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THE USE OF LINEAR VOIDS WITHIN
A STRUCTURAL FLOOR SYSTEM TO DISTRIBUTE
AND RETURN MECHANICAL SERVICES

by

HERMAN B. ZINTER

B. Arch., University of Minnesota, 1961

SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF ARCHITECTURE
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
June 1966

Signature of Author . . . .
Herman B. Zinter, 27 June 1966
School of Architecture and Planning

Certified by . . . .
Eduardo F. Catalano
Thesis Supervisor

Accepted by . . . .
Lawrence B. Anderson
Chairman, Departmental Committee on Graduate Students

72 Spring Street
Medford, Massachusetts 02155

June 25, 1966

Dean Lawrence B. Anderson
School of Architecture and Planning
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts 02139

Dear Dean Anderson:

In partial fulfillment of the requirements for the degree of Master of Architecture, I hereby submit an investigation in the use of linear voids within a structural floor system to distribute and return mechanical services.

Respectfully,

Herman B. Zinter

ACKNOWLEDGEMENTS

I am grateful to the following persons for their advice and assistance during the development of this thesis:

Eduardo F. Catalano	- Thesis Supervisor
Waclaw Zalewski	- Structural Engineer
Eliahu F. Traum	- Structural Engineer
Leon B. Groisser	- Structural Engineer
Sidney Greenleaf	- Mechanical Engineer

ABSTRACT

It is proposed in this thesis that linear voids within a precast concrete floor system be used as secondary ducts for the distribution and return of conditioned air. Incorporated in the geometry of this one-way system are provisions for air volume and temperature control mechanisms, water supply and waste systems, electrical power and communication raceways, and alternatives for room illumination, air diffusion, and acoustic control.

Post-stressed girders are incorporated within the thirty-inch structural depth of the floor system to provide a uniform four by eight-foot ceiling grid for modular space planning and partition arrangement.

Vertical mechanical services to a structural bay are contained within enlarged columns to reduce the dimensions of primary air supply ducts within girders. The columns are on thirty-two and seventy-two foot centers to provide a primary clear span of sixty-four feet.

Comparative data is presented on six planning modules; five commercial precast, cored-slab, concrete plank floor and roof systems; and on five series of linear building cores, ranging in width from twelve to forty feet.

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LIST OF TABLES AND GRAPHS

INTRODUCTION

As outlined in Appendix One, it was the aim of this project to design a building system, valid for many configurations, in which the elements of structure, mechanical services, and vertical circulation were integrated.

Collective preparatory work by class members was limited to the list of assignments included in Appendix Two.

A program for an educational facility, specifically for a School of Architecture, Planning, and the Visual Arts, was offered as a basis for study. The space requirements have been tabulated in Appendix Three.

It was intended that the direction of study be toward an alternative to the typical suspended ceiling system and that the structure, preferably of concrete, be exposed to visually contribute to the architectural expression. In addition, the following aspects were selected for initial study:

1. Investigations were to begin with analysis of linear, structural systems, presuming that more flexibility in deleting secondary elements of the structure was possible than with two-way construction.

2. Clearance requirements for automobile parking were to be included in determining the dimensions of a typical structural bay and the placement of cores.

3. The possibility of organizing the various elements of building cores into structurally-independent modular components which could be added or deleted without major adjustment of the core geometry were to be studied as a concept of 'linear cores'.

4. The possibility of using the voids within linear structures as secondary ducts for the distribution and return of mechanical services was to be investigated.

SECTION ONE - STRUCTURAL BAY

The following factors influenced the dimensions of a typical bay:

1. It was considered a requirement, for an efficient linear system in which the depth of the girder and beam were equal, that the ratio of the length of girder and beam be approximately 1:2. It then would become possible to incorporate the girder within the minimal structural depth of the floor system and thereby provide a flush and uniform ceiling grid for room planning. Bay dimensions of twenty by forty-feet, twenty-five by fifty-feet, and thirty by sixty feet were indicated.

2. It was assumed that the depth of the floor system would be three to four feet and that with this depth, if it were structurally effective, spans up to sixty and seventy feet would be reasonable using precast, prestressed concrete construction.

3. It was considered essential for most flexible planning to have vertical static forces concentrated at as few points as possible. This would become particularly important if columns were enlarged to contain air-conditioning ducts and other services. Proportionately, a minimal ratio of column area to useable floor area would require that enlarged columns be spaced at maximum distances.

4. Spans of forty-eight feet or more would be required for lecture halls and auditoriums. However, it was not indicated that the entire structural system be designed to accommodate the larger spaces without special conditions.

5. Recommended criteria for automobile storage and circulation within independent parking structures include the use of long-span construction and angle-parking (70-75 degrees) to permit ease of maneuvering, particularly in customer-parking facilities.

6. Dimensional refinement of the structural bay depended upon the selection of the planning module.

The primary span and perimeter dimensions of the structural bays of seven existing or proposed building systems for educational or research facilities were compared to the two bays of this project (see pages 54, 64, and 69) which have primary spans of 56 and 64 feet and perimeters of 178 and 194 feet. The following data is summarized from the drawings on pages 12 to 16:

Building	Span	Perimeter	Floors
Materials Sciences Building	23'	65'	4
Typical M.I.T. Academic Building	24'	78'	4
Free University of Berlin	25'	102'	4
Earth Sciences Building	48'	114'	19
Prototype Building (Torsuwan)	40'	160'	10
University of Buenos Aires	52'	182'	5
Prototype Building (Brunon)	60'	190'	4

Five preliminary bays which were studied for coordination of structure, core location, and parking are presented on page 19.

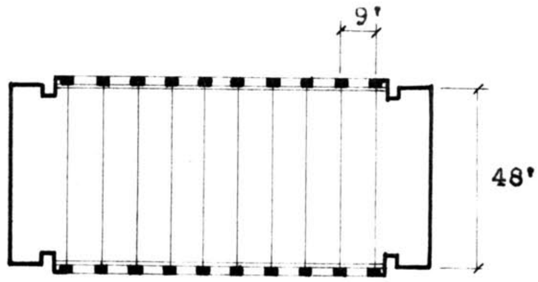
1. These studies were made with the assumption that mechanical services would be located within the cores and that columns would

therefore be dimensioned only from structural considerations. It was later found that if the depth of the floor system were to be minimal the length of the primary ducts within the girders had to be limited to approximately 60 feet.

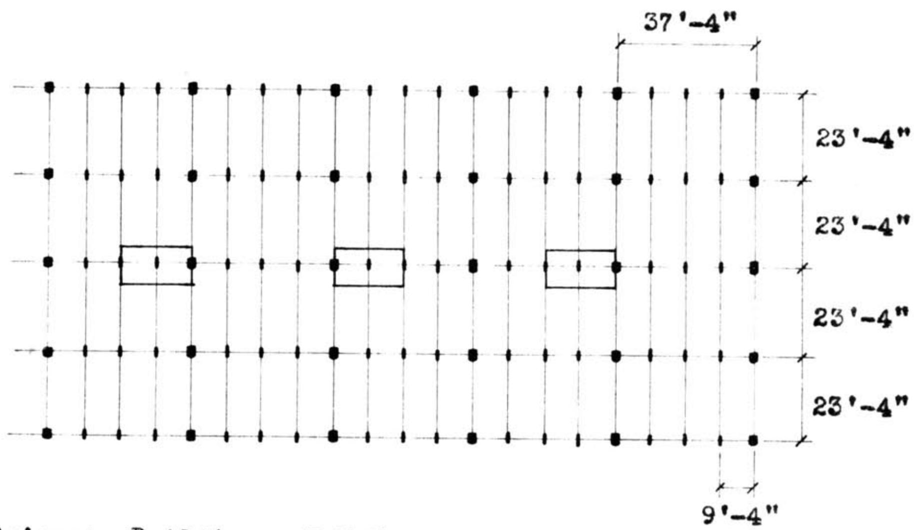
2. The drawings include two framing systems per bay. Cores have been limited in size and location by the dimension of openings between structural members which occur over parking storage aisles. Only framing systems which place the girder parallel with the variable dimension of the linear core (see page 68) satisfy the requirements of structure, core system, and parking.

3. Cores which support adjacent floor structure, as presented on pages 57 and 69, may be used with the alternate framing system of the first bay.

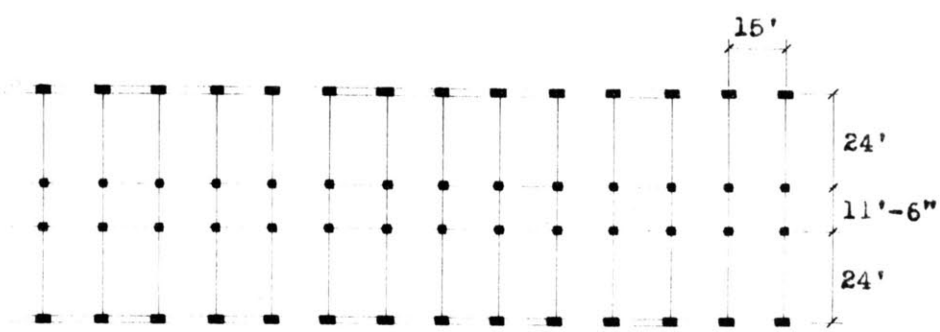
In the structural grids presented on pages 20 and 21, the space between girders is enlarged from 4 to 28 feet or to the approximate limit of flat-slab or typical precast concrete plank construction. This approach has the limitation which requires that the atypical bay be appropriately used only for specialized core elements, which would include lobbies, lounges, and other public or service spaces.



Earth Sciences Building - M.I.T. - 1964
I.M. Pei and Associates, Architects



Materials Sciences Building - M.I.T. - 1965
Skidmore, Owings, and Merrill, Architects

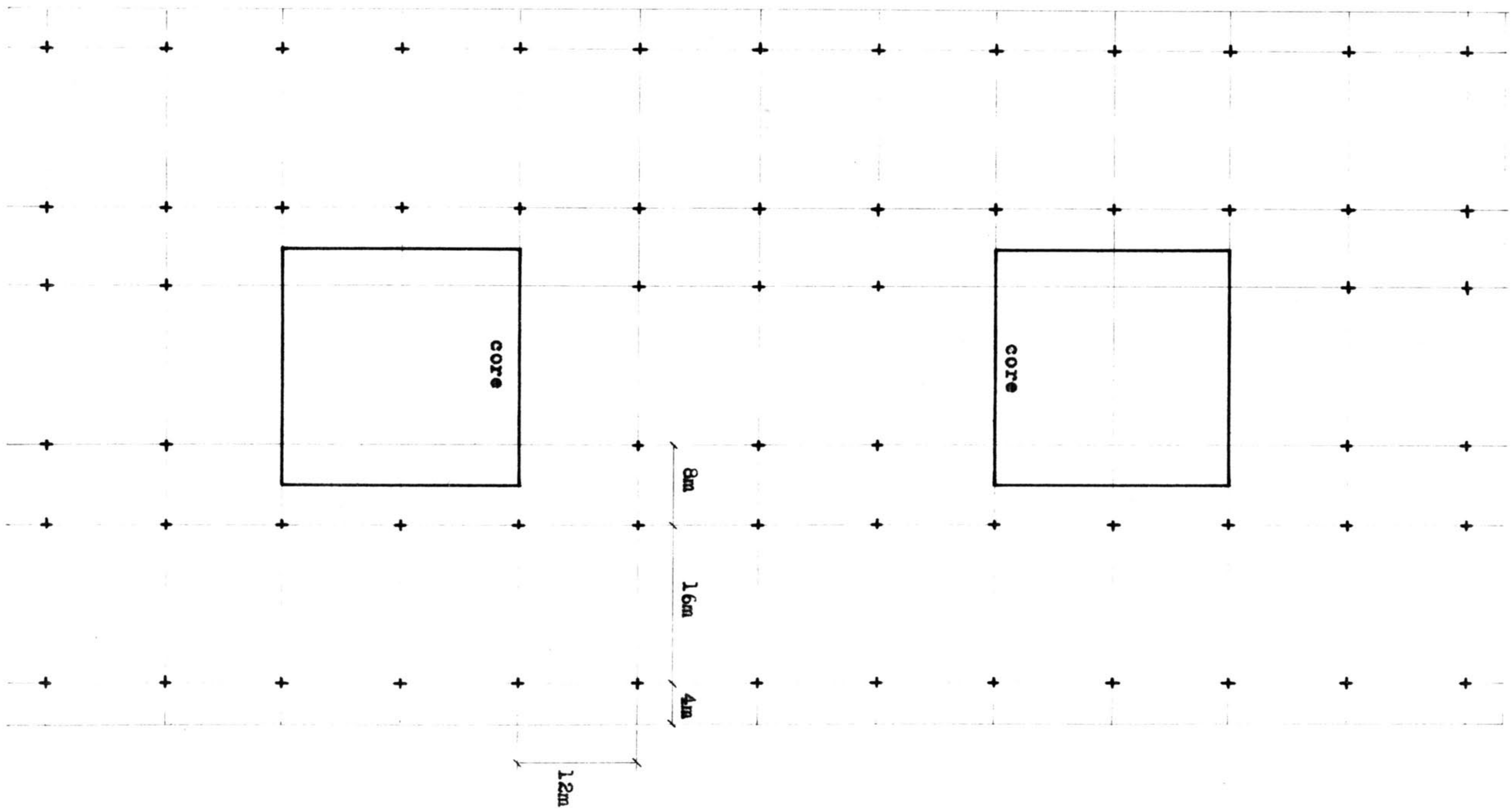


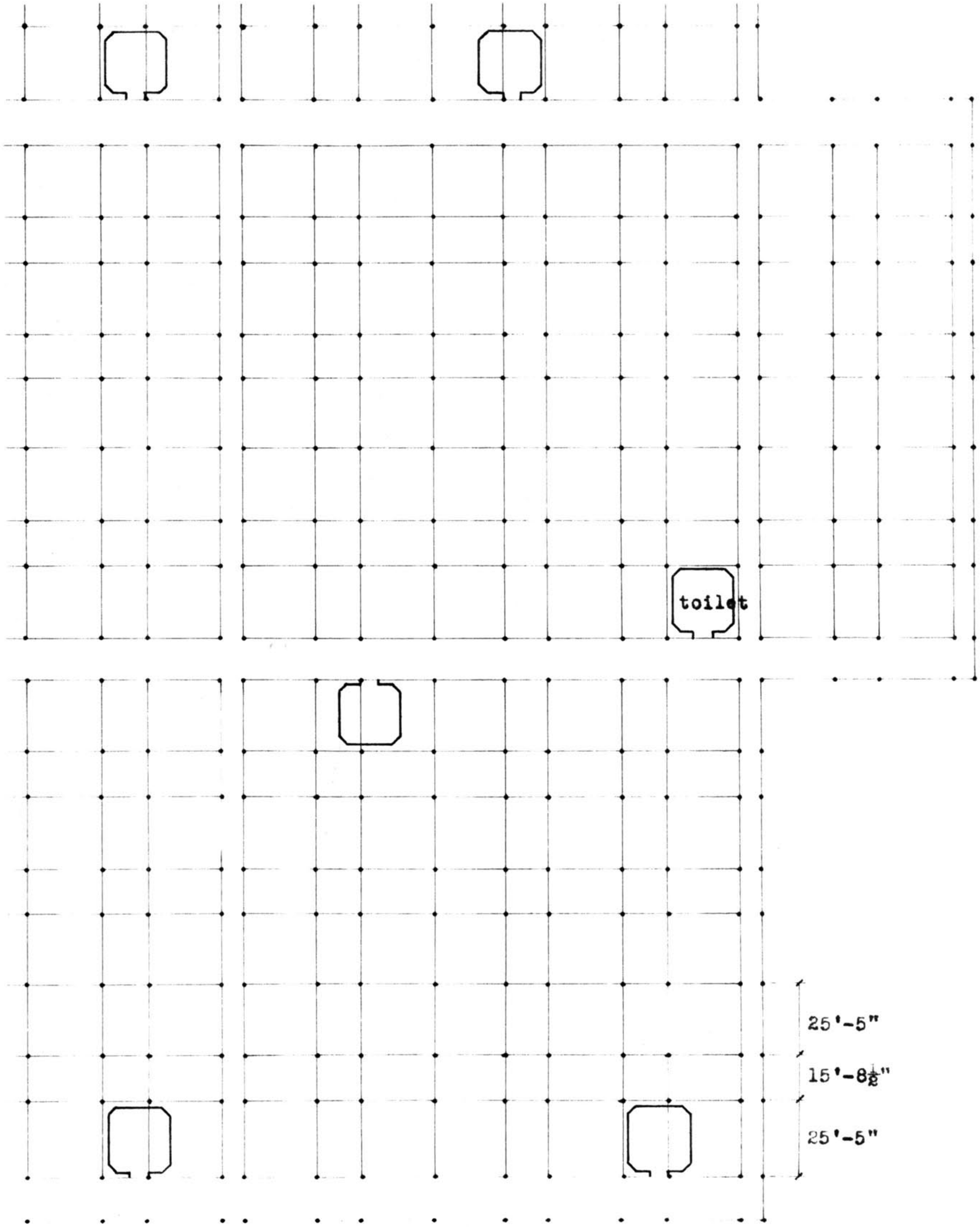
Typical Academic-Laboratory Building - M.I.T. - 1916
Welles Bosworth, Architect

Scale 0 50 feet

Prototype Academic Building - University of Buenos Aires
Horatio Caminos and Eduardo Catalano, Architects

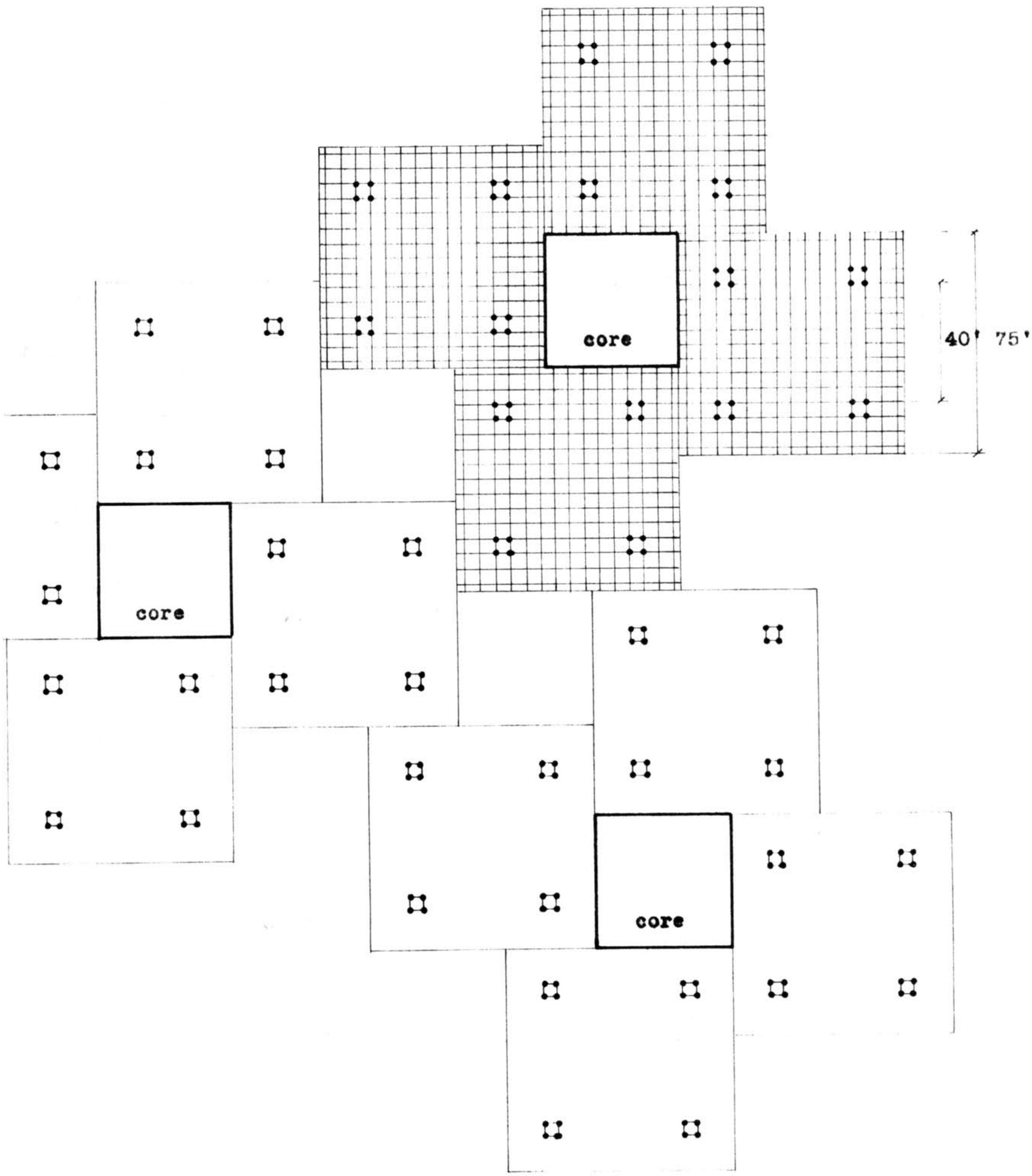
Scale 0 50 feet





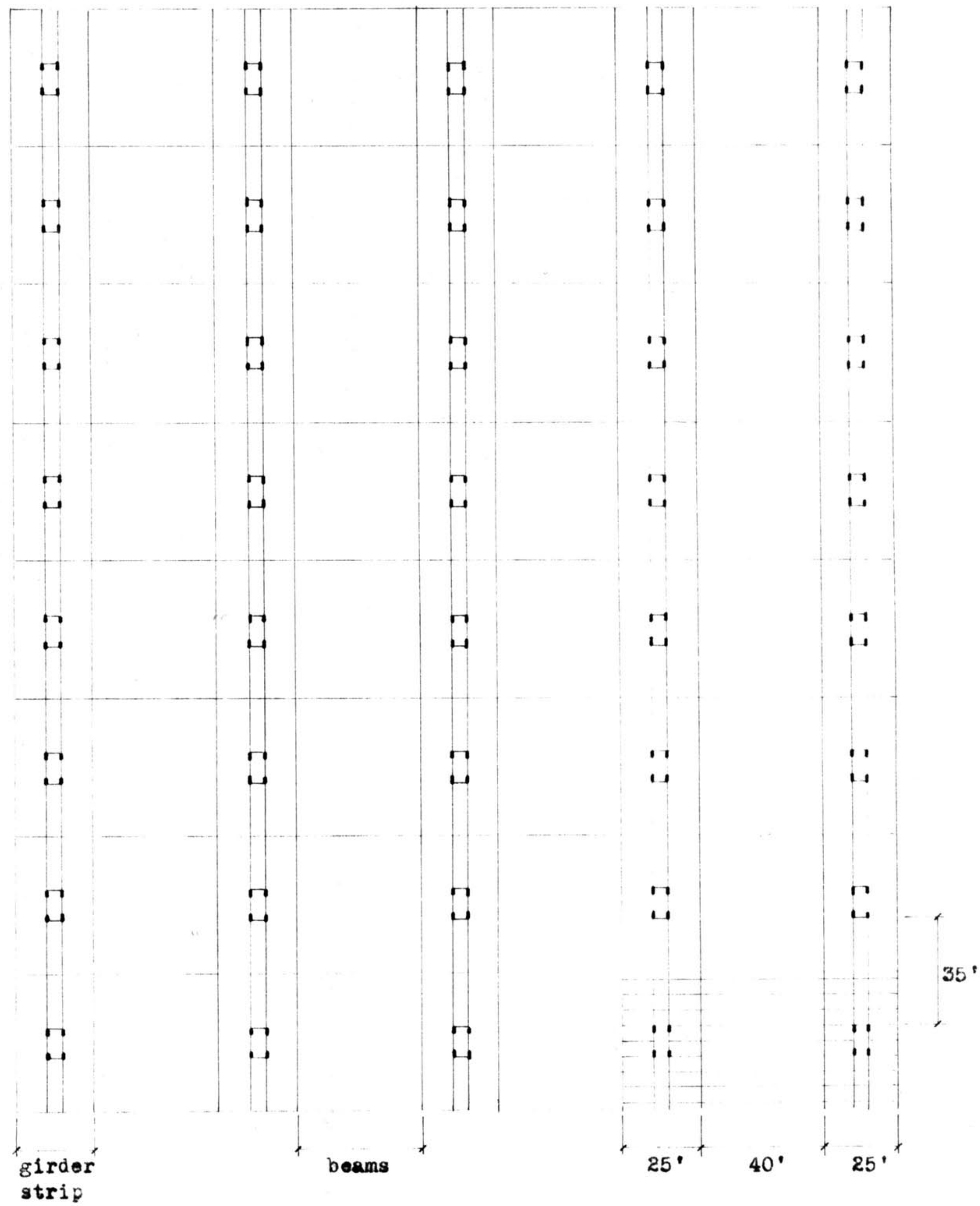
Berlin Free University
Candilis, Woods, and Josic, Architects

