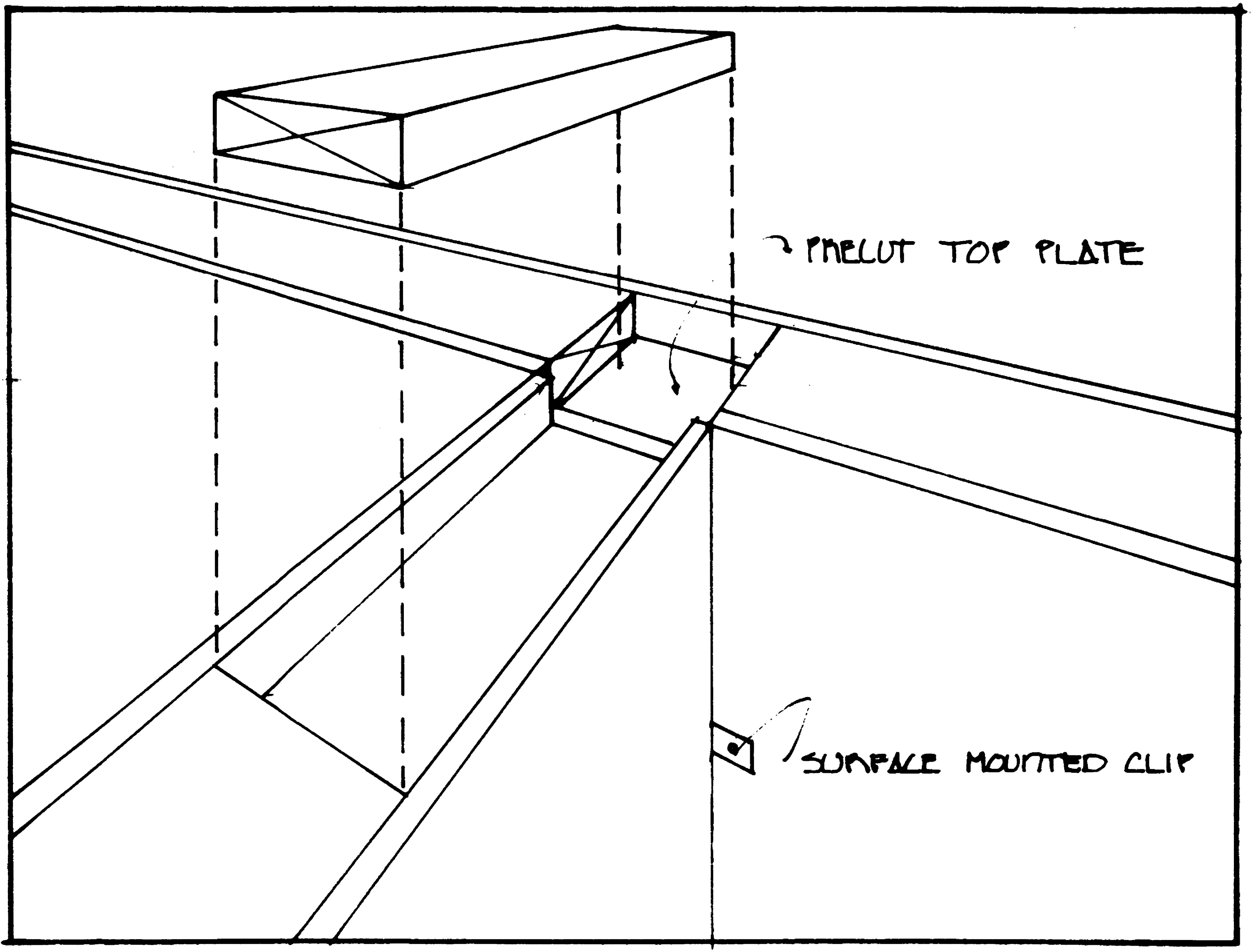


FIGURE 20 : CONNECTION DETAIL

FIGURE 21 : CONNECTION DETAIL



Flexibility

Figure 22. Bearing Wall System:

Although stacking the bearing walls of consecutive floors (A) is successful and allows for some flexibility (B), when the structural requirements of the two floors do not coincide (C, D, E, F, & G) the loads of the second floor must be resolved into concentrated loads (circles). This relative lack of standardization results in high construction and supervision costs.

Figure 23. Axial Loads:

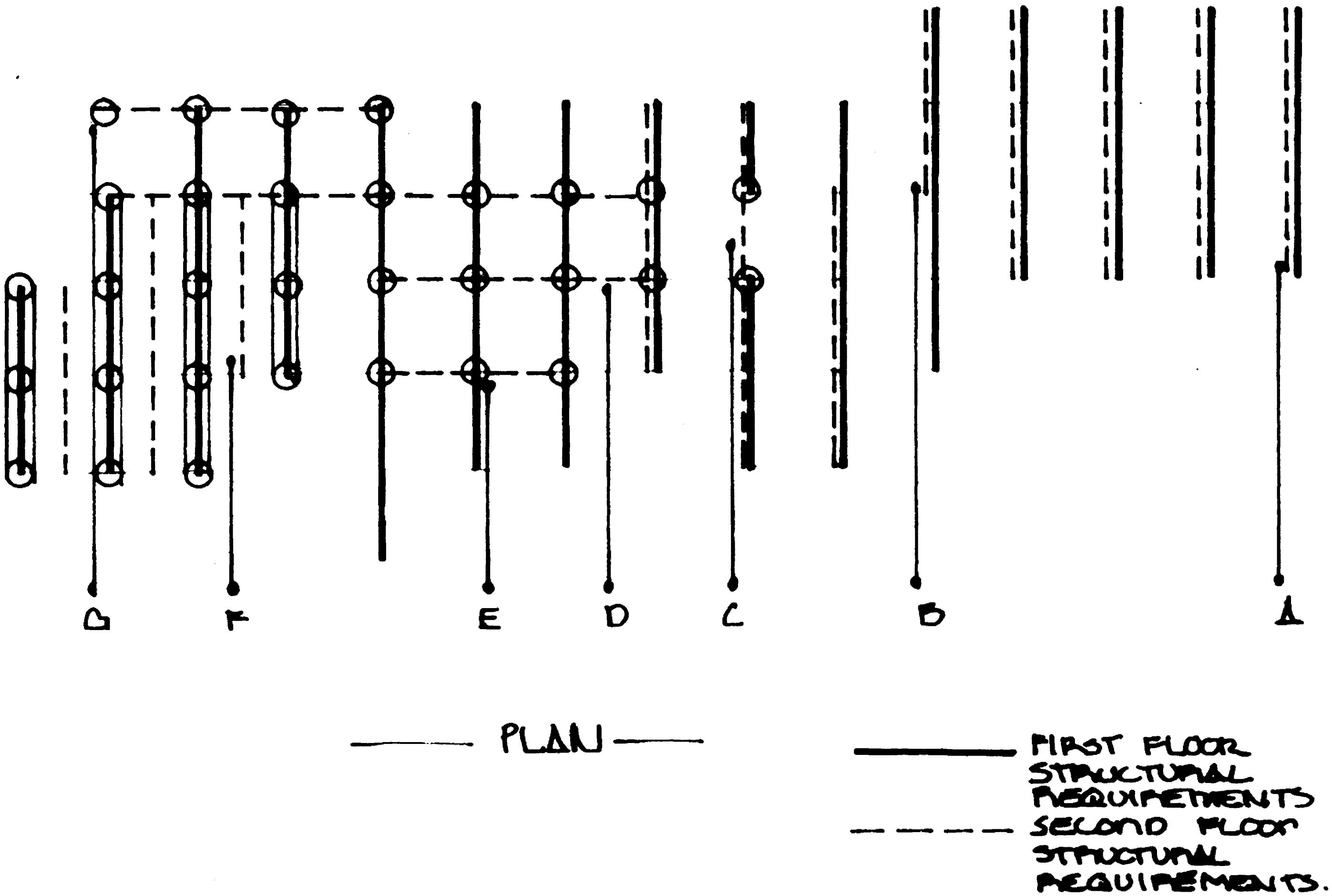
The need to standardize the structural system while retaining a reasonable amount of flexibility may be realized through the use of a system which resolves all loads into concentrated loads. The loads are then transferred to the ground axially: thus requiring only columns rather than constraining bearing walls.

Figure 24. Building Grids:

Through the use of both a structural and a planning grid a great deal of flexibility may be realized using three component sizes.

Figure 25. Spatial Variation:

FIGURE 22 : BEARING WALL SYSTEM



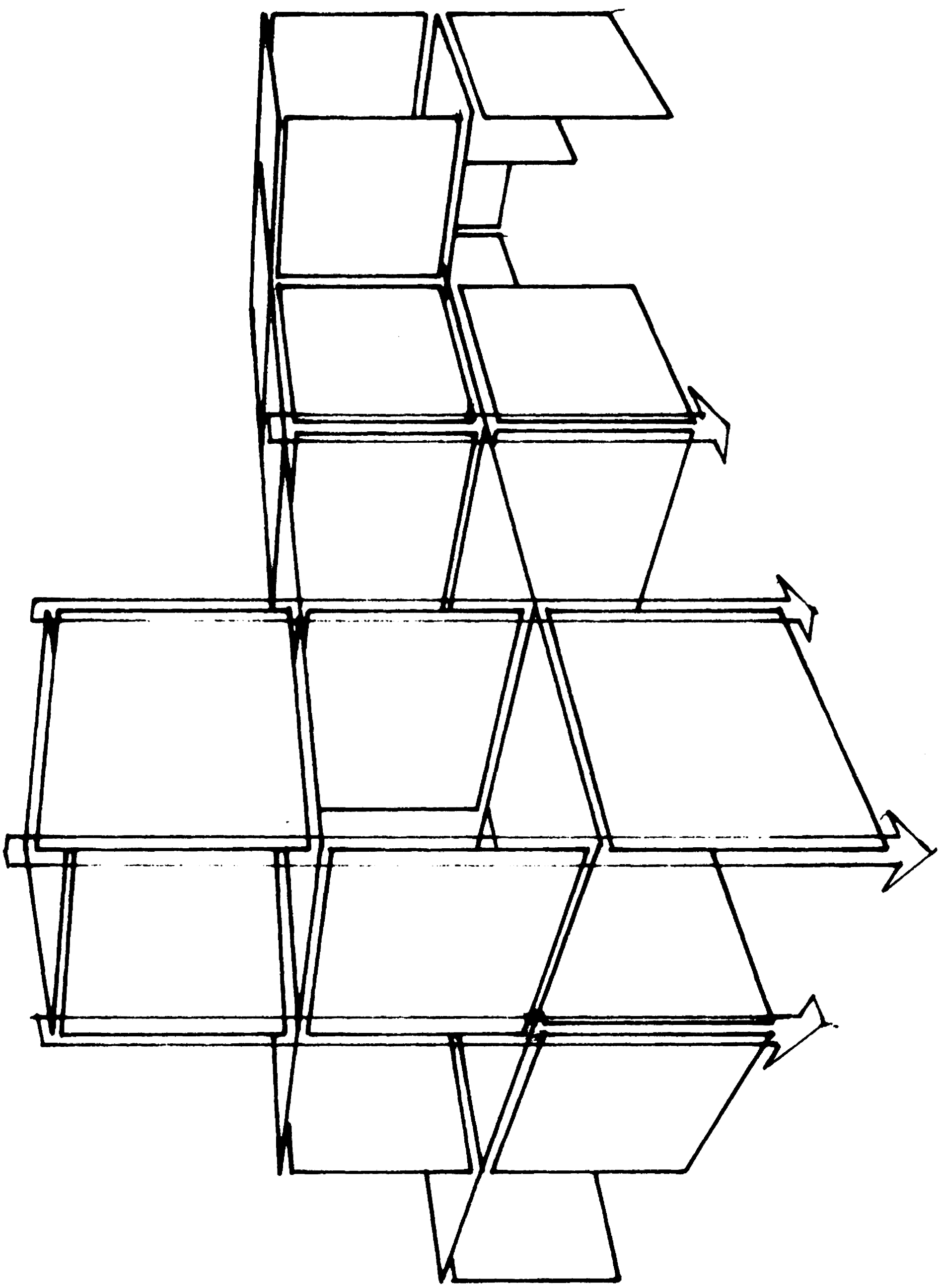
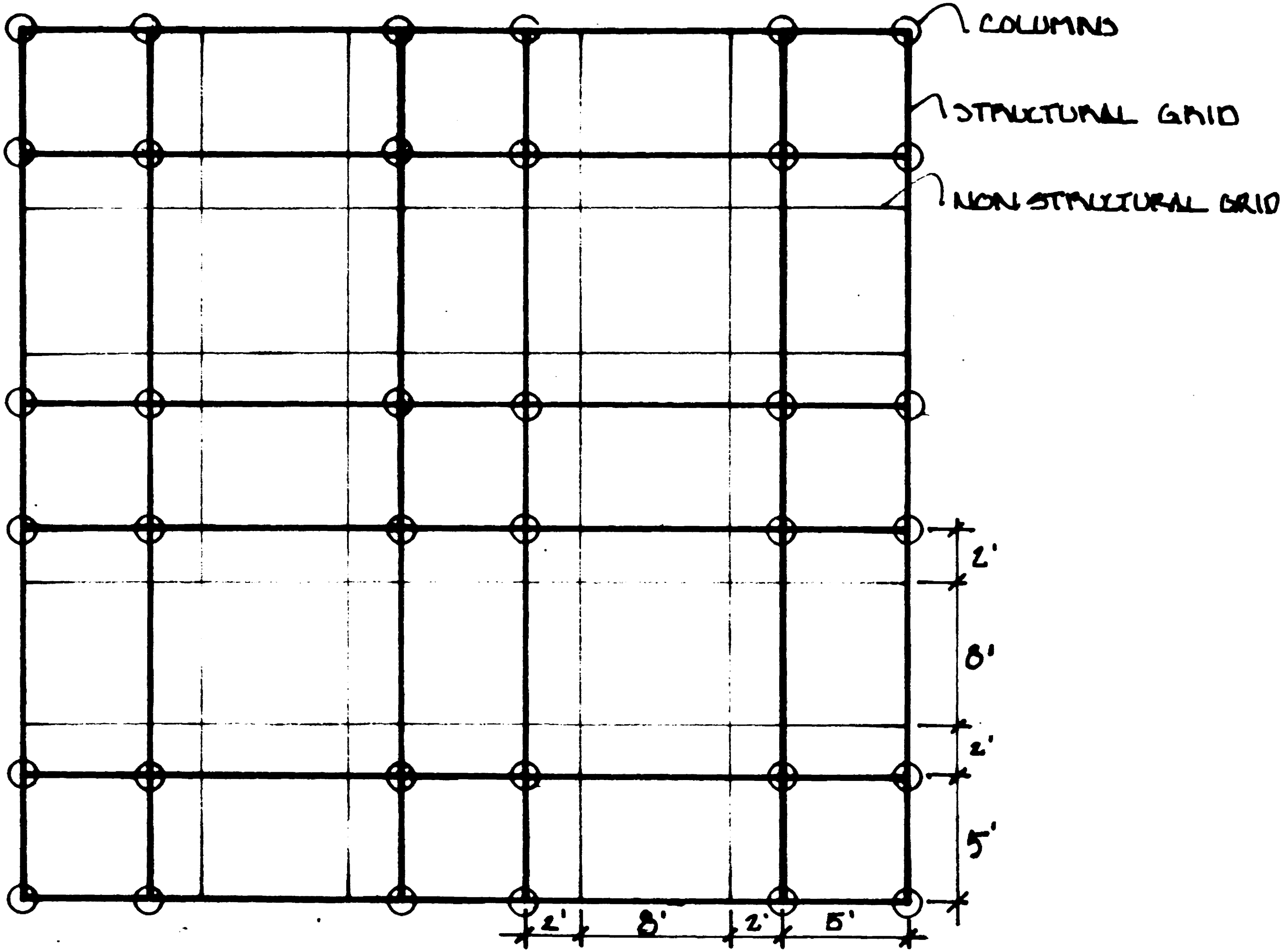


FIGURE 23 : AXIAL LOADS

FIGURE 24 : BUILDING GRIDS



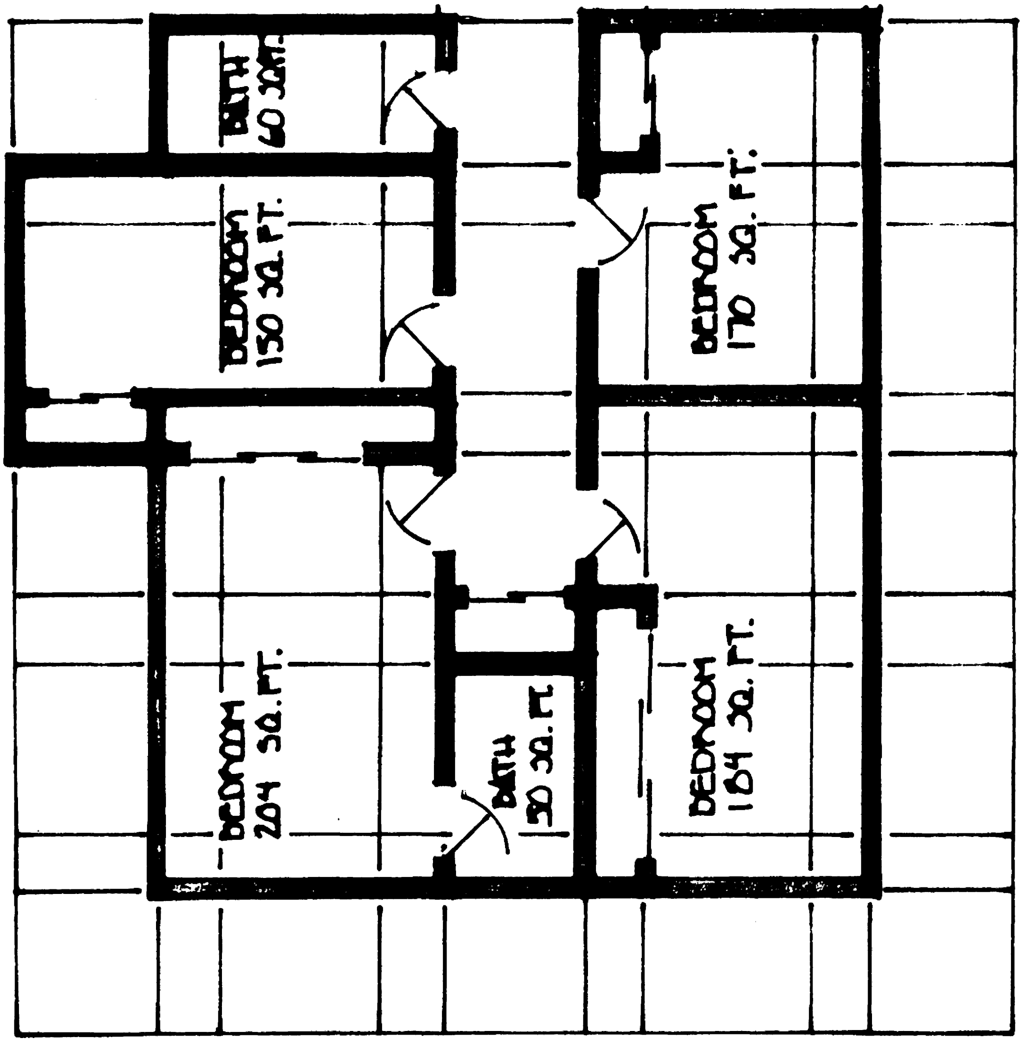


FIGURE 25 : SPACIAL VARIATION

A total of 23 unique spaces ranging from 10 sq. ft. to 288 sq. ft. may be used without the interferance of any columns. 4 spaces (225-289) may be used with only one column, and 5 (285-493) may be used with the interferance of two columns.

Details

Figure 26. Component Detail:

By handling the intersection of walls on both structural and planning grid similarly, through the use of columns contained within the walls, there is no need to differentiate between between the two, or walls that make inside or outside corners.

Figure 27. Column Detail:

Through the use of uninterrupted columns the control over vertical dimensions is more than adequate. By hanging the walls from the columns the opportunity to use the walls for both temporary and permanent lateral support presents itself.

Figure 28. Resolving Loads:

The need to resolves live and dead loads into concentrated axial loads at columns while controlling vertical tolerances posses a number of interesting problems.

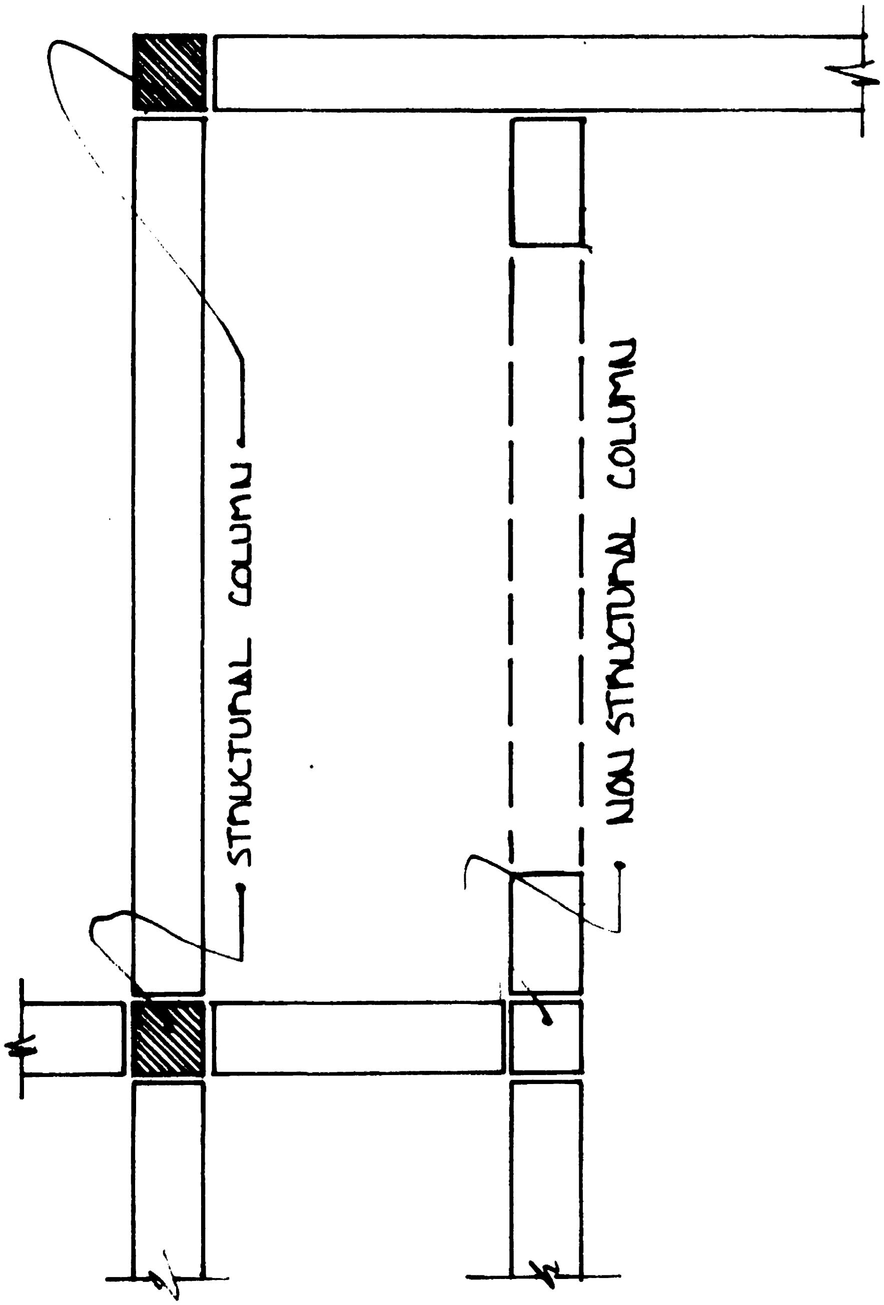


FIGURE 26 : COMPONENT DETAIL

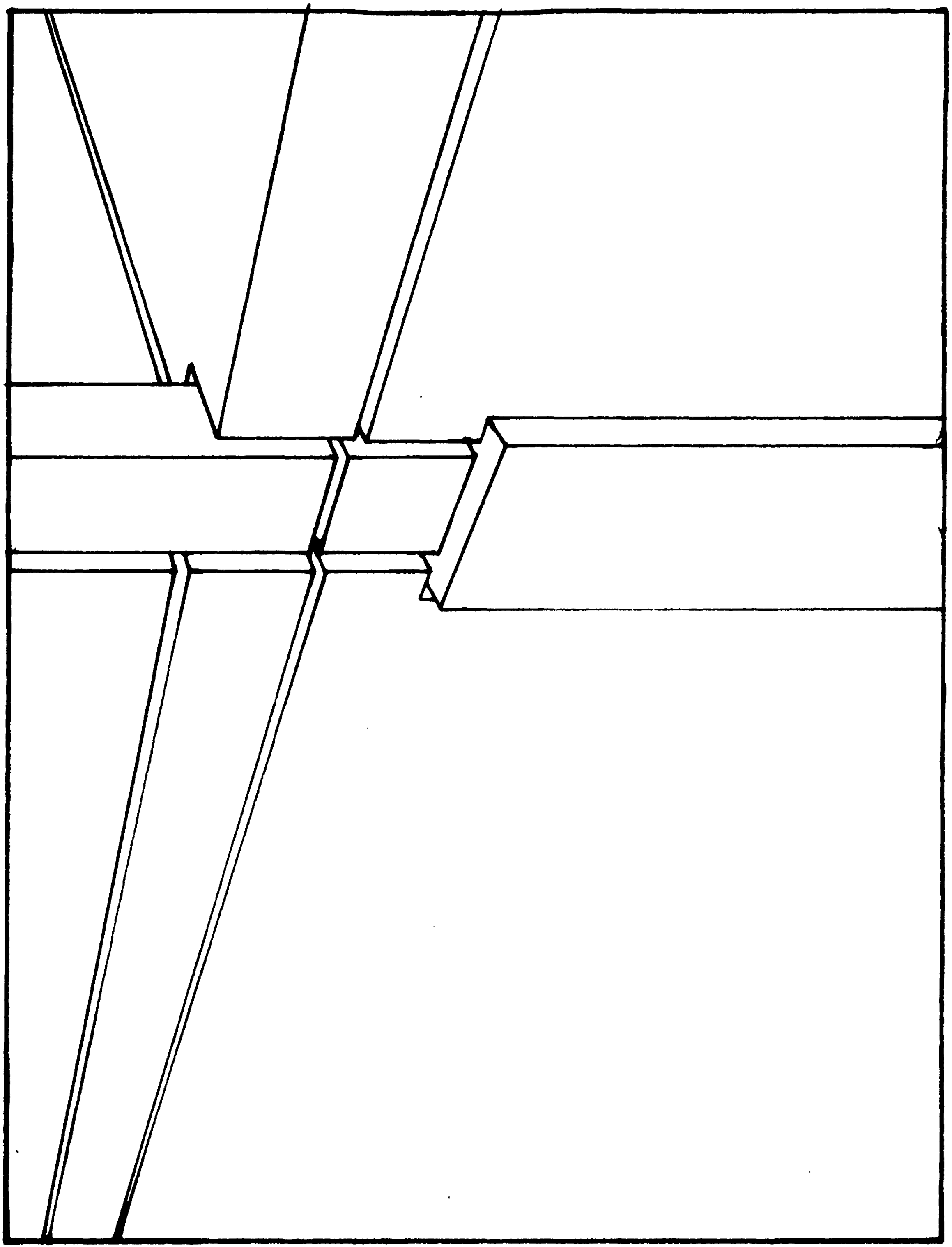


FIGURE 27 : COLUMN DETAIL

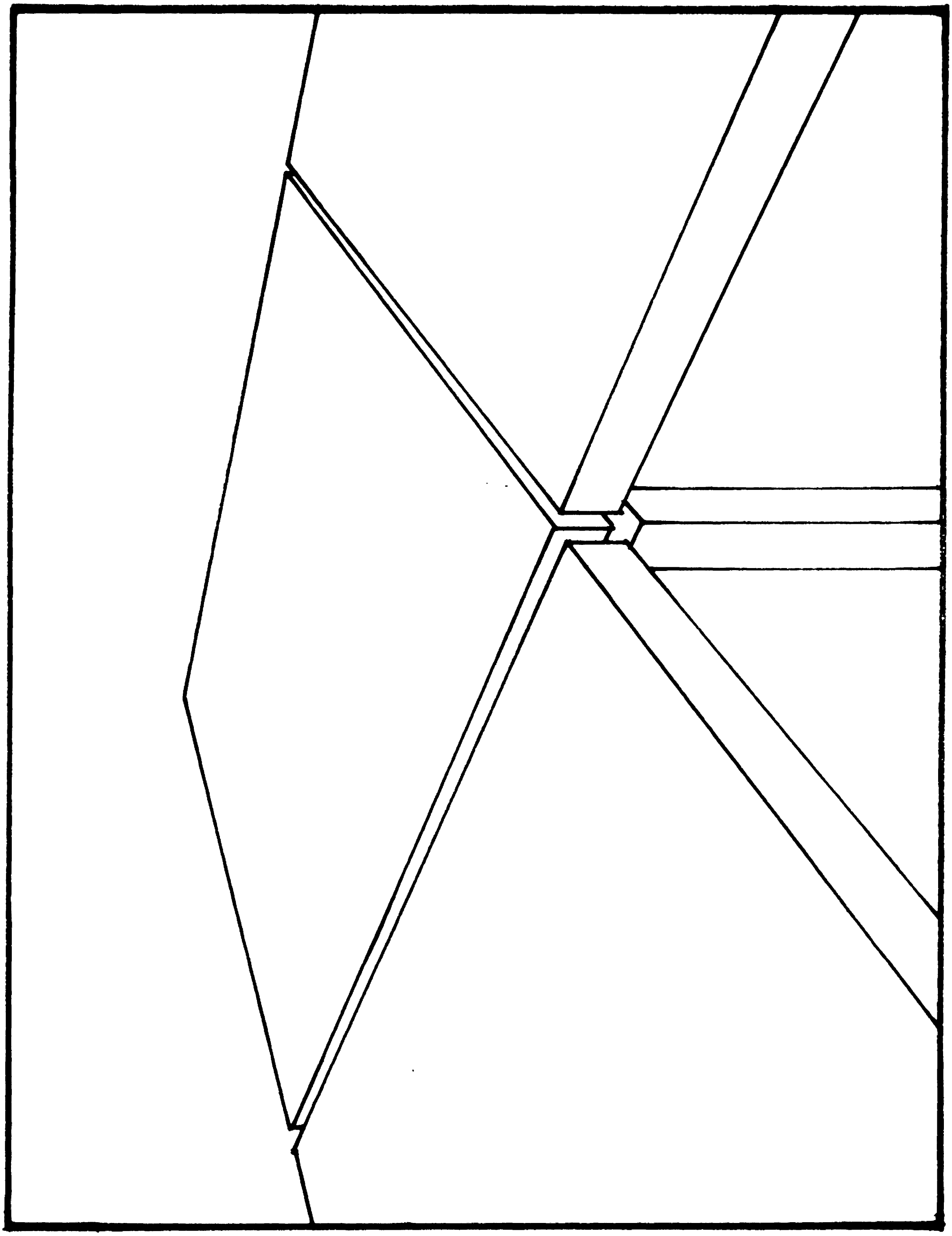
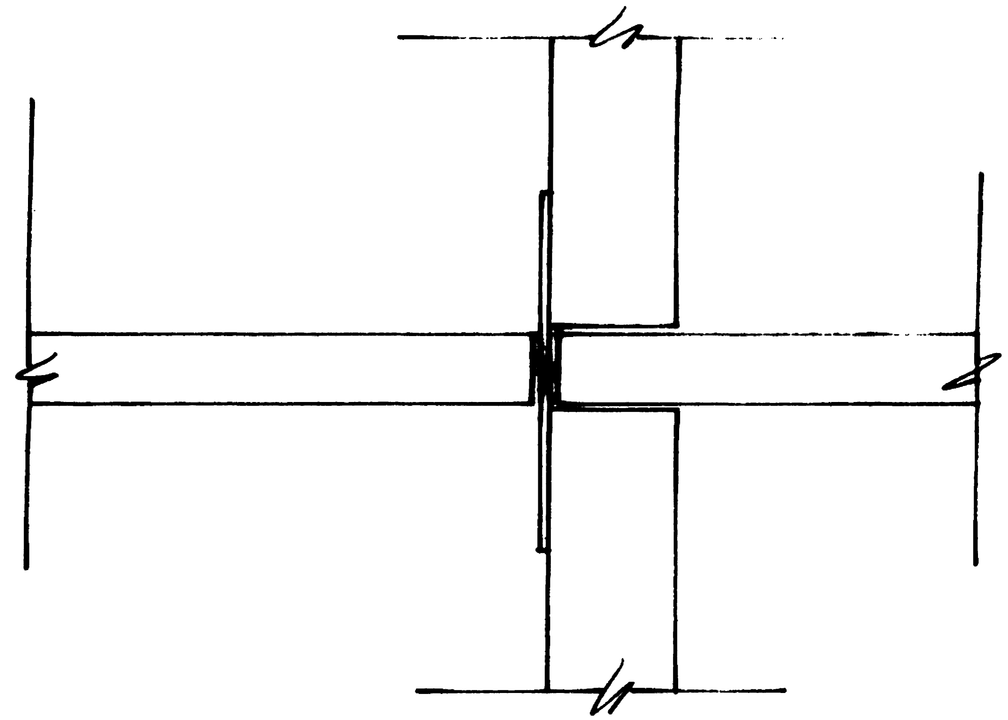


FIGURE 28 : RESOLVING LOADS.