Scale 0 — 50 **feet**



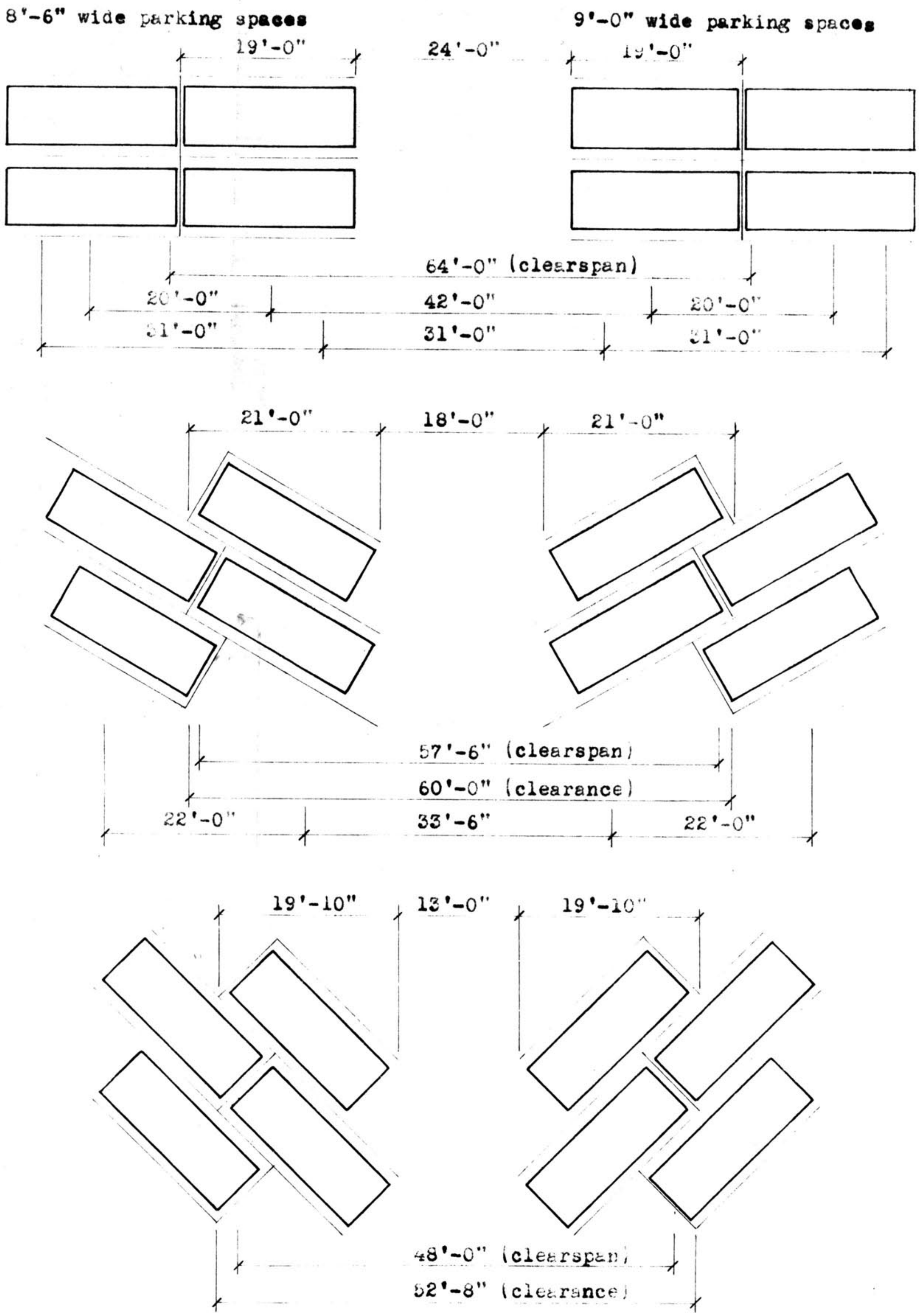
Prototype Building for Research and Development - 1965
M.I.T. Department of Architecture, Graduate Class (Torsuwan)

Scale 0 50 feet

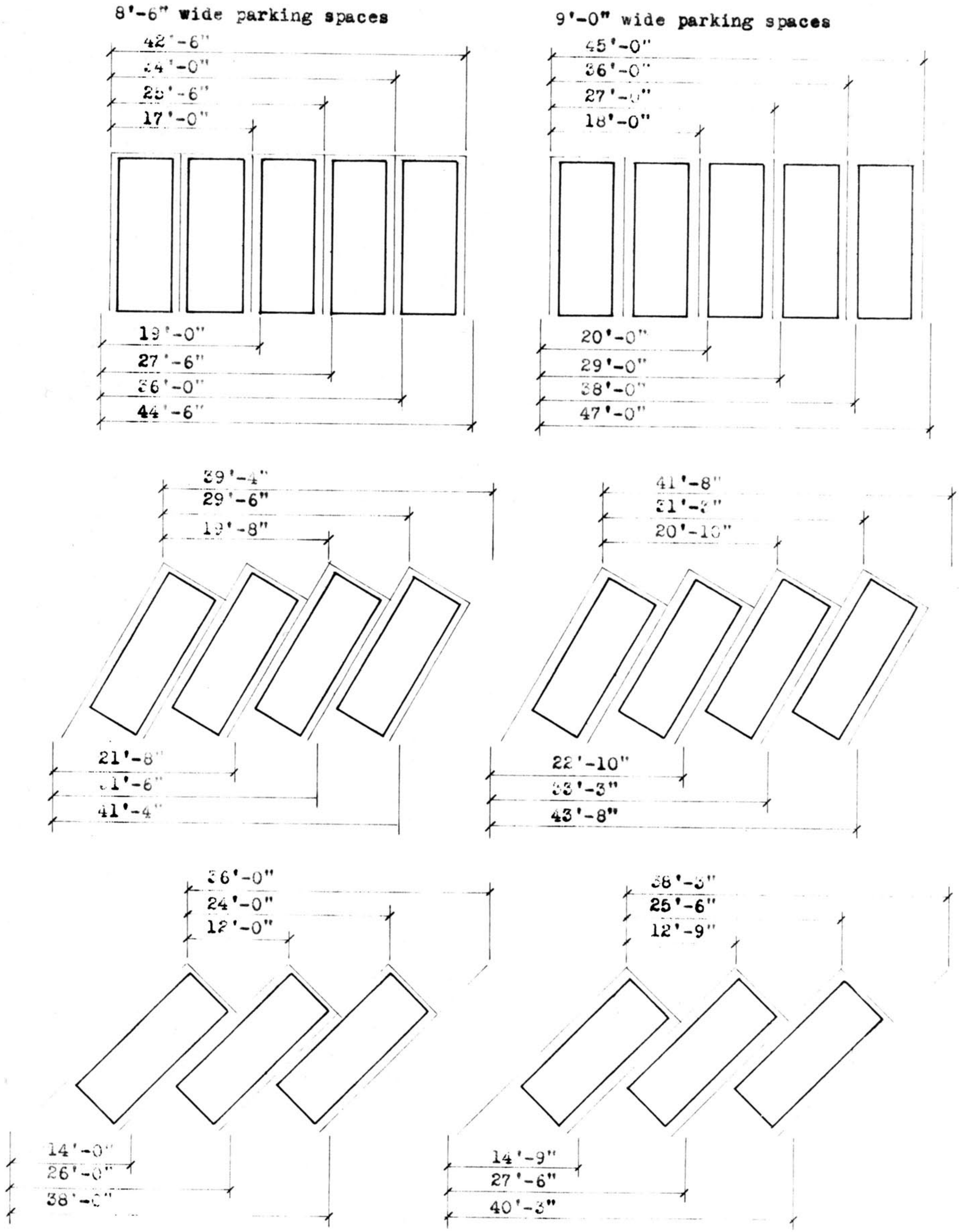


Prototype Building System - 1965
M.I.T. Department of Architecture, Graduate Class (Brunon)

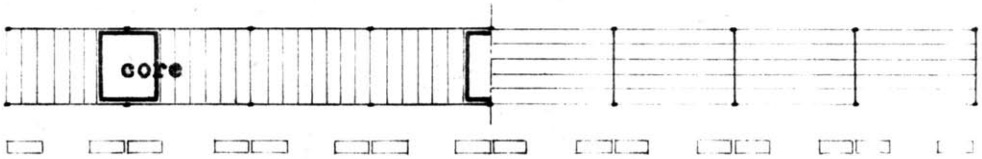
Scale 0 50 feet



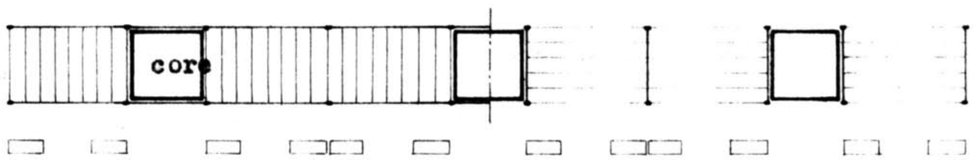
Clearances for Parking



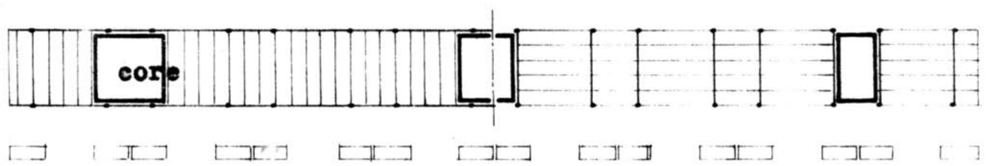
Clearances For Parking



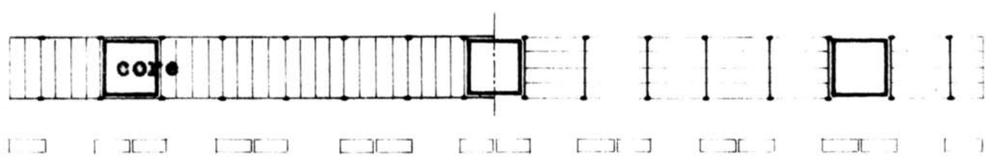
40'x 64' bay



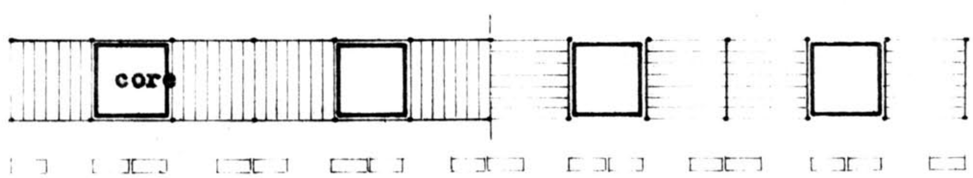
40'x 64' bay with 40'x 40' bay



40'x 40' bay with 40'x 20' bay

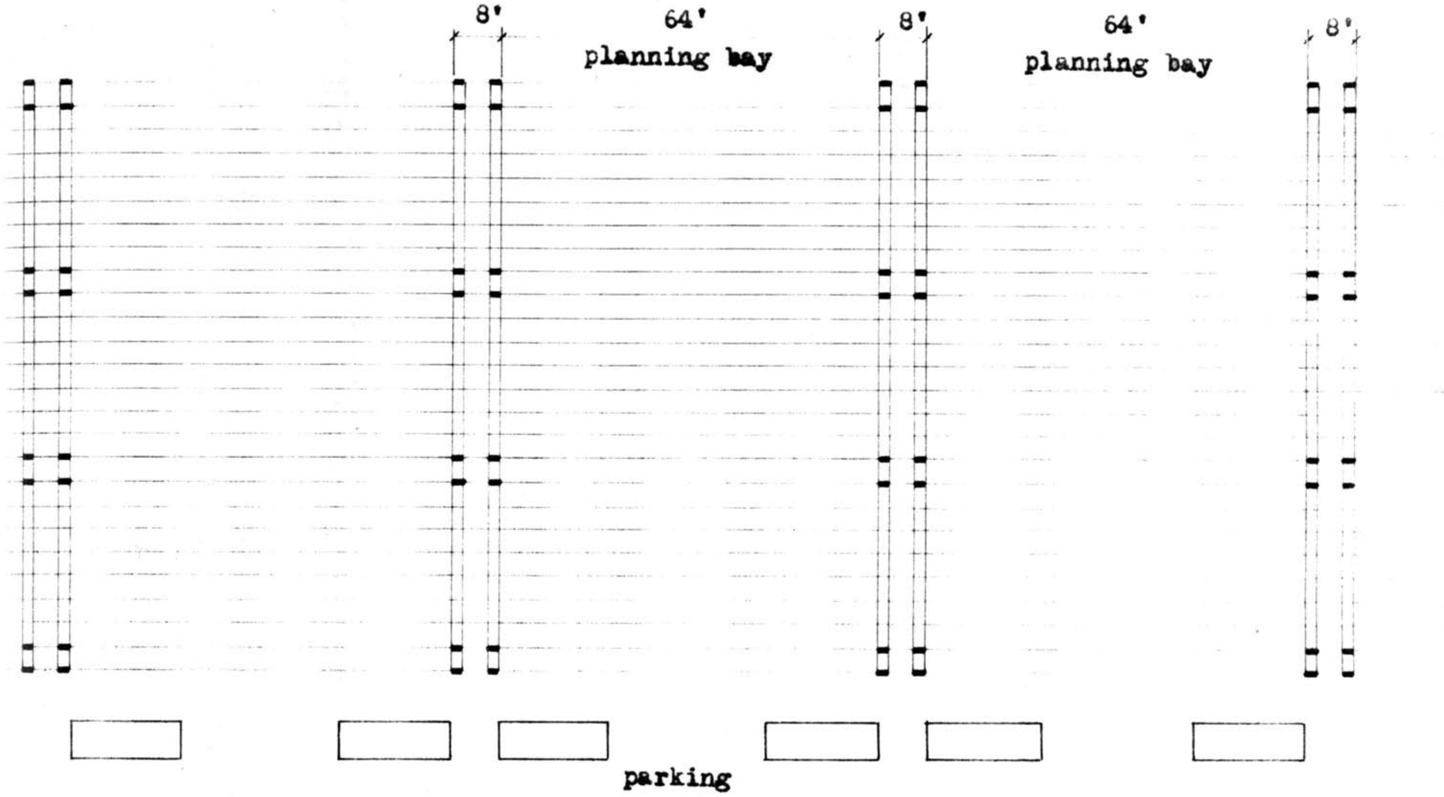


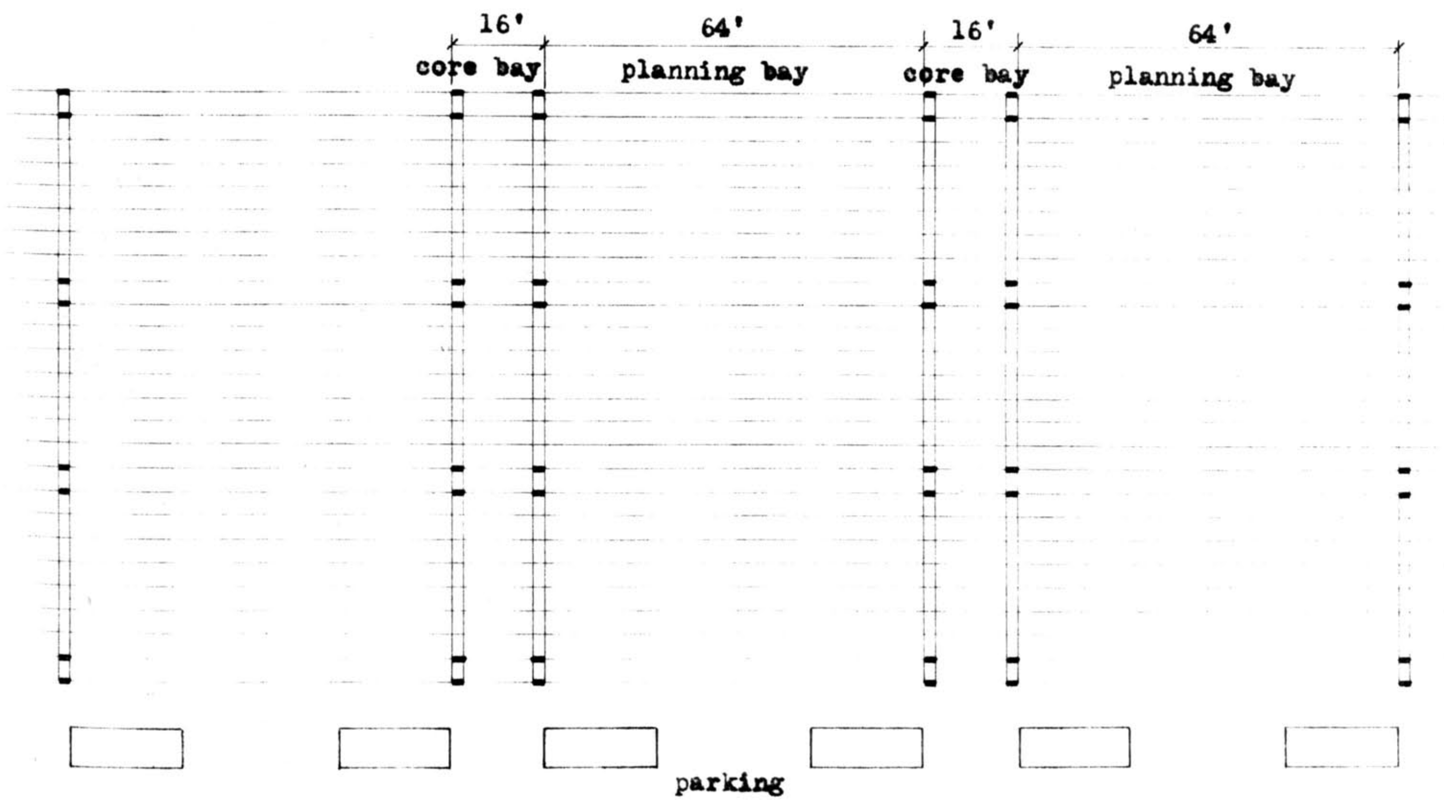
32'x 32' bay



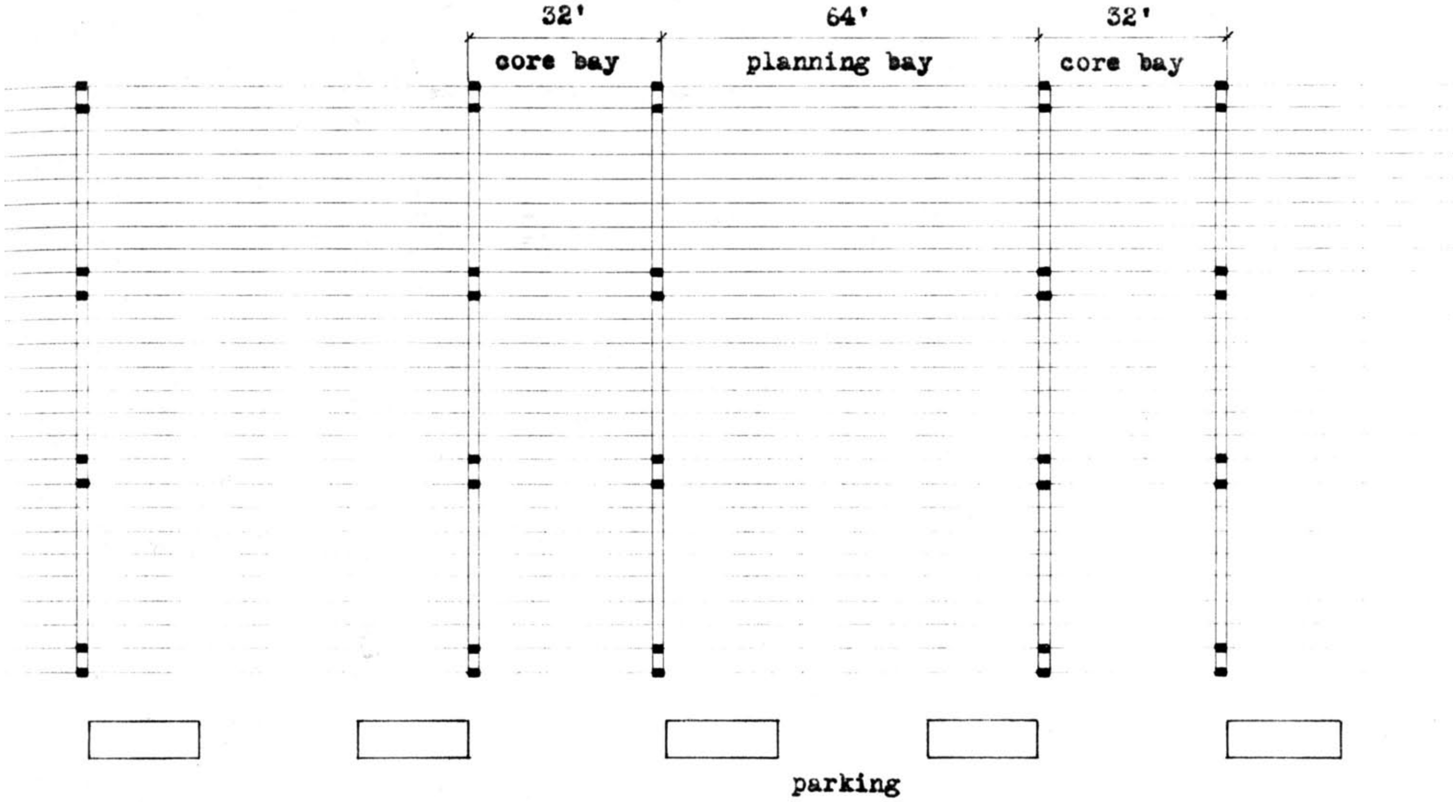
42'x 42' bay

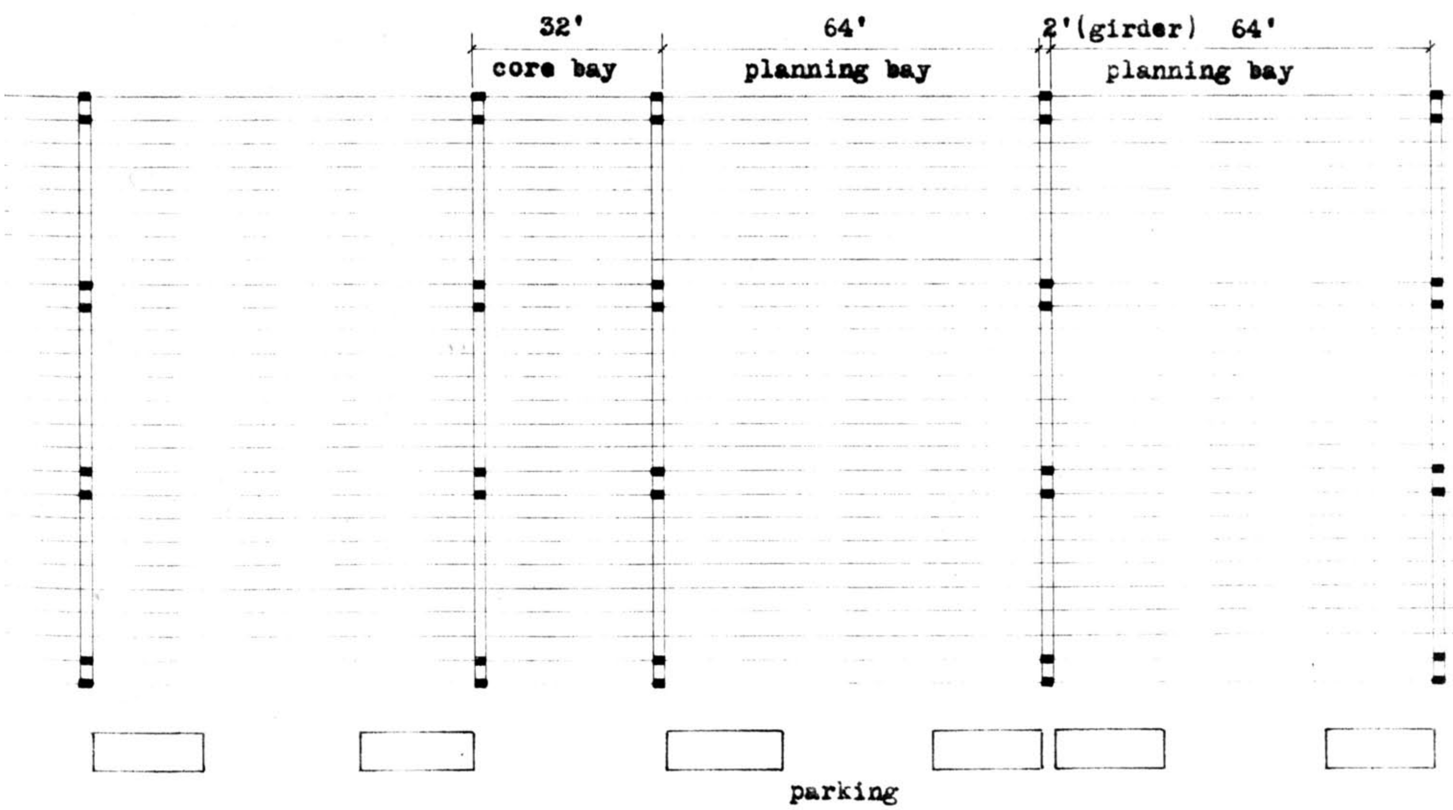
Coordination of Structure, Core Locations, and Parking





Coordination of Structure, Core Location, and Parking

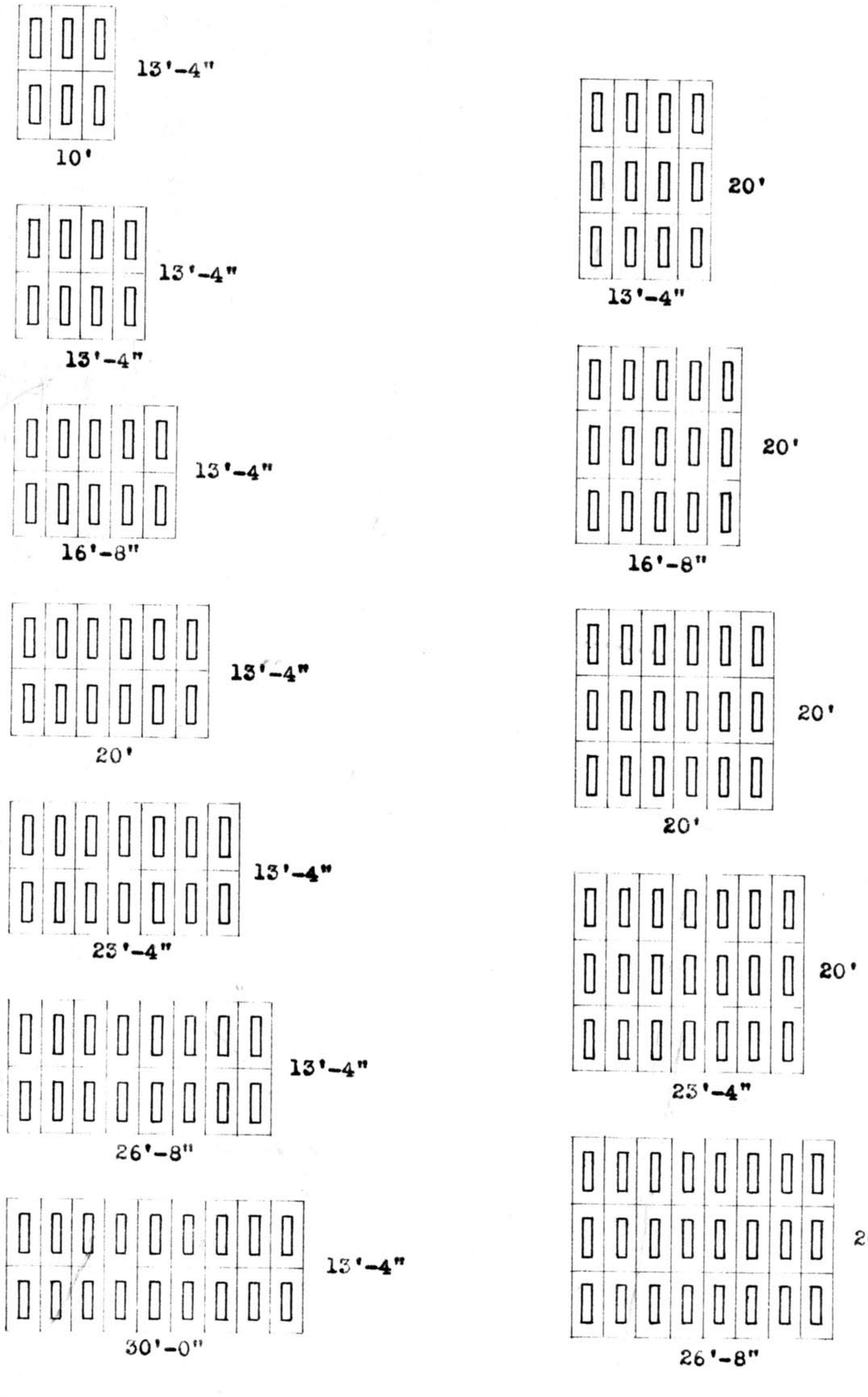




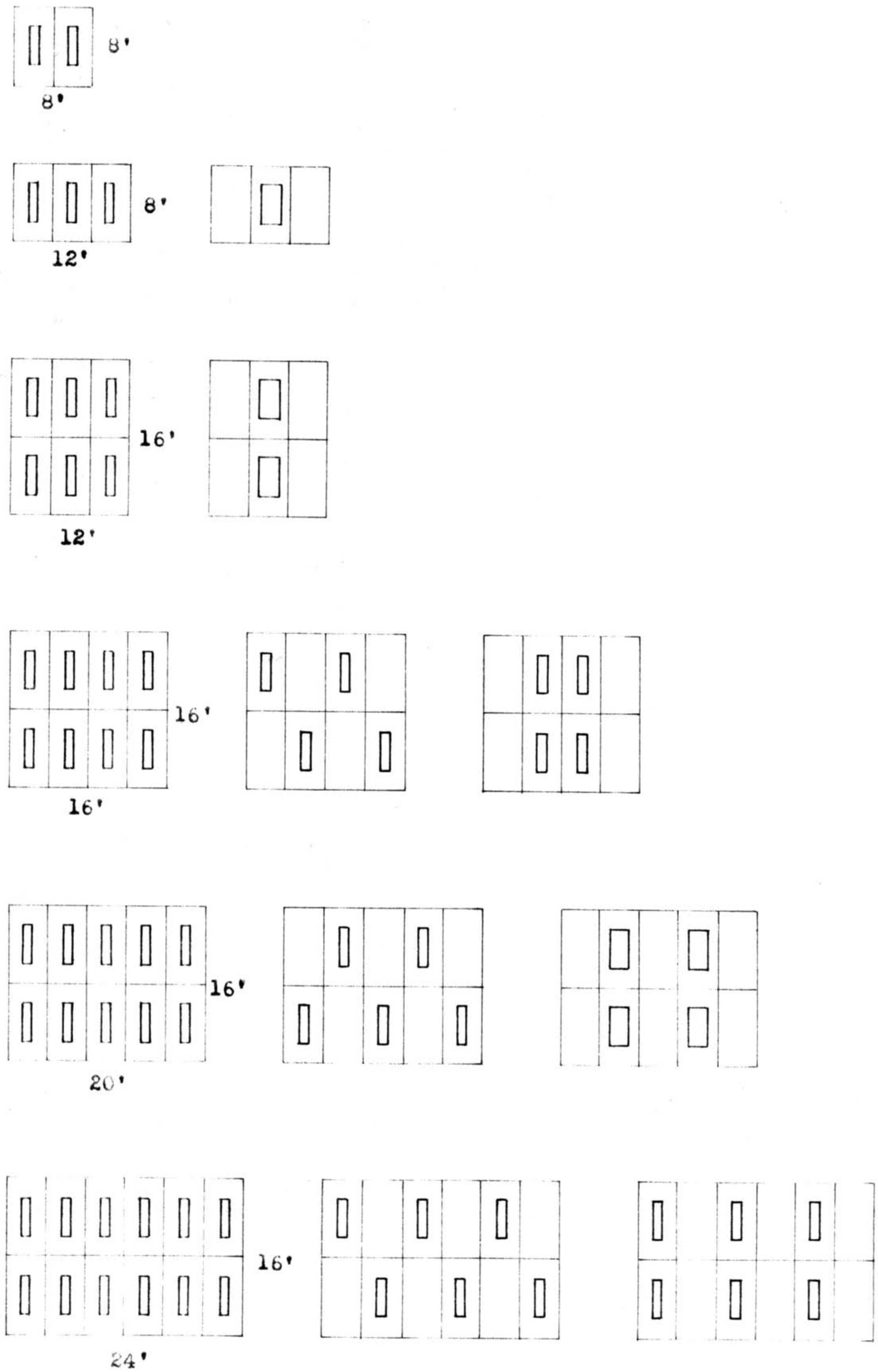
Coordination of Structure, Core Location, and Parking (continued)

Comparative Areas and Room Sizes of Six Planning Modules

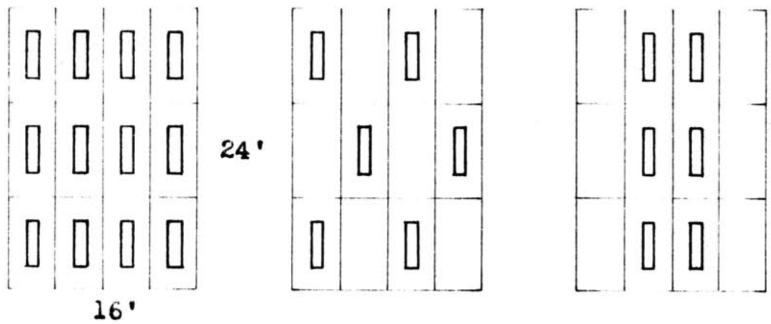
Module	3'x 6'	3'-4"x 6'-8"	4'x 8'	4'-4"x 8'-8"	5'x 10'	6'x 12'
Area of Module	18	21.8	32	37	50	72
Light Fixture	4' tube	4' tube	4' tube	8' tube	8' tube	8' tube
Room Sizes and Areas	12x9 108	13.3x10.0 133	8x8 64	8.6x8.6 74	10x10 100	12x12 144
	12x12 144	13.3x13.3 177	8x12 96	8.6x13.0 112	10x15 150	12x18 216
	12x15 180	13.3x16.6 221	16x12 192	17.3x13.0 225	20x15 300	24x18 432
	12x18 216	13.3x20.0 266	16x16 256	17.3x17.3 300	20x20 400	24x24 576
	12x21 252	13.3x23.3 310	16x20 320	17.3x21.6 374	20x25 500	24x30 720
	18x12 216	13.3x26.6 354	16x24 384	17.3x26.0 450	20x30 600	24x36 864
	18x15 270	13.3x30.0 400	16x28 448	17.3x30.3 525	20x35 700	24x42 1008
	18x18 324	20.0x13.3 266	24x16 384	26.0x17.3 450	30x20 600	36x24 864
	18x21 378	20.0x16.6 332	24x20 480	26.0x21.6 562	30x25 750	36x30 1080
	18x24 432	20.0x20.0 400	24x24 576	26.0x26.0 676	30x30 900	36x36 1296
	18x28 504	20.0x23.3 466	24x28 672	26.0x30.3 788	30x35 1050	36x42 1512
	18x32 574	20.0x26.6 532	24x32 768	26.0x34.6 900	30x40 1200	36x48 1728
	24x15 360	20.0x30.0 600	24x36 864	26.0x39.0 1014	30x45 1350	36x54 1944

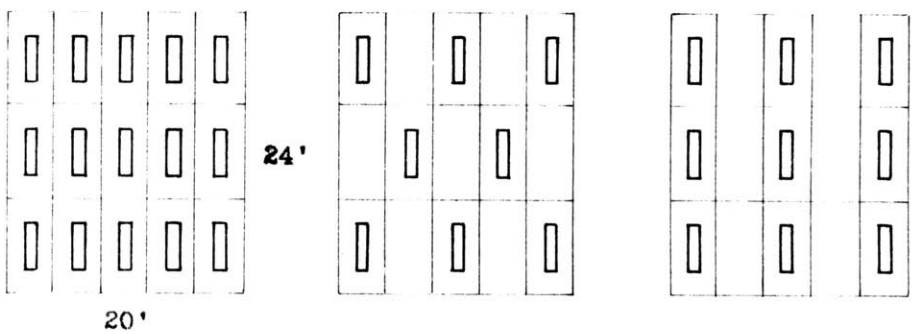


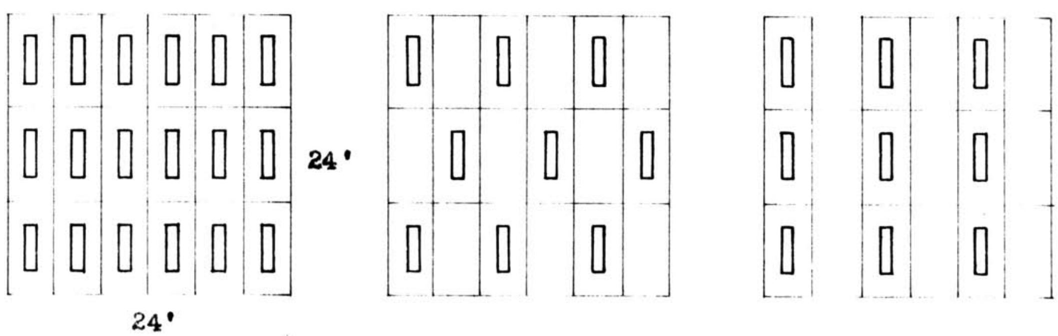
Room Sizes: 3'-4" x 6'-8" Planning Module (Showing Illumination Pattern)

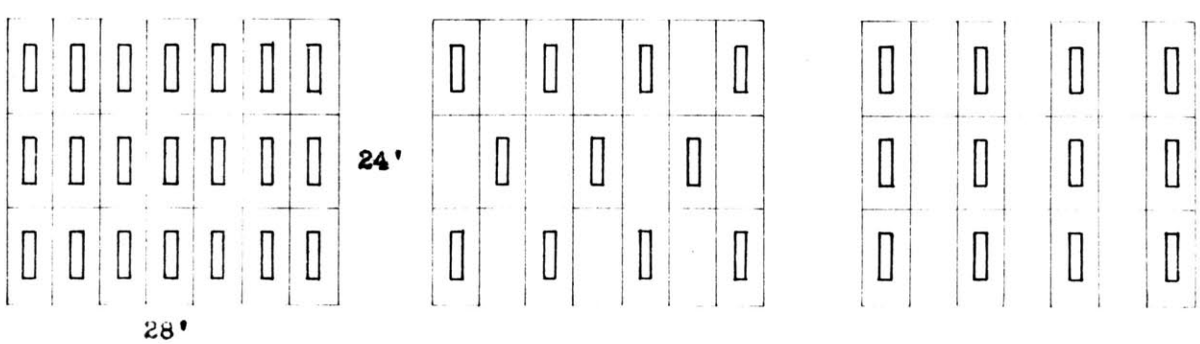


Room Sizes: 4'x 8' Planning Module (Showing Illumination Patterns)

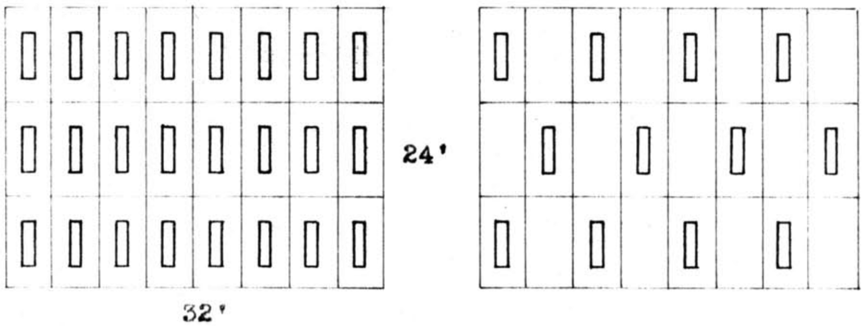


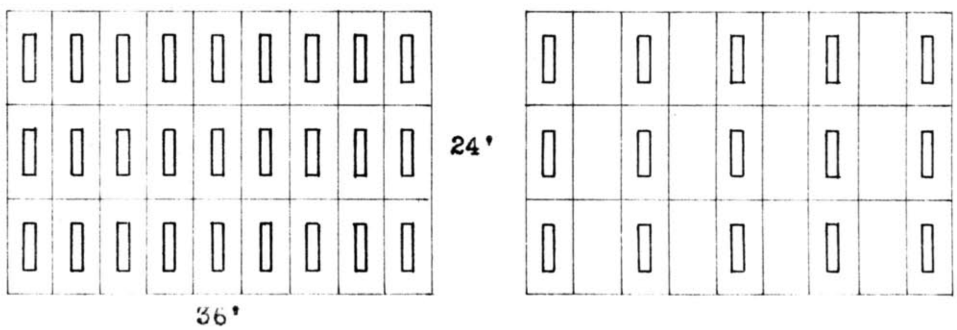


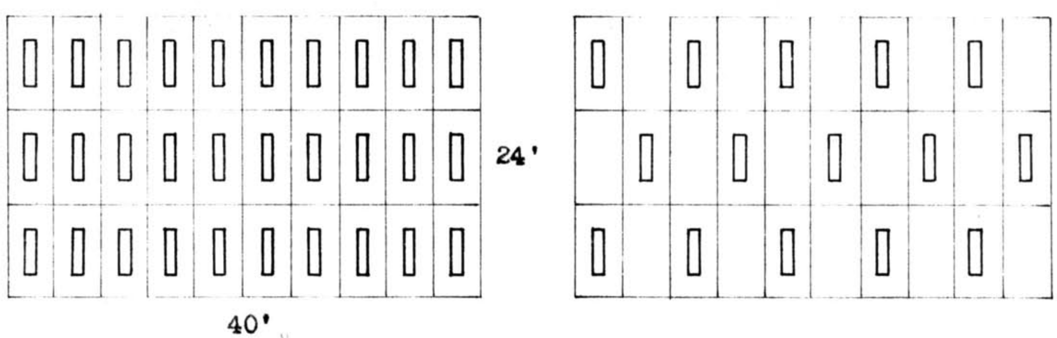


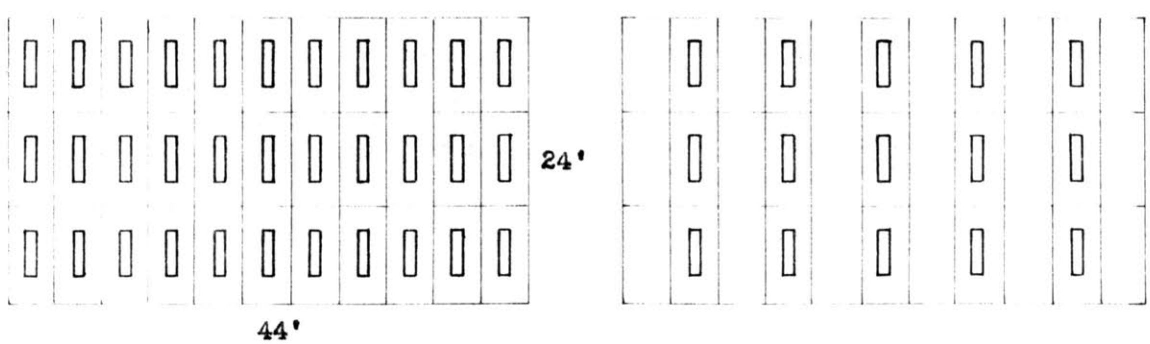


Room Sizes: 4'x 8' Planning Module (continued)

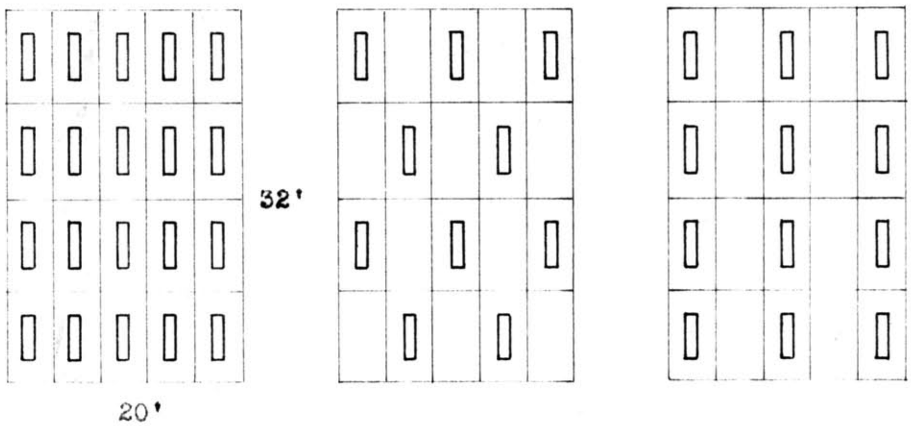


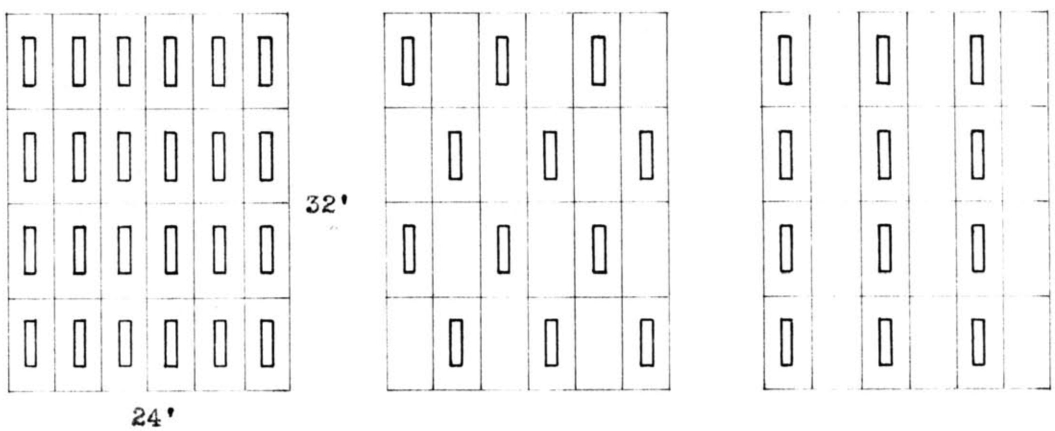


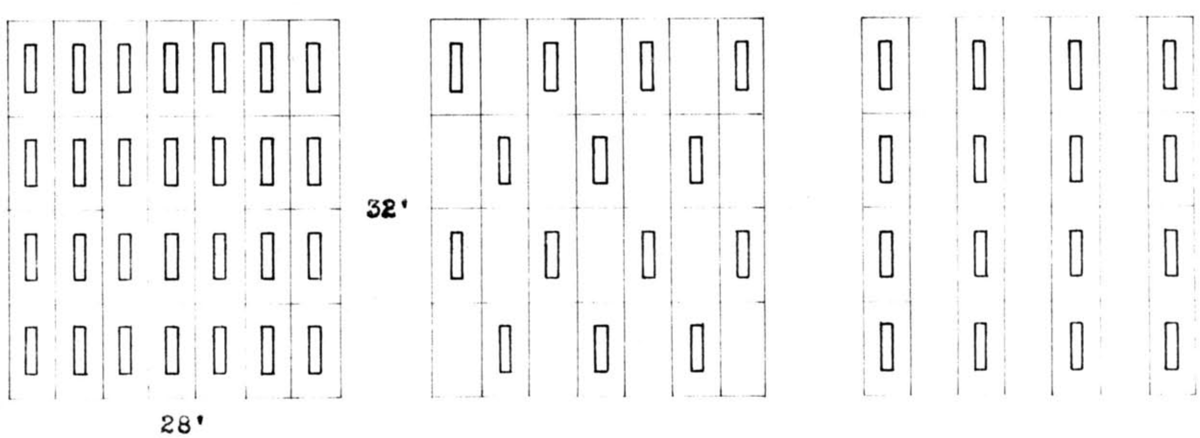




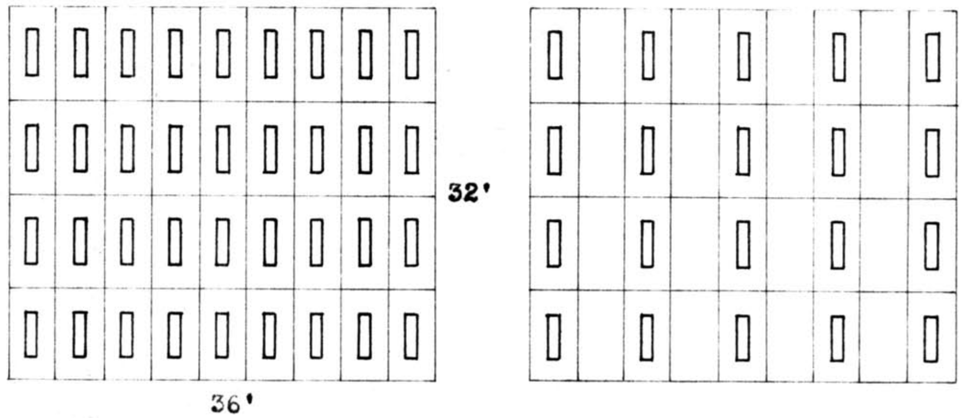
Room Sizes: 4' x 8' Planning Module (continued)