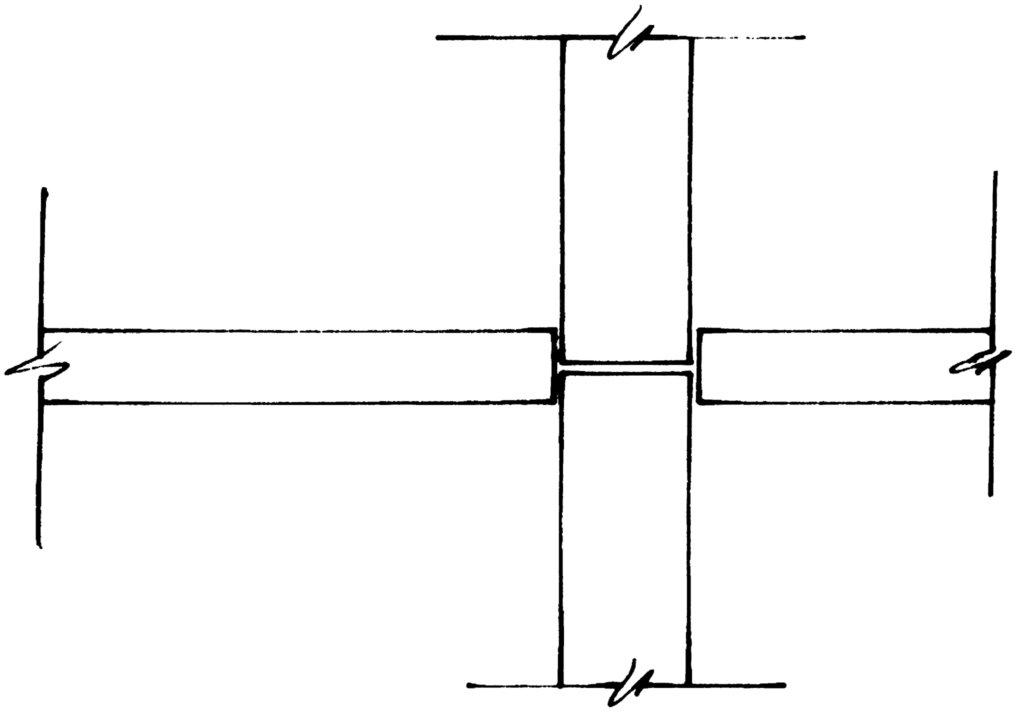


FIGURE 29 : STEEL VS. WOOD

Figure 29. Steel Vs. Wood:

Since wood members have relatively low tolerances and steel has potentially high tolerances it is advantageous to use a steel component to transmit the load from the beam to the column.

Figure 30. Static Equilibrium:

In order to avoid the use of bolts or screws in fastening the steel connector to the wood beam it is desireable to use a connection which will result in static equilibrium without the use of fasteners.

Figure 31. Non-Rigid Connection:

To insure the load is axial and that no moments are transferred through the connection to the column: the use of a non-rigid connection is necessary.

Figure 32. Critical Dimensions:

The use of this type of connection demands that the tolerances of a number of dimensions be carefully controlled.

Figure 33. Critical Dimensions:

To insure that loads remain axial in nature the dimensions of the dimensionally stable rectilinear components must be carefully controlled.

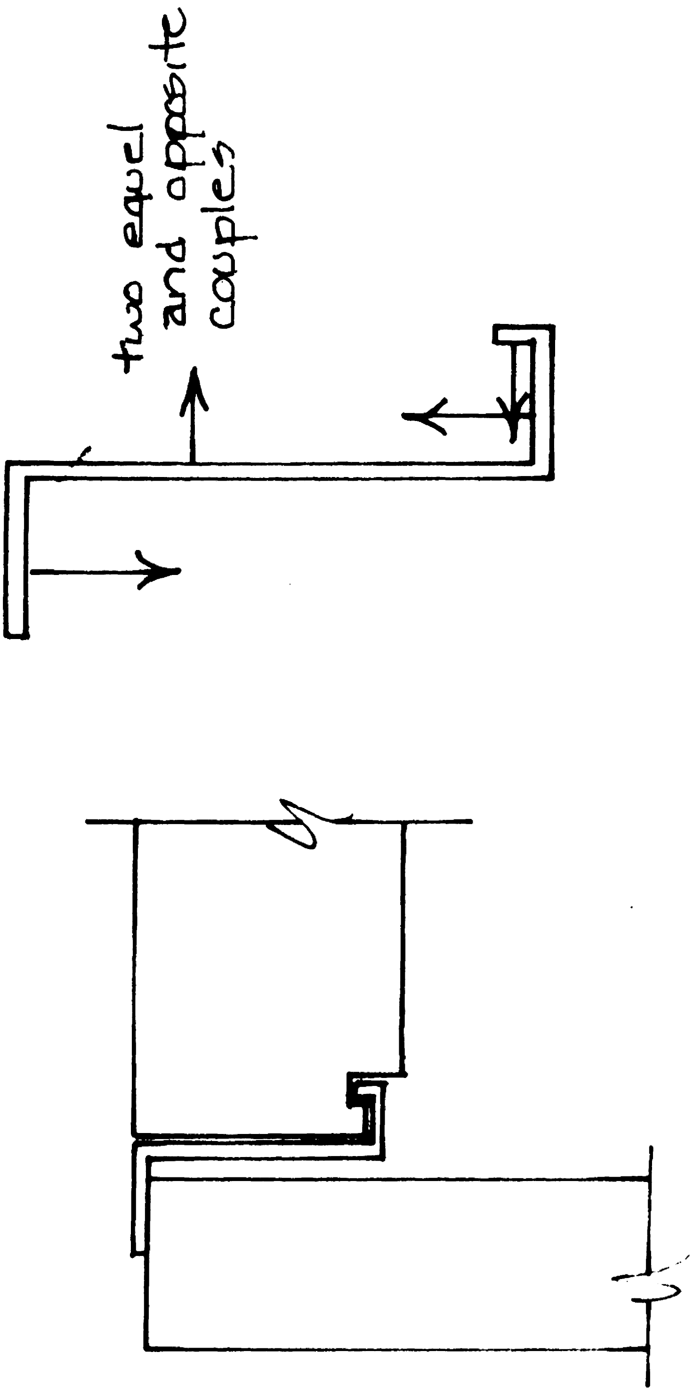


FIGURE 30 : STATIC EQUILIBRIUM

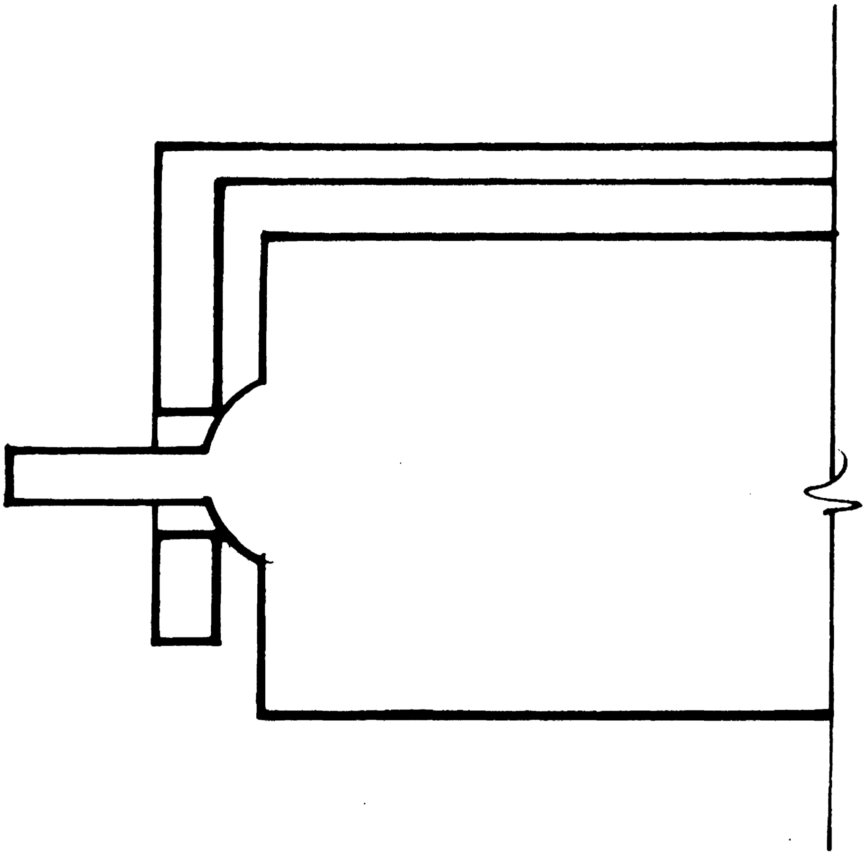


FIGURE 31 : NON-RIGID CONNECTION

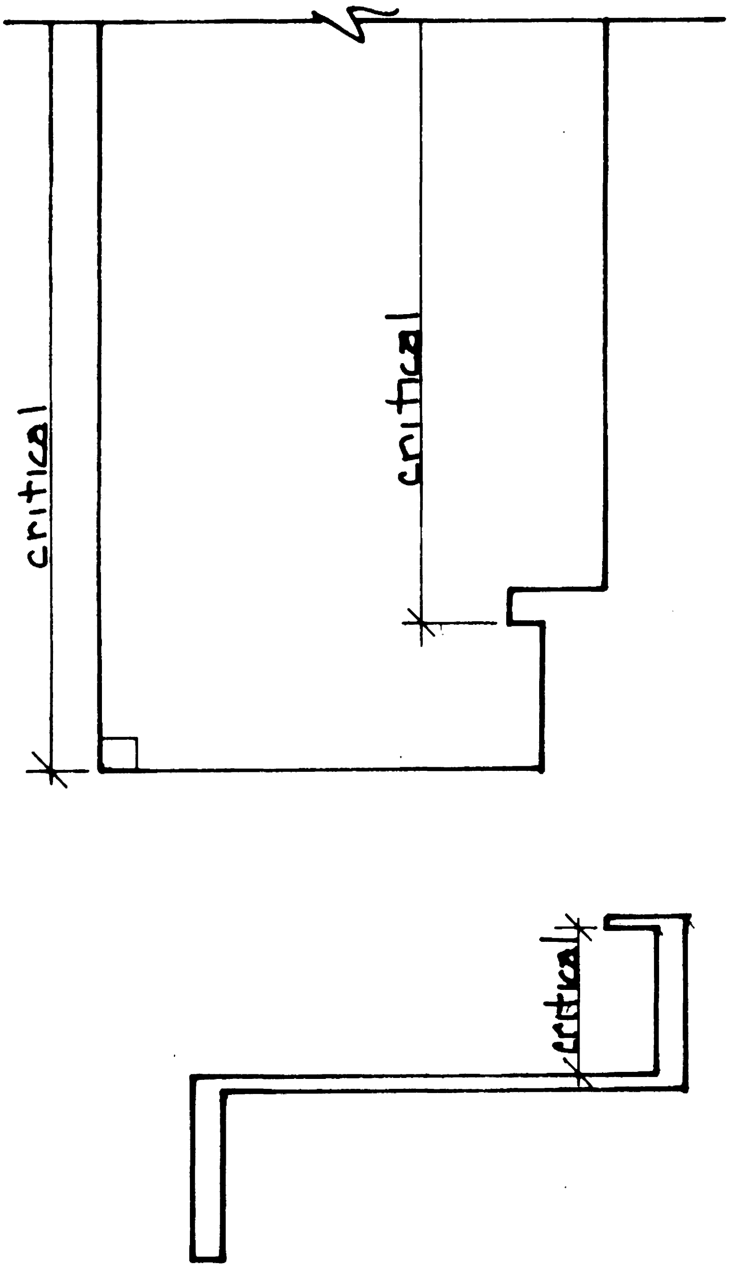


FIGURE 32 : CRITICAL DIMENSIONS.

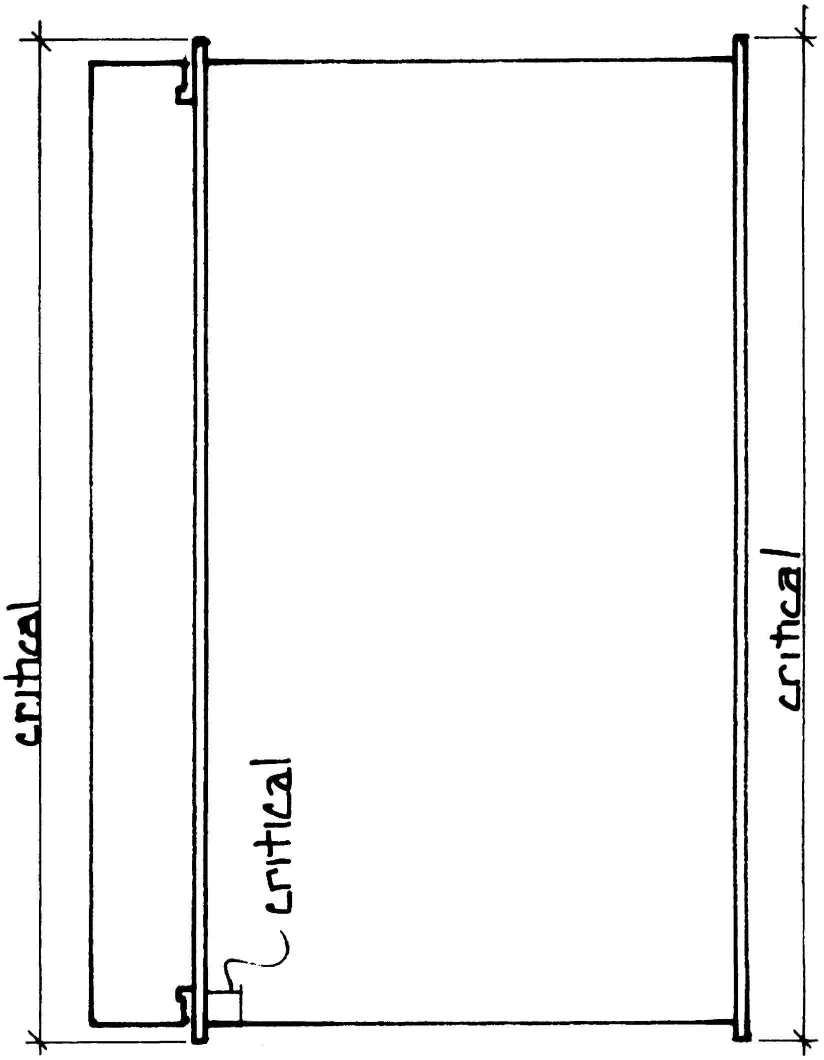
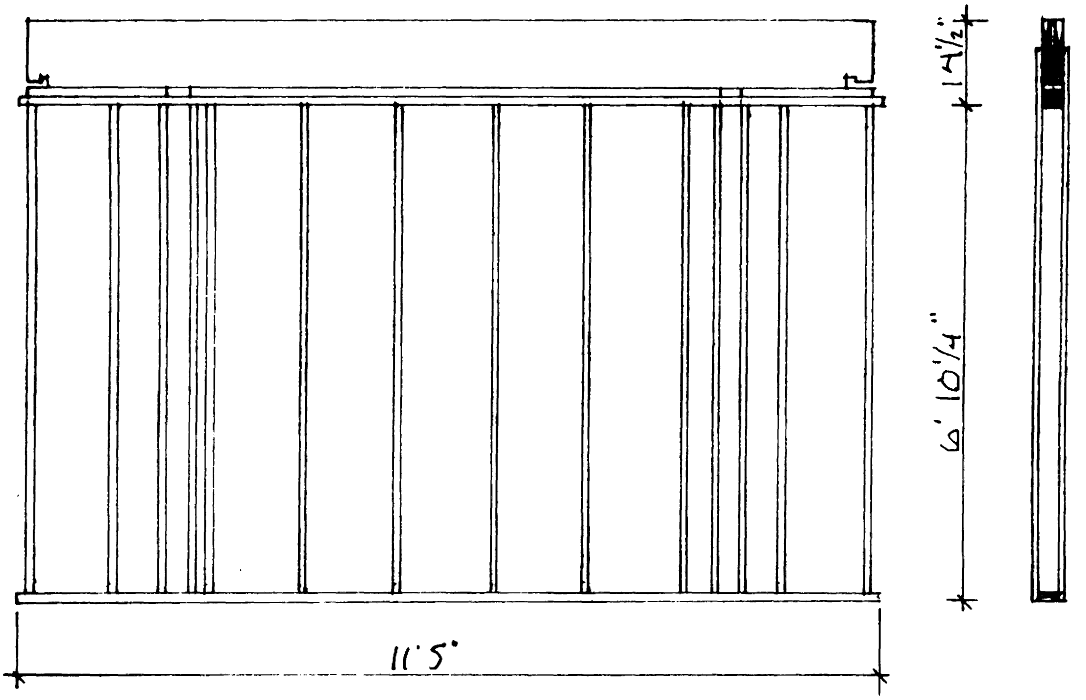


FIGURE 33 : CRITICAL DIMENSIONS



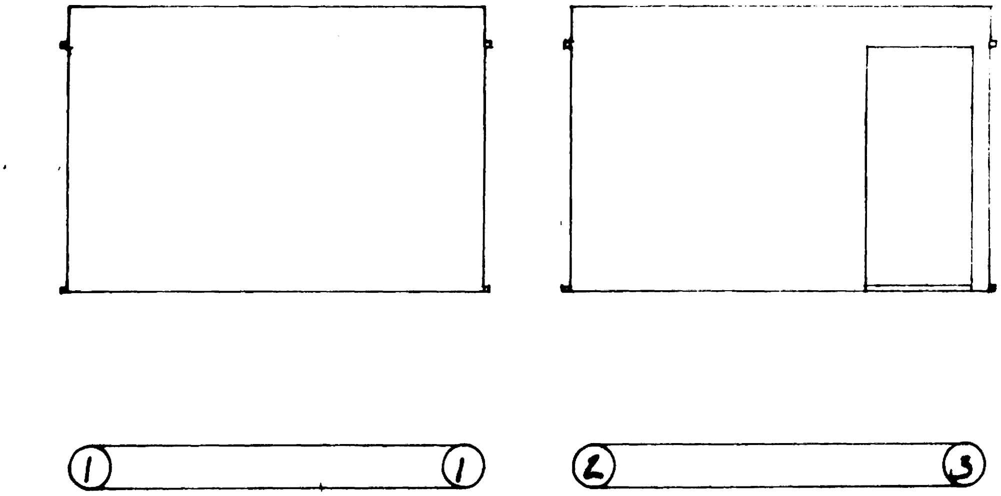


FIGURE 34 : STRUCTURAL PARTITIONS - INTERIOR

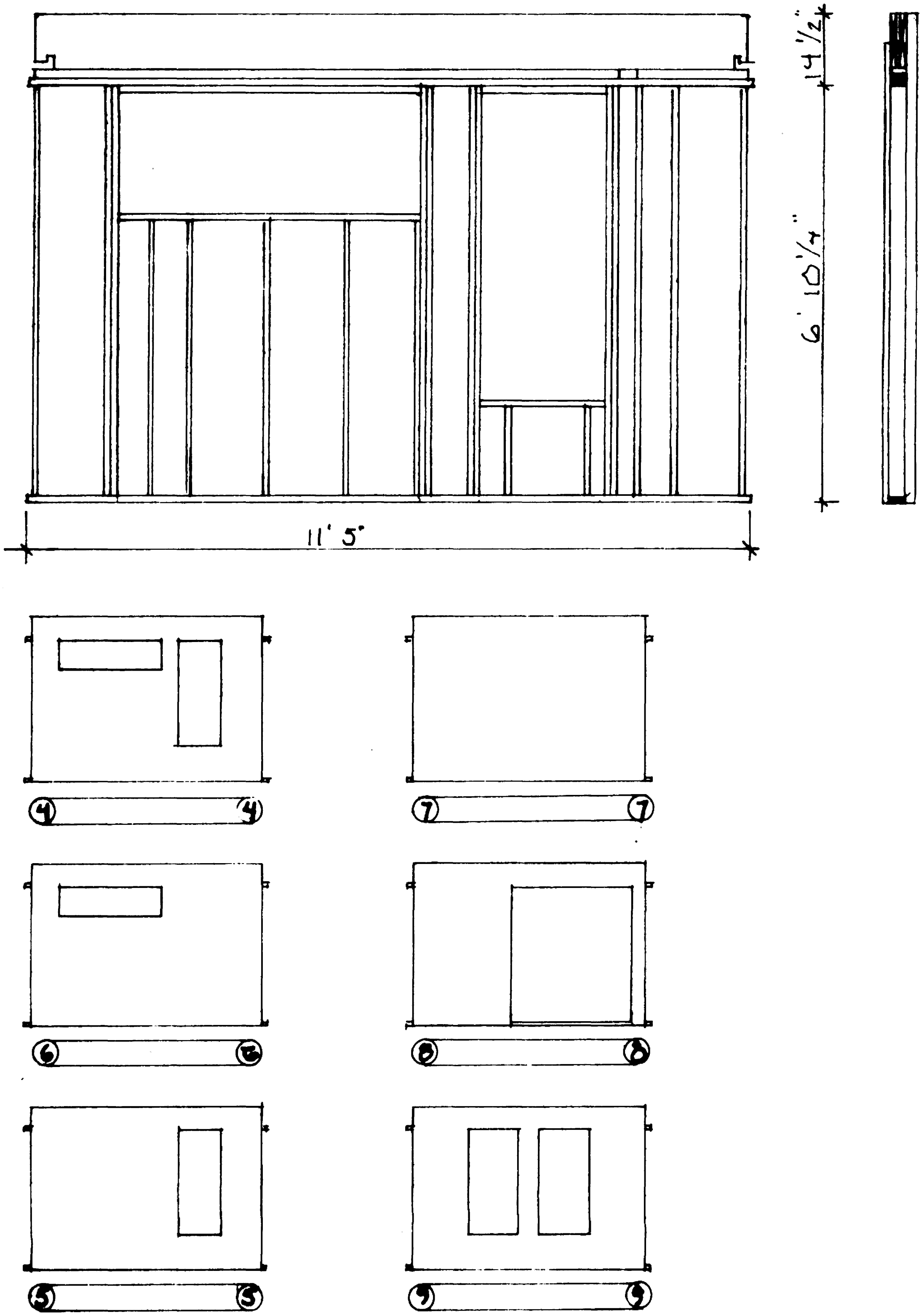


FIGURE 35 : STRUCTURAL PARTITIONS EXTERIOR

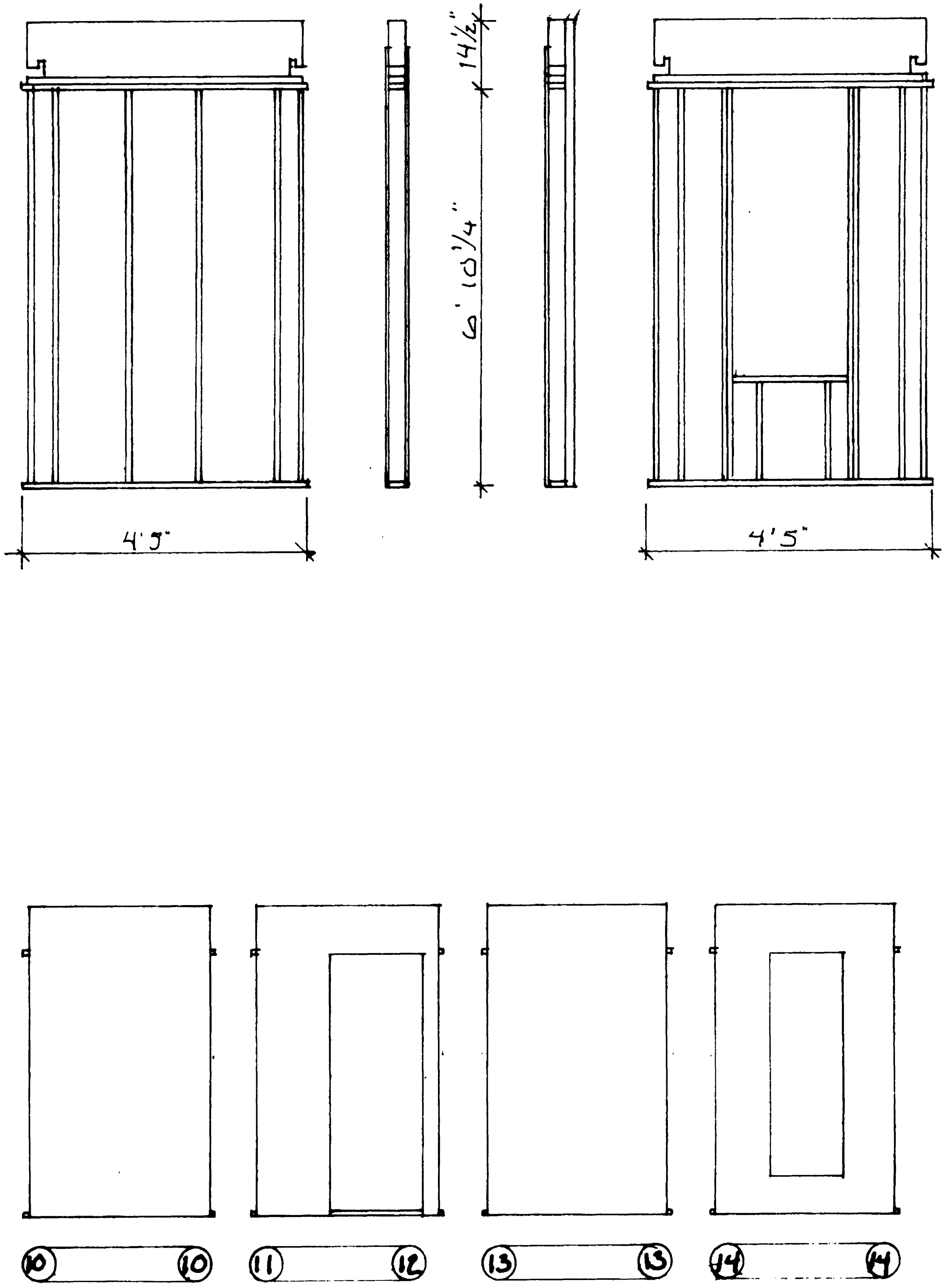


FIGURE 36 : STRUCTURAL PARTITIONS INT. & EXT.