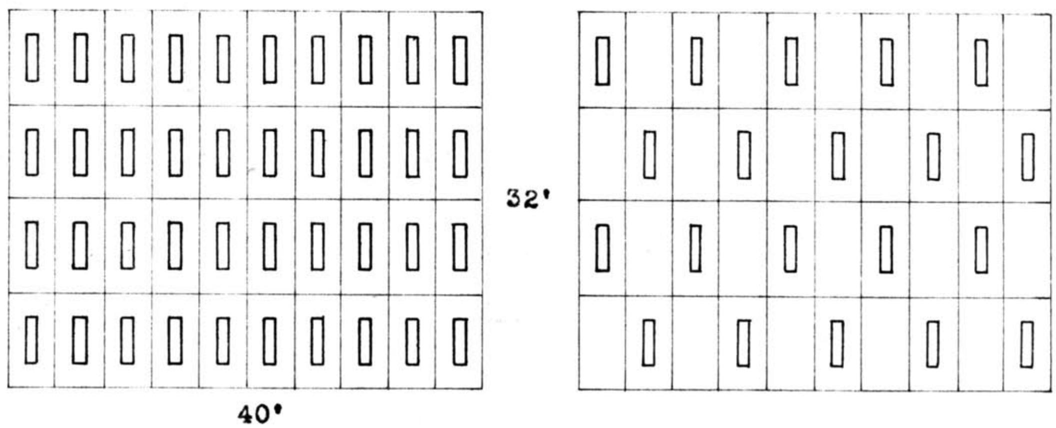


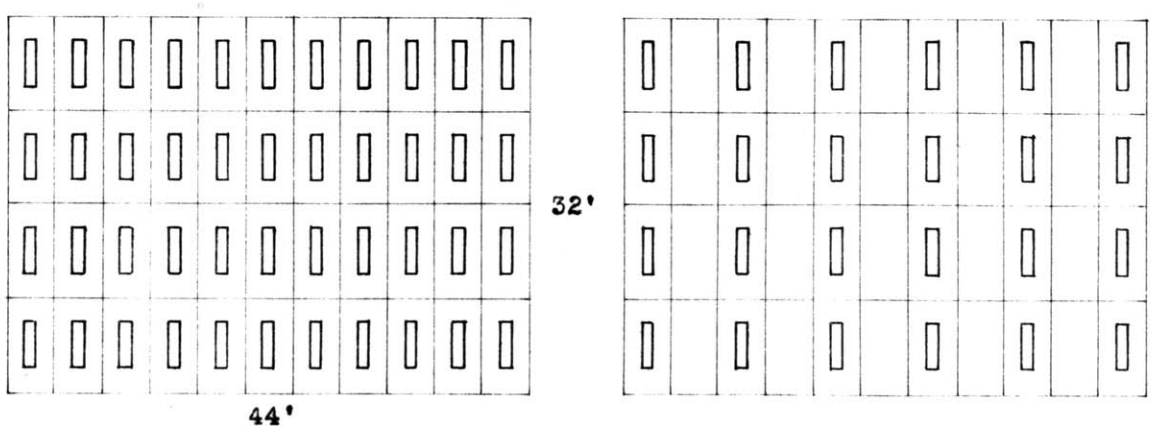




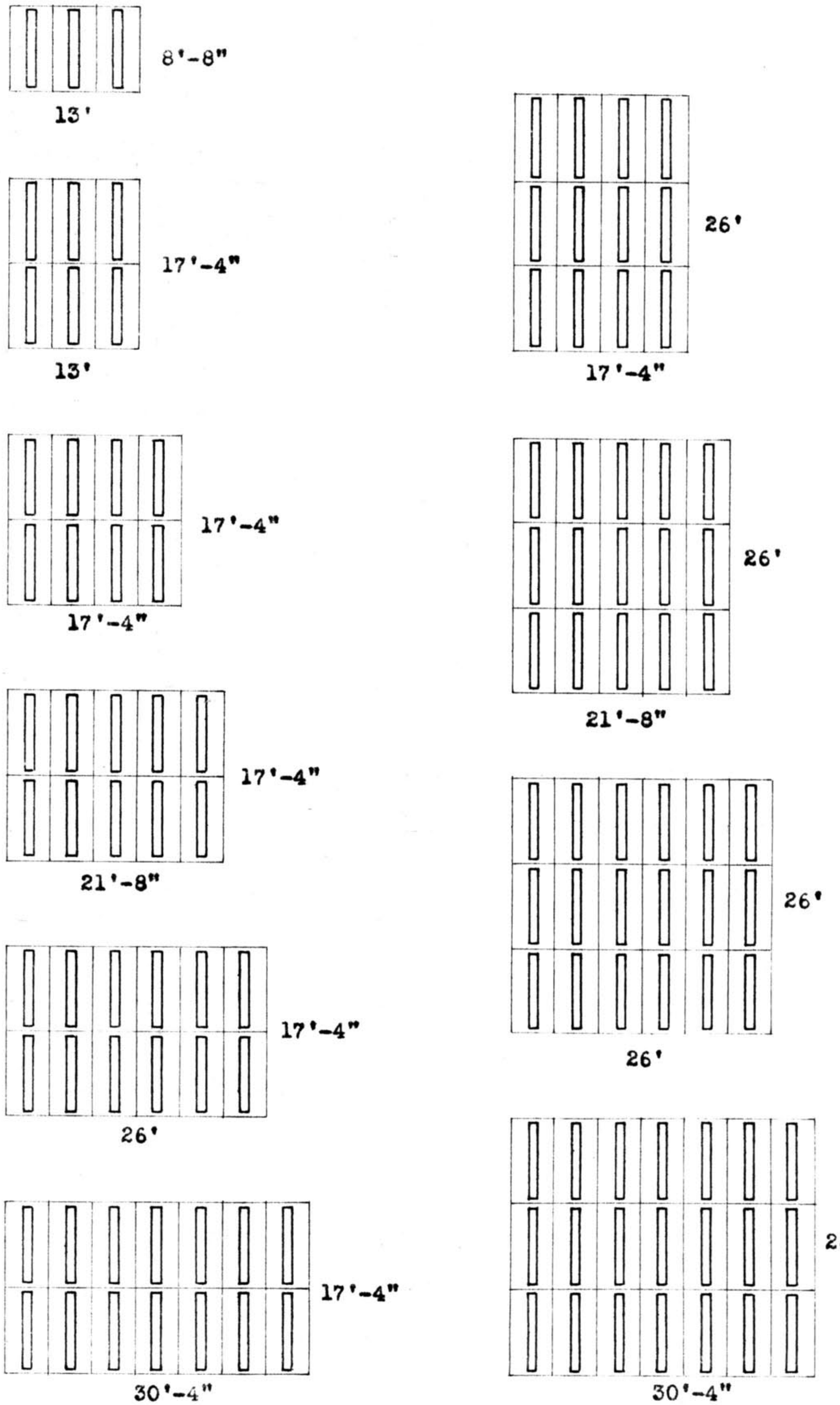
Room Sizes: 4'x 8' Planning Module (continued)



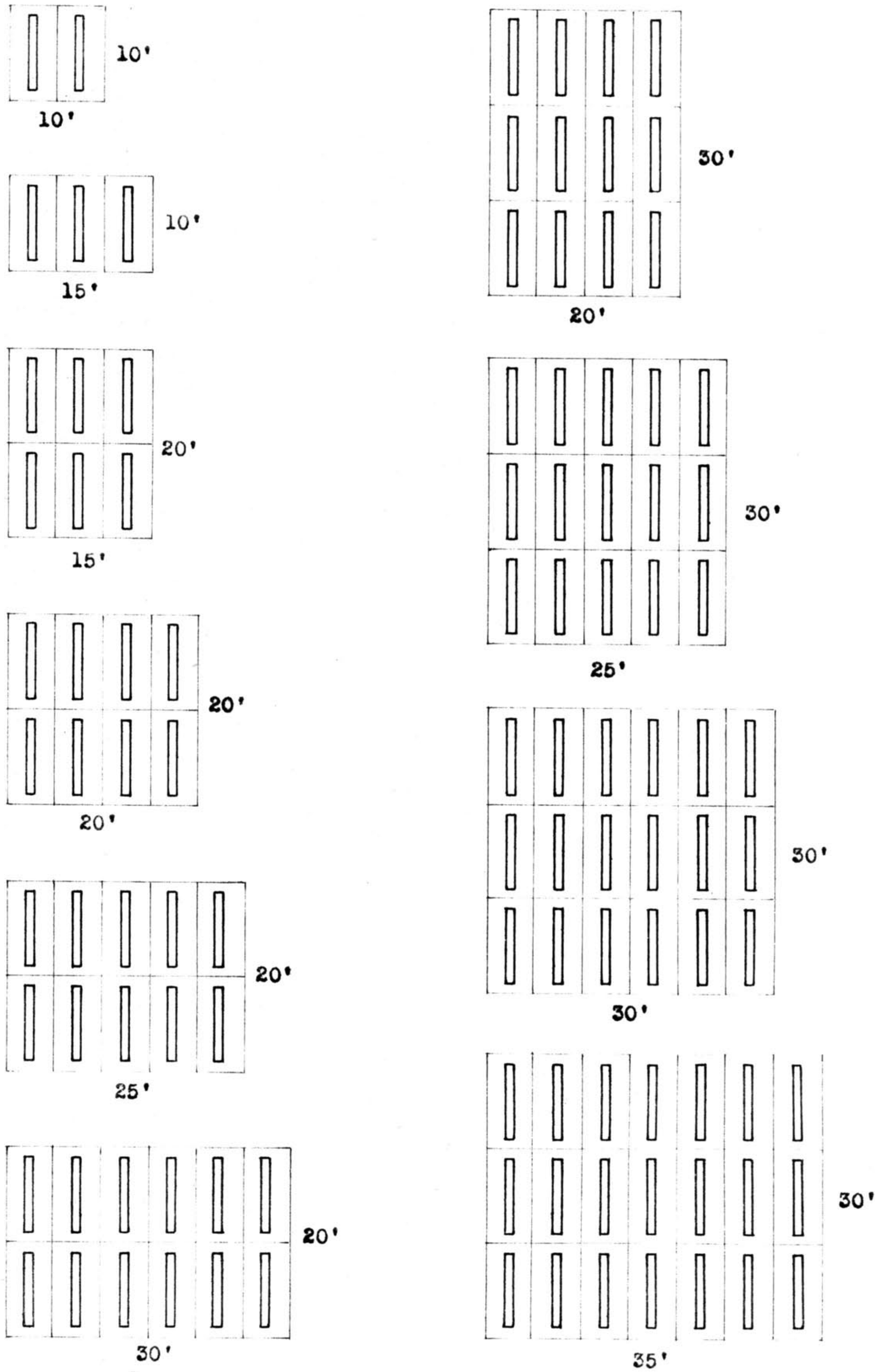




Room Sizes: 4'x 8' Planning Module (continued)



Room Sizes: 4'-4" x 8'-8" Planning Module (Showing Illumination Pattern)



Room Sizes: 5'x 10' Planning Module (Showing Illumination Pattern)

SECTION TWO - FLOOR SYSTEM

Comparative drawings were prepared of existing floor systems to examine the use of the effective structural depth and the means for integrating mechanical services. Ten systems have been presented on pages 33 and 34. These have been organized into two-way systems in which services have been placed above the main structural elements (School of Electrical Engineering and Consolidated Gas Company), within structural elements (Cummins Engine Company), and between the chords of truss elements for two-way distribution (Richards Memorial Research Laboratory and the School Construction System). The latter example, a steel system used primarily for single floor buildings, is contrasted with the concrete systems and multi-floor construction.

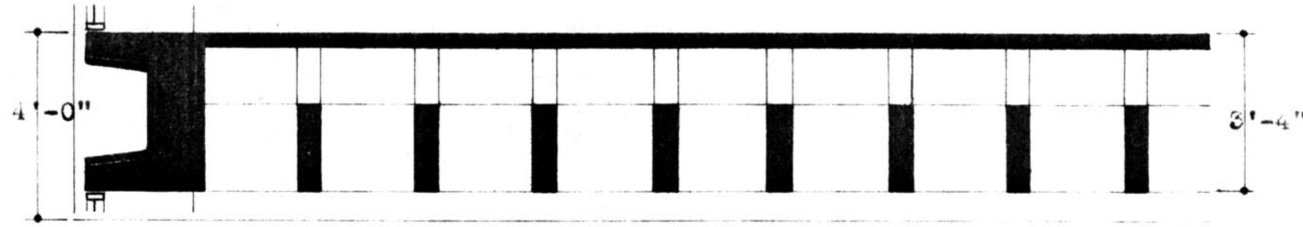
Three one-way systems are included in which the space between structural elements has been predominantly used for linear service distribution (IBM, Norton, and American Republic Office Buildings). A recent suspended ceiling system (CBS Building) and a non-structural approach to integration of services (Environmental Control Grid) complete the examples.

The span-depth ratios of these systems were compared to the characteristics of standard structural elements in which depth is completely a function of static requirements (page 35). There are several floor and roof systems which have linear voids suitable for the passage of air and other services. The cored slab systems (page 36) are for use with relatively short spans (table on page 37) except for one system which became the starting point for further investigation into more complete use of the structural depth of the floor system. The Dynacore plank, besides having the capacity for long-span construction, contains voids of sufficient size to more realistically accommodate the services required.

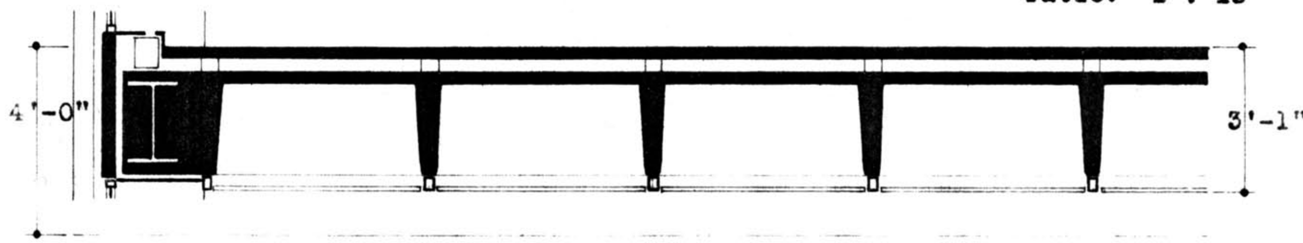
All of the precast, cored-slab systems have several disadvantages. Visually, the finished underside (ceiling) has no more interest than a cast-in-place slab. Acoustic material is required and the final effect is not significantly different from a typical suspended ceiling, without the advantage of complete flexibility which the suspended ceiling offers. Further, except for water supply lines and waste pipes of very short runs, the cored slabs do not offer space for pipes. If pipes were installed within a void, there is no possibility of access for changes or repair.

Analysis of the modules required for various services (air-conditioning, power-telephone, pipes) began, however, with variations of the Dynacore section, with individual beams separated along the girder to provide space for pipes (access from the floor below) and a visual break to conceal any variations in camber which these members require for long span application.

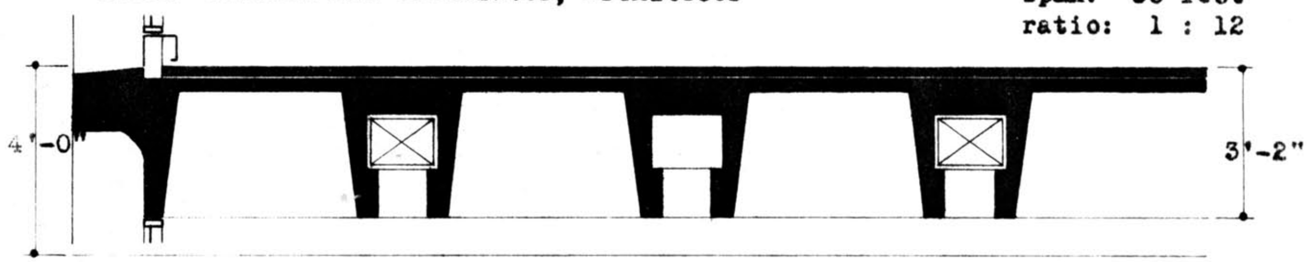
A preliminary structural system was developed using the Dynacore section of three linear voids for a service module of 8 feet. The girders have a depth of 3 feet and are not flush with the beams. Primary ductwork and pipes would be installed between the girders, and vertical services would be contained within cores. In this scheme, three linear voids at the column may not be useable because of the concentration of static forces at the girder connection.



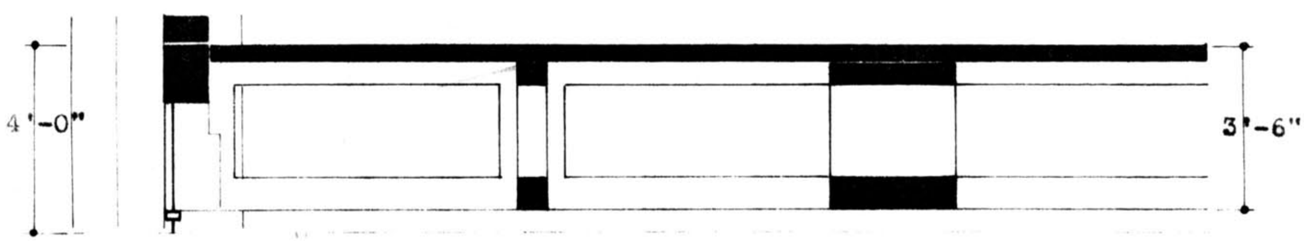
Moore School of Electrical Engineering - University of Pennsylvania - 1959
Geddes, Brecher, and Cunningham, Architects
span: 50 feet
ratio: 1 : 15



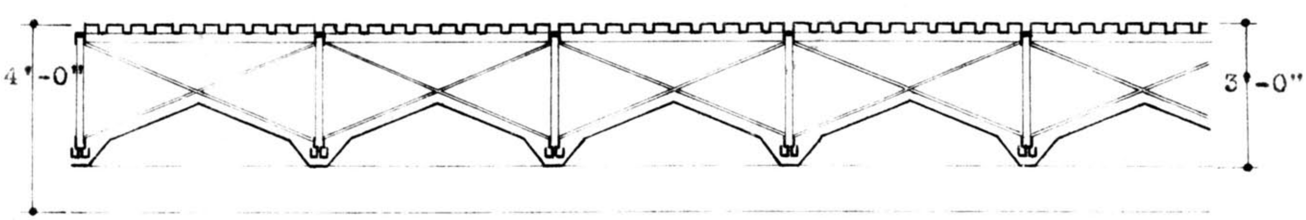
Michigan Consolidated Gas Company Building - Detroit, Michigan - 1963
Minoru Yamasaki and Associates, Architects
span: 30 feet
ratio: 1 : 12



Cummins Engine Company, Inc., Columbus, Indiana - 1964
Harry Weese and Associates, Architects
span: 36 feet
ratio: 1 : 11

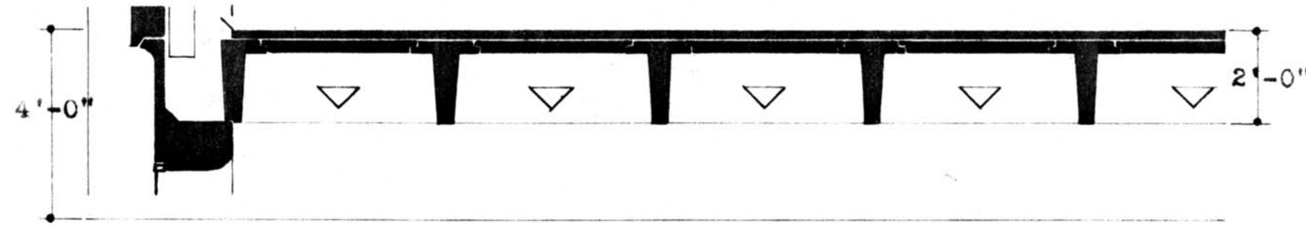


Richards Memorial Research Laboratory - University of Pennsylvania - 1960
Louis I. Kahn, Architect
span: 45 feet
ratio: 1 : 13

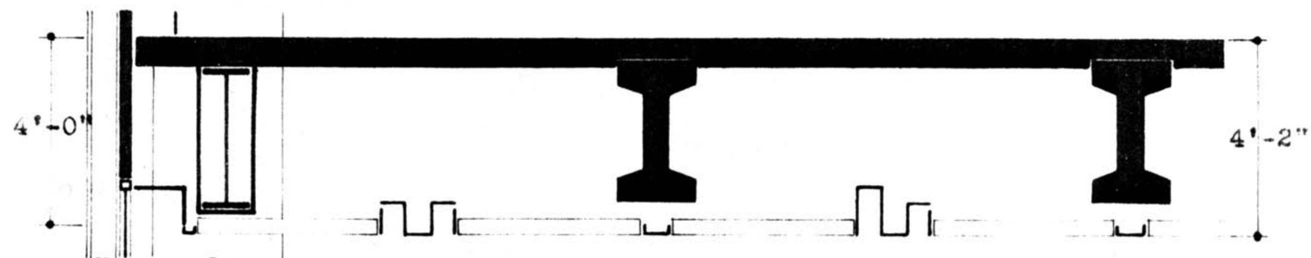


School Construction Systems Development - 1964
Ezra Ehrenkrantz, Project Architect
spans: 30-110 feet
ratios: 1:10 - 1:36

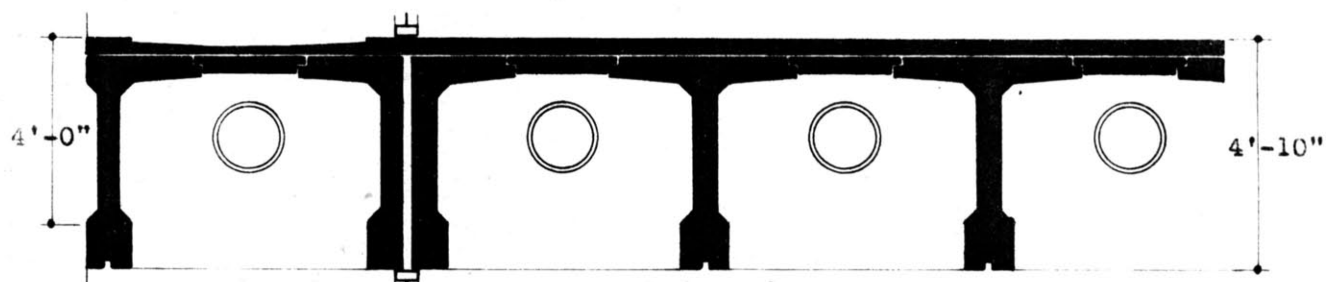
Sections Through Existing Floor Systems



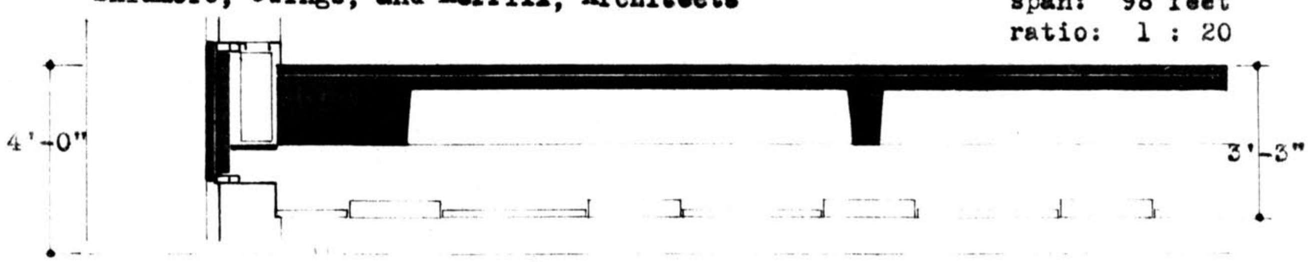
IBM Office Building - Milwaukee, Wisconsin - 1965 span: 30 feet
Harry Weese and Associates, Architects ratio: 1 : 15