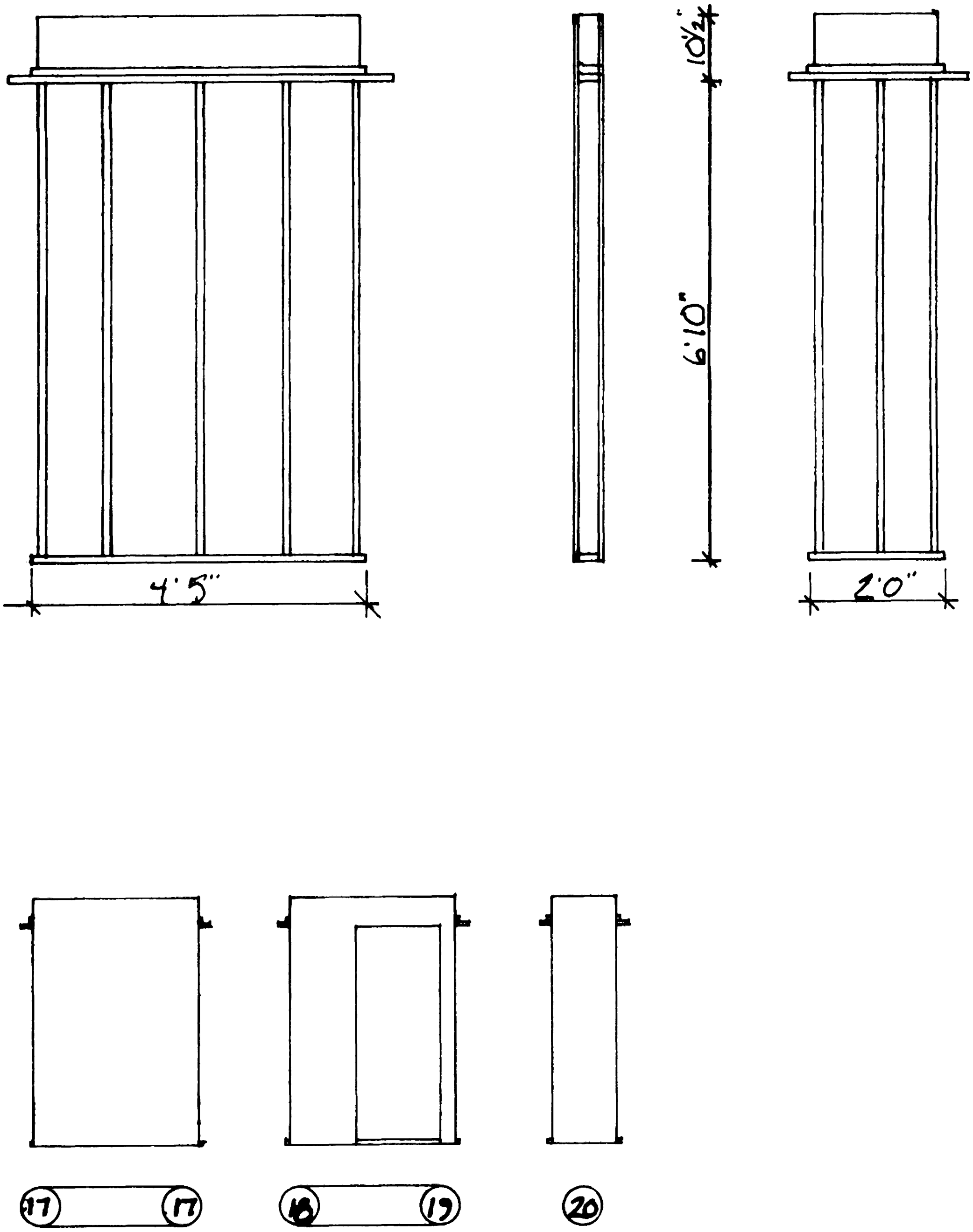


FIGURE 37 : NONSTRUCTURAL PARTITIONS

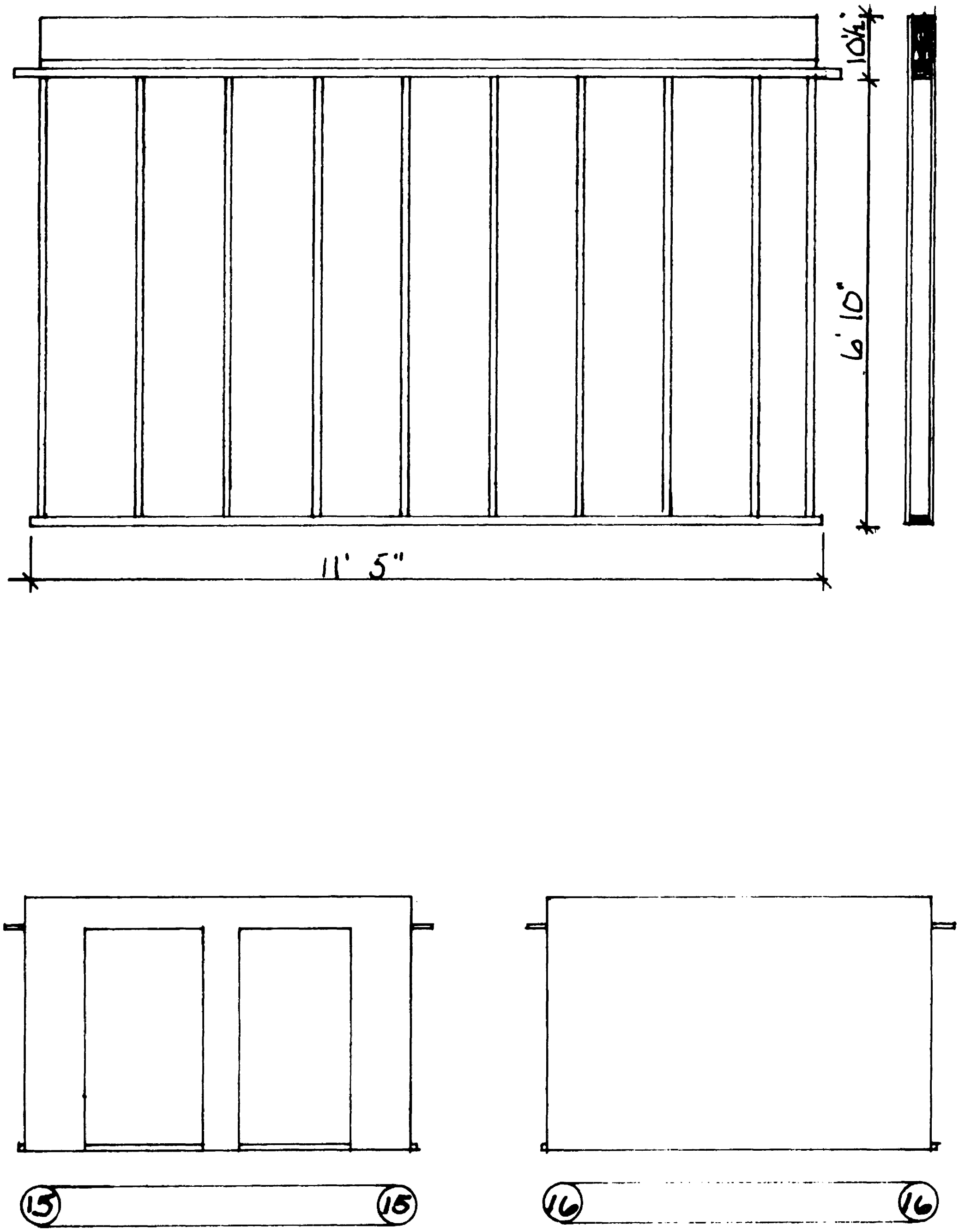


FIGURE 30 : NONSTRUCTURALL PARTITIONS

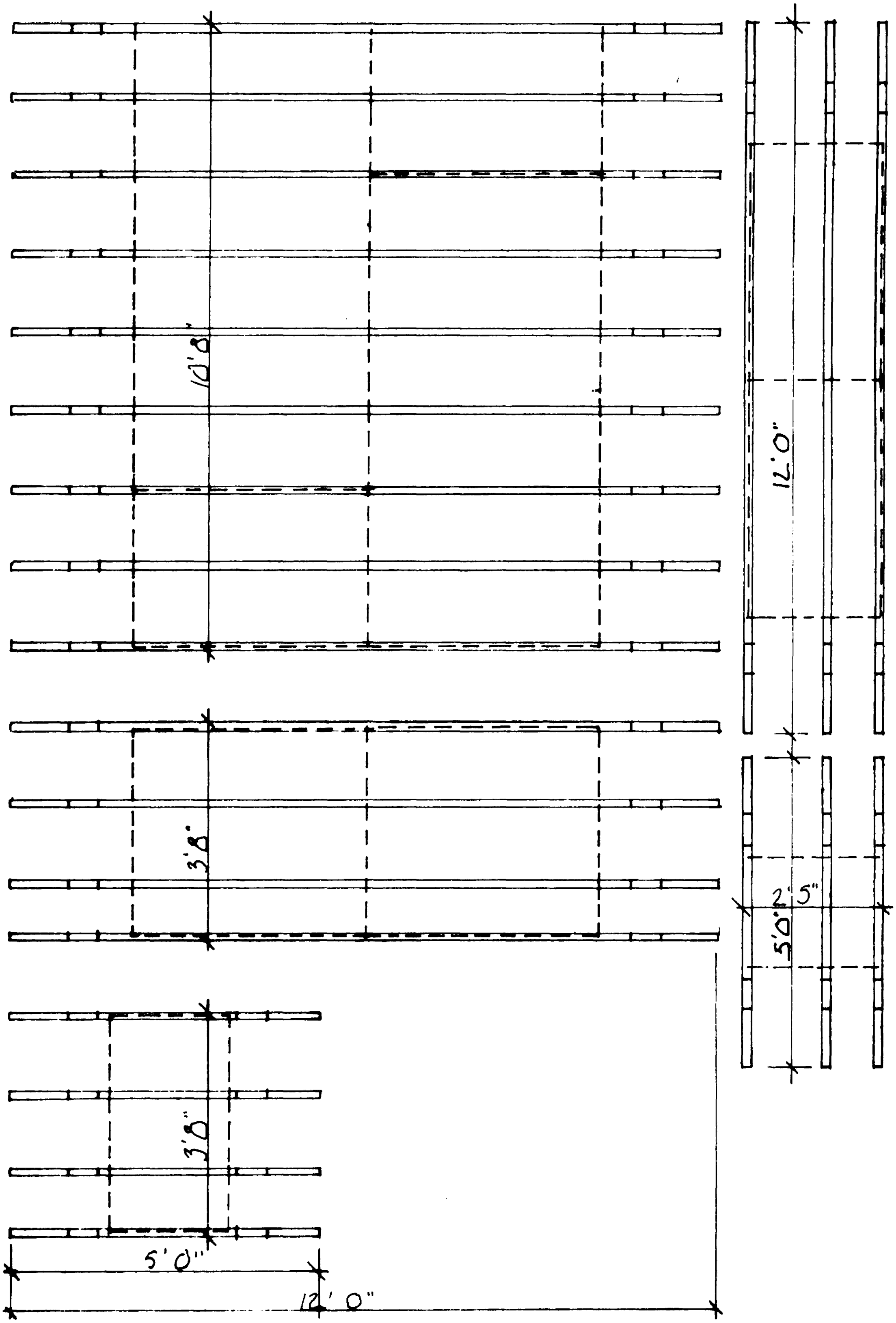
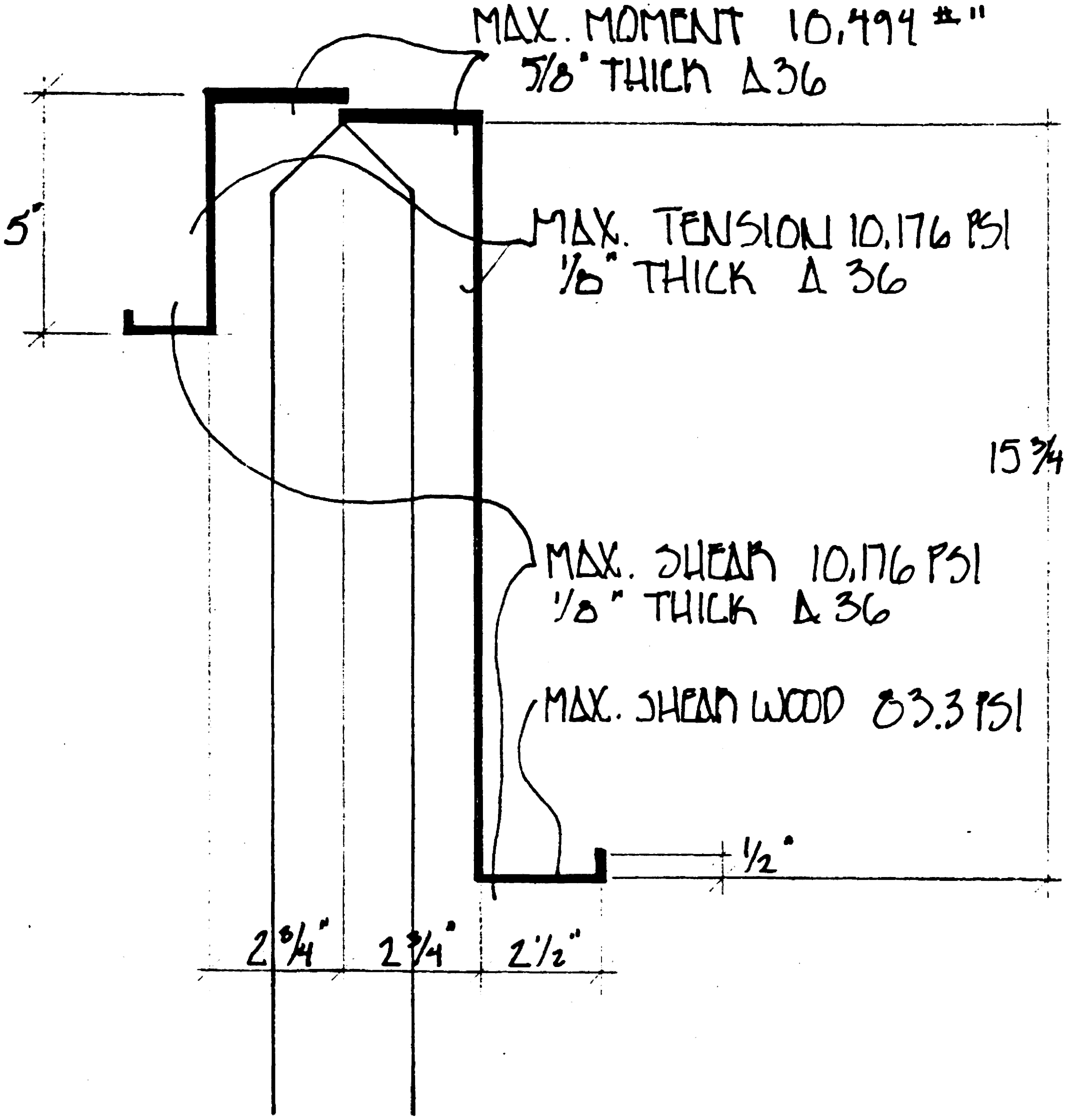


FIGURE 39 : FLOOR COMPONENTS

FIGURE 40 : STRESS DIAGRAM



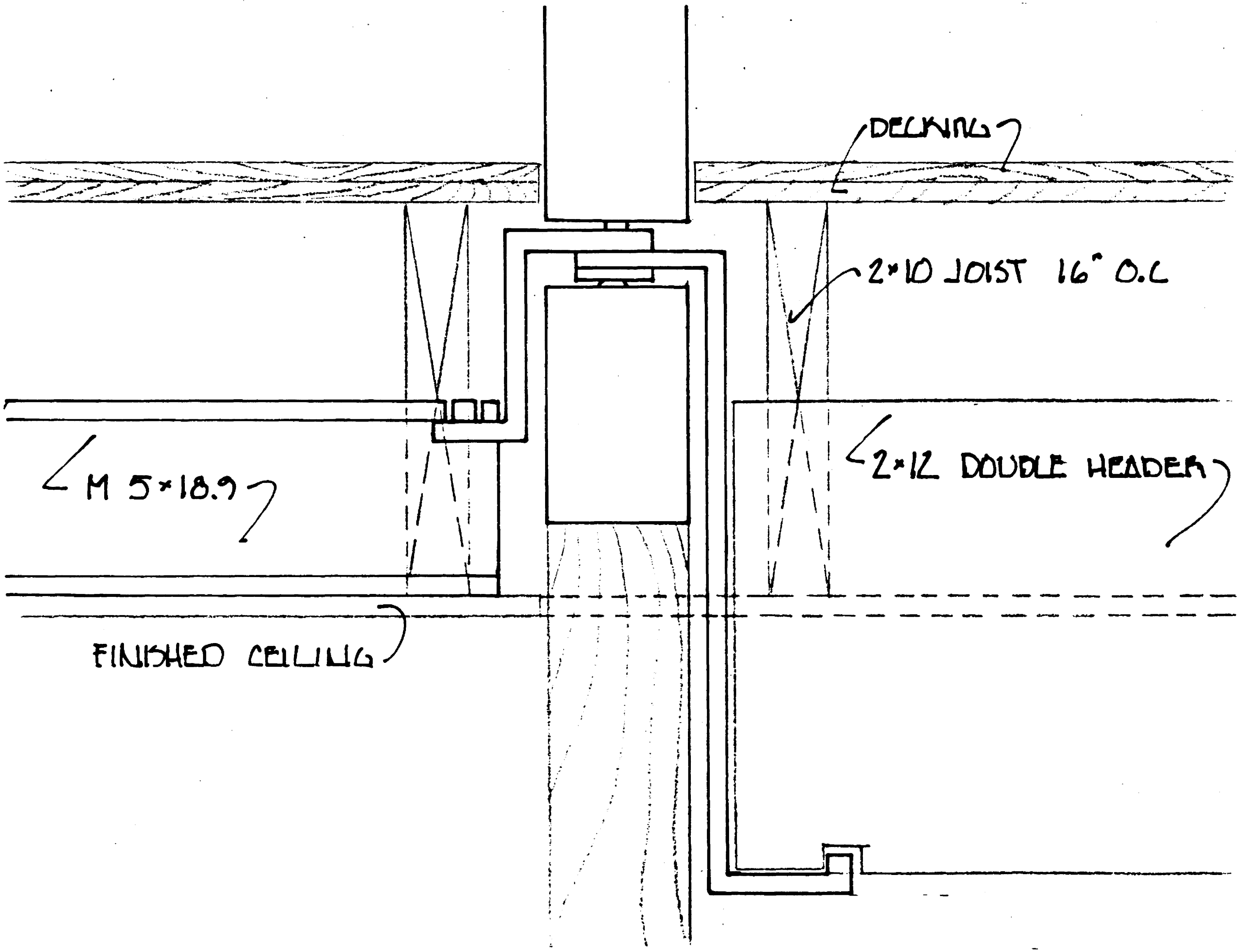


FIGURE 41 : COLUMN DETAIL

FIGURE 42 : EXTERIOR WALL DETAIL

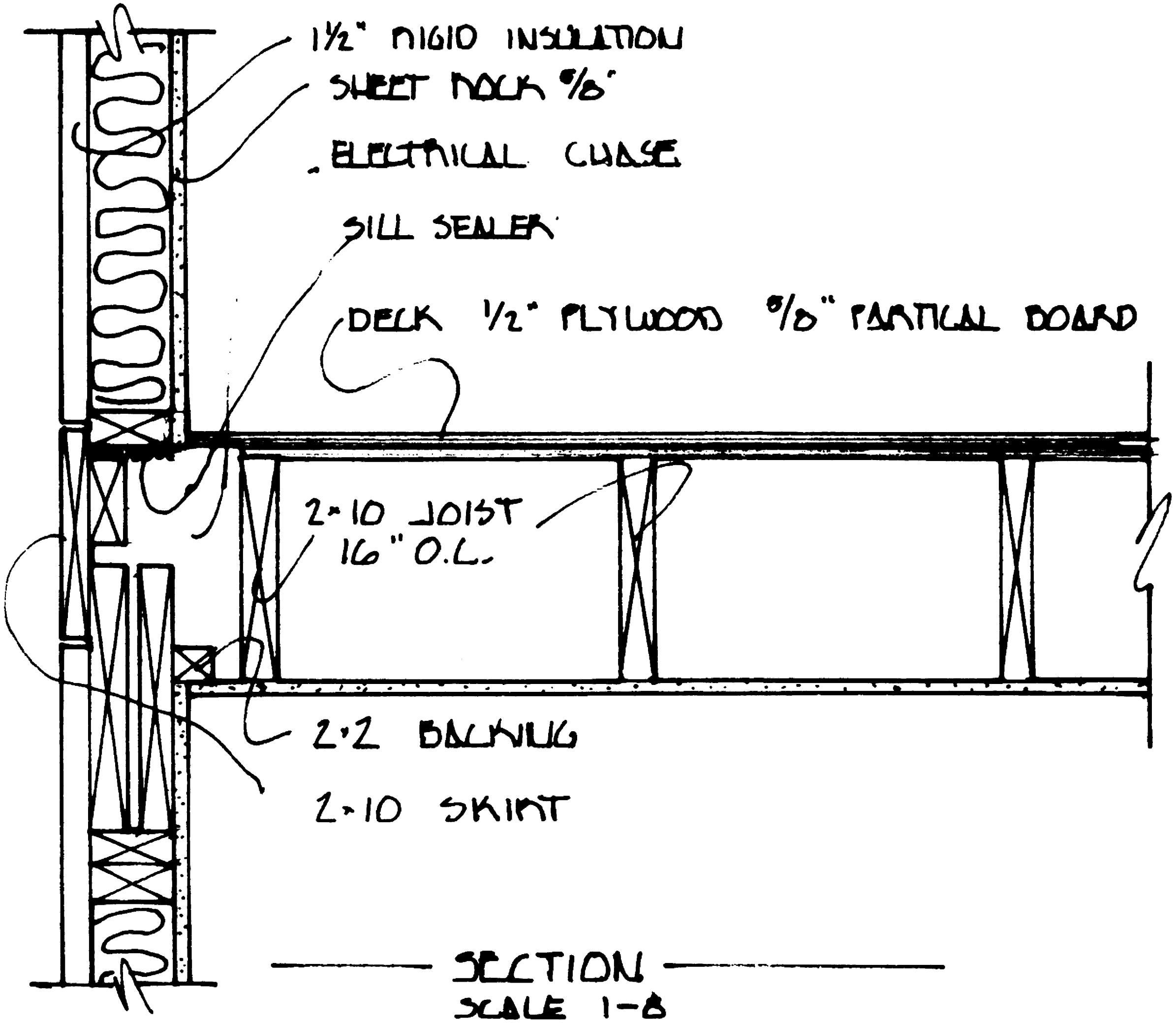


FIGURE 4.3 : NON STRUCTURAL PARTITION

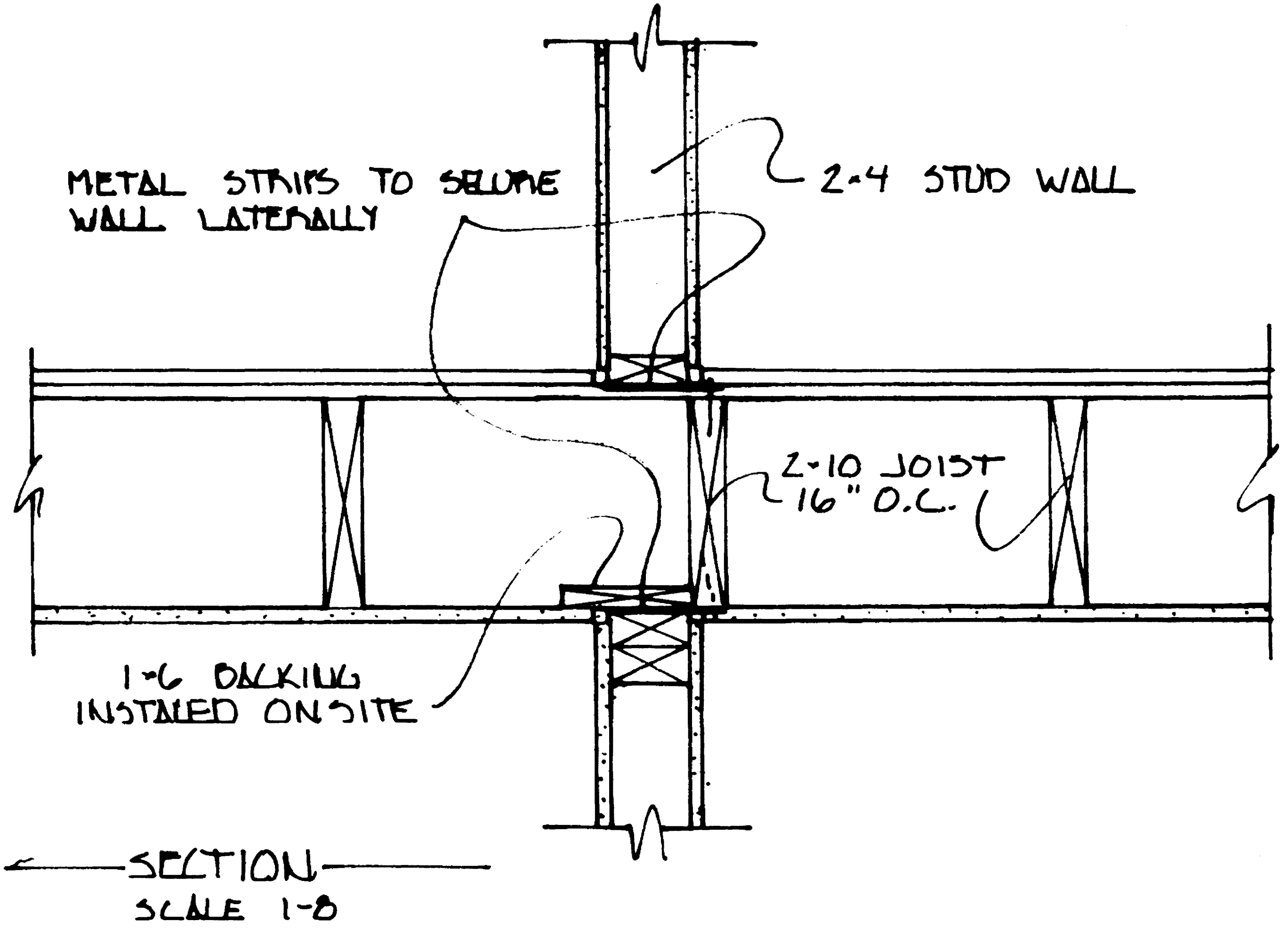
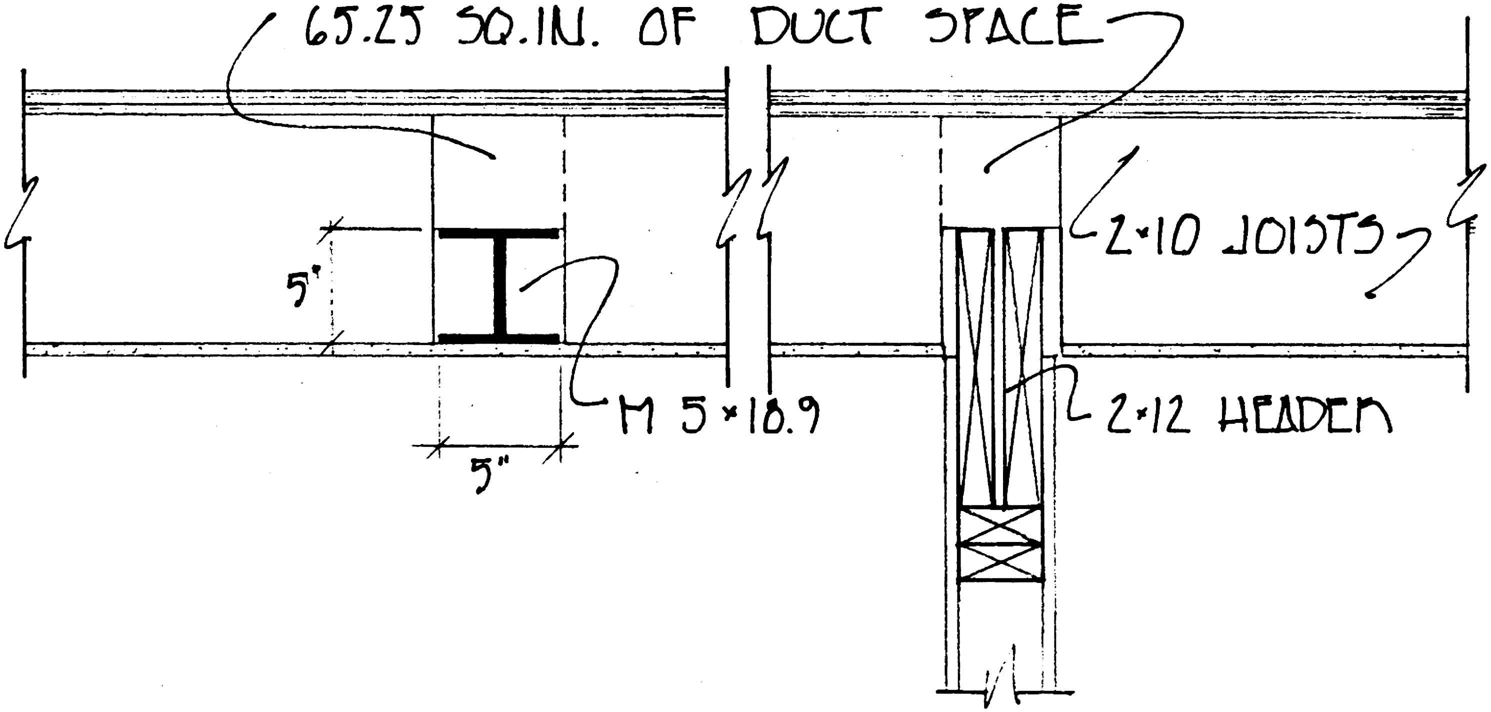