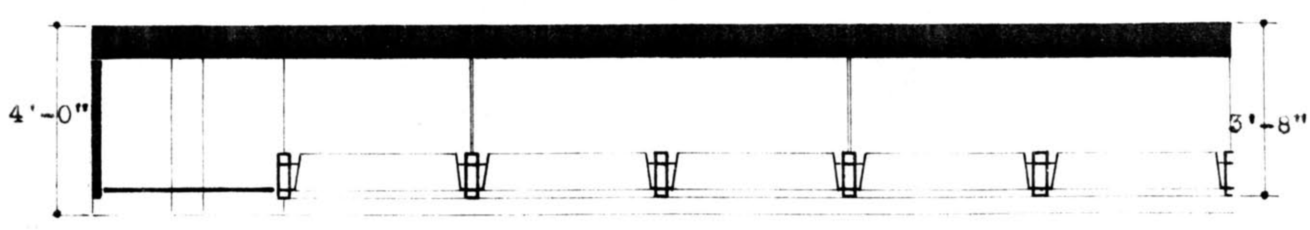
Norton Office Building - Seattle, Washington - 1960 span: 70 feet
Skidmore, Owings, and Merrill, Architects ratio: 1 : 20



American Republic Insurance Company Building- Des Moines, Iowa - 1965
Skidmore, Owings, and Merrill, Architects span: 98 feet
ratio: 1 : 20



CBS Building - New York - 1965 span: 35 feet
Eero Saarinen and Associates, Architects ratio: 1 : 21



Environmental Control Grid Ceiling System
Ernest Kump, Architect

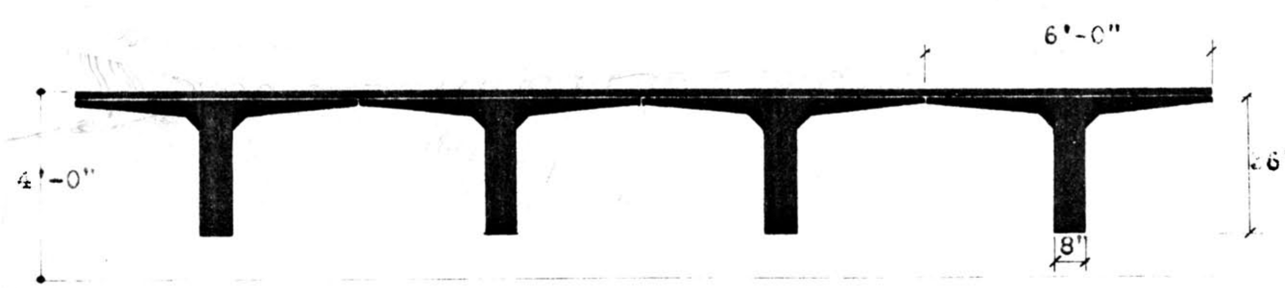
Sections Through Existing Floor Systems

Clear Span: 45 **feet (superimposed load: 100 psf) ratio: 1 : 27**

Clear Span: 55 **feet** **ratio: 1 : 27**

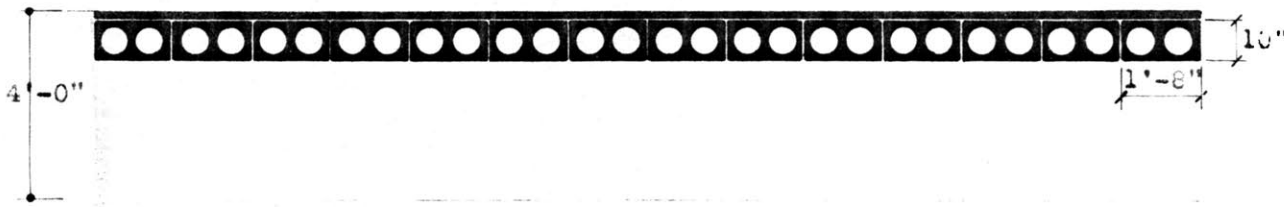
Clear Span: 60 **feet** **ratio: 1 : 26**

Clear Span: 70 **feet** **ratio: 1 : 26**



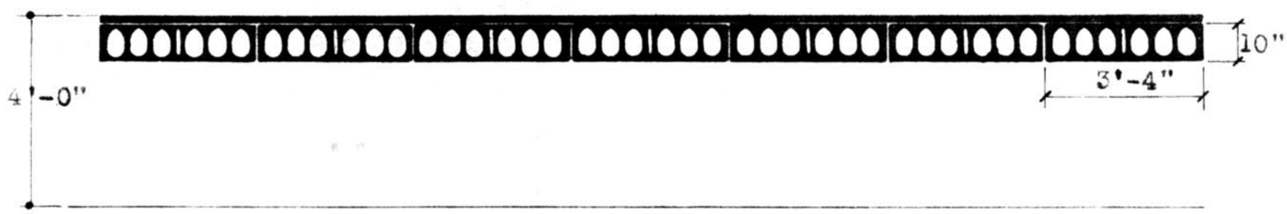
Clear Span: 80 **feet** **ratio:** 1 : 26

Dimensions of Standard Tee Sections

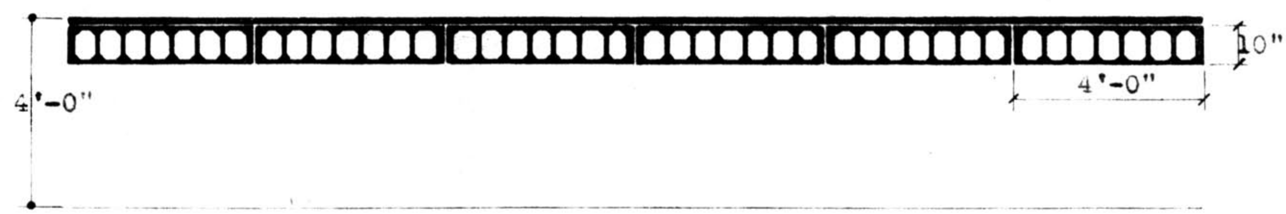


Flexicore

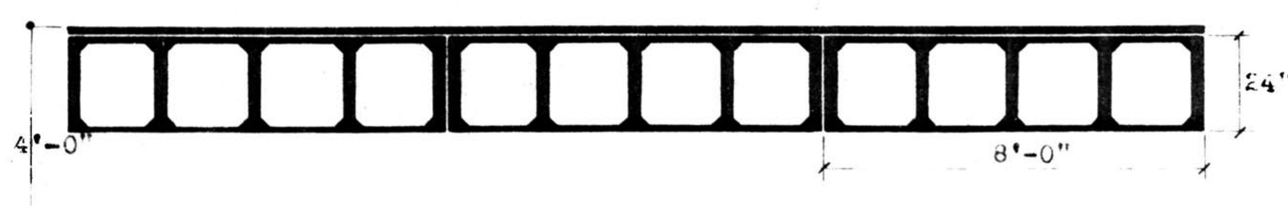
Rapidex-Doxplank



Spancrete

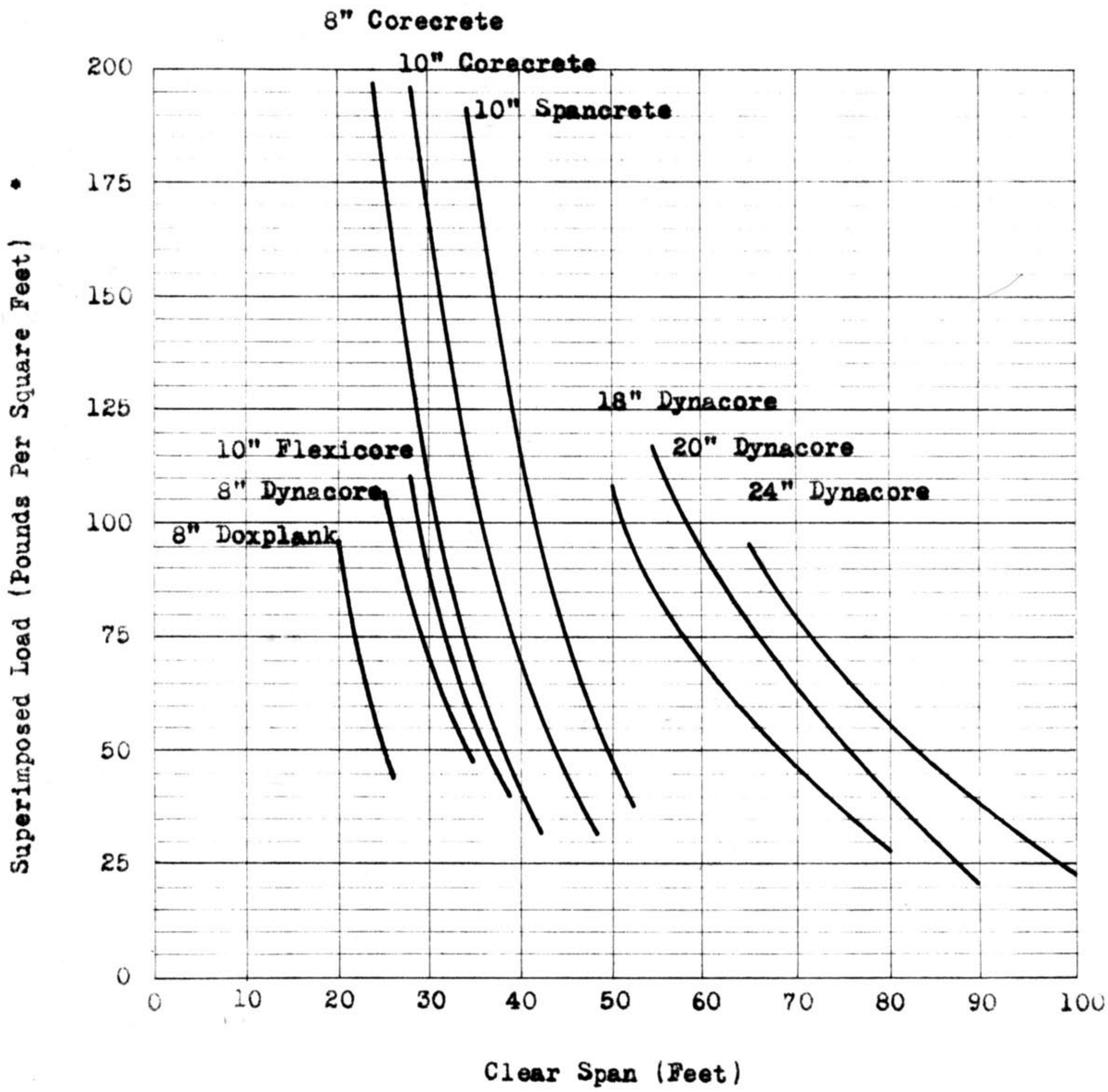


Corecrete



Dynacore

Dimensions of Standard Cored-Slab Floor and Roof Systems



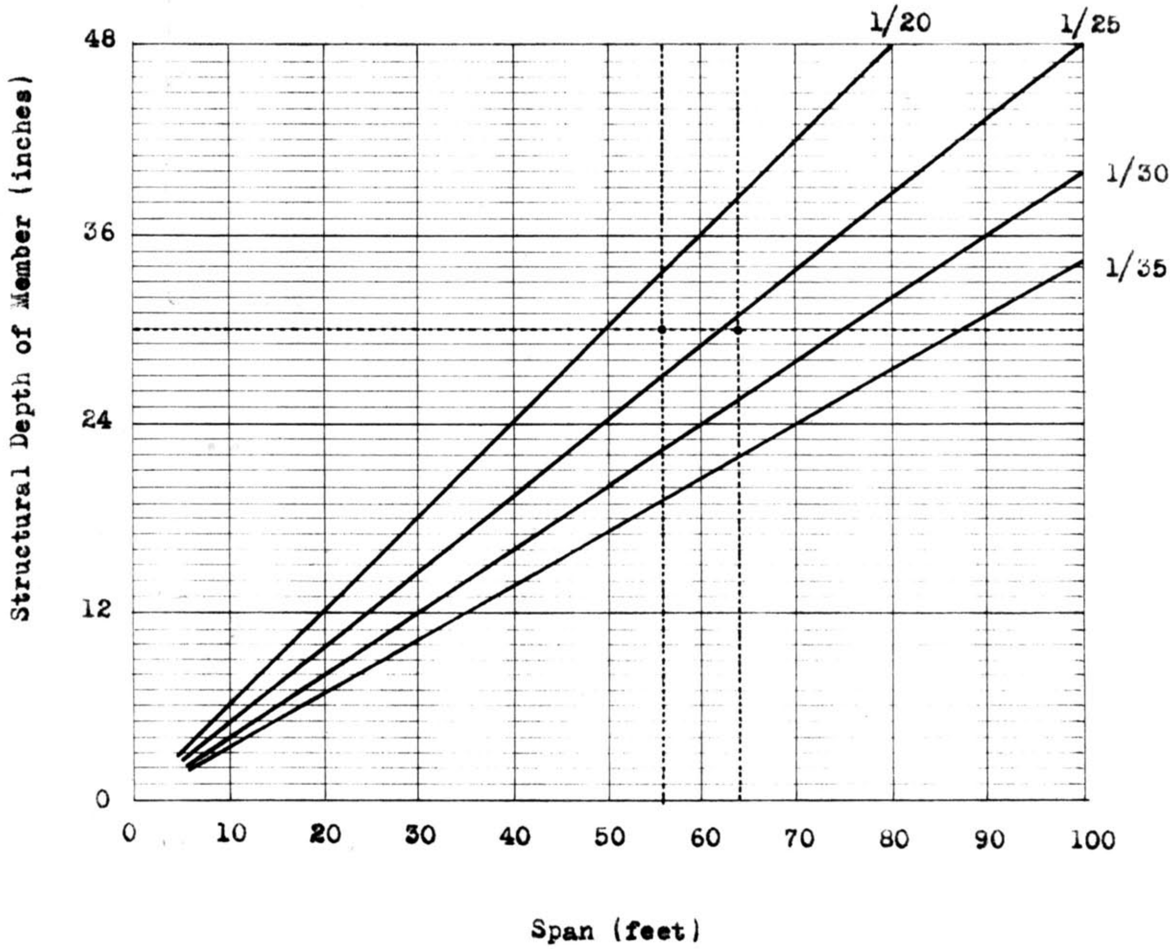
Comparative Structural Characteristics of Standard Cored-Slab Systems

*Loads shown are for members without composite topping

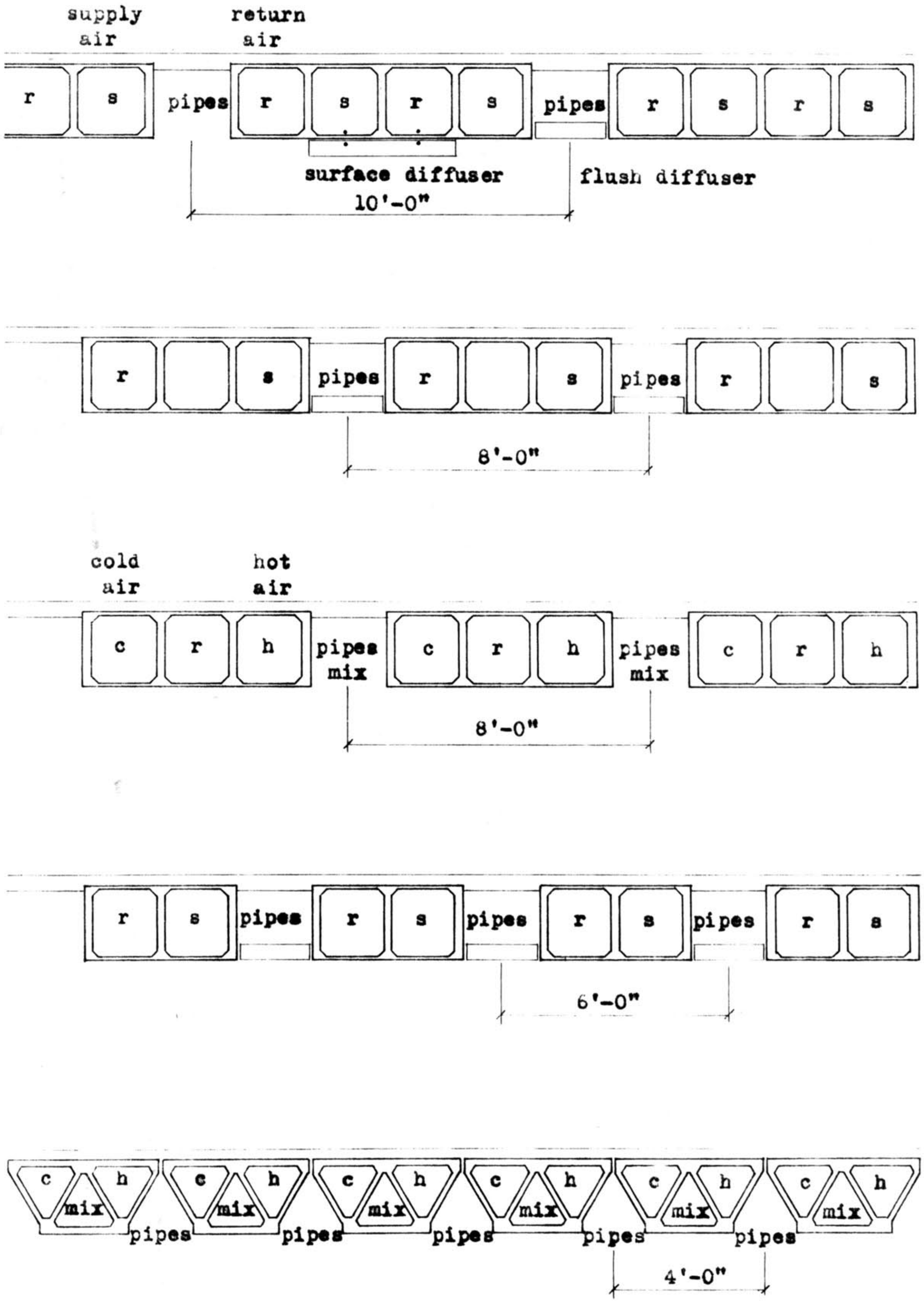
	depth of plank	width of plank	area conc./section	area single void	ult. str. conc.	weight of plank*	span **
	in.	in.	in.^{2}	in.^{2}	psi	psf	ft.
Flexicore (cast)	6 8 9 10	16	70	29	5000		23.2
Doxplank (precast)	6 8 10	16	85.5	32.5	3000		19.5
Spancrete (extruded)	4 6 8 10	40	218	11	4000	60	30.6
Corecrete (extruded)	4 6 8 10	48	219	25.5		57	30.9
Dynacore (cast)	8 12 18 20	96	299	110	5000	26.0	26.0
	24	96	499	440	5000	43.4	62.0

* without composite topping
** superimposed load of 100 psf

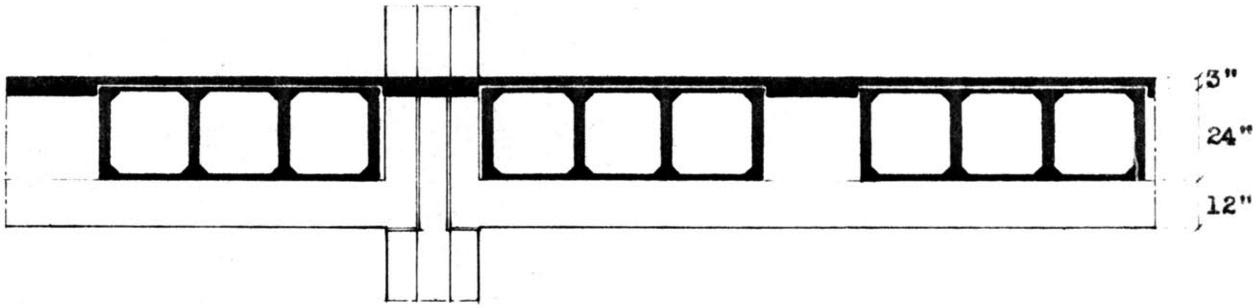
Comparative Data for Precast, Cored-Slab, Concrete Floor Systems



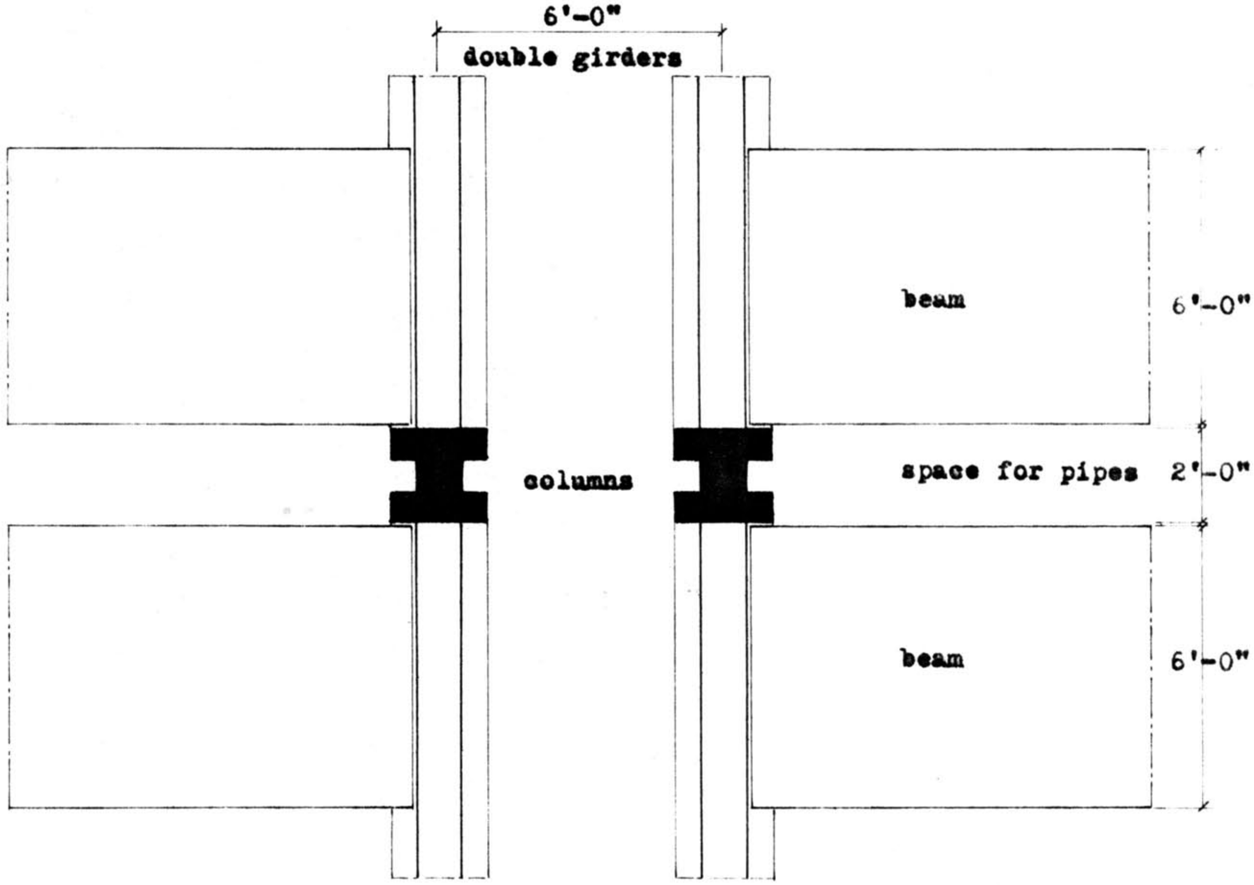
Ratios of Structural Depth to Span



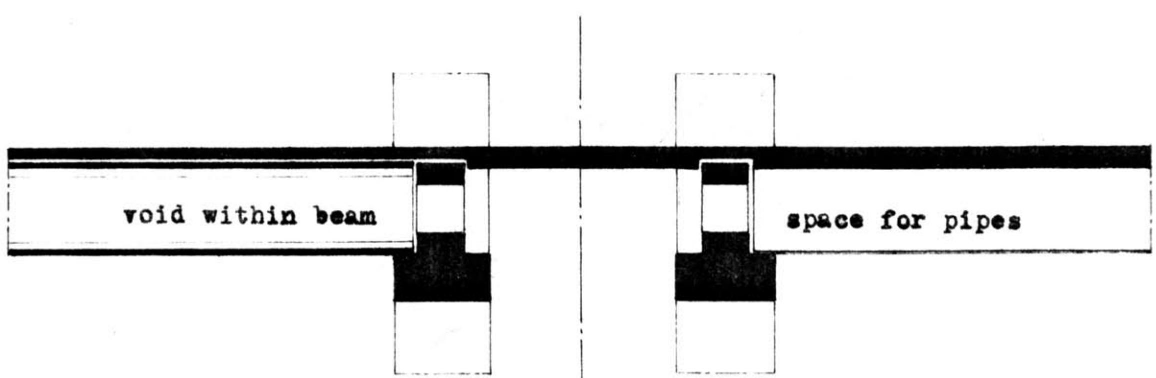
Service Modules: Floor Systems with Linear Voids