FIGURE 44 : FLOOR SECTION



— SECTION —

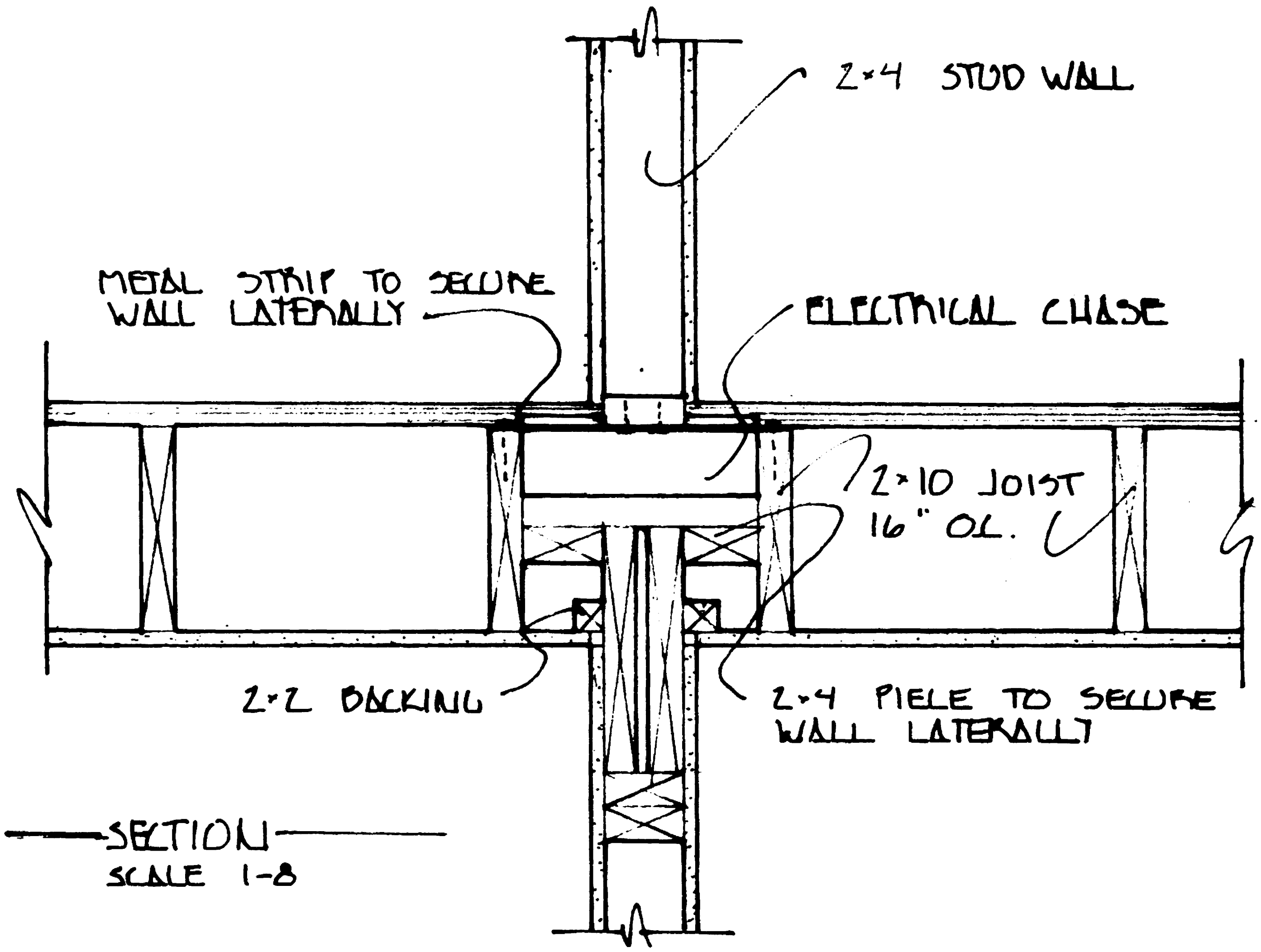
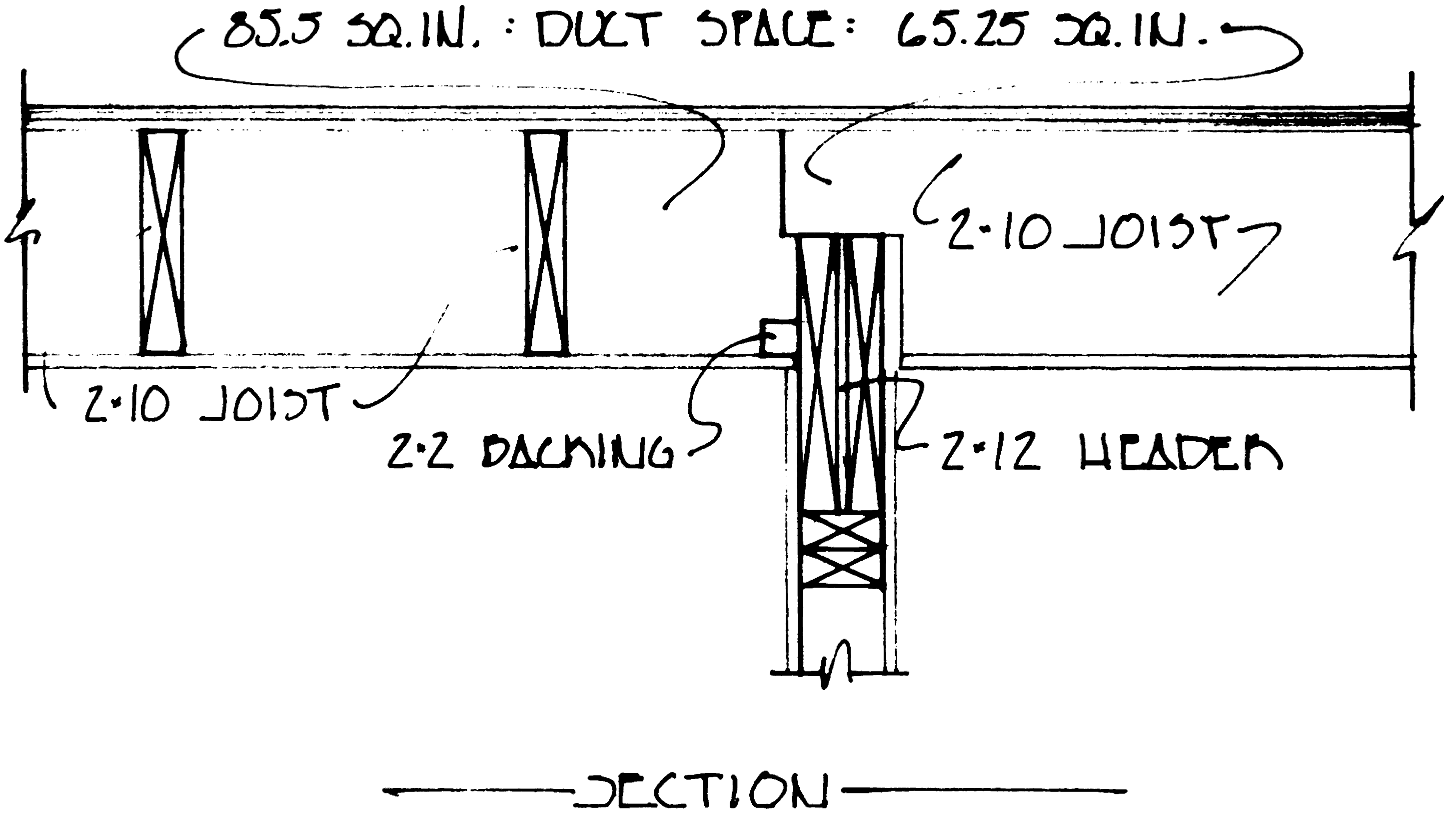