Section Through Beams

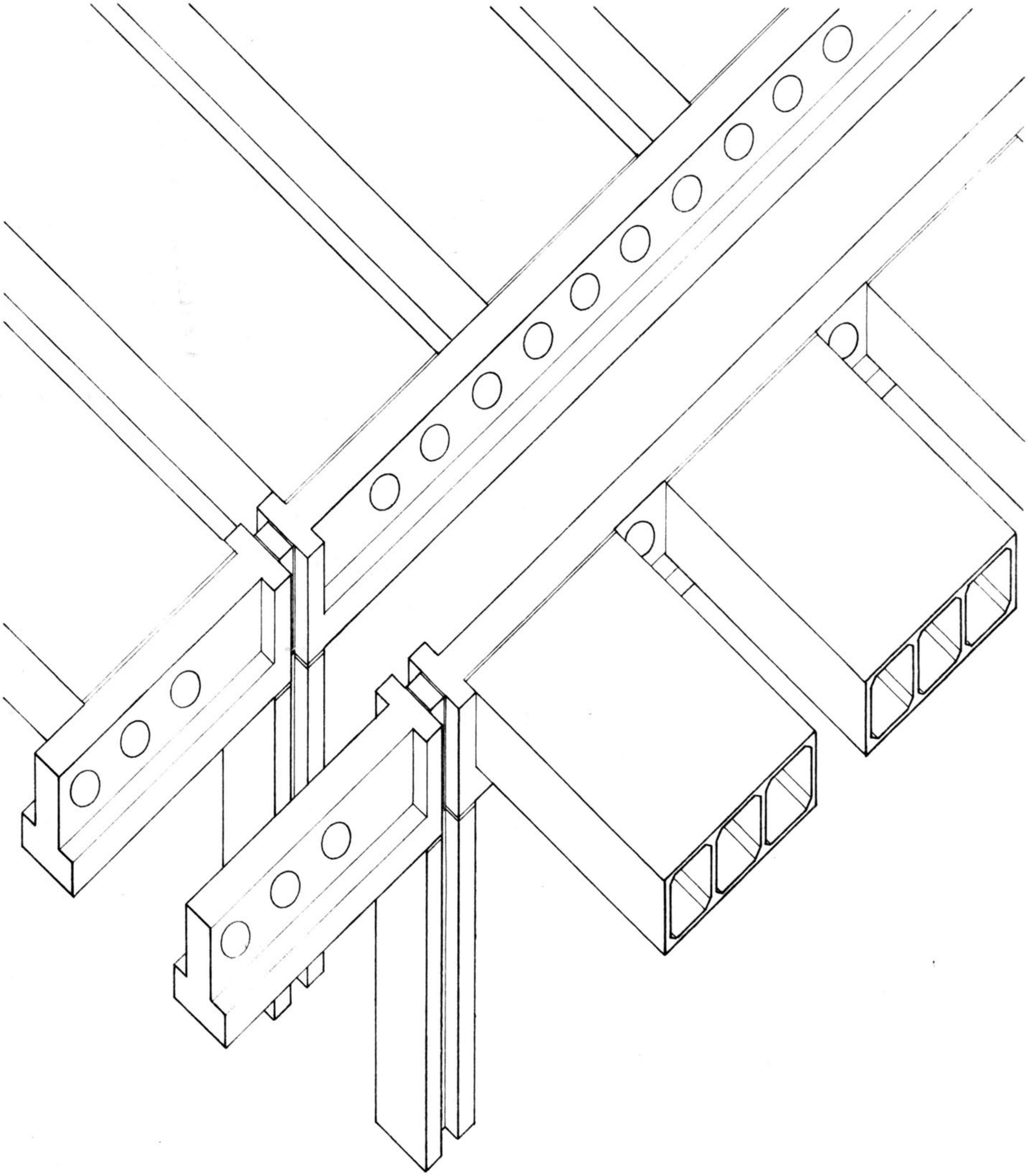


Plan (floor slab not shown)

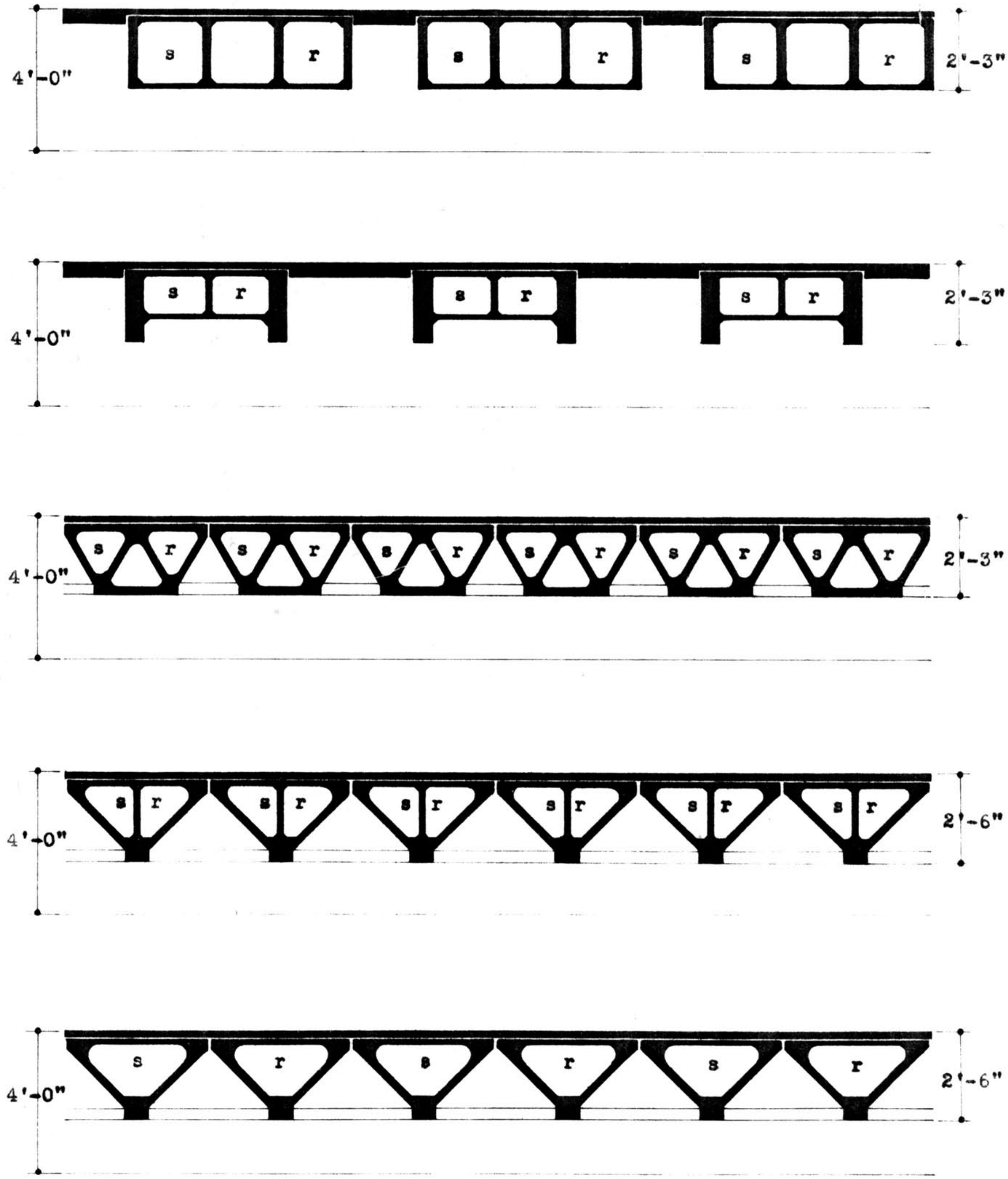


Section Through Girder

Sections of System Using Variation of Dynacore Plank



Anoxometric of System Using Variation of Dynacore Plank



Development of Floor Section

The possibility of modifying the rectilinear geometry of the Dynacore beam was then analyzed. It was noted that a triangular geometry would permit lateral transfer of forces with the possibility of limited two-way action, and that the horizontal solid ceiling condition was avoided.

It is the development of this geometry which is presented as the thesis. The basic elements of the system, which are illustrated on page 52, include precast beams of triangular section with one side of the section used as a horizontal upper flange, precast diaphragms of two basic types, and cast-in-place columns and capitals. Detailed development of these members has been graphically presented on pages 55 and 56.

A. Beams:

It is proposed that the beams be precast with typical mesh reinforcement and approximately five cables of high-tensile steel in the lower chord. In this system, which proposes structural bays of 64-feet clearspan, the beams would be cast 68-feet in length, 4-feet wide, and 27-inches deep.

The technique of extruding the section, applicable to cored-slab planks such as Spancrete and Corecrete (see pages 36 and 38) which have small voids, is not adaptable to the proposed geometry. It is therefore proposed that voids be formed with either re-useable, collapsable metal tubes which would be withdrawn from the ends of the beam (similar to the technique used in casting the Dynacore beams which are fabricated in lengths up to 100-feet), or with rigid tubes of foamed plastic or fiberglass which would be left in place to provide thermal insulation and acoustic absorption within the beam when the voids are used as secondary ducts in the air distribution system. The former technique requires that the section of the beam remain constant along the length to permit extraction of the formwork.

The upper flange of the beam is 2-inches thick (a 5-inch floor slab is provided by combining the flange with a 3-inch cast-in-place topping) and the webs are $2\frac{1}{2}$-inches thick. The lateral connection to adjacent beams along the top flange is reinforced by overlapping of protruding mesh.

An alternate method of forming the interior void of a beam may be more economical. Using this technique, only the lower two webs and the chord would be precast as a unit (the resultant section would approximate a Y-beam or a folded plate) with the top flange separately precast for installation at the site. While being transported from factory to site, the sloping webs of the beam will require restraint by a temporary yoke to prevent failure.

B. Diaphragms:

It is proposed that diaphragms and girder elements (which are widened diaphragms) be precast separately from the beams and reinforced with typical mesh. Diaphragms are required to provide lateral bracing at points along the span and limited lateral transfer of forces near the column (see page 54). These elements are separately precast to provide sufficient tolerance for alignment. It was advised that the proposal for diaphragms cast integrally with the beams (diagramed on page 53) would be visually and structurally (for girders) unsatisfactory since it is not possible to insure proper alignment of long members.

Diaphragms which are required for bracing are placed normal to the lower chords of adjacent beams and secured by post-tensioned cables. Mortar is applied to each end during the sequence of construction when beams and diaphragms are alternately placed (steps 4 and 5, page 48). A rod is drawn through the tube in the diaphragm to remove unwanted mortar.

C. Girders

Girders consist of diaphragms which have a greater width to receive the required number of post-tensioned cables. These diaphragms have upper chords which form a cavity between the sloping webs of adjacent beams, accessible from above the slab, for the placement of additional reinforcement and grout. This additional material, effectively increasing the structural section of the beam webs along the girder, is required to resist the compression force which increases near the column. The volume of the cavity can be varied as required.

The diaphragms have been laterally perforated to permit the passage of pipes and conduit. The shape of this perforation was studied with respect to the feasibility of filling the cavity with grout from above the slab and the amount of material required to resist static forces (see pages 53 and 55).

Girder diaphragms with cavity reinforcement and beams are alternately placed during construction. To preserve a continuous tube in the lower chord for the subsequent threading of cables, it is proposed that rods be inserted through beams and diaphragms before the placing of grout and withdrawn before bond is achieved, thereby 'extruding' the tubes. The alternate method would be the installation of typical cable sheaths.

Lateral continuity between girders is achieved by connecting the lower chords of opposite beams with a solid precast compression chord, 8-inches wide, 4 to 6-inches high, and 4-feet long. Tensile forces across the top of the girders are resisted within the floor slab.

D. Columns and Capitals

Columns and capitals are to be cast-in-place to provide vertical continuity. The effective structural section required to support half a bay per floor is divided between members of a paired column (see pages 54 and 55) to permit the use of all linear voids within beams along the girder. With this detail, vertical forces bypass the voids. Two paired-columns, spaced 4-feet apart and joined at the floor slabs, form a service column which encloses a shaft for the air distribution ducts, return air plenum, and pipes. Removable, non-structural panels complete the enclosure.

CONSTRUCTION SEQUENCE:

Some of the following phases of construction occur simultaneously. This list serves to outline the separate steps.

A. Preparation:

1. Precast beams, diaphragms, girder compression chords and slabs
2. Excavate, prepare footings and foundations
3. Erect scaffolding for first floor

B. Floor System:

4. Place first precast beam on scaffolding
5. Place precast diaphragms and cavity reinforcement
6. Place next precast beam
7. Place form rods for post-stressing cable tubes
8. Grout diaphragm cavities and progressively withdraw rods
9. Continue sequence of placing precast diaphragms and beams
10. Place precast girder compression chords

C. Column:

11. Erect column formwork, place column and capital reinforcement
12. Cast columns and capitals
13. Grout channels of girder compression chords
14. Place precast girder slabs

D. Post-stressing:

15. Thread cables
16. Install power and communication raceways, pipe sleeves
17. Adjust diaphragm reinforcement and set slab reinforcement mesh
18. Post-stress cables, grout tubes
19. Pour 3-inch finish slab

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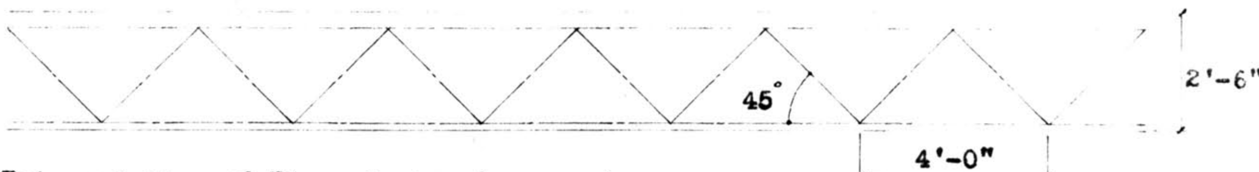
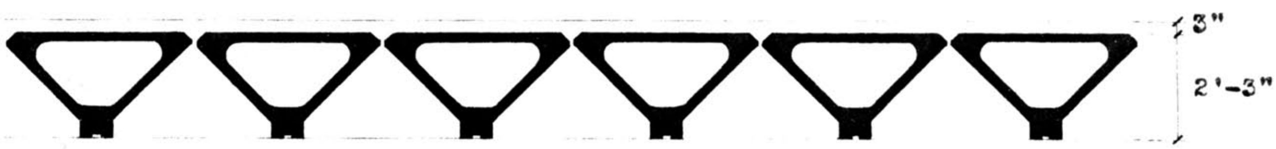
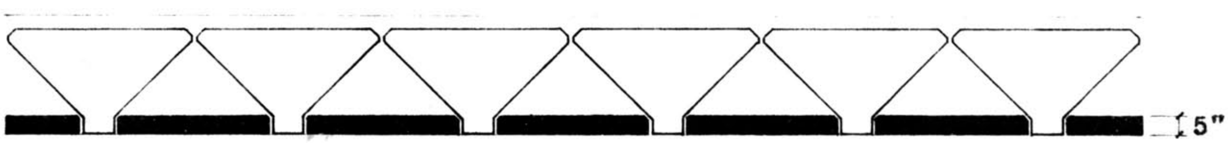


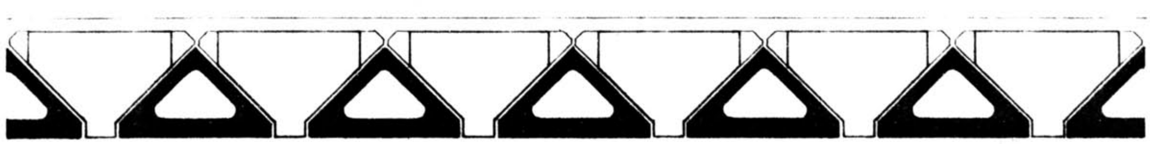
Triangulation of Floor System (one way)



Section: Beams



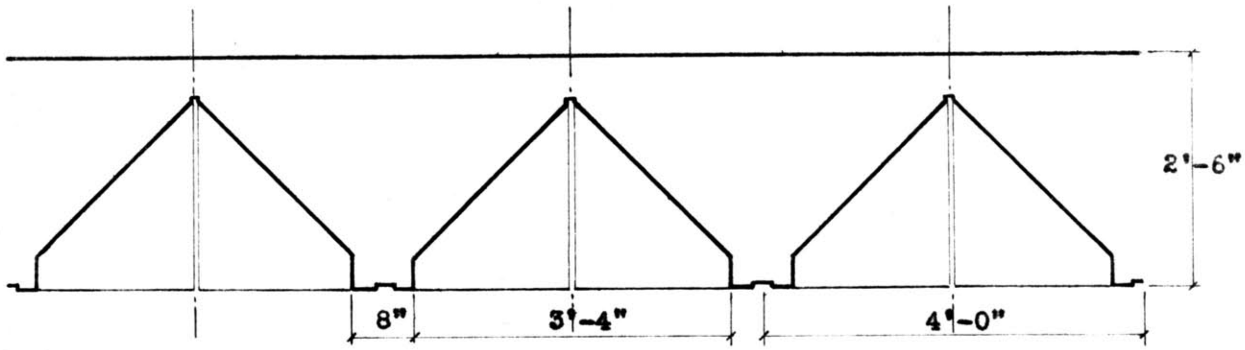
Section: Diaphragms, Type One



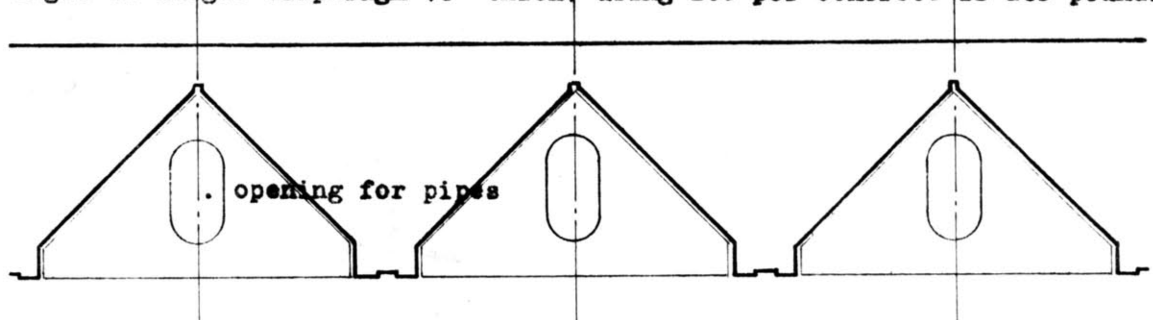
Section: Diaphragms, Type Two

Section: Girder assembly with cast-in-place columns and capitals

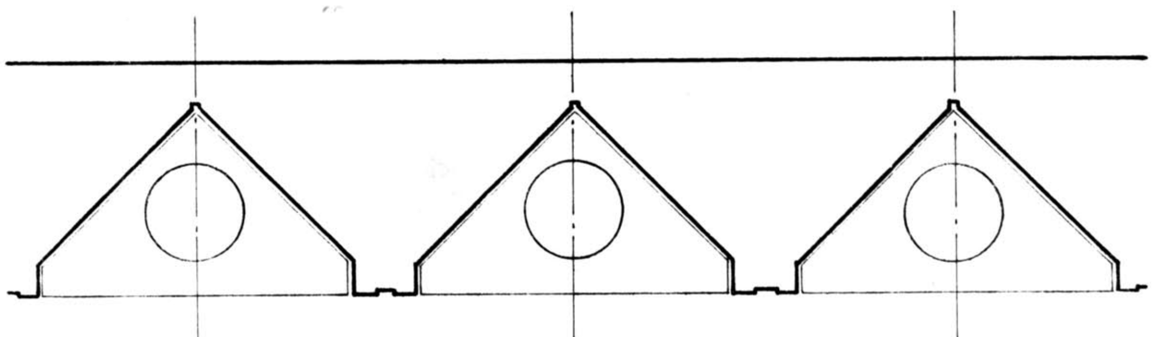
Elements of Floor System



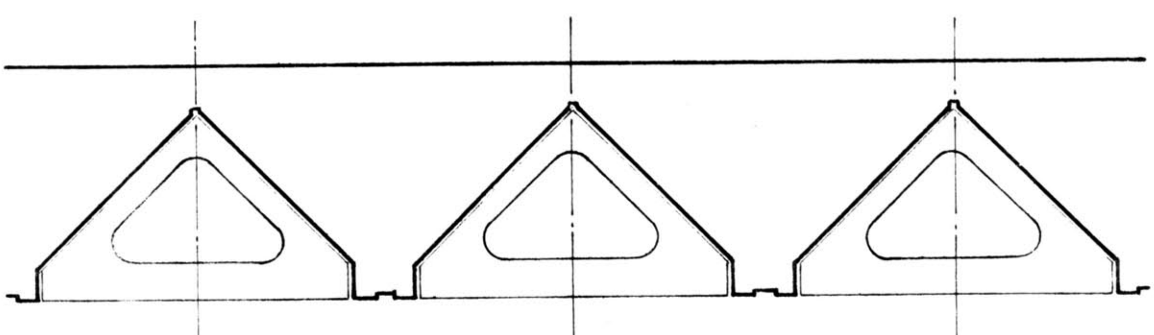
Diaphragm integral with beams (joints on structural module)
Weight of single diaphragm (6" thick) using 100 pcf concrete is 165 pounds



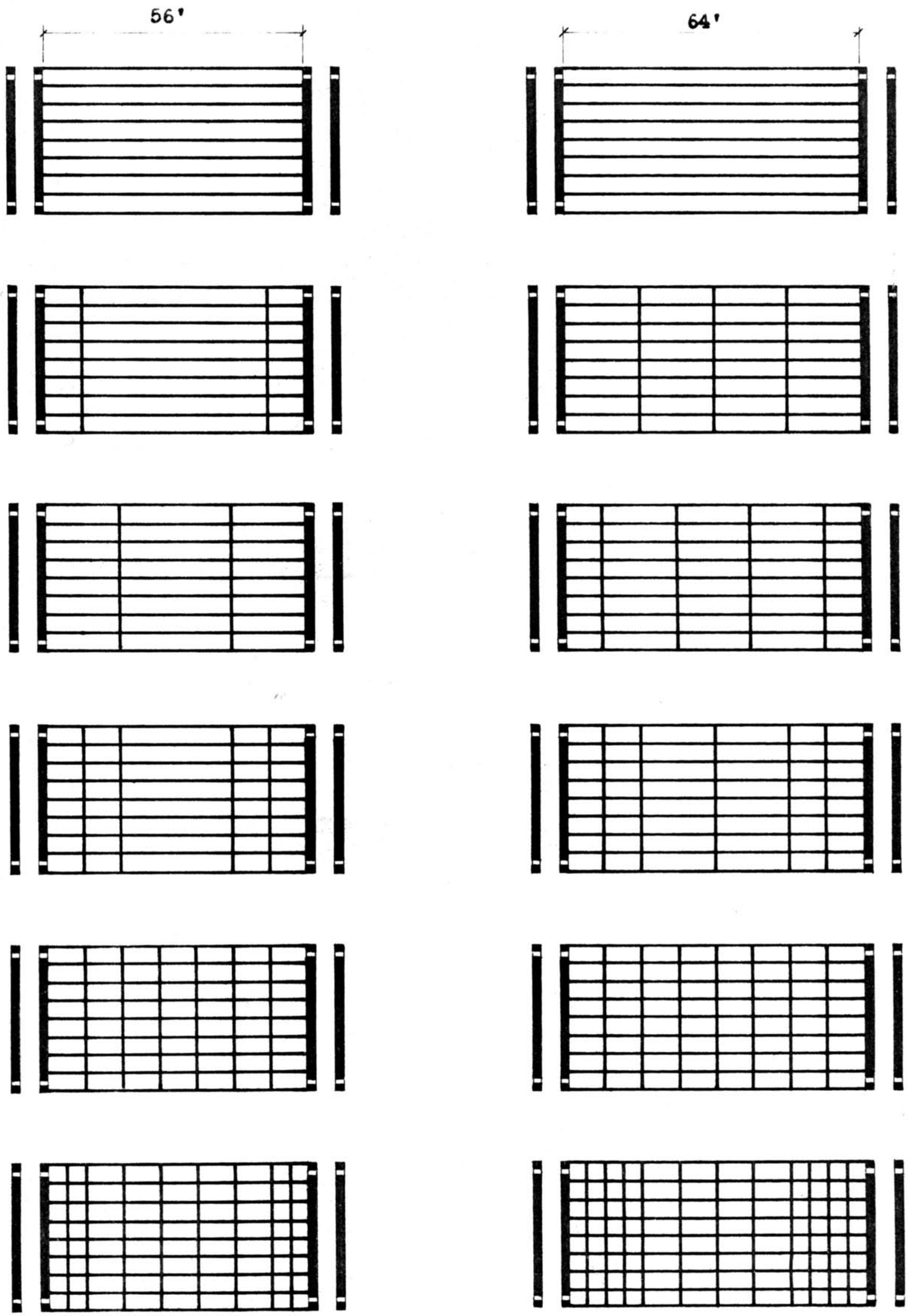
Diaphragm separately precast from beam (joints along lower chord)
Weight of single diaphragm (6" thick) is 149.5 pounds



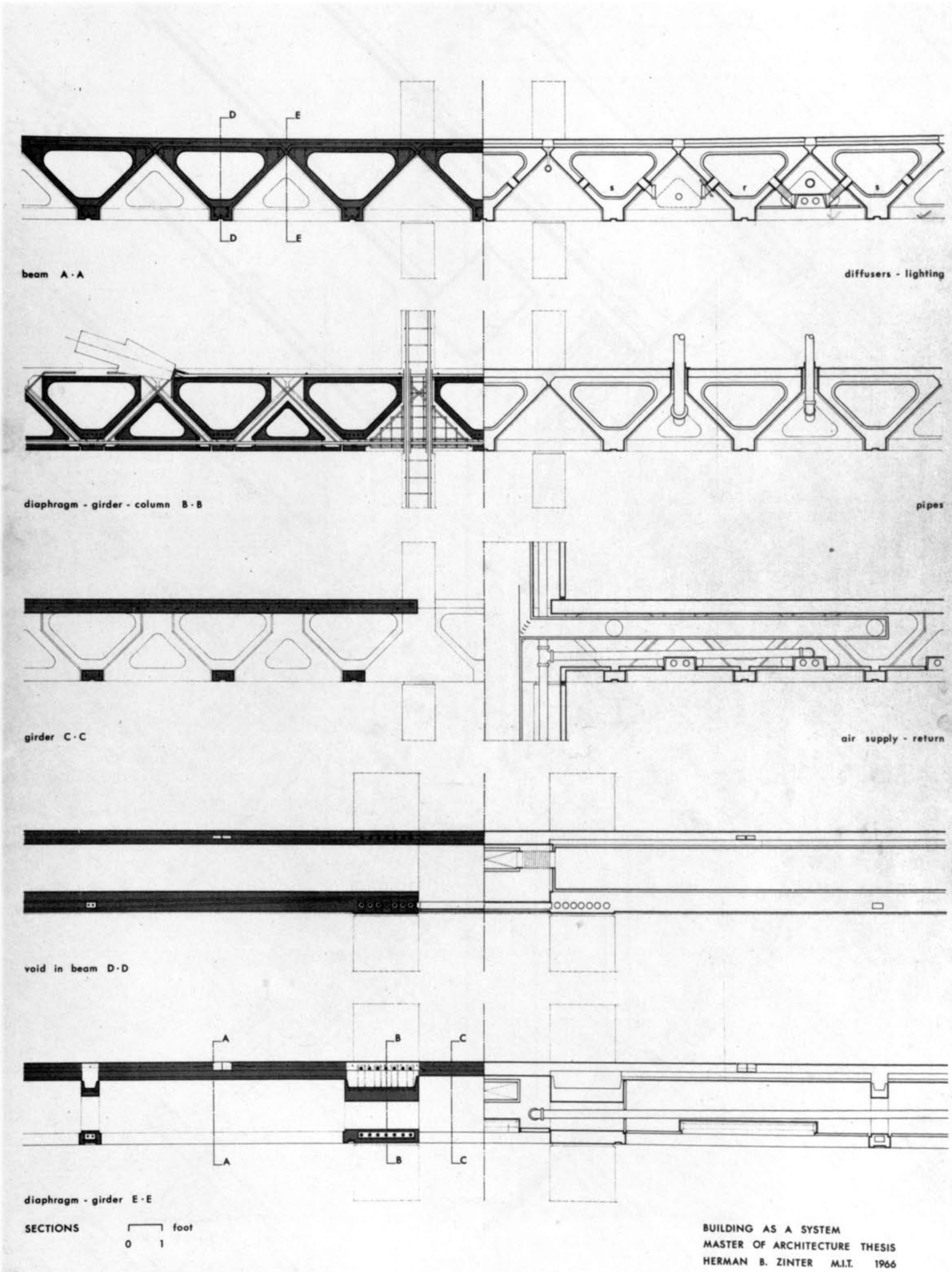
Diaphragm separately precast
Weight of single diaphragm (6" thick) is 126 pounds

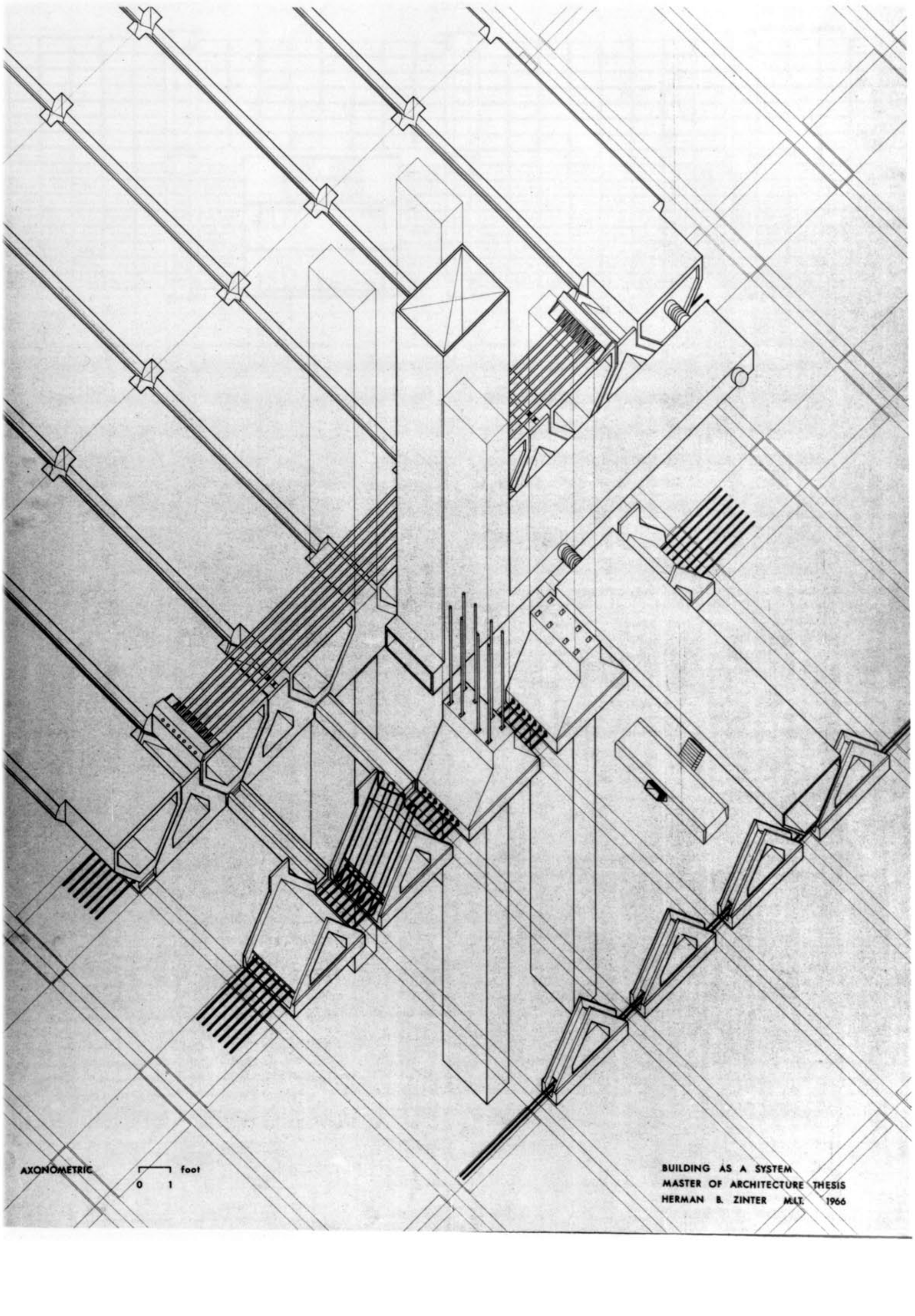


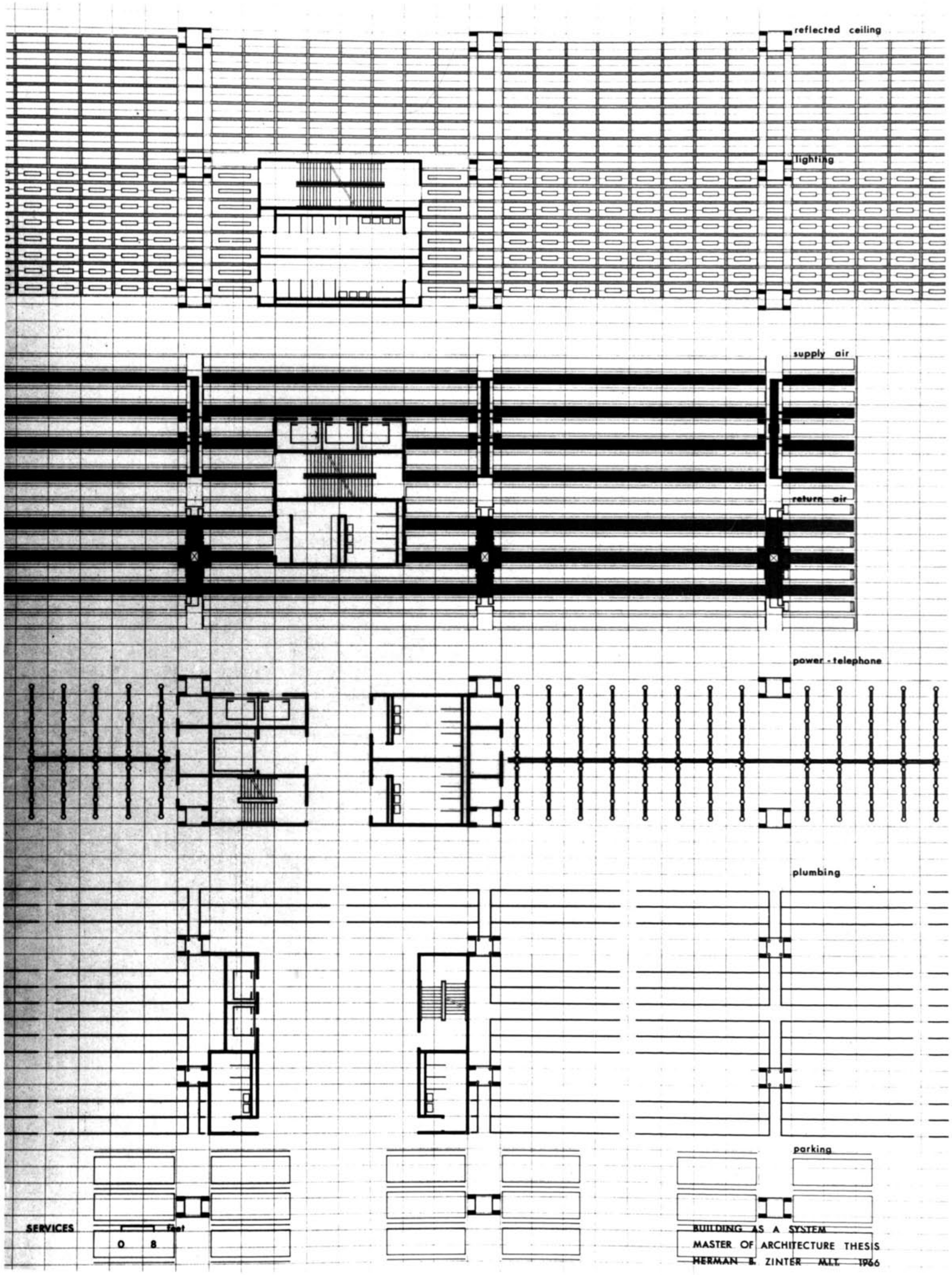
Diaphragm separately precast
Weight of single diaphragm (6" thick) is 108.5 pounds

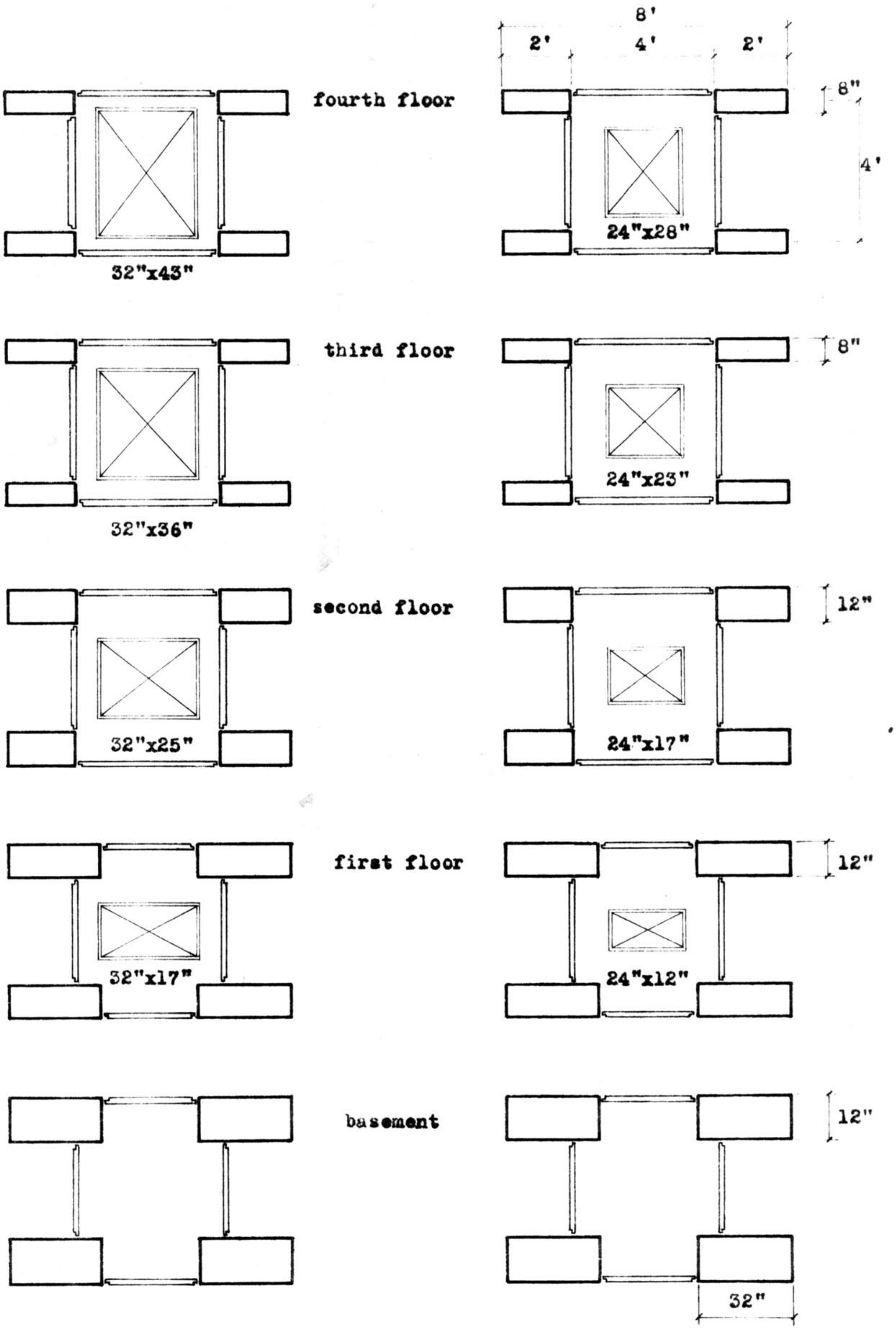


Diaphragm Patterns (Reflected Ceiling Plan) - Comparison of Two Bays

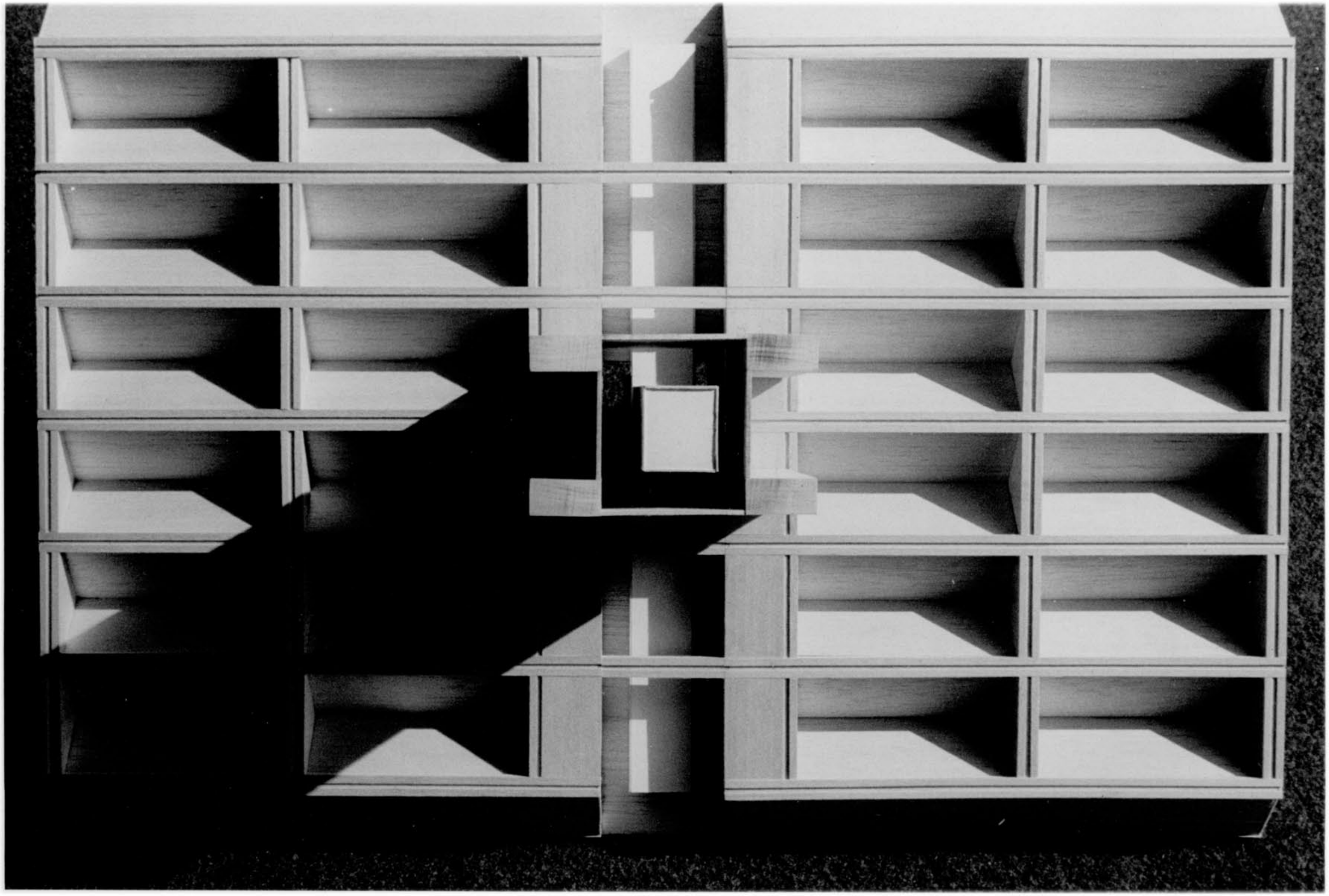

beam A·A
diffusers - lighting
diaphragm - girder - column B·B
pipes
girder C·C
air supply - return
void in beam D·D
diaphragm - girder E·E
SECTIONS
foot
0 1
BUILDING AS A SYSTEM
MASTER OF ARCHITECTURE THESIS
HERMAN B. ZINTER M.I.T. 1966

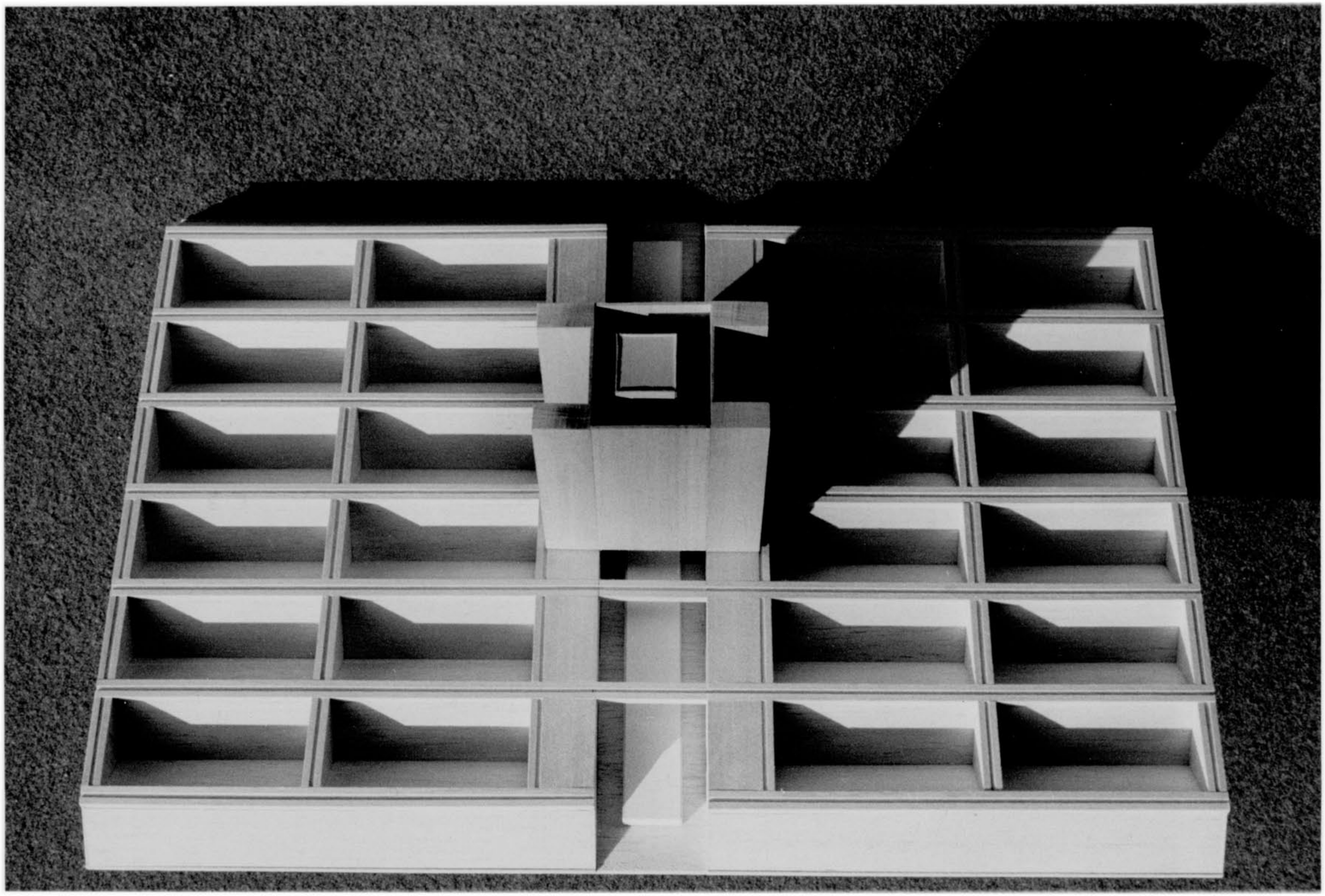

AXONOMETRIC
foot
0 1
BUILDING AS A SYSTEM
MASTER OF ARCHITECTURE THESIS
HERMAN B. ZINTER M.I.T. 1966

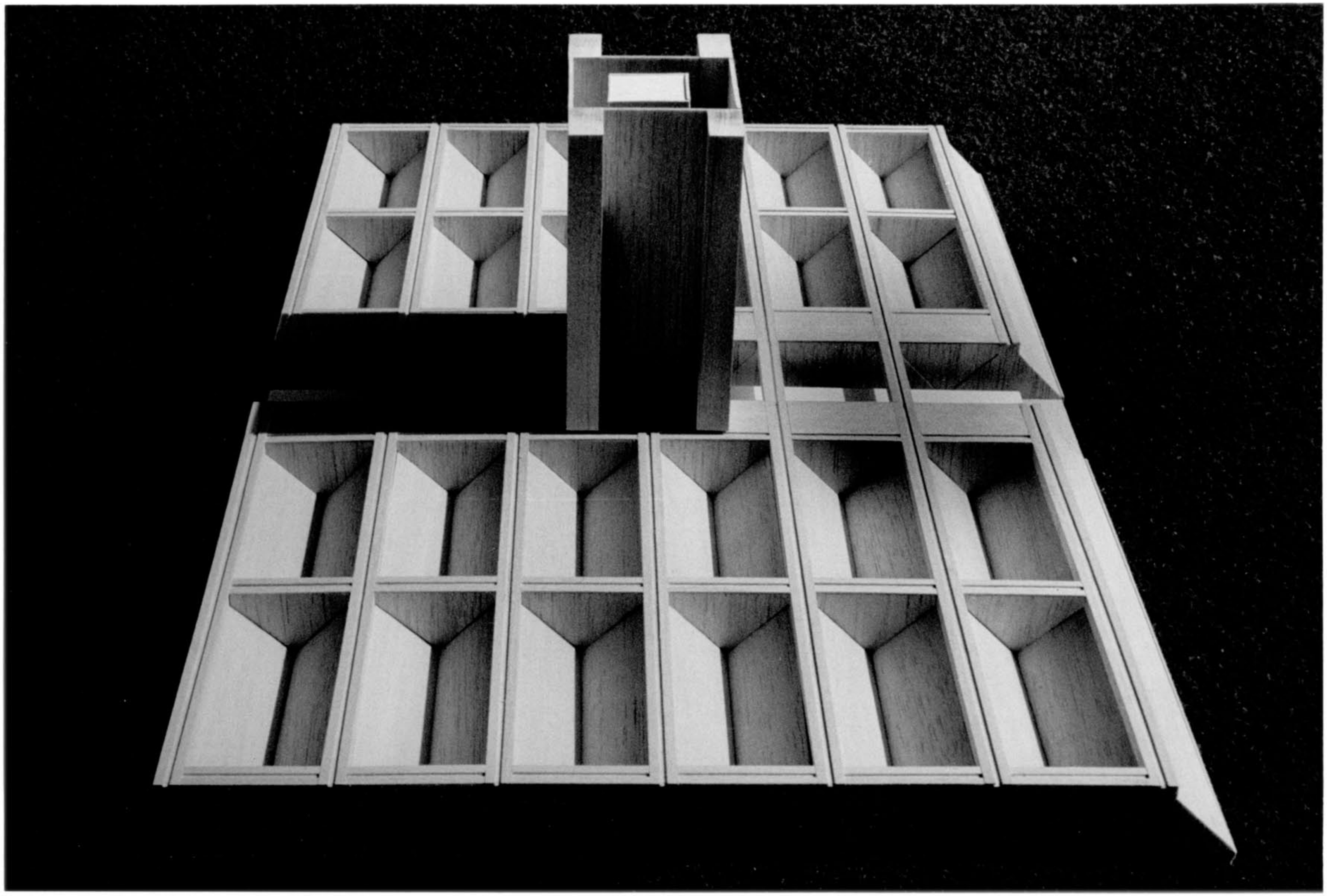

reflected ceiling
lighting
supply air
return air
power - telephone
plumbing
parking
SERVICES
feet
0 8
BUILDING AS A SYSTEM
MASTER OF ARCHITECTURE THESIS
HERMAN B. ZINTER M.I.T. 1966