FIGURE 45 : STRUCTURAL PARTITION DETAIL

FIGURE 46 : FLOOR SECTION



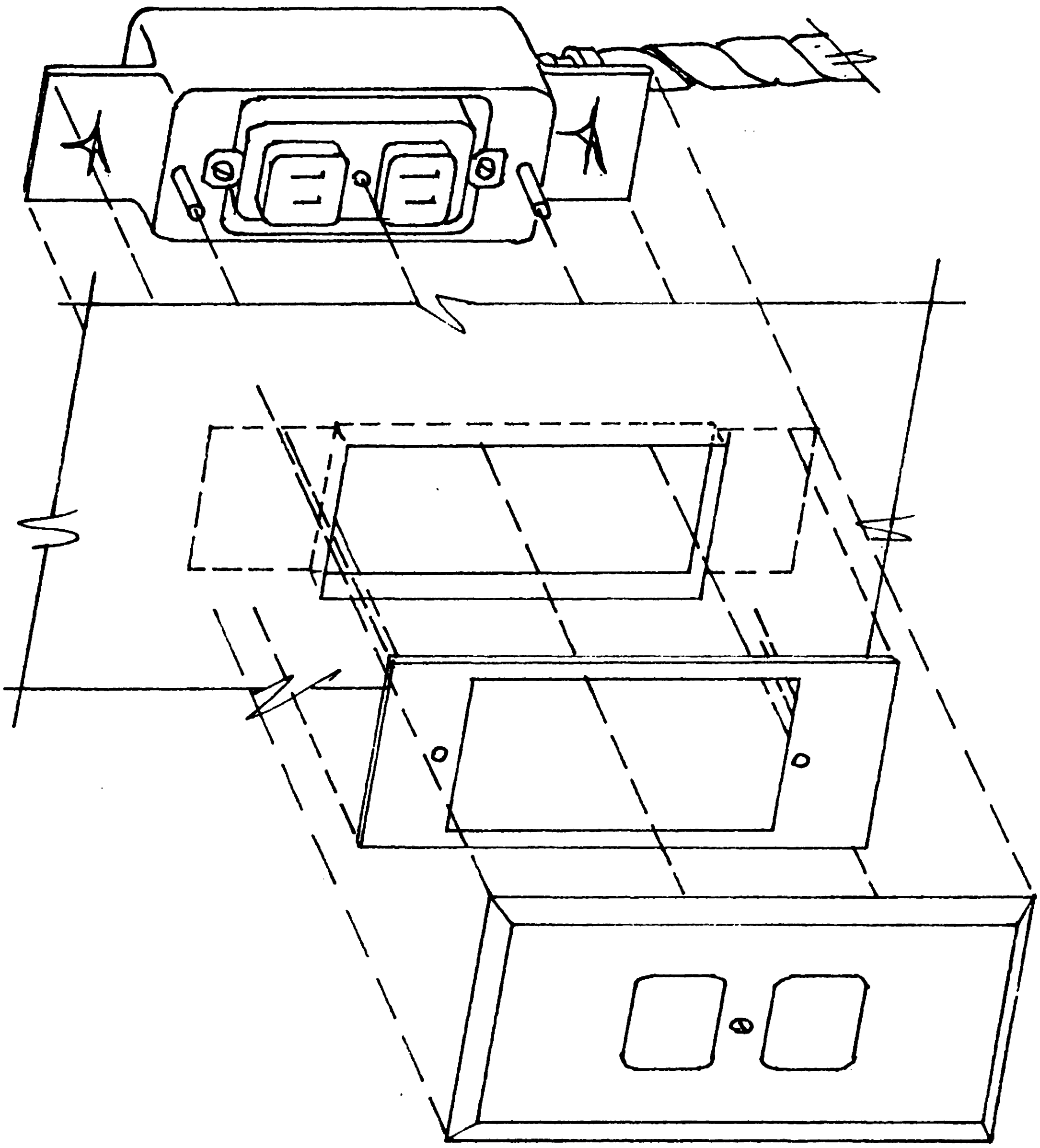


FIGURE 47 : OUTLET DETAIL

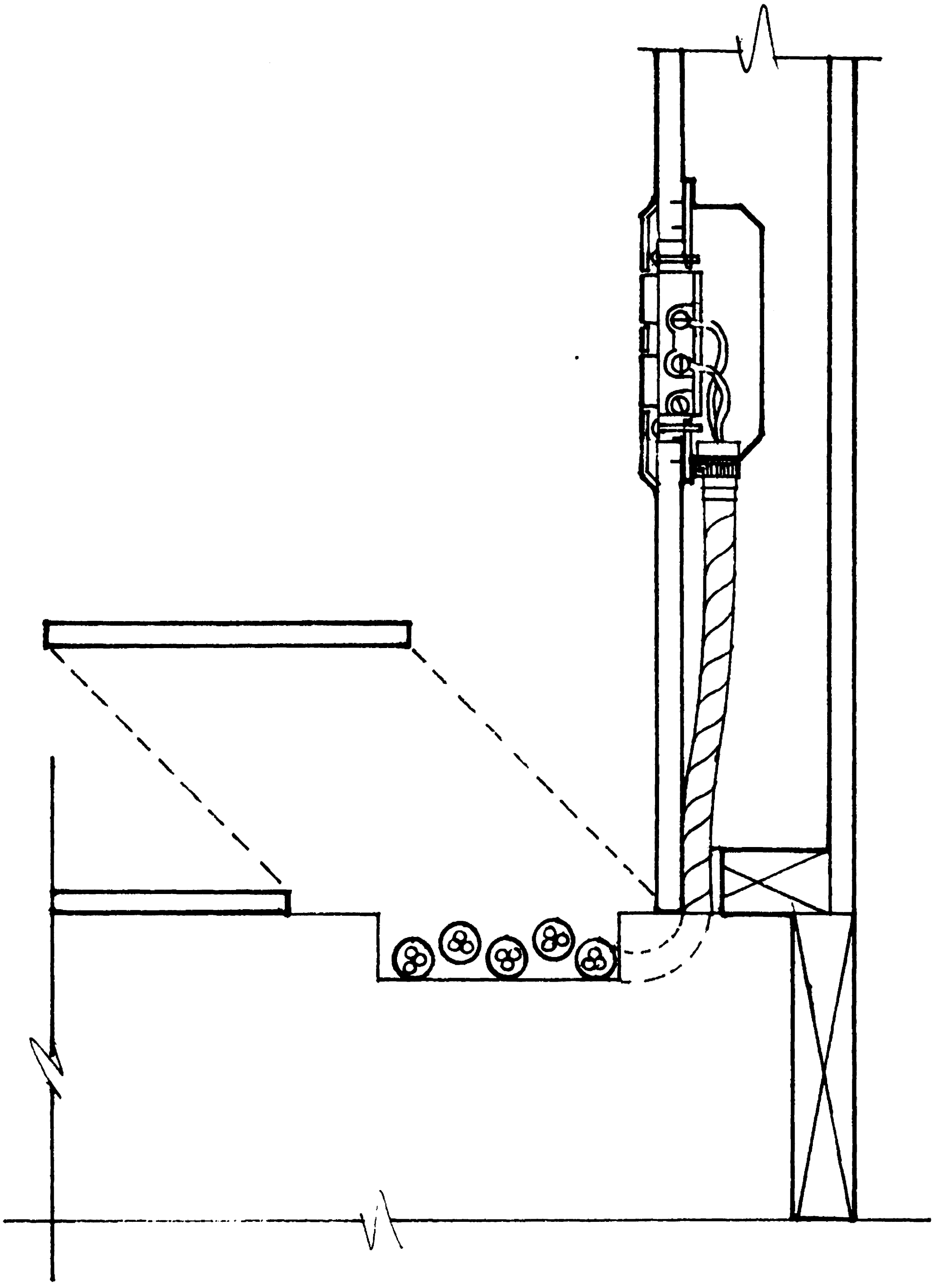


FIGURE 48 : RACEWAY DETAIL

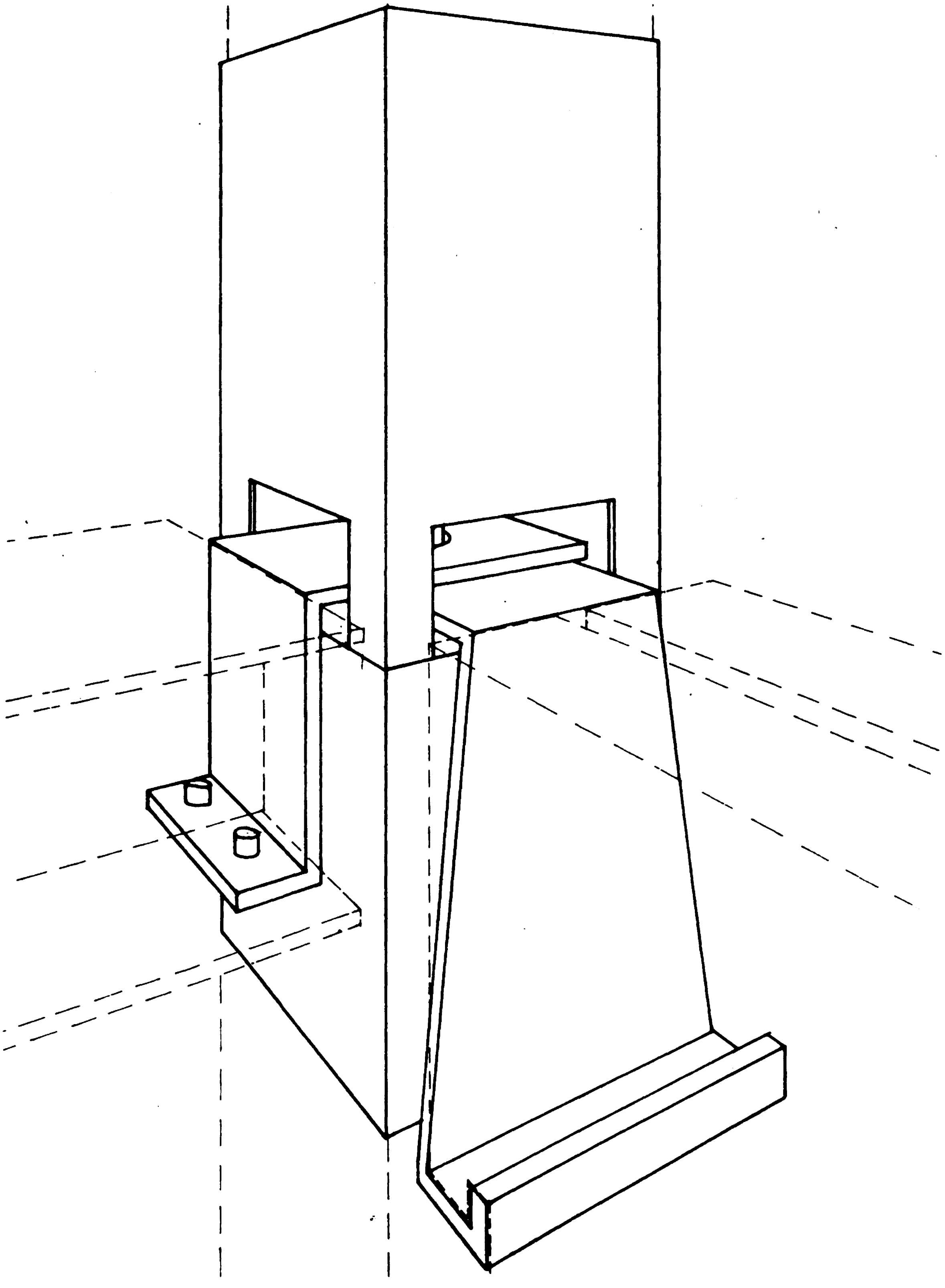


FIGURE 49 : CONNECTION DETAIL

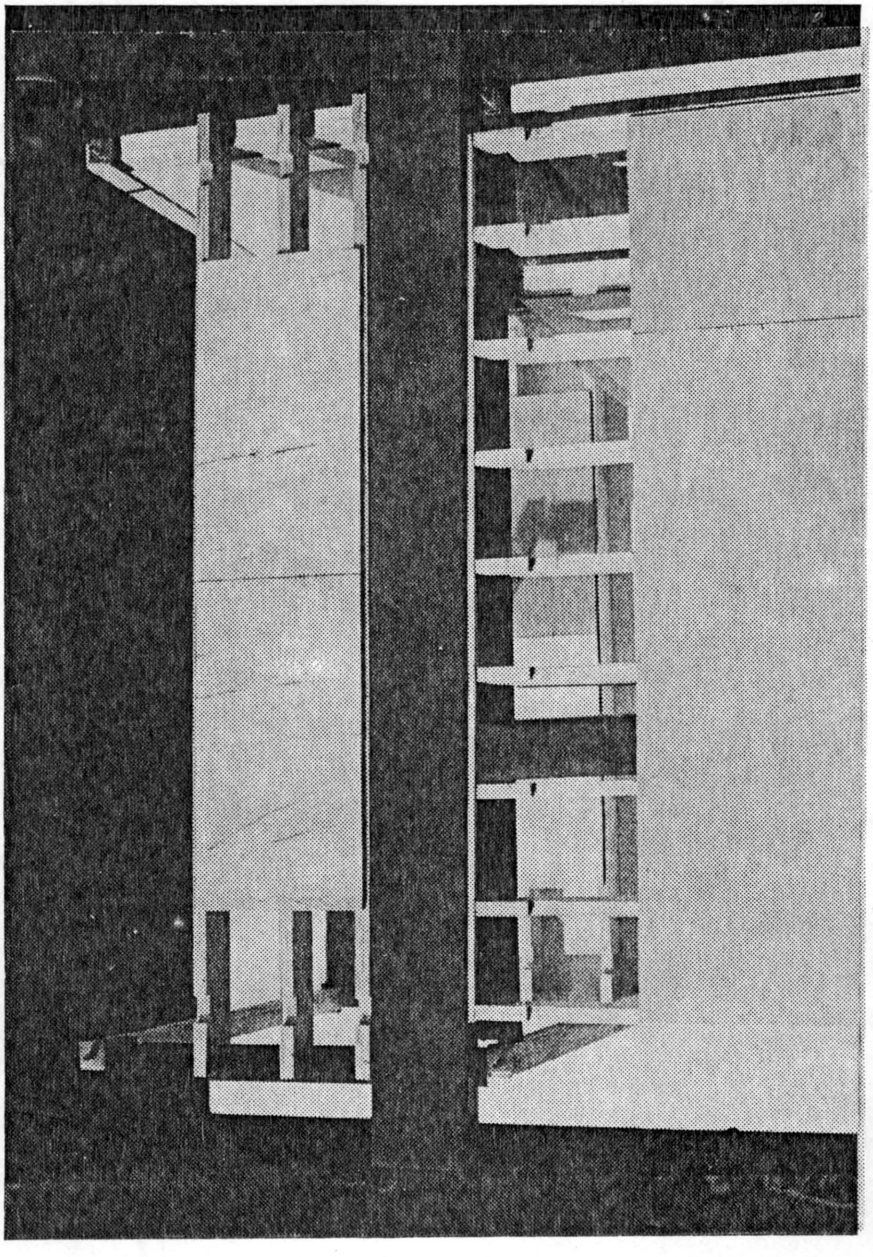


FIGURE 50 : MODEL HVAC DISTRIBUTION

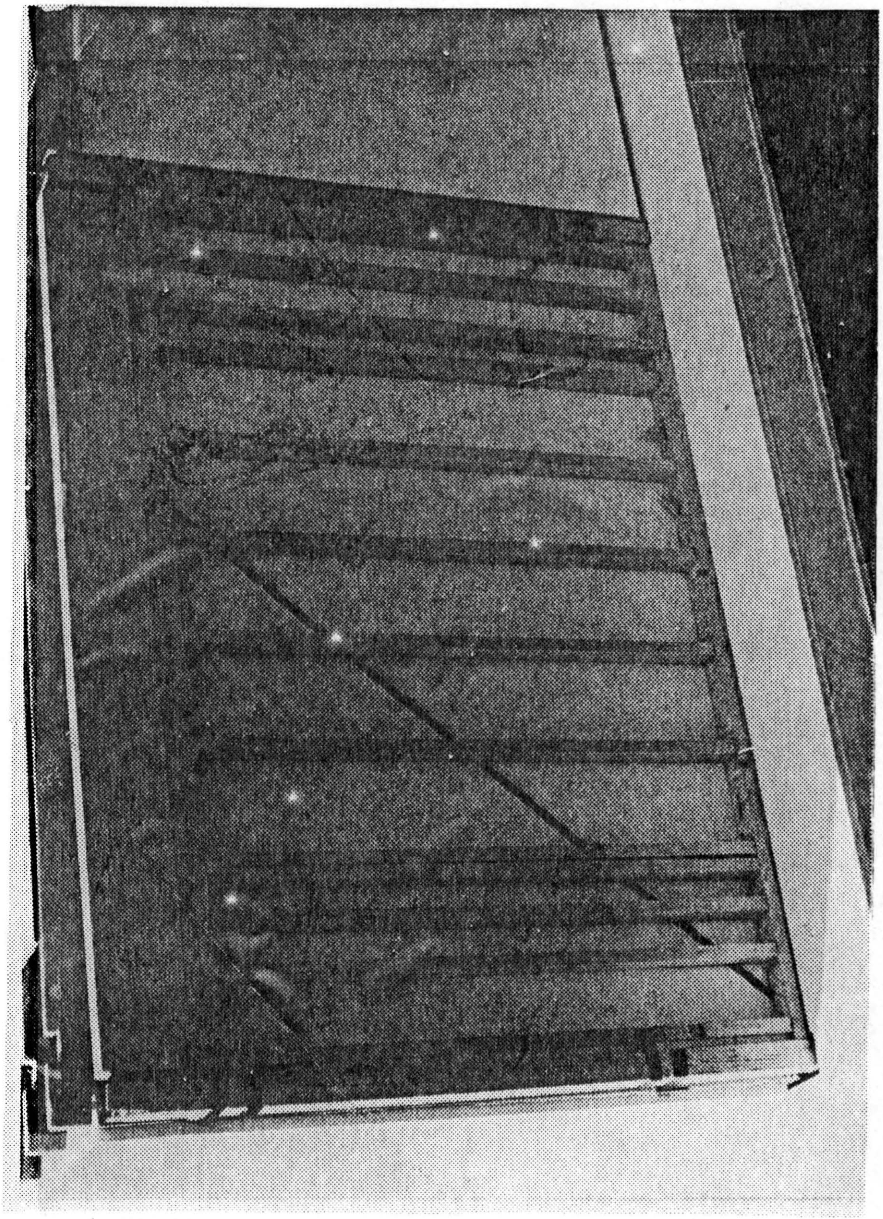


FIGURE 51 : COMPONENT CONSTRUCTION

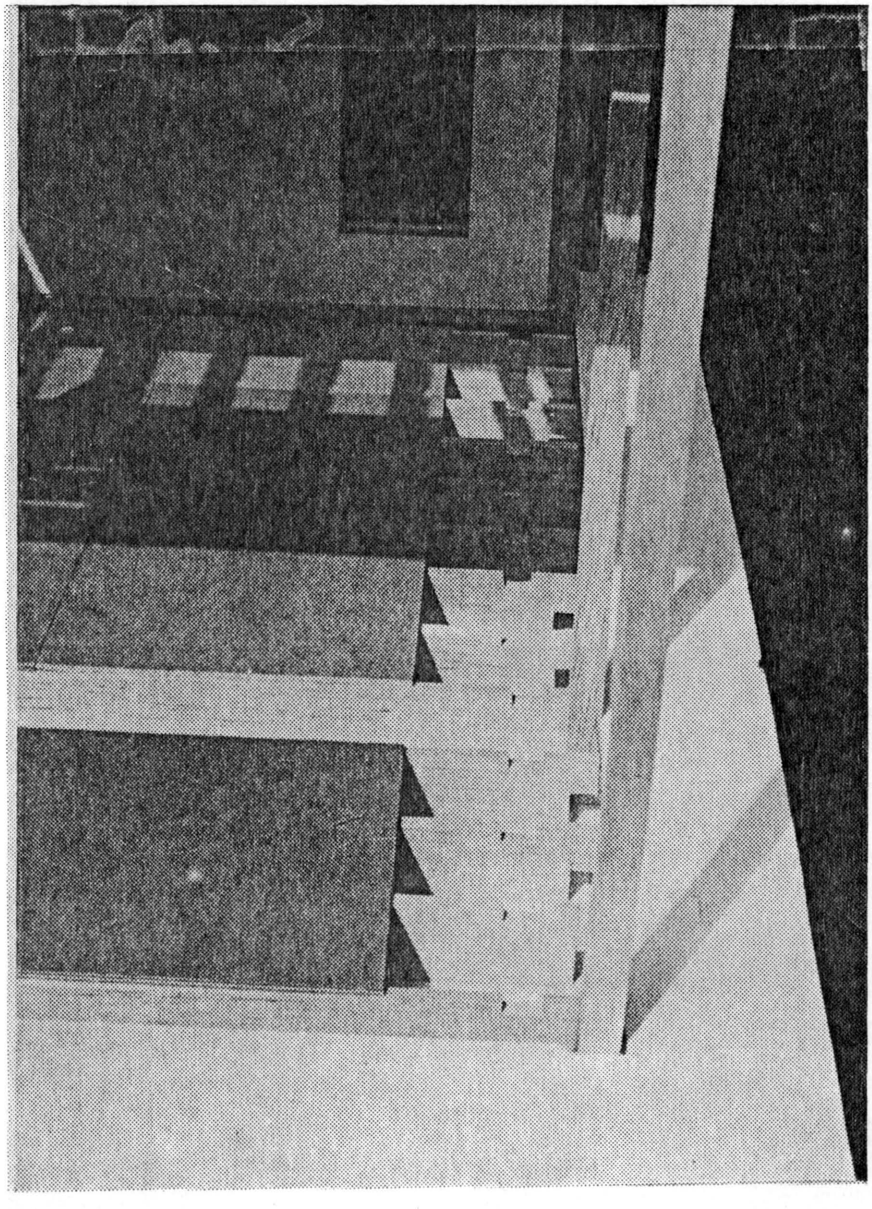


FIGURE 52 : MODEL - GENERAL VIEW

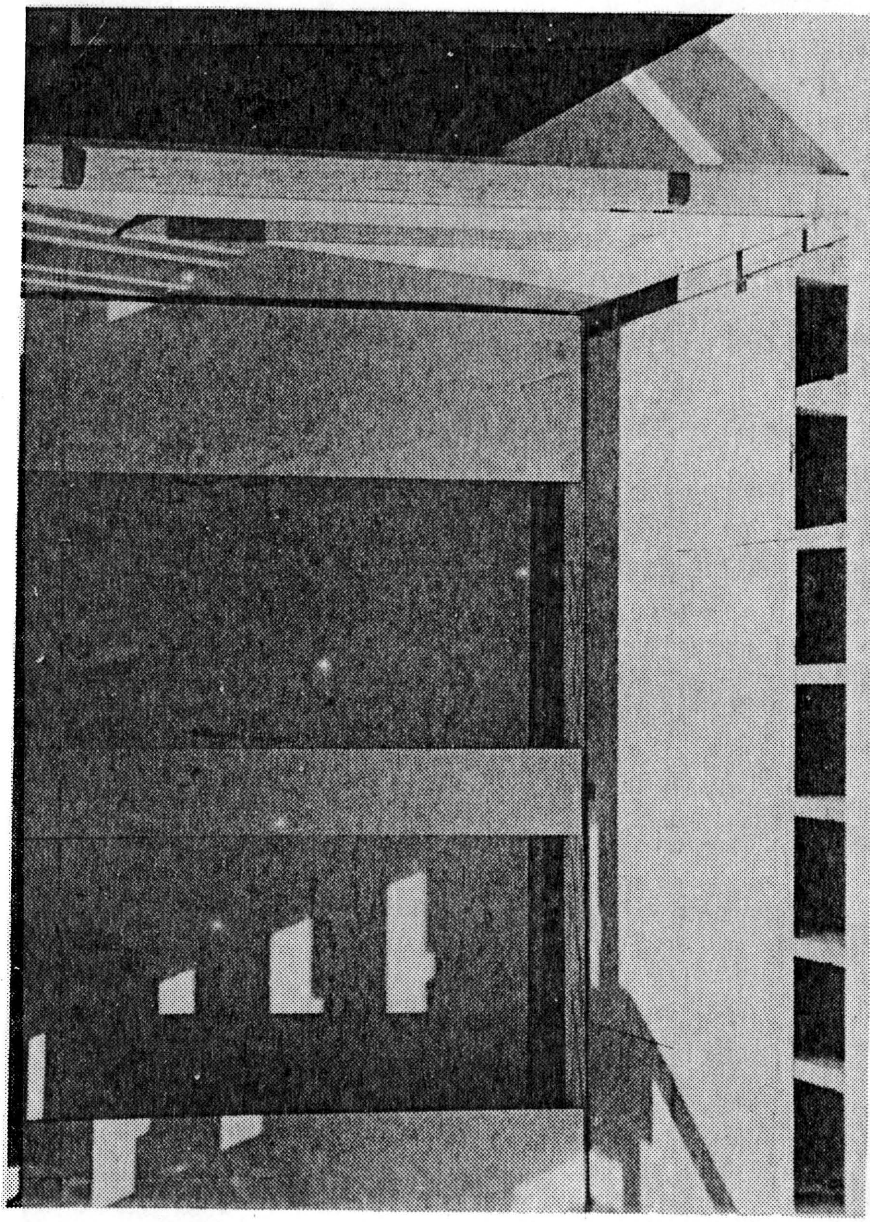


FIGURE 53 : MODEL- GENERAL VIEW

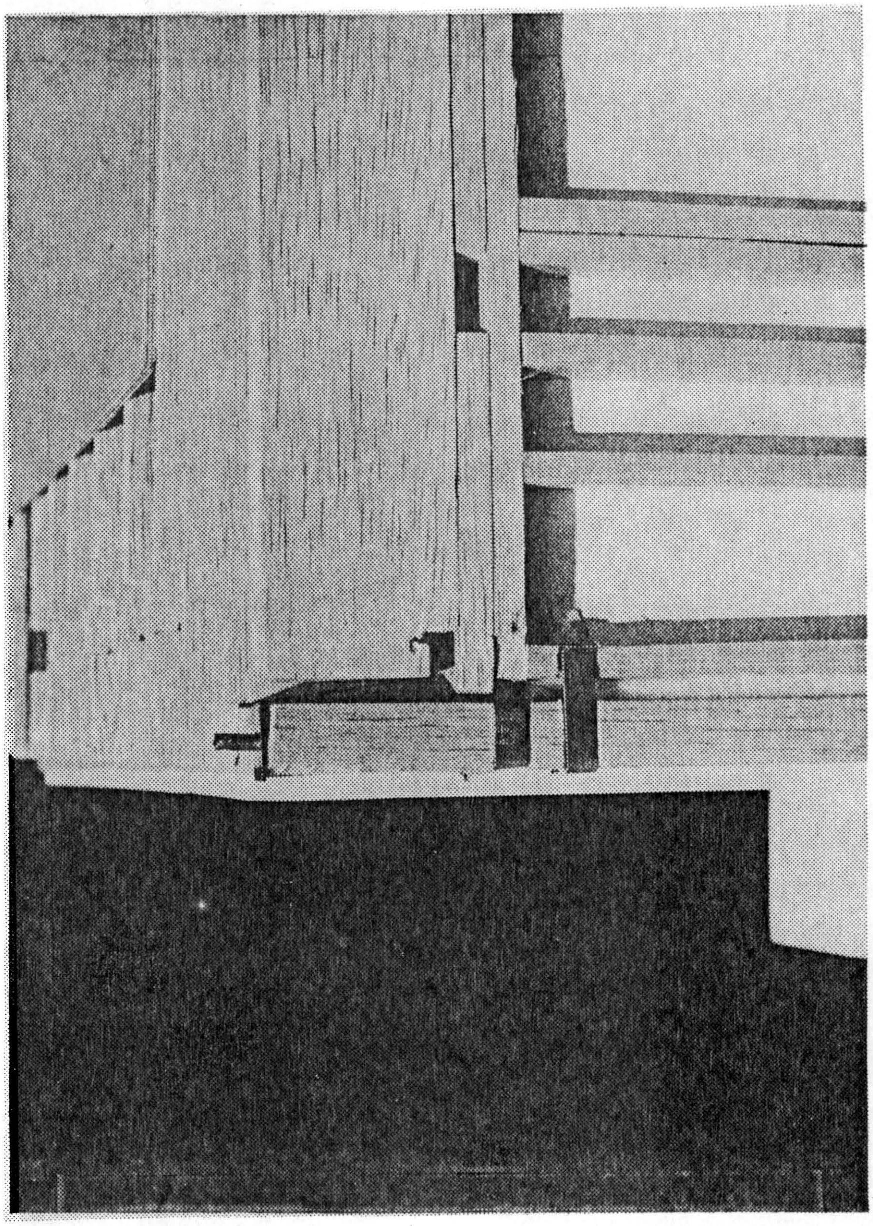


FIGURE 54 : MODEL - CONNECTION DETAIL

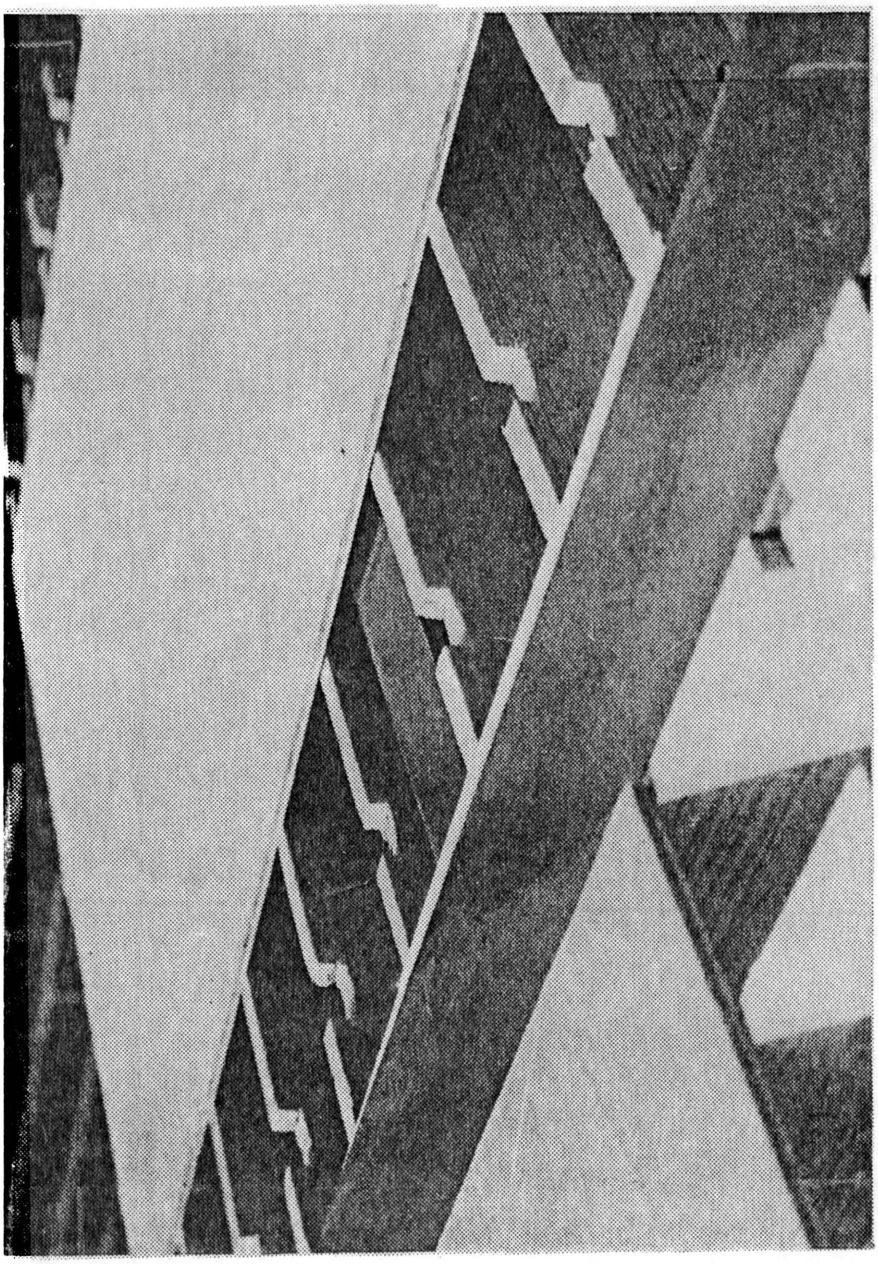


FIGURE 55 : MODEL - DECK

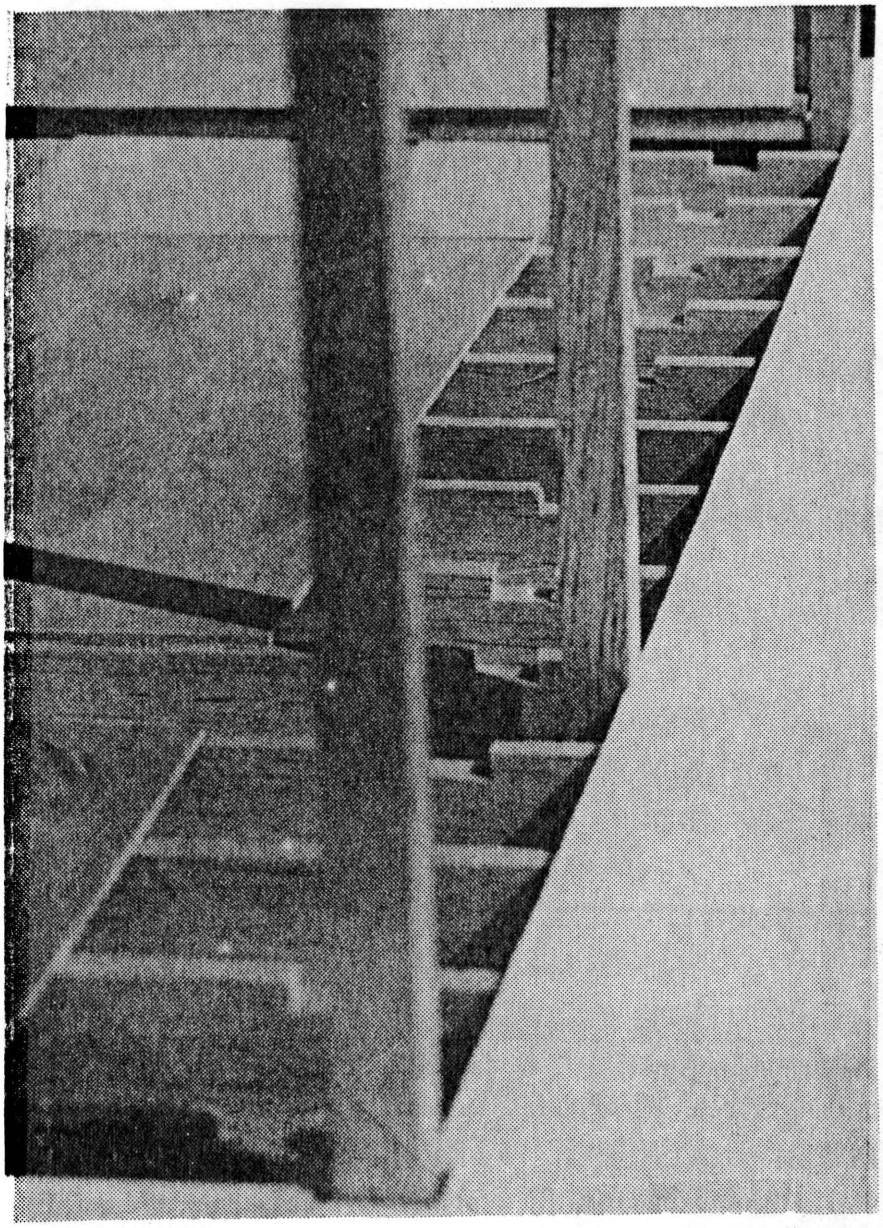


FIGURE 56 : RACEWAY DETAIL

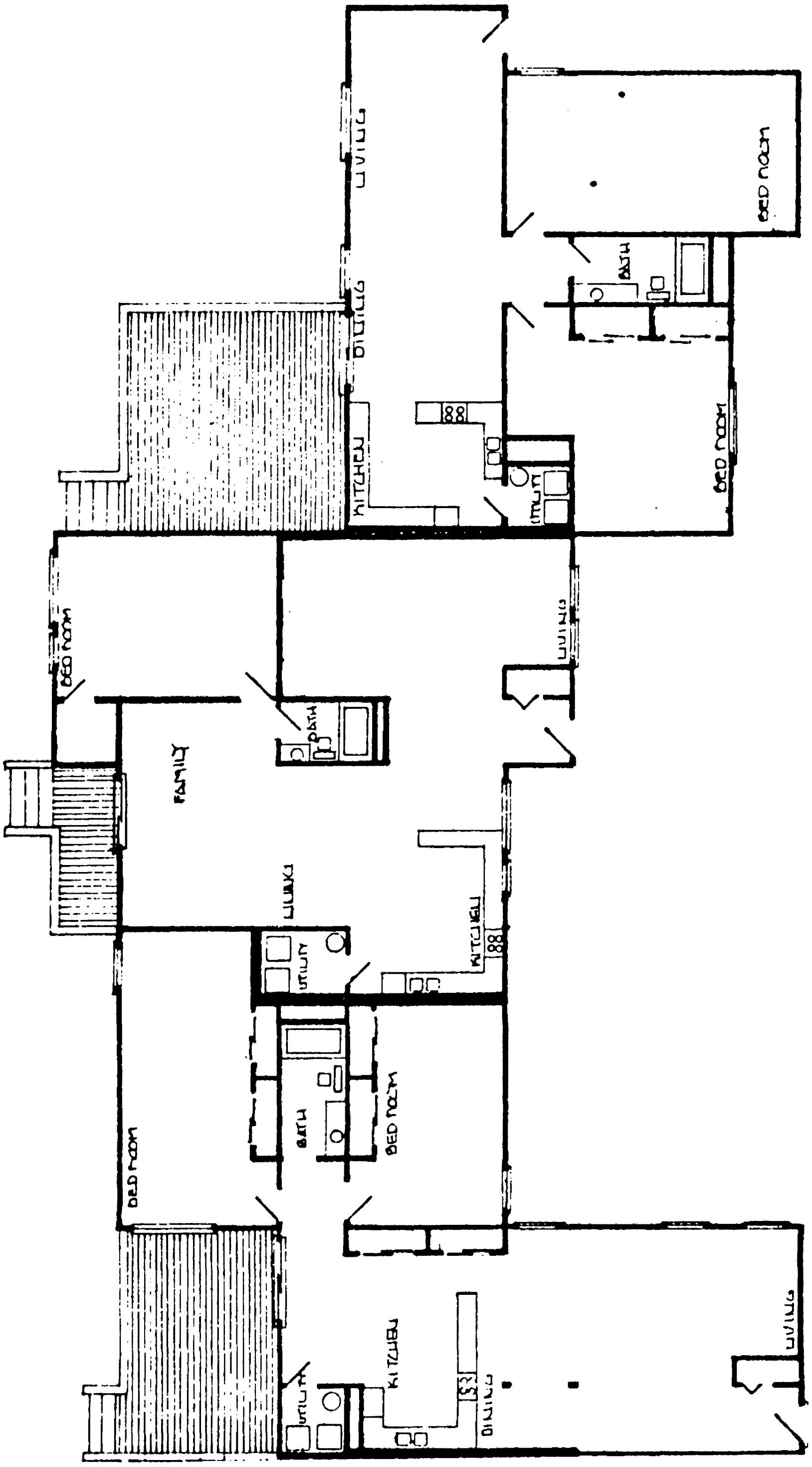


FIGURE 57 : PLAN GENERAL

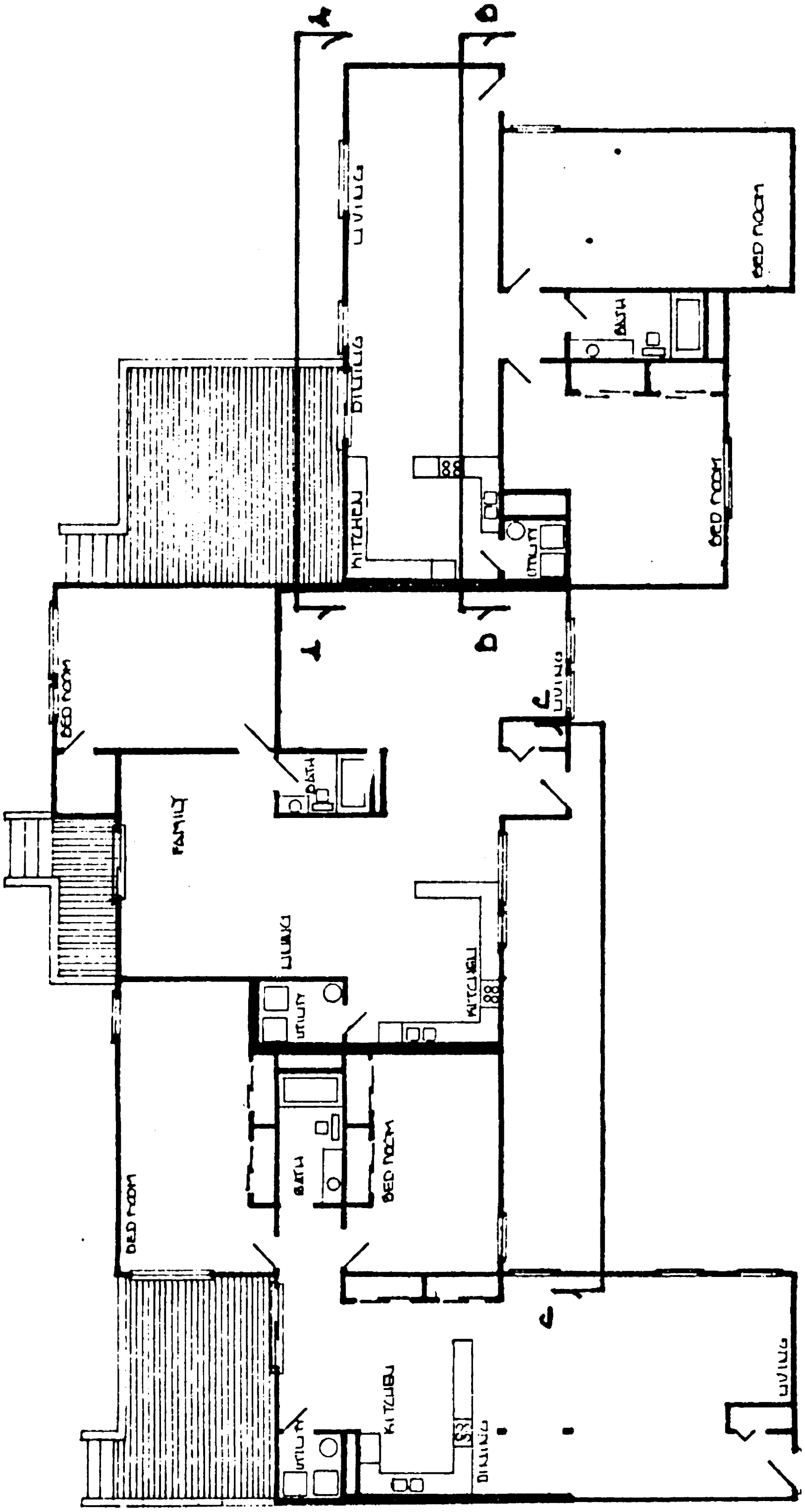


FIGURE 58 : PLAN DETAIL
ELEVATIONS FIG. 63

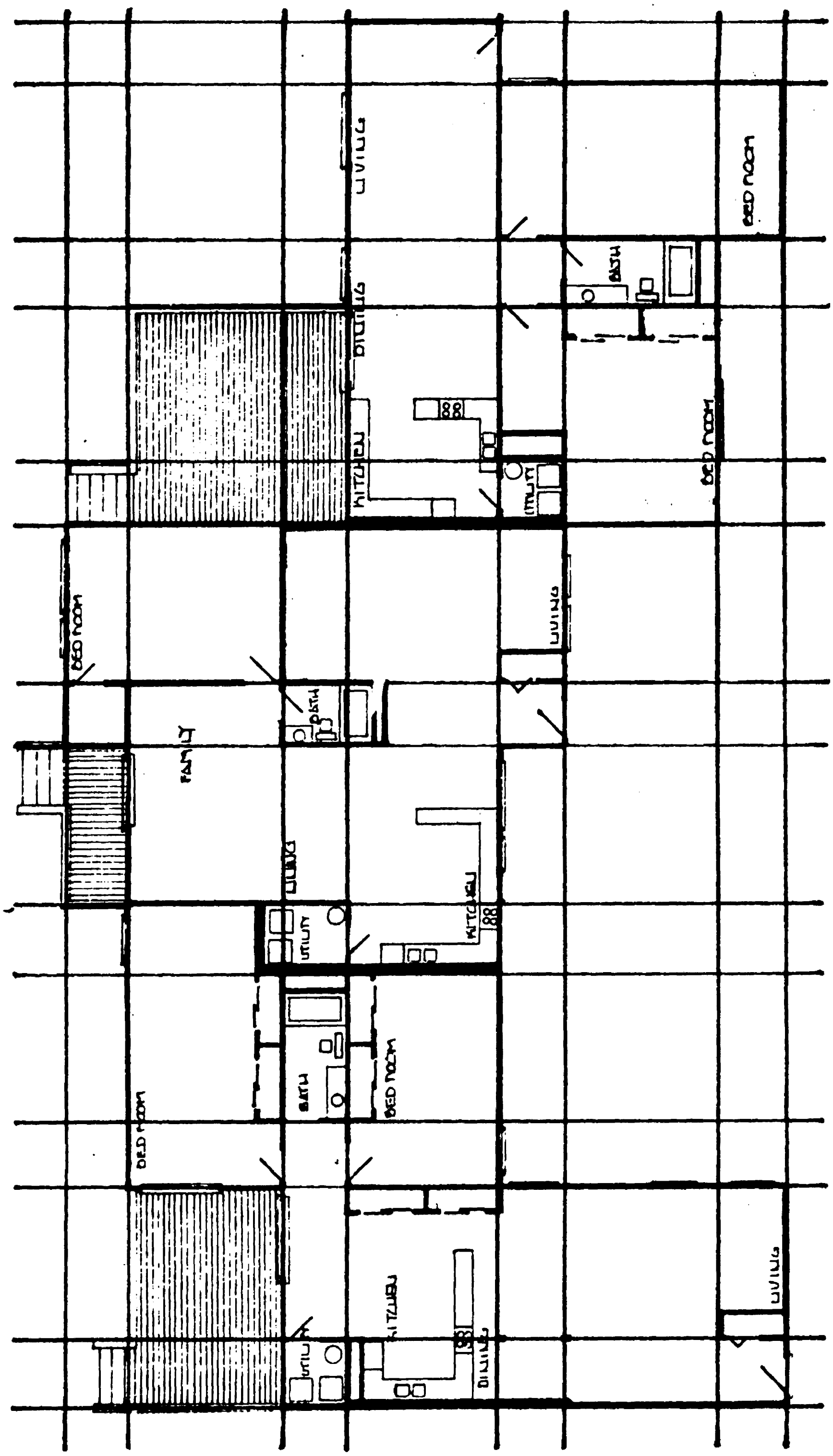


FIGURE 59 : STRUCTURAL GRIDS

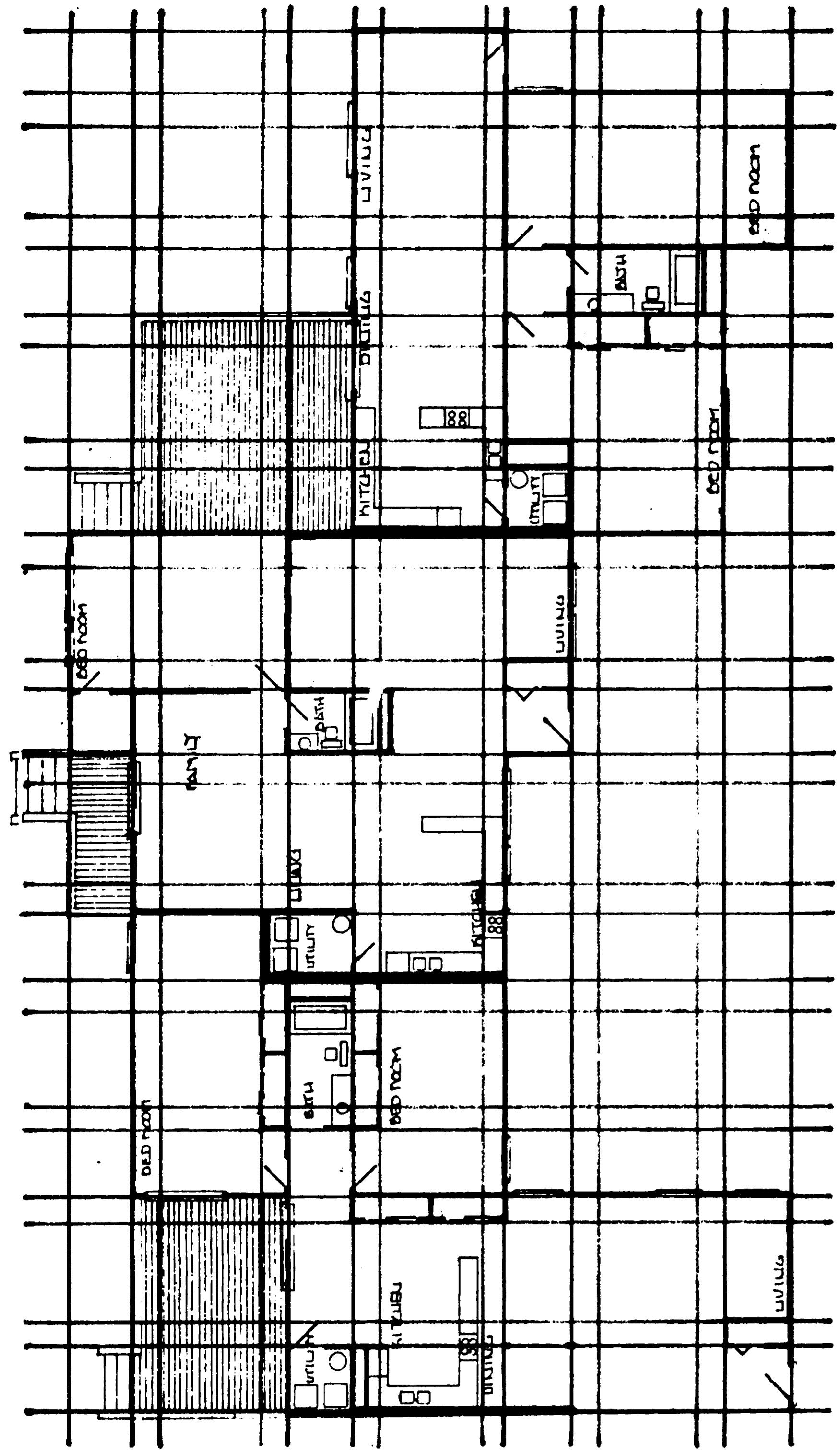


FIGURE 60 : STRUCTURAL & PLANNING GRIDS

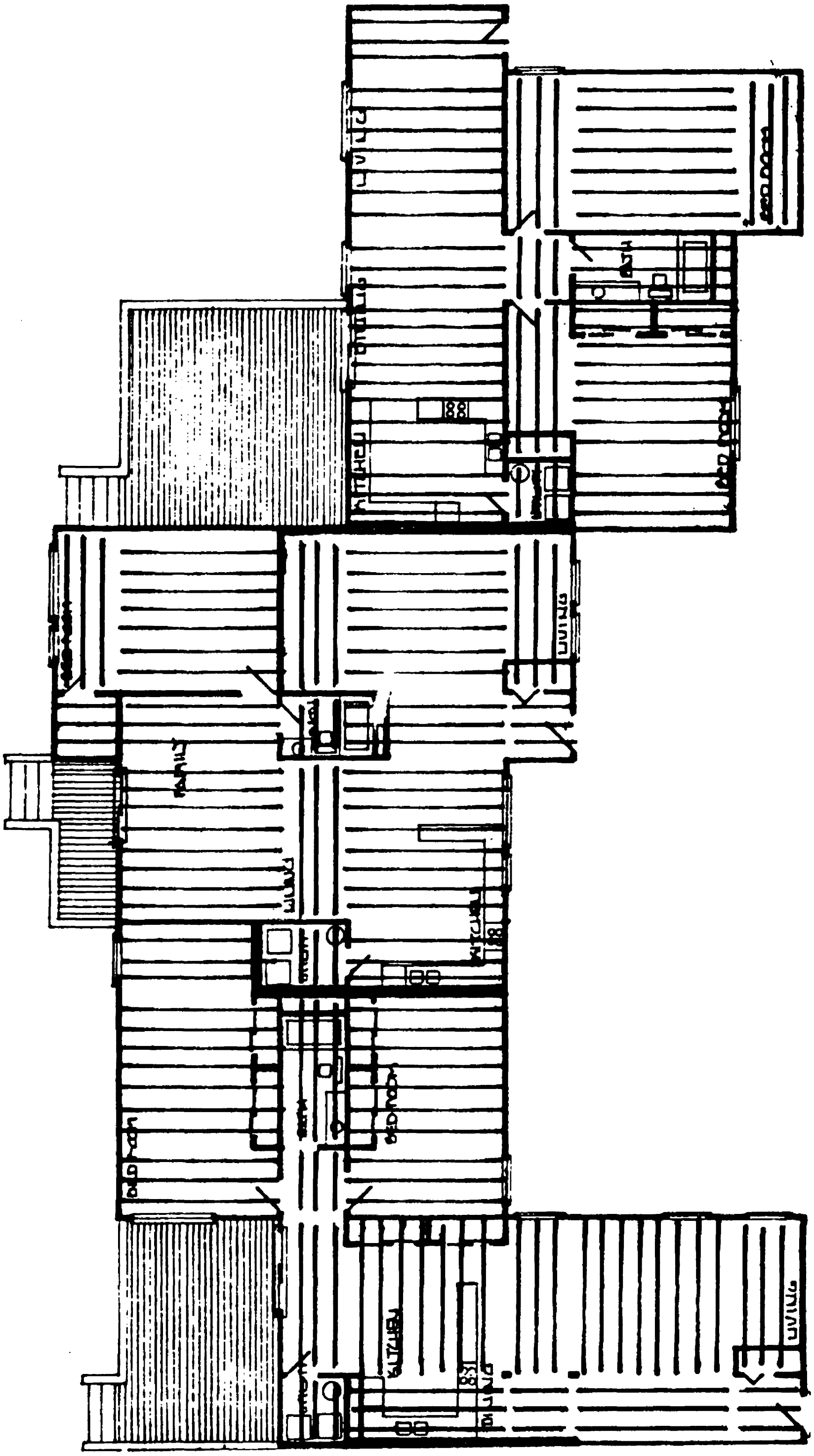


FIGURE 61 : JOIST PLAN

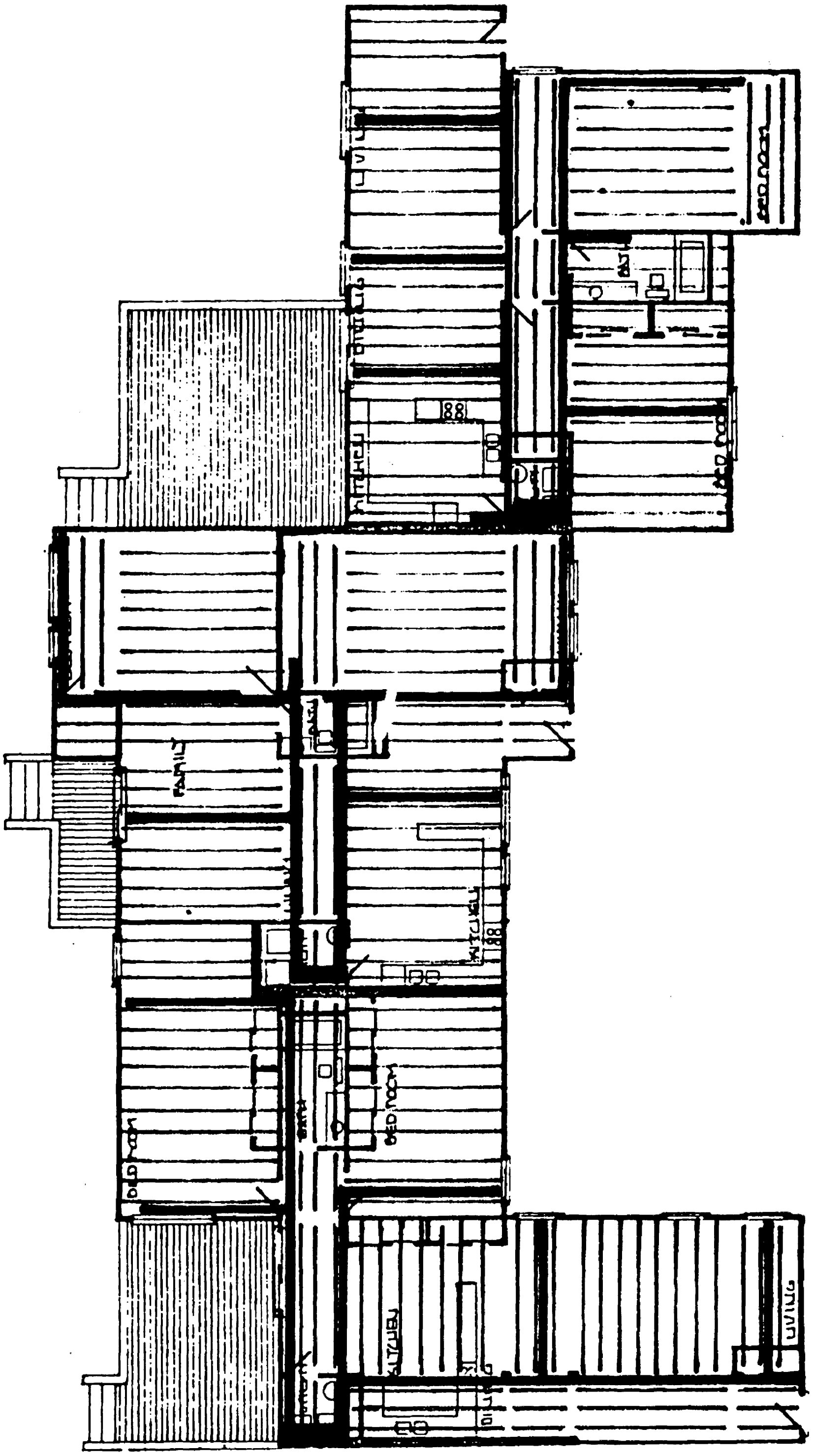


FIGURE 62 : HVAC DISTRIBUTION

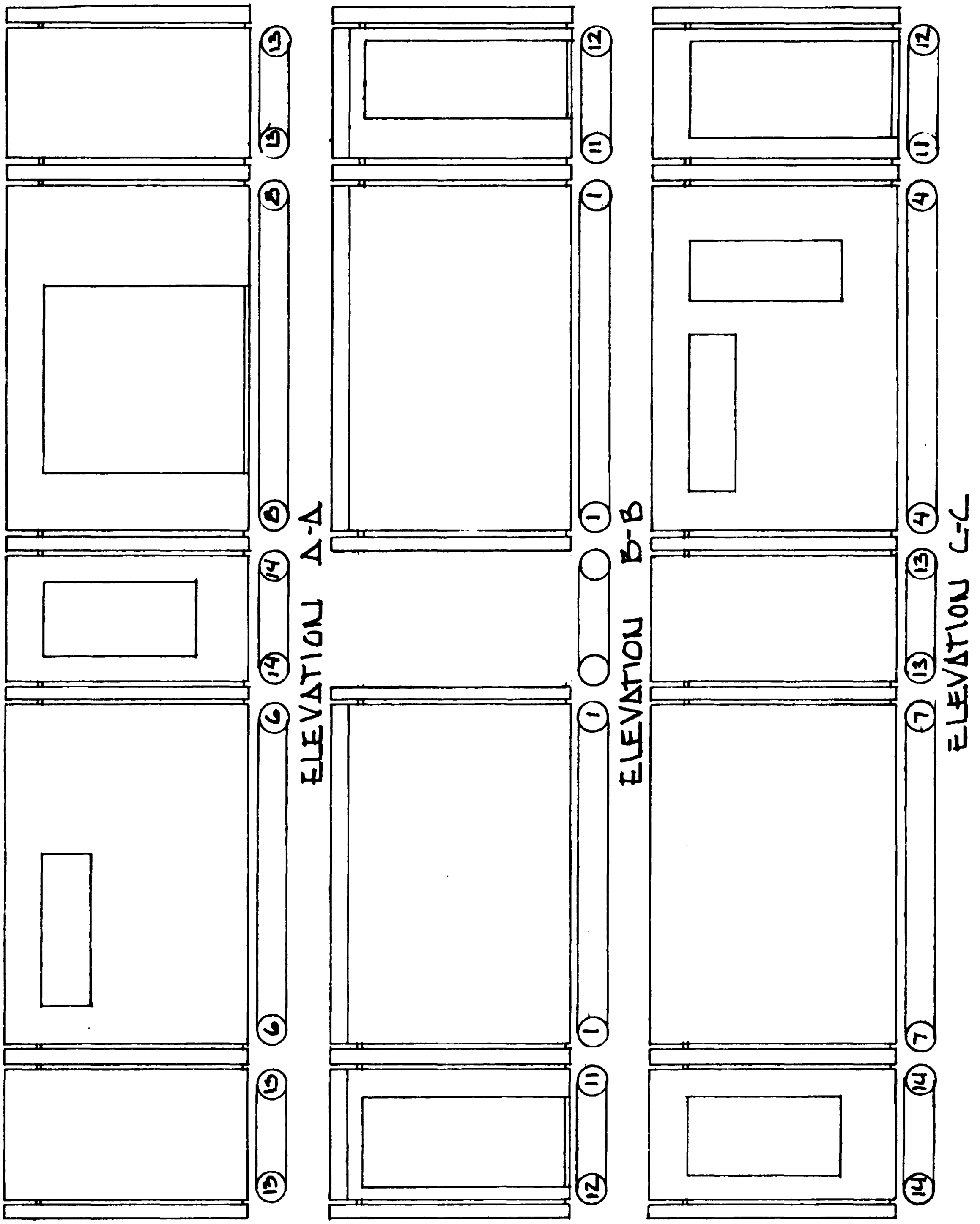


FIGURE 63 : PROPOSAL ELEVATIONS-COMPONENTS

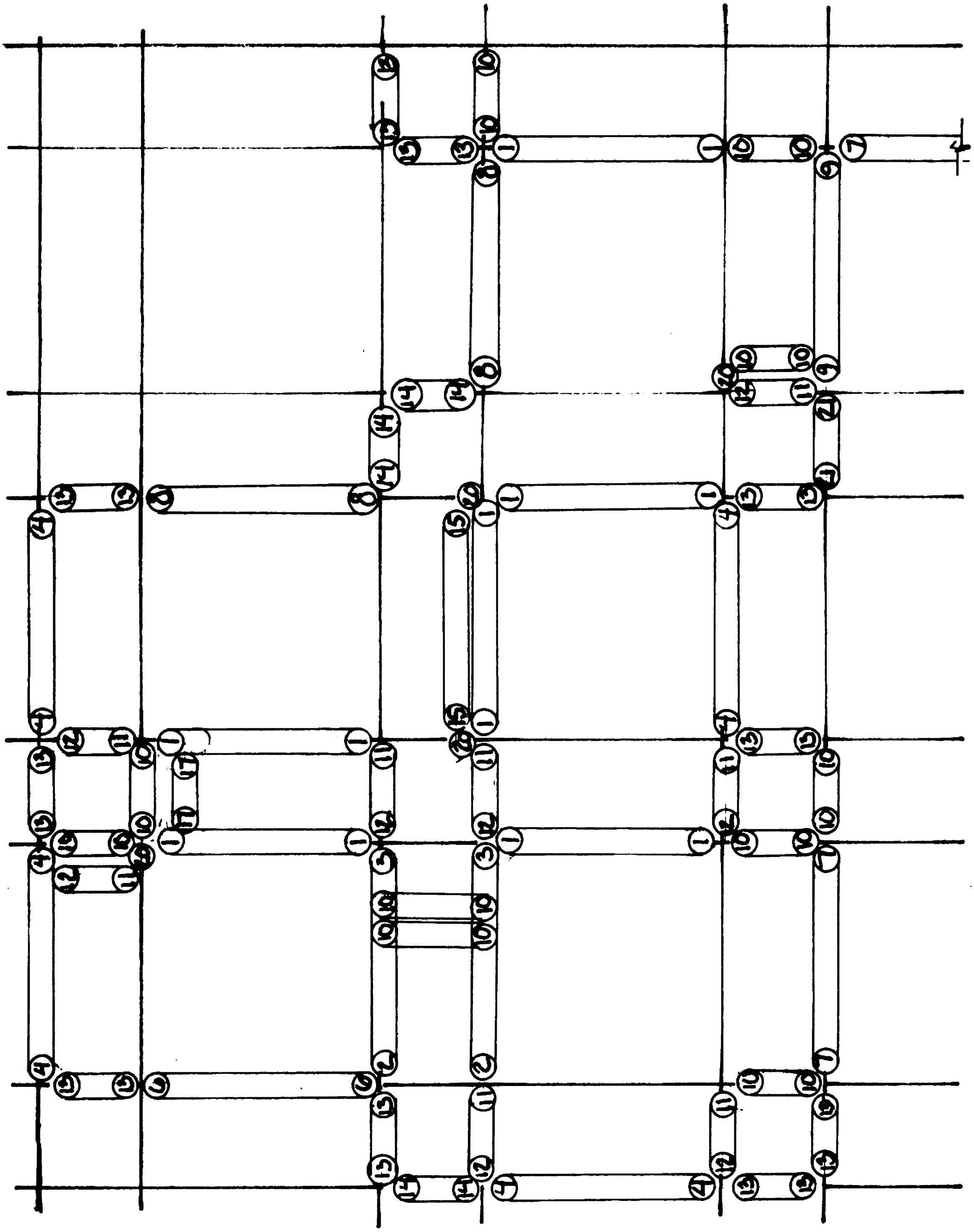


FIGURE 64 : CONSTRUCTION DOCUMENTS

Evaluation

Although the success of this type of proposal is ultimately tested in actual applications it is often very helpful and informative to generate a theoretical model with which to test the proposal.

To do this a hypothetical project was developed and both conventional approach to construction and the construction system proposed within this paper were applied to the project and evaluated as to their effectiveness.

Since it is difficult to evaluate the relative qualities (aesthetic, social, etc.) of the separate solutions it was assumed that neither system would necessarily be superior in this respect. Thus leaving economics as the major tool with which to measure the relative success of the proposal.

Project Description

Location	Blacksburg, Virginia
Land	15 Acres
Number of Buildings	25
Number of Apartments	300
Number of Bedrooms	540
Gross Building Area	307,800 Sq. ft.
Net Living Area	267,660 Sq. ft.

OUTLINE SPECIFICATION

Exterior Walls

2 x 4 Construction on 16" centers

1/2" Intermediate density fiberboard

Texture 1-11 siding

3 1/2" Fiberglass insulation R-11

Corner Bracing required

Interior Walls

2 x 4 Construction on 16" centers

1/2" Dry wall

Floor Framing

Floor Joist 2 x 10 16" O. C.

Wood Bridging with angle cuts for Joist spans over 8'0"

1/2" C-D Plywood Sub-flooring

5/8 x 4'8' partical board for underlayment

Roofing

1/2" C-D Plywood sheating on standard wood trusses 24" O. C.

15 Felt

235 Asphalt class "C" self-seaving shingles.

Heating

Electric

Economic Evaluation

It was next necessary to estimate both the value and the cost of these projects.

Since there are numerous examples or residential construction in the Blacksburg area similar to that outlined here, relatively accurate construction costs could be easily attained. Similarily documentation of the construction process as a function of time were also available.

For simplicity in handling the data, the construction process was divided into eight stages as outlined below.

Stage One - Foundation 5.3% Total Cost
$8,157 per building

- Excavation - backfill
- Footings
- Permits and Fees
- Slabs
- Underfloor plumbing
- Block work

Stage Two - Rough carpentry 20.9% Total Cost
$32,169 per building

- Structural steel
- Rough hardware
- Framing lumber

Rough carpentry

Stage Three - Insulation Ready 22.7% of Total

$34,939 per building

Rough plumbing

Rough heat

Rough electric

Roofing

Windows/doors

Siding

Stage Four - Drywall 11.7% of Total

$18,008 per building

Insulation

Drywall

Stage Five - Interior Trim 9.4% of Total

$14,468 per building

Trim carpentry

Kitchen cabinets

Finished hardware

Stage Six - Paint 2.4% of Total

$3,694 per building

Interior paint

Exterior paint

Stage Seven - Finish 24.4% of Total

$37,556 per building

Sheet goods

Finish HVAC

Finish plumbing

Finish electric

Carpet

Appliances

Stage Eight - Clean Up 3.2% of Total

$4,925 per building

Clean up

Fine grade top soil

Landscape

Punchlist

Total cost per building $153,943.

Each building has 12 apartments.

Average Sq. ft. is 10,706 per building.

Cost Summary

To estimate the total cost of such an undertaking it is necessary to estimate expenses such as financing, land, closing costs, etc. To do this we must first evaluate the value of the project. One method for doing this is called the income approach to value.

First the income from the property is estimated.

Number of Units	Type	Sq.Ft.	Rent Per Sq. Ft.	Yearly Rent
30	1 br.	626	31.6	$ 71,280
60	1 br. & den	764	28.5	$156,960
120	2 br.	894	26.7	$344,160
60	2 br. & den	1065	24.3	$186,480
30	3 br.	1062	25.8	$ 98,640

Total Units	300
Total Rentable Sq. Ft.	267,660
Gross Annual Income	$857,520
Less Vacancy/Collection Loss (4%)	-34,300
Auxiliary Income	+13,739
Total Gross Income	$836,959

From this figure is subtracted the operating expenses and the interest on the land:

Gross Annual Income	$836,950
Less Operating Expenses (approx. 38%)	-$318,044
Less Interest on Land ($450,000 10%)	-$ 45,000
Total Annual Net Income for Interest On and Recapture of Value of Improvements =	$473,914

This figure represents the value of the building not of the project. To find this figure the building value is capitalized at the current capitalization rate (9.8%) and the value of the land is added.

Building Value	$473,914
Building Value Capitalized 9.8% $473,914/.098	$4,835,857
Plus the Value of the Land	450,000
The Value of the Project	$5,285,857
First Mortgage Loan 75% of value	$3,964,392
Loan Requested	$3,965,000
Floor of Loan (3,965,000:85)	$3,370,250
Construction Loan (3,370,350:80)	$2,696,200

With this information we can estimate the total cost of the project:

Land	$94,000
Direct Building Cost	$3,847,900
Landscaping	322,000
Taxes (during construction)	8,595
Misc. closing costs	29,737
Overhead & Profit (Builders)	192,395
Contingency	96,197
Financing	
Perminant	
Bank Discount 1%	39,650
Loan Brokerage 2%	79,300
Construction	
Interest at 11%	272,900
Bank Discount 2%	53,900
TOTAL PROJECT COST	$5,036,574

Project Schedule

Before we can outline the entire project schedule it is necessary that we have a feeling for the amount of time this type of project would take to plan and organize. Since this type of responsibility is that of the architects it will be helpful to study the architects budget and allocation of fees:

Budget for Construction	$2,696,200
Basis for Architectural Fee	6.25%
Estimated Architectural Fee	168,512

Allocation of Fees

Profit	17%	$28,647
Consultants		
Construction Management	10%	$16,851
Landscape Architect	8%	$13,481
Direct Expenses (other than Salaries)	3%	$ 5,055
Indirect Expenses	30%	$50,553
Direct Salary Expenses	32%	$53,924

Allocation of Direct Expenses

			Hours
Project Administration	5%	$15/hour	180
Master Planning/Programming	8%	$15/hour	287
Schematics	15%	$10/hour	808
Design Development	17%	$10/hour	916
Working Drawings	35%	$8/hour	2559
Specifications	5%	$8/hour	337
Bidding	5%	$8/hour	337
Construction Administration	10%	$8/hour	674

The actual time this project would be in the architects office would of course be dependent upon the size of the office and the amount of other work it is involved in. For the purposes of this project it is assumed that there are 8 full time people involved on the project: the project architect, a job captain, a designer, a field man, and four draftsmen.

Figure 65 represents the project schedule from inception through completion.

In Figure 66 a more detailed diagram of the schedule may be seen.

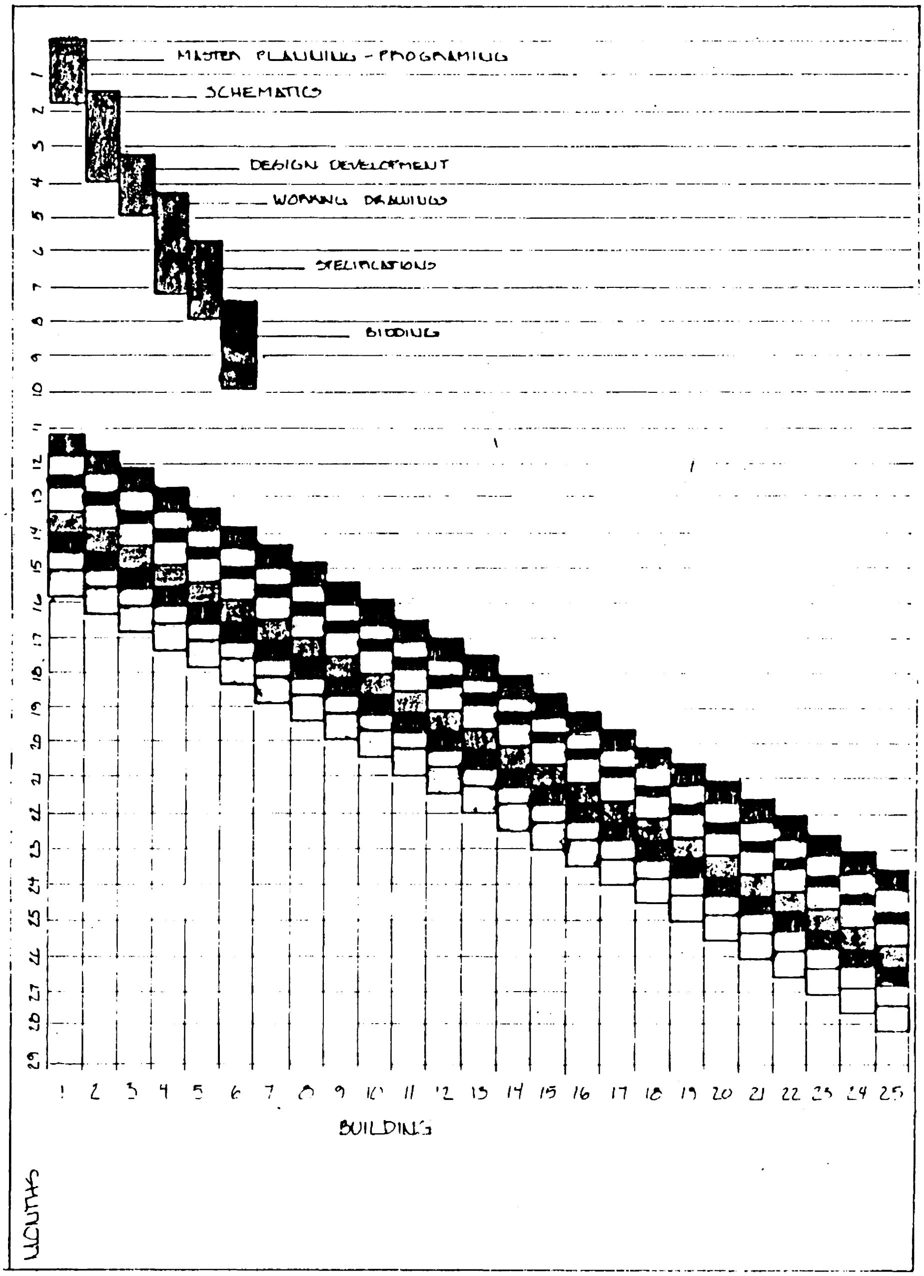


FIGURE 65 : CONSTRUCTION SCHEDULE - CONVENTIONAL

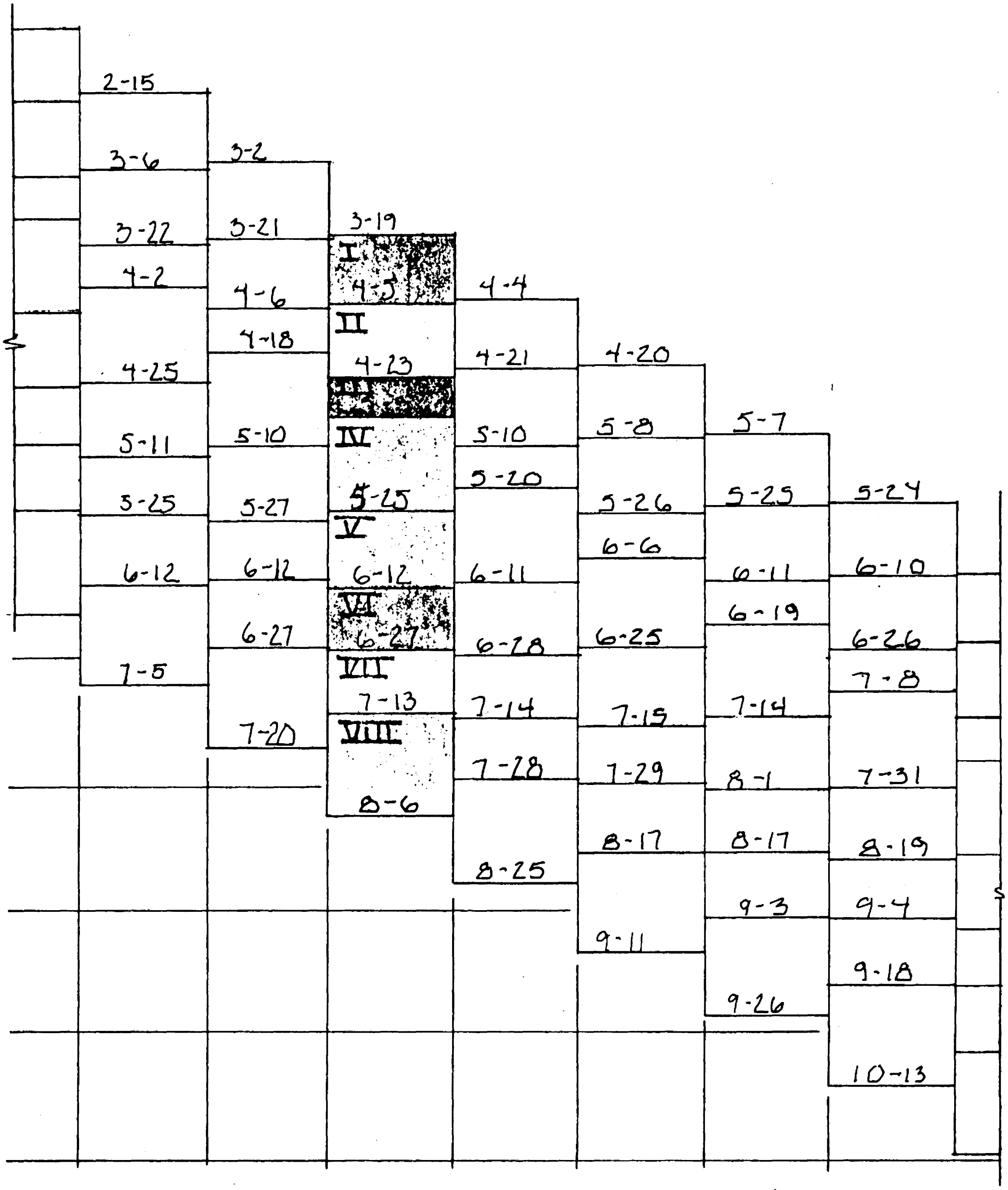


FIGURE 66 : DETAIL - CONSTRUCTION SCHEDULE

Proposal

It becomes obvious that there are two ways in which time savings may be realized during the construction process.

Figure 67 represent the possiblity of reducing the duration of a number of process. This may be done through the use of standardization, prefabrication, industrialization, etc.

Figure 68 represents the possibility of reducing the time lag between different buildings. This presents a major opportunity to reduce construction time. Since the time lag between buildings is determined by the process with the greatest duration if that process may be reduced significantly it will result in a sizable savings in time.

For example the processes with the longest durations in this type of construction are rough carpentry and drywall. Rough carpentry has been allocated 17 days for completion in the preceding schedule. If this time is reduced significantly one of the other proccess, drywalling, becomes the limiting factor.

For example if the time lag between buildings is reduced by 6 days per building the overall savings would be 6(25) or 150 days.

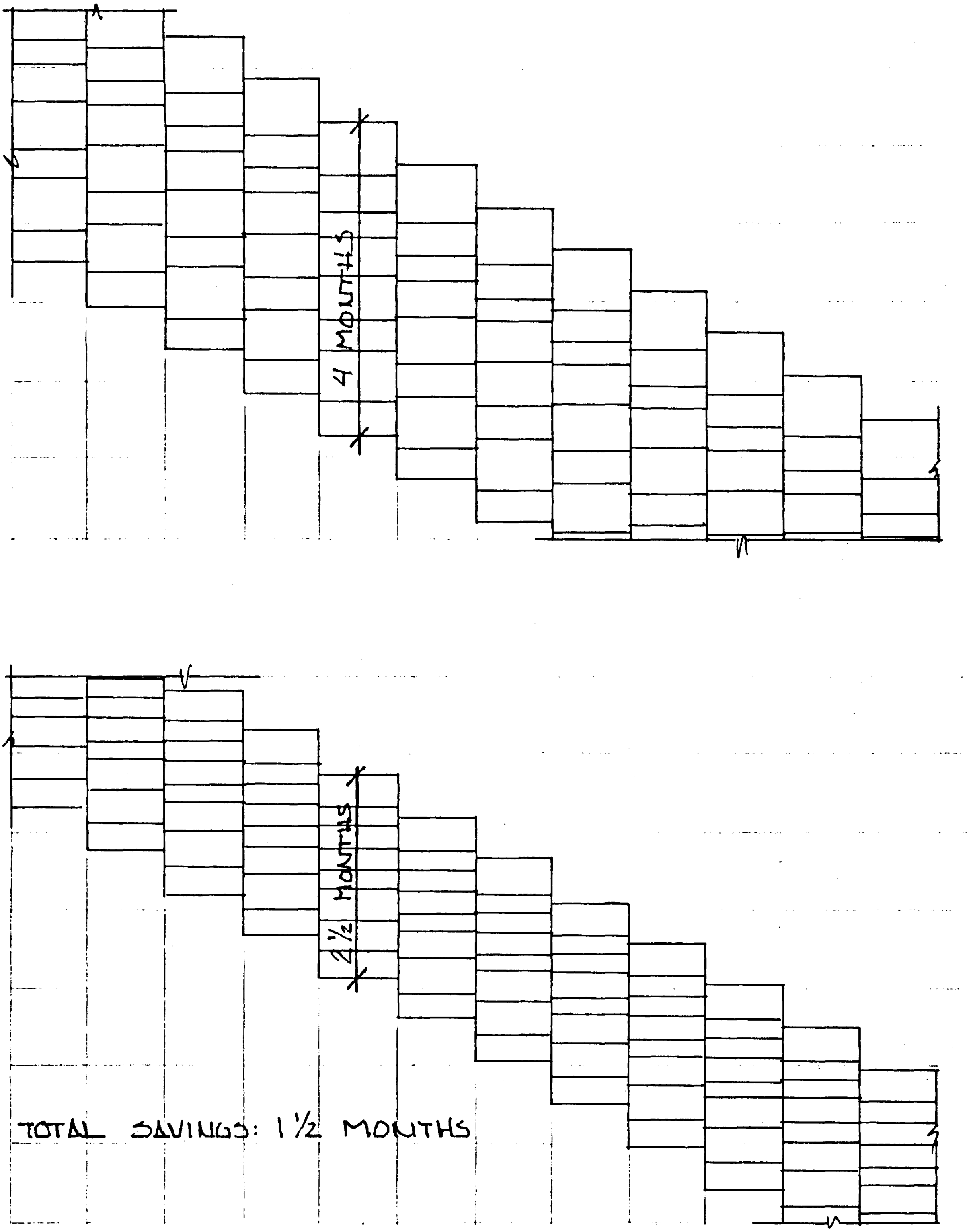
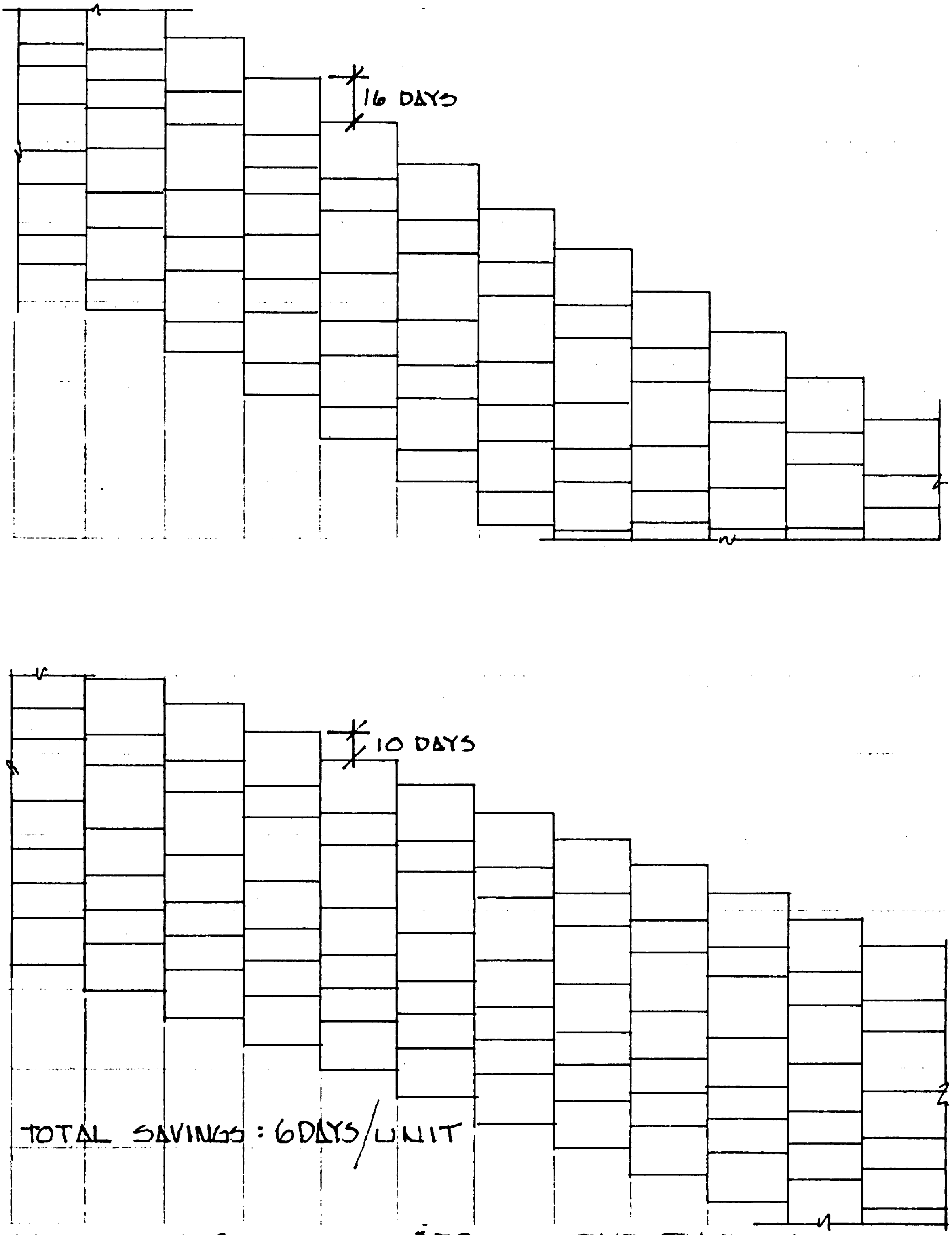


FIGURE 67 : REDUCING THE DURATION OF SEVERAL ACTIVITIES



TOTAL SAVINGS : 6DAYS/UNIT

FIGURE 68 : REDUCING THE TIME LAG BETWEEN BUILDINGS.

Figure 69 represents a schedule that reflects a reduction from 17 days to 9 days in time lag between buildings. This 8 day reduction is the result of using the penalized system proposed in this paper which effectively reduces the time needed for rough carpentry and drywall process to take place.

Reduction of construction time to or beyond this point would of course require efficient construction management. Thus a reallocation of architectural fees.

Budget for Construction		$2,696,200
Basis for Architectural Fee		6.25%
Estimated Architectural Fee		$ 168,512
Allocation of Fees		
Profit	17%	$ 28,647
Consultants		
Construction Management	15%	$ 25,277
Landscape Architect	8%	$13,481
Direct Expense (other than salaries)	3%	$5,055
Indirect Expense	30%	$50,553
Direct Expenses	27%	$45,498

Allocation of Direct Expenses

			Hours
Project Administration	5%	$15/hour	181
Master Planning/ Programming	13%	$15/hour	472
Schematics	20%	$10/hour	1089
Design Development	22%	$10/hour	1199
Working Drawings	20%	$8/hour	1362
Specifications	5%	$8/hour	340
Bidding	5%	$8/hour	340
Construction Administration	10%	$8/hour	681

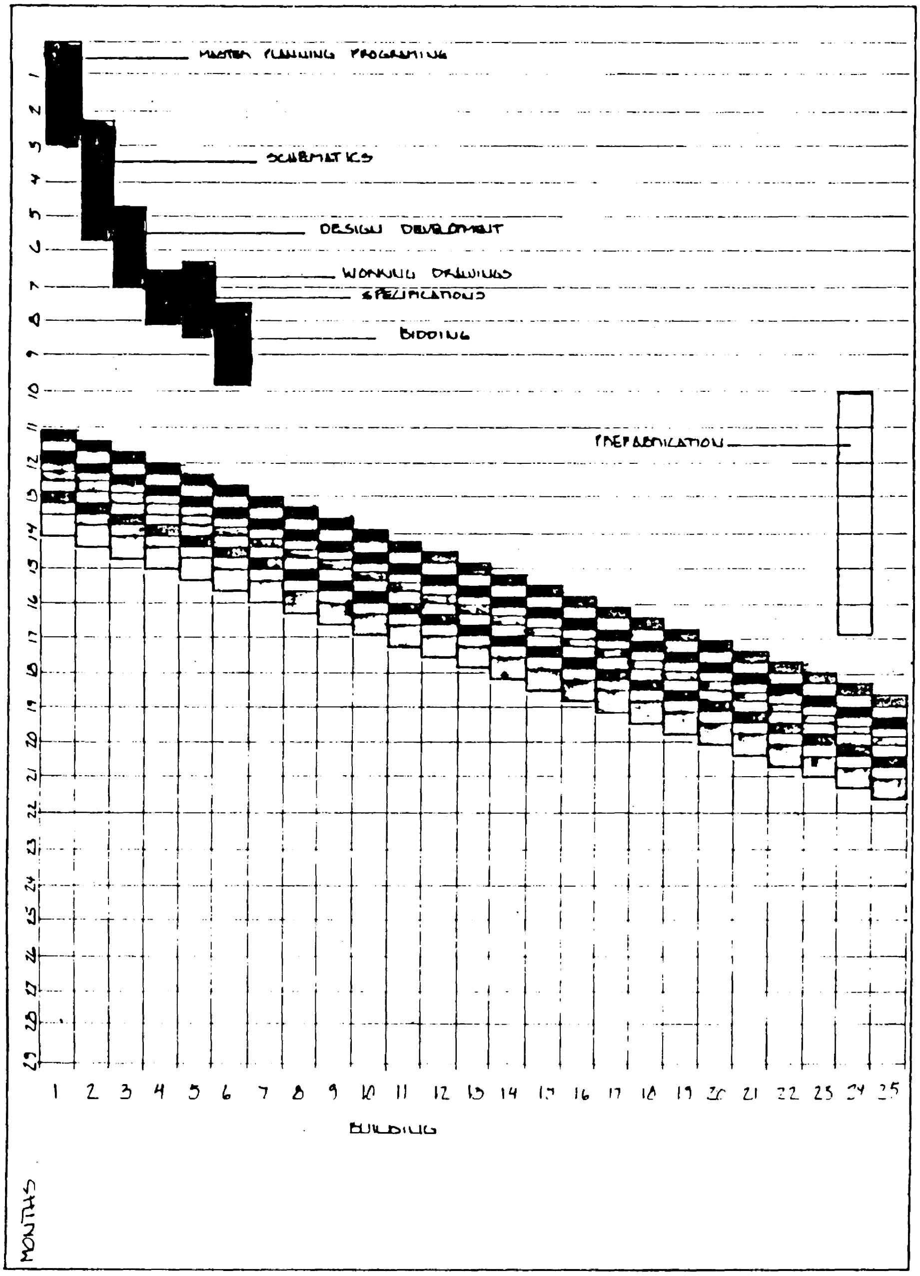


FIGURE 69 : CONSTRUCTION SCHEDULE PROPOSED

Economic Evaluation

As indicated in Figure (69) there has been a change in the staging of the project.

- Stage One - Pre-fabrication
    - Fabrication of all structural and non-structural walls
    - Fabrication of floor/roof components
    - Siding
    - Drywall
- Stage Two - Foundation
    - Excavation backfill
    - Permits and Fees
    - Footings
    - Slabs
    - Underfloor Plumbing
    - Block work
- Stage Three - Erection
    - Erection of Components
    - Structural steel
- Stage Four - Insulation Ready
    - Rough plumbing
    - Rough heat
    - Rough electric
    - Roofing
    - Windows/doors

  - Finish Siding
- Stage Five - Drywall
  - Finish Drywall
- Stage Six - Interior Trim
  - Trim carpentry
  - Kitchen cabinets
  - Finish hardware
- Stage Seven - Painting
  - Interior Paint
  - Exterior Paint
- Stage Eight - Finish
  - Sheet goods
  - Finish HVAC
  - Finish plumbing
  - Finish electrical
  - Carpet
  - Appliances
- Stage Nine - Clean Up
  - Clean up
  - Fine grade topsoil
  - Landscape
  - Punchlist

To compare the costs of these two systems three factors were considered: material, labor, and contingency (resulting from uncertainty of future prices).

The following is a comparison of the two systems costs.

Description	Cost	% change	Contingency Category L,M,H	Contingency Factor %	Projected Cost
Excavation Backfill	500		L	3	485
Footings Slabs	3350		M	3.5	3232
Block	2716		M	3.5	2621
Structural Steel	2296	+30%	H	7.5	2760
Framing Lumber	22585	+ 5%	M	3.5	22884
Rough Carpentry	15797	-20%	M	3.5	12195

Rough Plumbing	7858		M	3.5	7583
Rough Electrical	4860	-10%	M	3.5	4222
Rough Heat	6322		H	7.5	5847
Roofing	1769		H	7.5	1636
Doors Windows	5677		L	4.5	5421
Insulation	3025		M	5.5	2858
Drywall	11150	-10%	M	5.5	9483
Internal Trim	6687		M	5.5	6319
Tile	1498		H	7.5	1385
Paint	3701		M	5.5	3497

Kitchen Cabinets	5072		L	4.5	4843
Finish Hardware	2712		M	5.5	2563
Finish Electrical	3578	- 5%	M	5.5	3212
Finish Heat	5836		H	7.5	5398
Finish Plumbing	7785		M	5.5	7356
Appliances	10654		M	5.5	10068
Carpet	7600		M	5.5	7182
Landscape	2156		L	4.5	2059
Misc.	8733		M	5.5	8252
Total	153917				143361

With this information we may estimate the total cost of the project:

Land	$ 94000
Direct Building Cost	3584000
Landscaping	322000
Taxes (during construction)	5814
Miscellaneous Closing Costs	29737
Overhead and Profit	179200
Contingency	89600
Financing	
Permanent	
Bank Discount 1%	39650
Loan Brokerage 2%	79300
Construction	
Interest @11%	123575
Bank Discount 2%	53900

Total Project Cost	$4600776

Thus comparing this figure with that of the conventional cost of $5036574, we realize a savings of approximately 9.47%.

Summary

As has been demonstrated in the above example, the opportunity to reduce the total cost of a project through reduction of construction time is one which has a substantial return.

In evaluating the success of this proposal, one must keep in mind the implications of the 9.47% figure and realize that it is dependent upon a number of factors.

For example, if this system was applied to a larger project, the 9.47% figure would increase almost proportionately. That is if the project was twice the size this figure may be as large as 15 or 16%. Similarly, if the economy becomes less stable, this figure will rise. Of course the converse of both these points is also true.

Finally, one must consider the opportunities presented here for further research. The most important opportunity to act upon here is that of further reducing the construction time lag discussed earlier. Through study into and resolution of inefficiencies, further savings due to reduced construction time may be realized.

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3. Ibid., page 54.

4. "Way House Prices Are Soaring," Nations Business, Volume 65, September 1977, page 52.

5. Time, op. cit., page 52.

6. Time, op. cit., page 52.

7. "House Hunters and Builders Still in Trouble-The Reasons," *U. S. News and World Report*, Volume 79, Sept. 8, 1975, page 54.

8. *Time*, op. cit., page 50.

9. "New Unpredictability of Prices and Supply," *AIA Journal*, Volume 61, May 1974, page 19.

10. Ibid., page 19.

11. "George Heery States The Case For Discipline In Support Of Architecture," *Architectural Record*, Volume 154, July 1975, page 41.

12. "Construction Management, In Miama Test, Saves $1.5 Million," *Architectural Record*, Volume 161, January 1977, page 75.

13. *Architectural Record*, Volume 154, Op. cit., page 41.

14. *U. S. News & World Report*, Dec. 9, 1974, op. cit., page 54.

Appendix - The Timely Cost of Construction

The concept that "Time is money" is by no means new, but is of increasing importance, especially in the field of construction.

As the time related costs of construction increase they make up a larger portion of the overall cost of a project. As this proportion becomes larger it provides a greater opportunity through which to reduce the cost of housing. For example: in the middle 60's the difference between the cost of a project completed in 8 months as compared to one completed in 24 months may have been only 5%. But in the 70's with high inflation, high interest rates, and market fluctuations the difference in price between these two projects may be 20% or more.

What follows is a discussion of a number of time-related costs of construction and an evaluation of the effect of construction duration on the ultimate cost of a project.

For convenience in illustrating some of the following concepts a feasibility study will be used. The study, conducted by a New York broker/realtor, involves a 795 unit apartment community situated on 45 acres of land 25 miles North-West of Chicago. Considering location and the fact that the study was conducted for a 1973 completion date, the data should be conservative if anything.

Although it is not indicated in the study, I feel that it is reasonable to assume that the case study would have taken approximately 24 months to complete. To illustrate the effect of construction duration on total project cost I will compare the figures from this project to those of the same project with an 8 month construction duration. I understand that at this point a 66% reduction of construction time may be optimistic and this must be kept in mind in reviewing the following conclusions.

Construction Funding

The basic concepts involved in the financing of a construction project are fairly simple. After a commitment for a long term mortgage is obtained, the borrower must obtain a construction loan; a loan to pay the bills during construction. This loan is short term and will be paid off by the mortgage loan upon the completion of construction. To minimize risks, the amount of the construction loan is usually only 75-80% of the permanent financing, which in this case is $13,500,000. The construction loan would then be approximately $10,800,000.

A portion of this amount would be disbursed in monthly draws to take care of bills that have accumulated to that time. The cost of this construction loan has three components: a brokerage fee, the banks discount, and interest.

The brokerage fee and the bank's discount are both constant, and must be paid in advance. For this reason these costs are not affected by the duration of construction. The interest is however, and the following equation estimates the interest costs of a construction loan:

$$\frac{\text{loan amount}}{\text{months of loan}} \times \frac{\text{interest rate}}{12} \times 1+2+3+4 \ldots \text{months} -1$$

By substituting the proper numbers and using a current interest rate of 11% we find that for a 24 month completion date the interest would amount to $800,055. The same calculation using an 8 month completion date would result in $243,495 or a savings of $556,560.

$556,000 is approximately 3.2% of the total project cost, a figure which would become more significant during periods of higher inflation.

Taxes

The taxes levied on land during construction can amount to a sizable sum. In the example study these taxes totaled $190,000. Taxes are usually stated as a proportion of tax per $100 of assessed value per year and thus a constant rate over time. The result of reducing the construction duration to 8 months would effectively reduce this tax figure to $63,333. This represents a .7% reduction in total project cost.

Unrealized Profits

In comparing a project that is completed in 24 months to one completed in 8 months it can be seen that the 8 month project is producing a return to its investors for 16 months before the 24 month project is completed. This is referred to as unrealized profit, and may be computed for our example study by subtracting the annual expenses and the annual mortgage payments from the annual income and multiplying by the difference (in years) in completion time.

(2,540,832 - (889,673 + 949,152)) x 4/3
(2,540,832 - 1,838,825) x 4/3
702,007 x 4/3
$936,009 would be the total unrealized profit.

If the project investors were in a 10% leverage position this would result in the investors recouping 52% of their original investment in the 8 month project before the 24 month project was completed.

Although the impact of unrealized profit on the initial cost of a project depends on many factors and would be very difficult to quantify, a general statement may be made to the effect that: In comparing the cash flows of these two projects from an investors point of view the 8 month project is considerably more desireable and in most cases would reduce the risk associated with that investment. By reducing the risk of an investment investors in an efficient market would be willing to accept a lower return on investment. This may amount to as much as 2% or $364,608.

Inflation and Unpredictable Prices

"The United States learned to live with the predictable and uniform inflation of the 60's and early 70's. But unfortunately this has changed in recent years, although inflation is still with us it is no longer predictable and far from being uniform".[9] The sudden emergence of energy shortages has combined the world market fluctuations and price controls to produce random scarcity in material and supplies with corresponding price jumps.[10] This new unpredictability of prices affects many everyday decisions of most businesses especially small ones and business that have long lead times.

For example in the 60's predicting the price of a product to be produced and delivered a year from the present data was simple. The current price was increased by the current rate of inflation plus some measure for contingency which may have been 1 or 2% depending on a number of factors. But today with prices sometimes doubling in a year the process of predicting the future has become more difficult and often hazardous. This problem may be minimized in businesses which are adequately diversified but what about small business who's total investment may be affected by such a price jump. What is the effect of time on the uncertainty of such decisions.

The result of this new unpredictability is that small business, in an attempt to protect their own interests, have resorted to high contingency bidding. In some cases, as documented in a March 26, 1974, Wall Street Journal article titled Broken Promisises - Many Contracts Now Aren't Worth Paper They're Printed On, many small businesses are simply backing out of contracts they do not feel they can not economically fill.

This problem is often compounded when, for instance, in the building industry the general contractor, realizing that he may have trouble enforcing his contracts, must also resort to high contingency bidding in an attempt to protect his own interests. Contingency on top of contingency of course must be paid somewhere along the line, often by consumers in the form of high artificially inflated prices.

To determine the effect of this unpredictability of future prices we may set up a series of sequentially probable events. Figure 70 represents such a series of events. Each circle represents a possible rate of inflation and each square represents the connected probability of its occurance. Thus by assigning values to each circle and each square we may determine the expected value of the sequence by summing the products of the conditional probabilities and the expected value of each possible outcome.

It is then possible through properly manipulating the interest rates and their probabilities of occurance to simulate different situations. For example: Figure 71 represents a situation in which every 8 months there is a possibility of inflation being 6%, 9%, or 12% with the probability of each occuring 3/10, 4/10, and 3/10

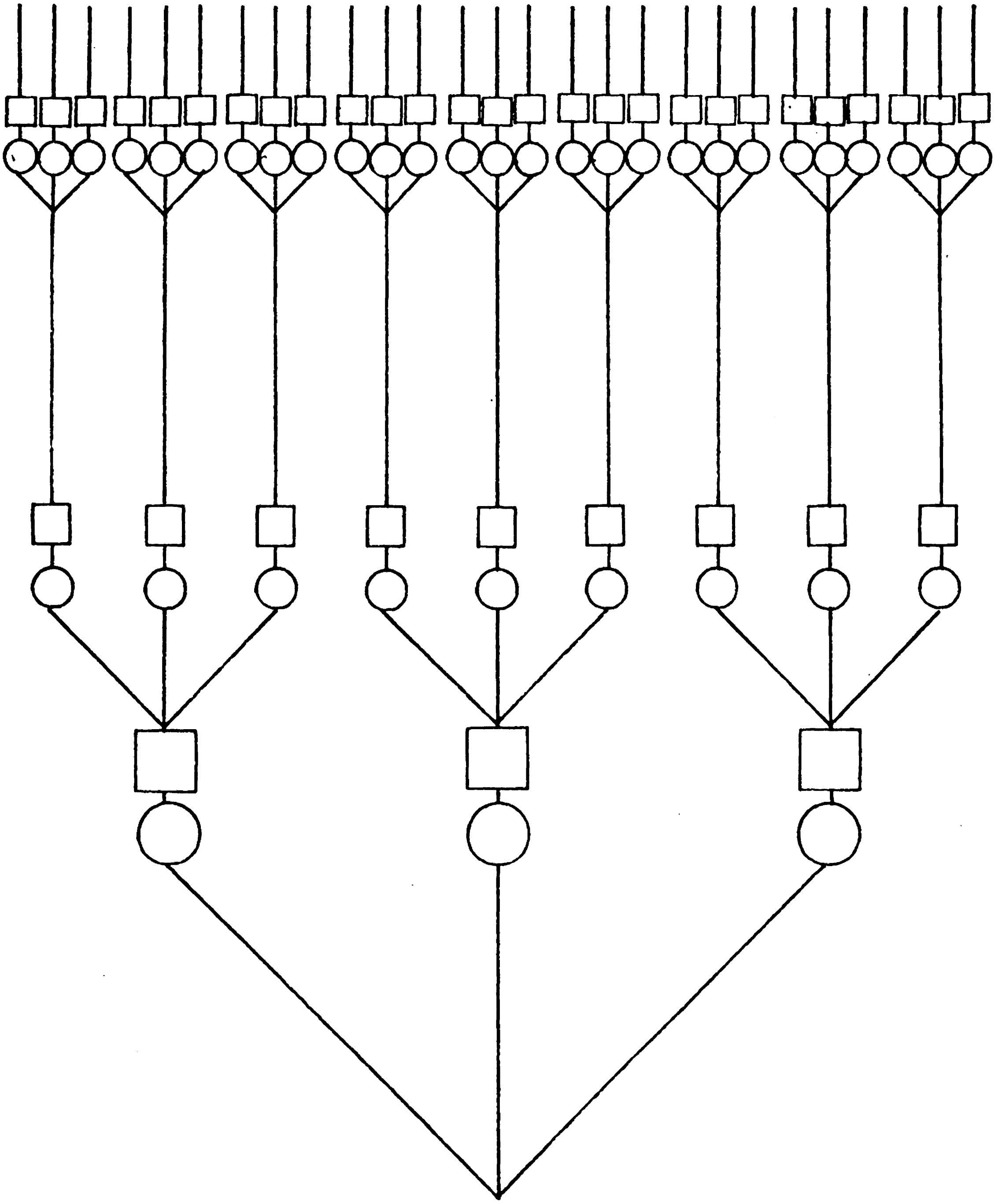


FIGURE 70 : SEQUENTIALLY PROBABLE EVENTS

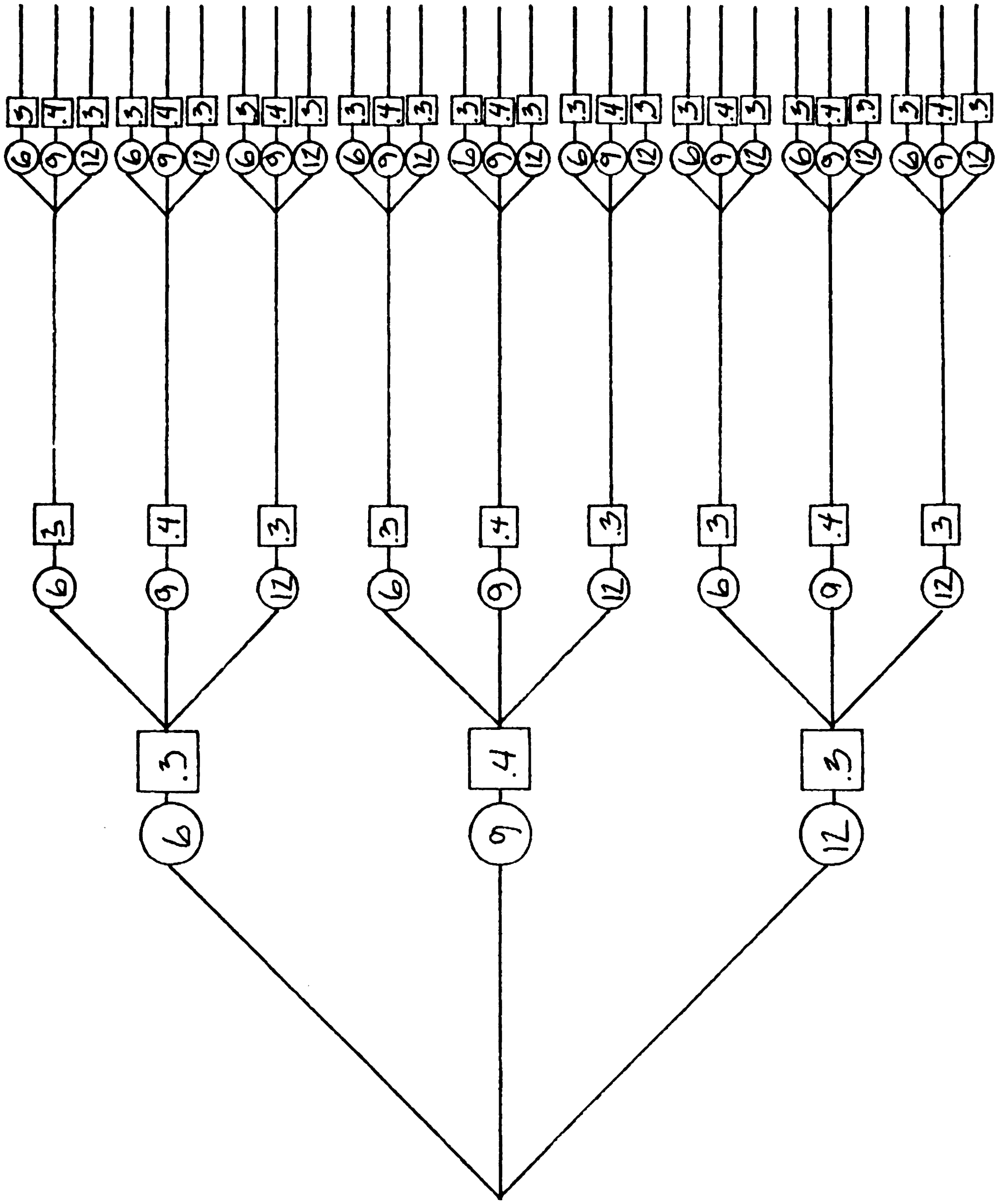


FIGURE 71 : EXAMPLE : INFLATION 6%, 9% & 12%
PROBILITY 3/10, 4/10, & 3/10

respectively. The expected value after 8 months is 1.09 and after 24 months is 1.295. These values are represented in Figure 73 by vertical black lines and are both labeled 1.09. Let us accept this as the actual (most probable) rate of inflation.

We may now model the actions of a risk averse person by changing the squares in Figure 70 from probabilities to decision points. Now we can see in Figure 72 that we may simulate the same inflation rates as were in Figure 71 but represent the aversity through weighting the individuals choice to the higher inflation rates. The expected value of this series will represent the value this particular individual would demand in return for taking the risks shown. We may then change these decision points to model increasing or decreasing degrees of aversity.

We may also change the rates of inflation to illustrate the effects of different possible outcomes. For example, a distribution of 6%, 9%, and 12% would be a more stable situation (investment) than a 6%, 9%, and 18% distribution since the possibility of an 18% increase exists in situation 72 where the worst possible outcome is only 12% in situation 71.

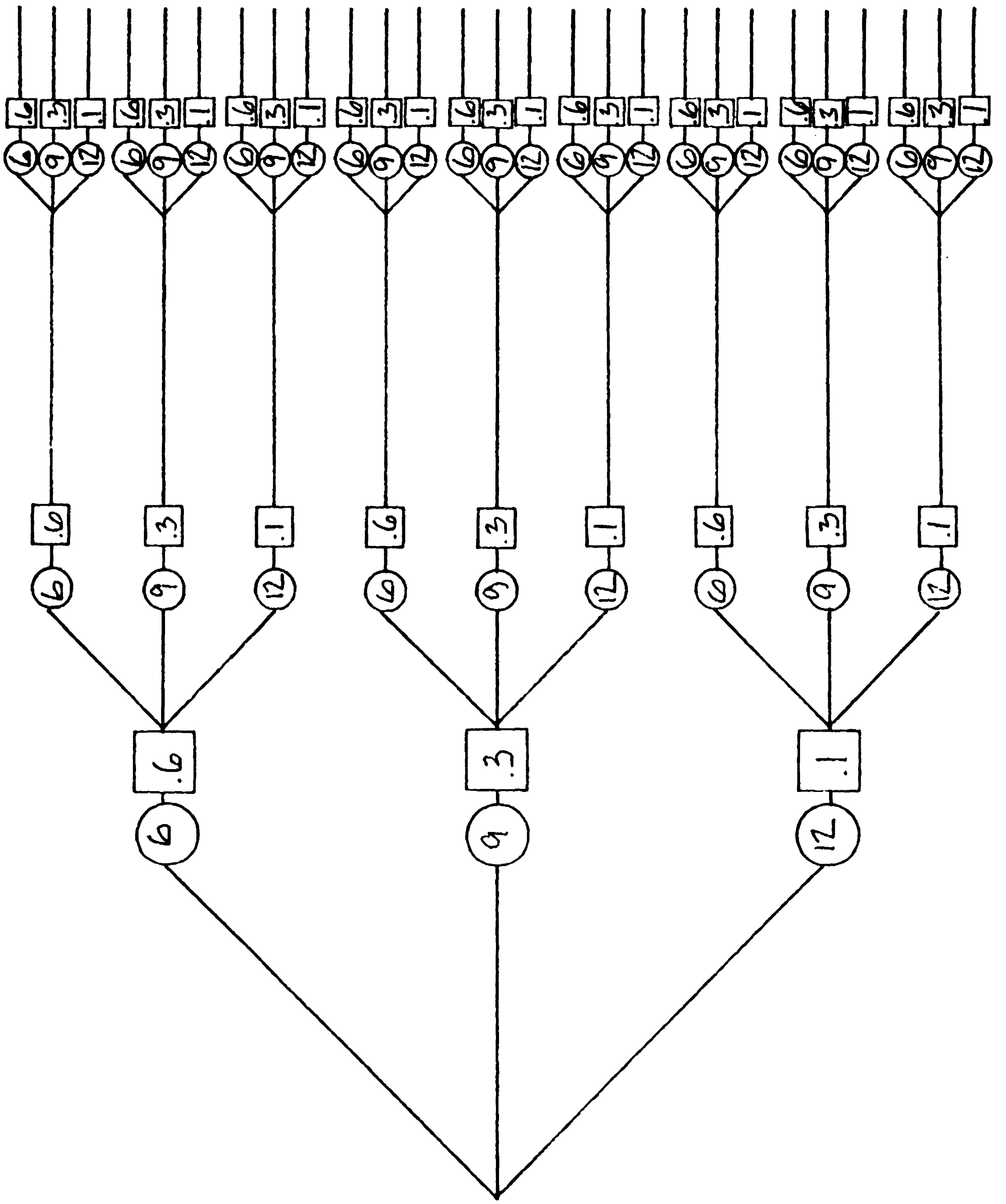
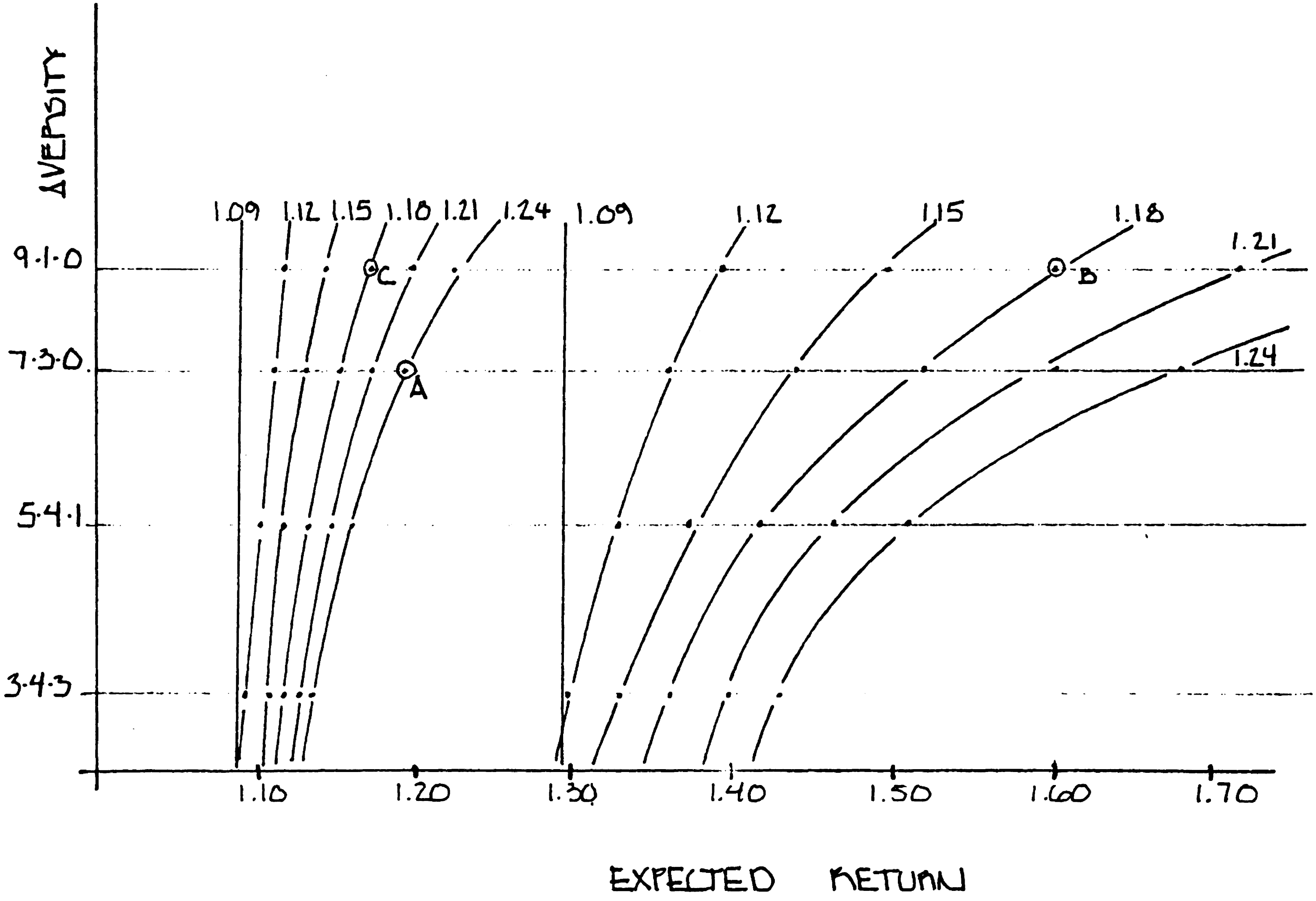


FIGURE 72 : MODELING AVERSITY

FIGURE 73 : AVERSITY & EXPECTED RETURN



Referring to Figure 73, the first set of 6 curves represent the expected values of 4 progressively risk averse people (horizontal lines) in 6 situations of varying stability (curves). For example point "a" represents the situation depicted in Figure 74.

In evaluating the curves if you read from left to right along the horizontal lines the intersection of these lines with the curves represent the expected return of a certain level of risk aversity in a particular level of stability. For example: point "c" represents the expected return (17.2) of a very risk averse (9, 1, 0) person in a situation where the worst possible outcome would be an 18% rate of inflation. (Of the three possible rates of inflation only the highest has been changed in generating the data for this graph. The first two have been held constant at 6% and 9%).

If this graph is read up and down along the curves we see the affect of increasingly risk averse people on an investment with a constant stability.

The second set of six curves represent the same process only over three 8 month periods. Now we may evaluate the effect of time on the expected value of an investment. For example: Points "b" and "c" represent the same investor investing in two projects of the same

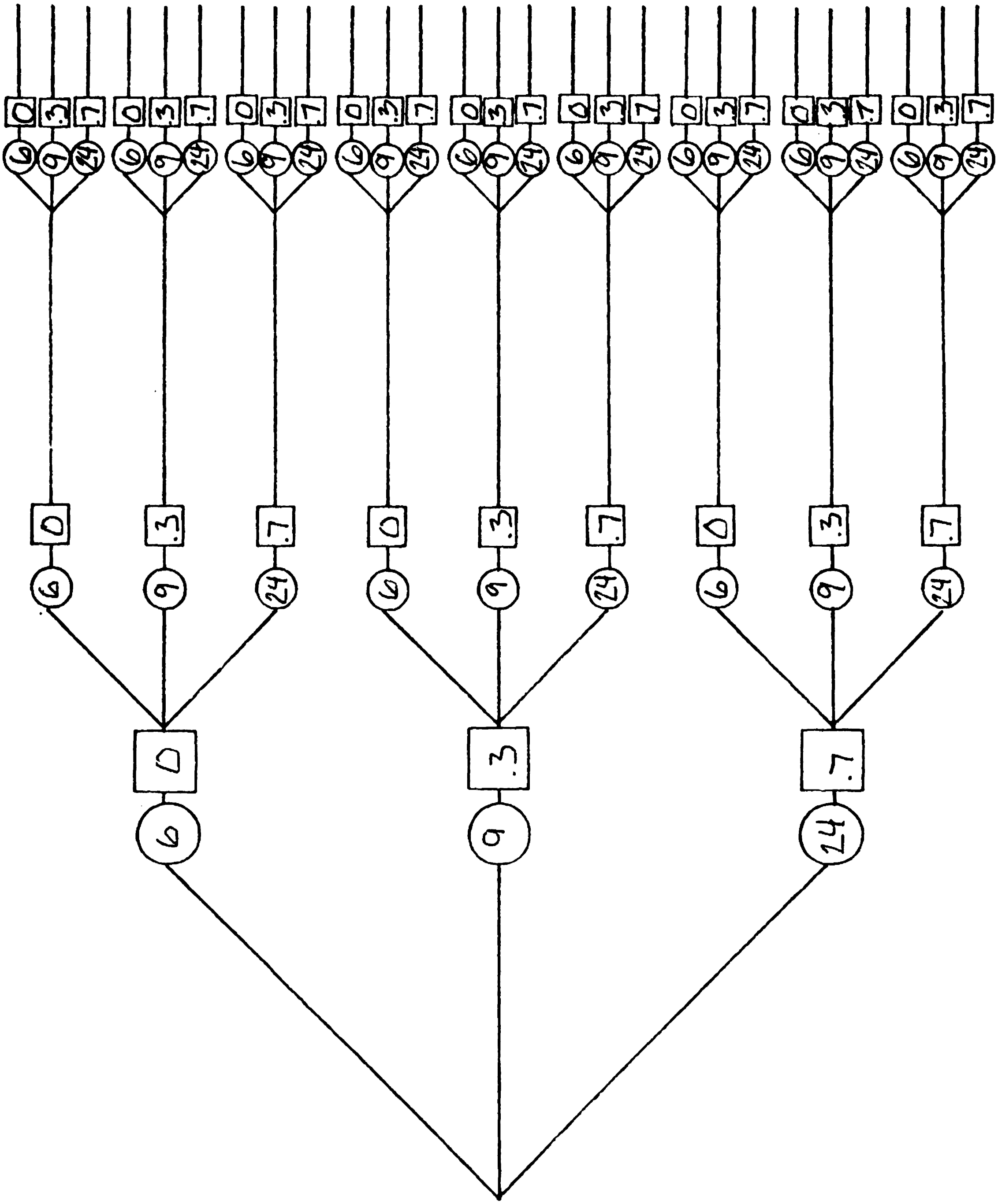


FIGURE 74 : REPRESENTATION OF POINT "A"
FROM FIGURE

risk but over a different period of time. Project "c" is to be completed in 8 months and project "b" is to be completed in 24 months. The outcome of the 8 month investment is that the investor requires a 17.2% return on an investment who's most probable outcome is 1.09. Thus a contingency of 8.2% is demanded. The 24 month investment requires a 61.5% return on an investment who's most probable outcome is 1.295 or a contingency of 32%.

The difference between these two contingencies (23.8%) represents the price one pays this investor to enter into this investment for 24 months instead of 8.

For example: if the investor represented here was a plumbing contractor who is approached for a bid on a project whose present value is approximately $100,000 and he was asked to bid the job for completion in 8 months and in 24 months. His bid for 8 months would be $117,200 and for the 24 month project it would be $161,500. If the rate of inflation for the plumber did remain approximately at the expected value of 9% the plumber would have over bid the 8 month project by $8,200 and the 24 month project by $31,977. So the cost to the purchaser of this plumbers services 24 months in advance rather than 8 months was $23,777 or 21% of the projects value.

It is difficult to translate this rather general model into hard figures that we may use in the real world but rather the model's values lies in its illustrative power. It illustrates that when dealing in a business such as the construction industry where many contractors and subcontractors are small nondiversified businessmen, in an unpredictable economy such as it exists in the United States today. The premium that is paid for work to be done at increasingly distant dates in the future is very high. Conversely the reward for reducing this period of time is equally high.

Thus the opportunity here is tremendous. If an architect can reduce the construction time by, as in our example, 66% from 24 months to 8 months a savings of as much as $3,007,000 or 16.5% of the total projects cost may be realized.

Construction Management

"Construction management is that group of management activities, over and above normal architectural and engineering services, related to the construction program - carried out during the pre-design, design, and construction phases - that contributes to the control of time and costs in the construction of a new facility." [11]

It should be understood that through the use of this definition it is not inferred that construction management will always be apparent in the pre-design, design, and construction phases of a project nor it is inferred that construction management exists only in large projects but that it is an integral part of all successful projects large and small and may exist in many forms.

Need or Value

The need for efficient construction management can be linked to one fact: time is money. The ability to organize men, materials, and activities in time may determine the success or failure of a project.

The number of activities necessary to build even a small project like a single family house requires a high level of organization. Without this organization, time works against you, increasing the time-related costs involved in construction such as; interest on loans for construction, and land, taxes, inflation, overhead and profit. In large multi-million dollar projects these costs can amount to a sizeable percent of a building's cost. For example, in Miami CM Associates, a construction Management firm, was responsible for the scheduling, cost control, evaluation of design decisions in terms of time and cost, and managing the procurement and construction of a 250,000 square foot high school. In comparing this project with a similar 238,000 square foot high school built at the same time, in the same county using a general contracting approach and a linear schedule it was found that the use of construction management not only built the highschool ten months faster (21 months as compared to 31 months), but saved approximately 1.5 million dollars or 15% of the total budget.[12] From this we may conclude that construction management is a possible alternative through which sizable savings in construction costs may be realized.

Forms of Construction Management

It should be understood that construction management is used as a general term and may represent many different situations.

The example cited earlier involved a construction management firm, CM Associates, a group of highly trained professionals using sophisticated techniques, and included involvement in every phase of a project from the early planning stages to constructions end. On the other hand, there is the field superintendent of a builder/developer concern whose involvement is often only in construction. Although the sophistication and scope of these jobs vary greatly, the objectives are the same and they are both involved in construction management.

Architects and Construction Management

It is obvious that the field superintendent of a developer/builder has very little control over the early decisions that are made concerning the units he builds.

This is also true in some respects of construction management firms that are allowed to participate in the evaluation of early architectural proposals. What I am referring to here is the fact that construction management is limited in its affect on construction by the extent to which existing construction systems facilitate their objectives. The development of a construction system that facilitates the objectives of construction management may prove economically desirable overall even though it may be awkward, inefficient, or more expensive at particular states of construction. For example, as discussed earlier, a construction system that would reduce construction time by 66% could be 10% more expensive and still provide a savings of about 15% in the overall cost of a project.

Objectives of Construction Management

"... the control of time and costs in the construction of a new facility." [13]: Here in lies the major objective of construction management. There are many techniques that have been developed to handle this type of problem. Because these techniques fall within the specialized field of construction management and out of the scope of this discussion we will not pursue the individual techniques. Instead I will handle the techniques as a conglomerate, identifying characteristics of the whole rather than of the parts.

To gain control over the ultimate time and costs of a project it is first necessary to identify, organize, and coordinate the smaller components that contribute to the overall time and cost.

Identifying the component parts of a construction project is rather straightforward though by no means simple. The component parts of a project for the purposes of this paper will be referred to as activities. These activities include all necessary jobs in the completion of a project; all subcontracts, supervision, accounting, expediting, inspection, ordering, etc. The number of activities is of course dependent on the type and size of the project undertaken and for even the simplest of projects there may be 100-120 necessary activities. For this reason the efficient organization and coordination of the activitieis in time becomes a complex task.

The three most important factors limiting the efficient organization and coordination of activities in time are; the number of activities, the duration of each activity, and the relationships between the activities. Of course by the time a project has reached the construction phase the majority of these factors are already determined. However, let us identify some alternatives that would facilitate more efficient time and cost effective organization and coordination during the construction phase.

Number of Activities

Intuitively, all other things being equal, if we could reduce the number of on-site activities necessary to build a project we could simplify construction management. This could be achieved in at least two ways; reducing the variety of activities or by decentralizing activities.

Duration of Activities

In discussing the duration of an activity it must be kept in mind that duration can be measured in at least two ways. It can be measured in man hours which is job related, or it can be measured in activity hours which is time related. The difference between these can be illustrated by the example of a plumber who, because of outside circumstances such as weather or a scheduling mistake, did a one man hour job in 7 days. To control the duration of activities we must then control both of these factors.

There are at least two ways to control the man hours required to do a task through either simplification or standardization. Simplification refers to the relative number of component parts and standardization refers to the limited number of ways in which the component parts may be used together. The relative simplification and/or standardization will have a direct relationship to both the time required and the level of skill needed to execute an activity.

To control the other component of duration we must become as independent as possible from outside circumstances. Although this is sometimes impossible and often not beneficial, we should attempt to do so when circumstances prescribe. Of course the major circumstance which is beyond our control is the weather. It may prove to be to our benefit to decentralize some construction activities that are easily affected by weather and are capable of being moved off site.

Another factor to be considered when discussing activity duration is the concept of trip generation. This refers to the fact that some trades must go to a site on four separate occasions to complete one general activity. For example: plumbers, for a single family house, must show up early in the construction process to do the under floor, later they must return to do the rough plumbing, they must return again to connect gas lines and tap into the meter, and their last trip is to install the fixtures: a total of four trips. If this could be reduced to two or three everyone would benefit because of easier scheduling and fewer costly delays.

The Relationship of Separate Activities

The relationship between separate activities is probably the single most determining factor contributing to the organization of a construction project. The fact that a conventionally built house can not be framed until the foundations have been poured is a relationship that obviously constrains the coordination of a construction project. Interdependent and overlapping activities are two examples of types of constraining relationships in the organization of the construction process.

Interdependent activities are activities that depend on either the completion of another activity or proper decisions made during another activity before they may proceed. For example: a plumber is depending on the carpenter to plan for the plumber's needs. Often, for one reason or another, the carpenter does not and the construction process is slowed down while either the carpenter corrects the problem or the plumber works around it.

Overlapping activities are situations where the same space has a number of uses. For example; when an electrical crew arrives on a job to rough cut a house, one of the electrictions spends the better part of a day drilling holes through floors, plates, studs, joist, etc. Although all overlap is not necessarily inefficient, there are certainly some areas in which some improvement could be realized.

Summary

It has been shown that in many instances that time is becoming a major component of a projects cost. For this reason construction management has been successful in reducing overall costs of projects.

As explained earlier, the possible benefits that may be obtained through efficient construction management are in many ways limited by the extent to which existing construction systems facilitate construction management's objectives. Of course by changing construction systems to better facilitate efficient construction management we will no doubt infringe on set patterns of construction in other fields which may have adverse affects. For this reason proposals that modify construction systems should attempt to make changes within the existing framework.

What I am proposing is that even though the construction systems we use today are successful and built upon sound reasoning, they are becoming less efficient (economically) as the factors contributing to the cost of construction change. For example; the extent to which the time related costs of construction have become an increasingly large portion of construction costs has not yet been reflected in the basic responses of architecture in general. This presents a realistic opportunity for the architectural profession to improve the cost of housing in the U.S..

Land

In recent years land prices have risen faster than any other major component of housing in the United States. Between 1967 and 1974 developed land prices rose at the average yearly rate of 13.4%.[14] Although the price of land can not be controlled by the architectural profession its efficient use presents a major opportunity through which the cost of housing may be reduced.

It is clearly demonstrated, in many projects, that some people think that since the cost of land per unit will decrease as the intensity of land use is increased, the simple solution to high land costs is to increase the density until the cost is sufficiently diminished.

However, the limit to which we may increase the use of land, and in so doing decrease the cost of housing, depends upon many complex considerations, considerations which are primarily based within the concept of human response to the built environment.

Although a study of human environmental factors is outside the scope of this research the general implications of human factors should be kept in mind while developing and evaluating increased density housing proposals.

Unit Size

Interest in unit size stems mainly from the fact that unit size is approximately directly proportional to unit cost. Since an architect can control unit size he may thus control unit cost.

The problem then becomes one of determining an appropriate unit size. Unfortunately in developing a system which is to be applicable at a national scale it is found that the spatial requirements of people in different parts of the country, different economic situations, etc. will vary greatly. Even within similar demographic groups living in different areas of the United States we find large differences. For example: The average size of a 3 bedroom apartment in Washington, D. C. may be 40% smaller than a similar apartment in some part of the northwest.

From this it becomes apparent that any decision unnecessarily restricting unit size will diminish its usefulness. Unfortunately some restrictions are necessary mainly as a result of our desire to standardize. As we will find, the primary constraints that will restrict unit size, such as the systems structural requirements, will reduce unit size flexibility.

The responsibility of the architect at this point is to produce a standardized framework that responds, to these primary constraints, while allowing the secondary constraints, i.e., unit size, as much flexibility as possible.

Scale of Production

In recent years many proposals have been made that attempt to resolve the rising cost of housing through the use of large scale production. These proposals have had relatively little real success. In most cases this is the result of applying a good solution to the wrong problem. More specifically: mass production has a limited number of applications, and when improperly applied will not be successful.

It must be realized that the implications of mass producing products are many and that there is not always an economy of scale. As we move from onsite construction through local prefabrication to regional mass production we find many factors, not just scale of production changing. Factors such as capital structure, relationships of working capital to sales, assets to sales, raising allocating and accounting for capital and management techniques to name a few. A simple example may illustrate this point best.

Lets examine the component costs (material, labor, capital investments, management and transportation) of three building components at 3 scales of production: (on site, local prefabricated, and regional mass production)

1) A non-standard stud wall
2) A standard flight of stairs
3) A vitrified china water closet

It would be found in producing the non-standard stud wall that the increasing transportation, capital investment, and especially the management costs could not offset any economies realized in materials and labor at the local or regional scales of production. In fact the management costs of producing such non-standard products alone would most likely be prohibitive. Thus for a non-standard product such as this on-site construction would usually be most economical.

In the case of a standardized flight of stairs; if an appropriate scale of production, over which capital investments may be deferred, can be achieved, the economies realized in material and labor at the local scale may offset the capital investment. But since in this case the product being produced is of relatively low technology few further economies may be realized at a regional scale of production which with its increased transportation costs would most likely be unfeasible. Thus for standard products which have a sufficient volume over which the capital investment may be deferred local prefabrication may be most economical.

Products such as toilets lend themselves best to mass production. Being of relatively high technology, the capital investment necessary to produce them must be deferred over a large volume of products; thus effectively prohibiting on-site or local prefabrication.

These examples may be some what oversimplified but begin to point up a mistake often made: assuming that there are always economies to scale.

The responsibility of an architect at this point then is to realistically evaluate all the implications of different scales of production for each component and make proposals that are as realistic as possible.

Standardized Components

The value of standardized components has been known and used widely for many generations in the building industry. Components come in many shapes and sizes ranging from the use of pre-cut studs, prefabricated roof trusses, and the use of entire rooms as components.

The value of a system of standardized components may be illustrated by Figure 75 in which the use of standardized wall sections are used. Figure 75A represents the wall layout of a conventional house. It can be seen that the dimensions of nearly all of the components are unique. In Figure 75B nearly the same spaces are formed using only four components. It may be seen that there is little lost through the use of a standardized system of components. The quality and quantity of space do not necessarily suffer. But what is to be gained through the use of standardized components?

Although the benefits from standardizing this scale of building component for one house is neglagable if the components were to be used in a 400 unit apartment complex the benefits become apparent. Benefits are realized through the possible use of prefabrication, an economy of scale, and a general simplification of the entire project.

Standardizing components and the way in which they interface can resolve a complex project into a relatively small number of simple tasks. But what do we standardize?

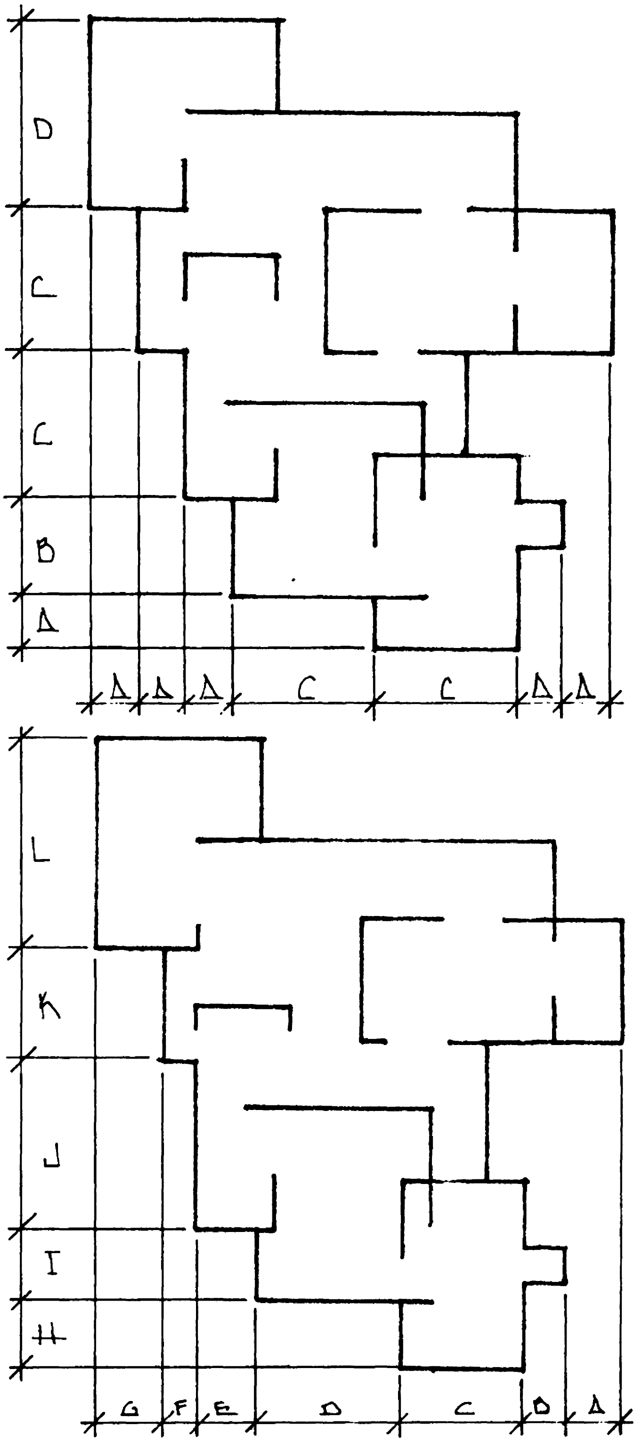


FIGURE 75 : USE OF STANDARDIZED COMPONENTS

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An Architectural Response to the Housing Crisis

by
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(Abstract)

An investigation into the characteristics of the housing crisis was conducted to identify a number of opportunities through which the architectural profession might contribute to the resolution of the housing crisis. These opportunities were evaluated and used as organizing elements in the development of an architectural response.

It was decided that a construction system was needed which would reduce the cost of housing through the use of standardization, prefabrication, and a close attention to facilitating efficient construction management while not unnecessarily constraining decisions which were related to the specific user or site.

It was determined that a prefabricated system of standardized components that interfaced in a simple and consistant manner using both conventional methods and materials would best service this purpose.

Such a system was proposed and a number of sample applications were developed and evaluated.