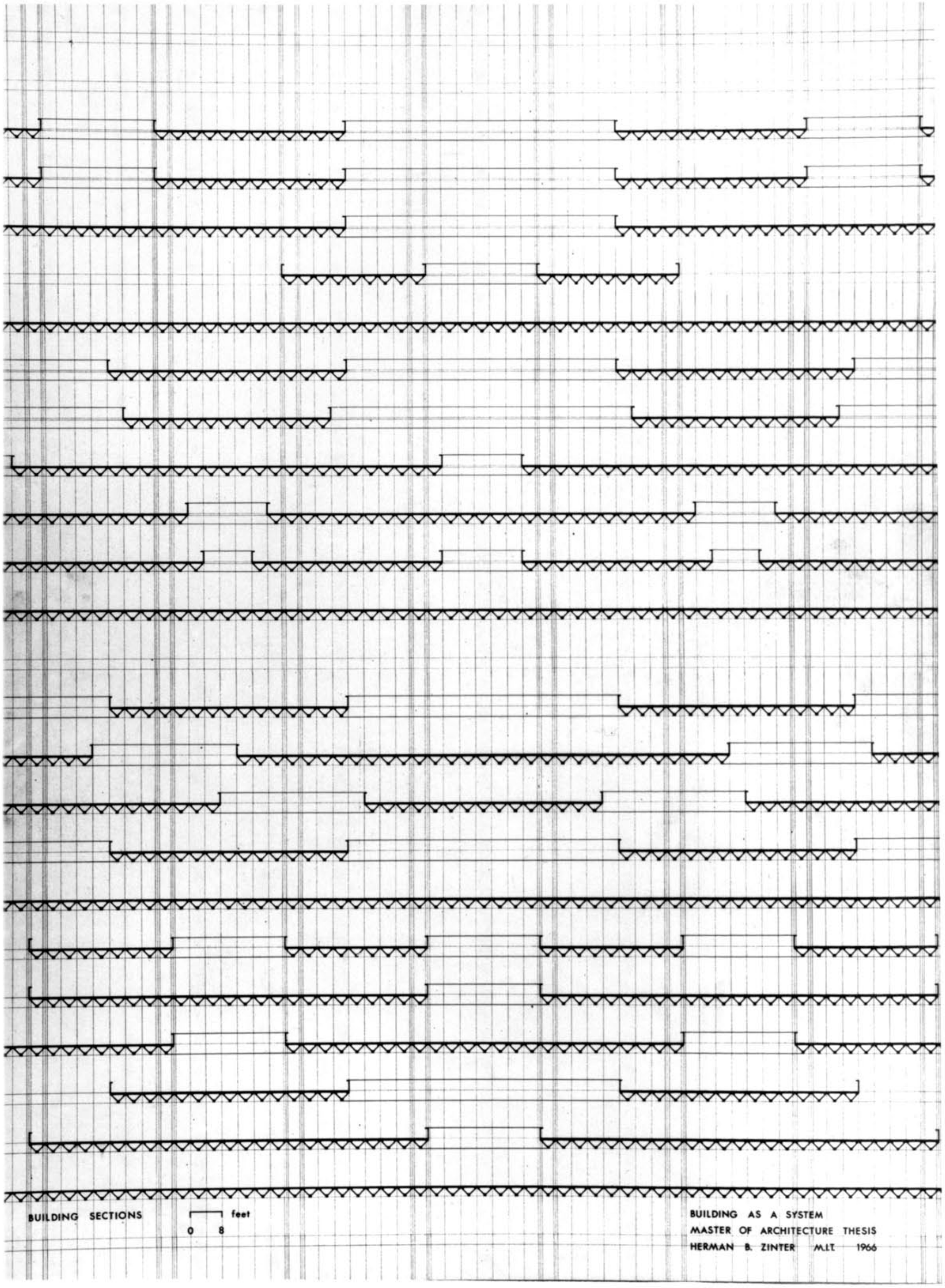


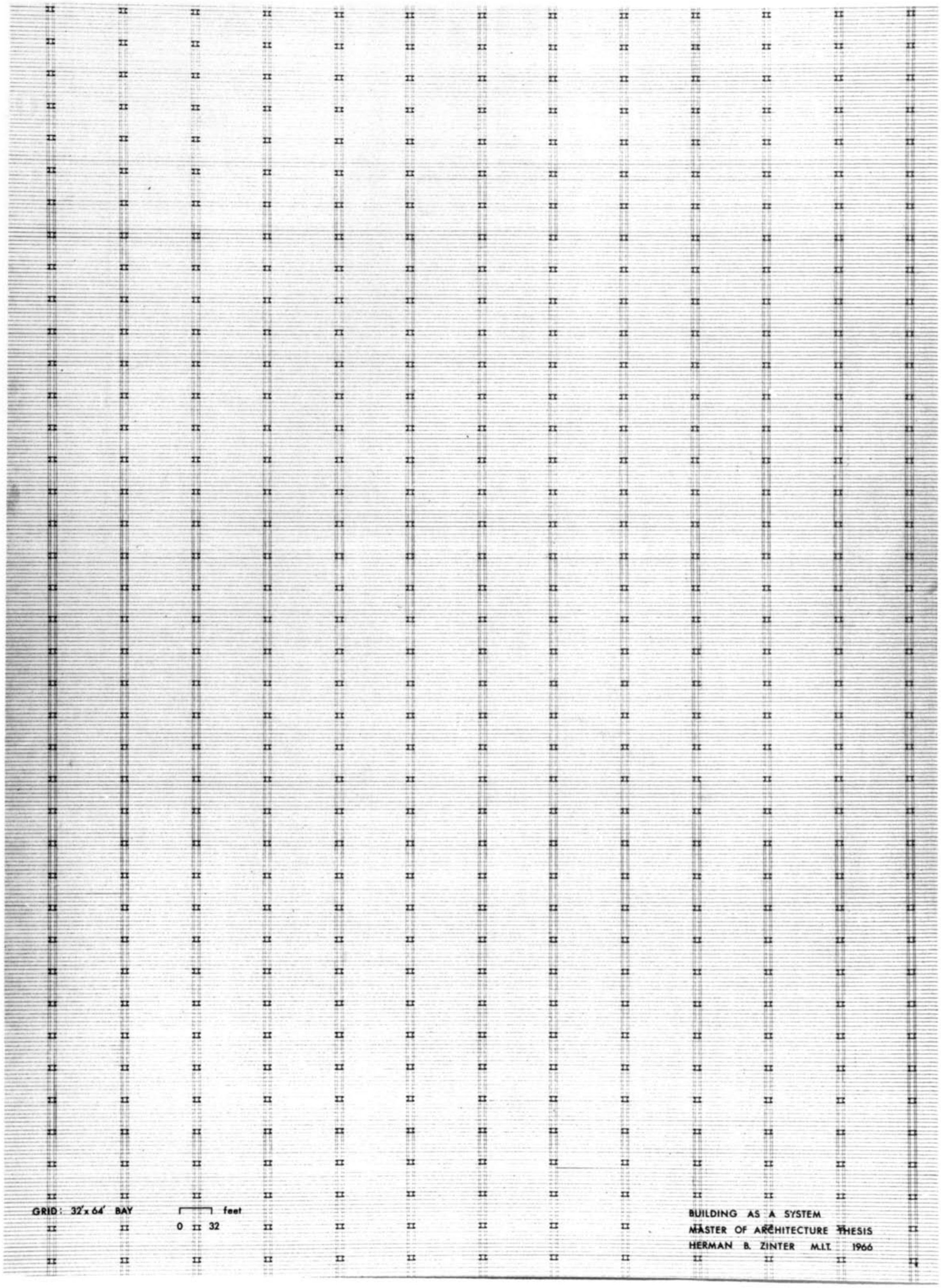
Variation of column and vertical duct dimensions with height

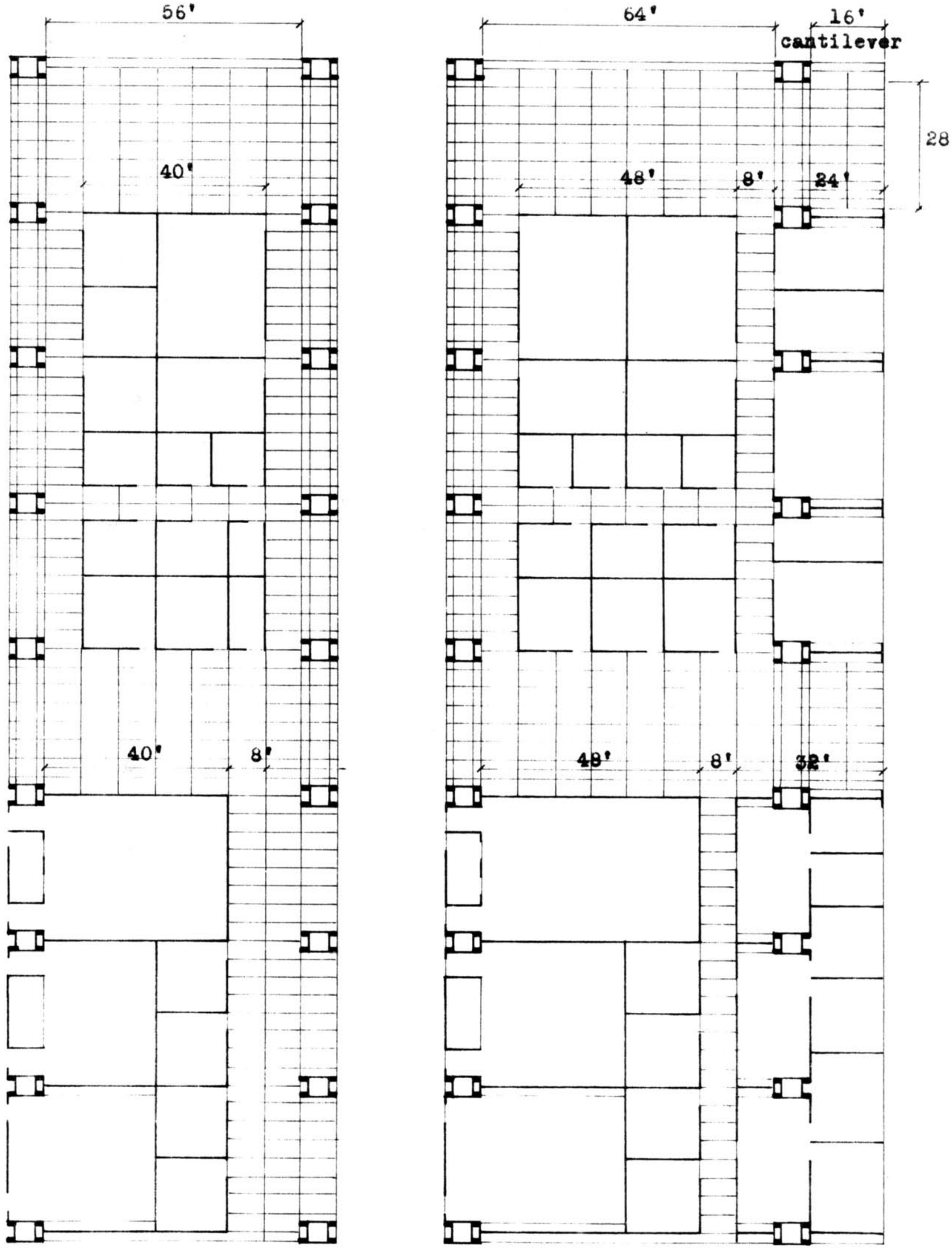







BUILDING SECTIONS
feet
0 8
BUILDING AS A SYSTEM
MASTER OF ARCHITECTURE THESIS
HERMAN B. ZINTER M.I.T. 1966


GRID: 32' x 64' BAY
feet
0 32
BUILDING AS A SYSTEM
MASTER OF ARCHITECTURE THESIS
HERMAN B. ZINTER M.I.T. 1966



Room Planning and Circulation - Comparison of Two Bays

SECTION THREE - LINEAR CORES

The typical elements of cores within buildings which form the permanent vertical service columns require shafts (stairs, escalators, elevators, freight elevators, and pipe and duct spaces) or slabs (toilets, cleaning closets, power and communication equipment closets or rooms). These elements are generally organized into clusters and less frequently into chains--or linear cores. Examples of the latter system are found in a newspaper shop for the Greensburg, Pennsylvania, "Tribune-Review" (Louis I. Kahn, architect), which has a core 14-feet by 120-feet, and in the IBM Office Building, Milwaukee, Wisconsin (Harry Weese and Associates, architects), which has a core 12-feet by 153-feet. The advantage of this system of core organization is that components may be added or deleted without revision of the basic core geometry or internal circulation.

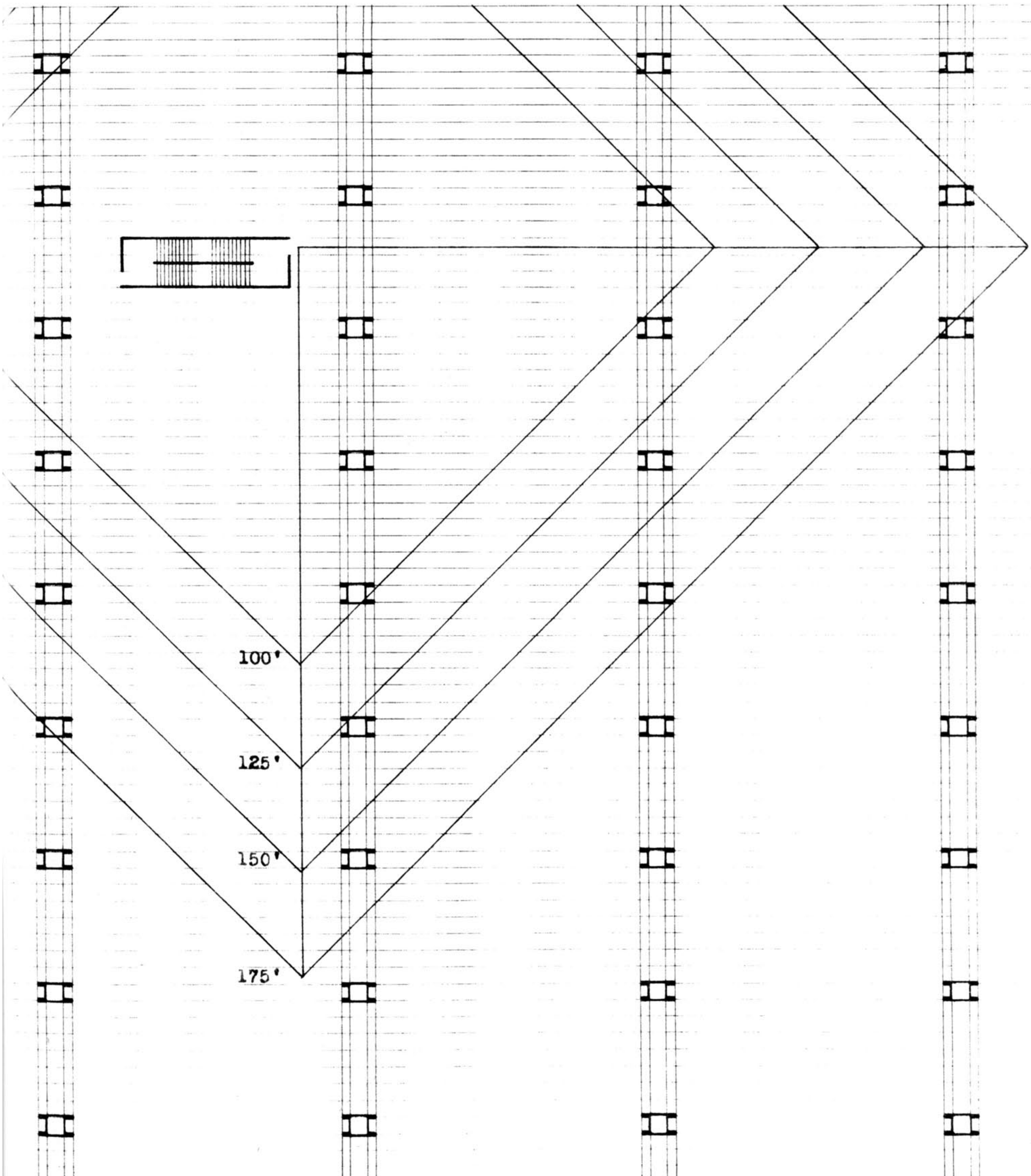
Minimal dimensions of individual elements were studied for coordination with planning modules. The examples presented on pages 70 to 75 have been planned for a 4-foot by 8-foot module, and developed for five increments of width: 12, 16, 24, 32, and 40-feet. The resultant lengths of core assemblies which correspond to these widths have been compared on page 68. It was intended that assemblies such as those illustrated, and including lobbies, lounges, and other public spaces, would form a service and circulation spine within the structural grids presented on pages 20 and 21. However, except for the 12 and

16-foot wide core systems, the length of the chain of elements did not fully utilize the space of, and therefore justify a separate, atypical bay within the grid.

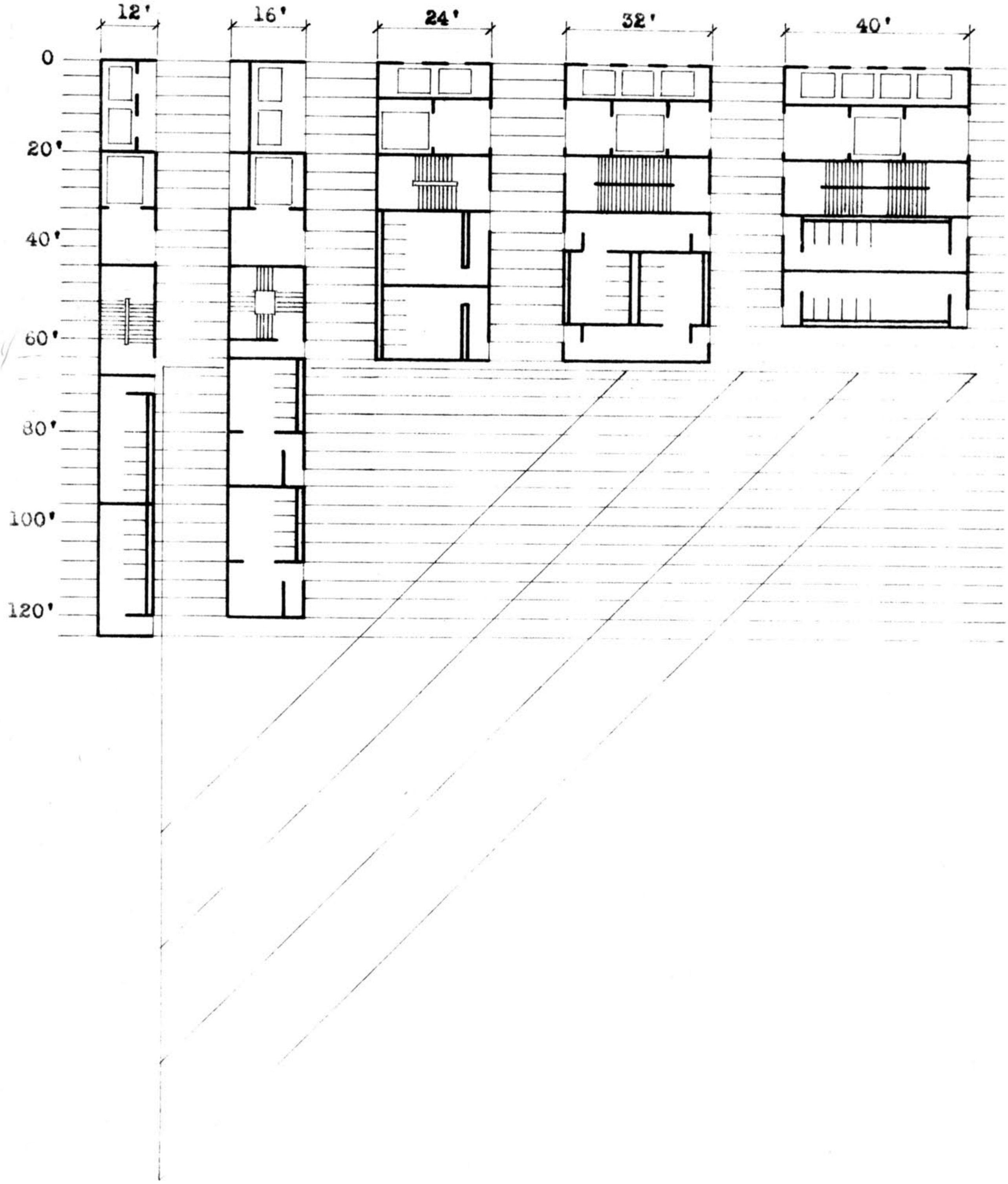
No research was found which offered criteria on the density of core elements by type over a given area. That is, within a structural grid, which in theory has no limits, what patterns would be formed by core elements placed by criteria at desirable distances from similar type core elements? Building codes define maximum distances to emergency exits for various type occupancies and construction. The geometry of this criteria, which is not a radius when room arrangements are superimposed, is presented on page 67.

The density and pattern of toilet facilities of uniform size is suggested in the diagram of the structural grid for the Free University of Berlin on page 14. It was considered more realistic, however, to provide within a system of core elements a geometry which permitted several sizes. In the examples presented on pages 70 to 75, the number of fixtures may be increased or decreased within limits without modifying basic circulation or utility patterns. At the limit where it becomes necessary to modify the geometry, it will be found that to maintain convenient distances from points within the grid, another facility will be required.

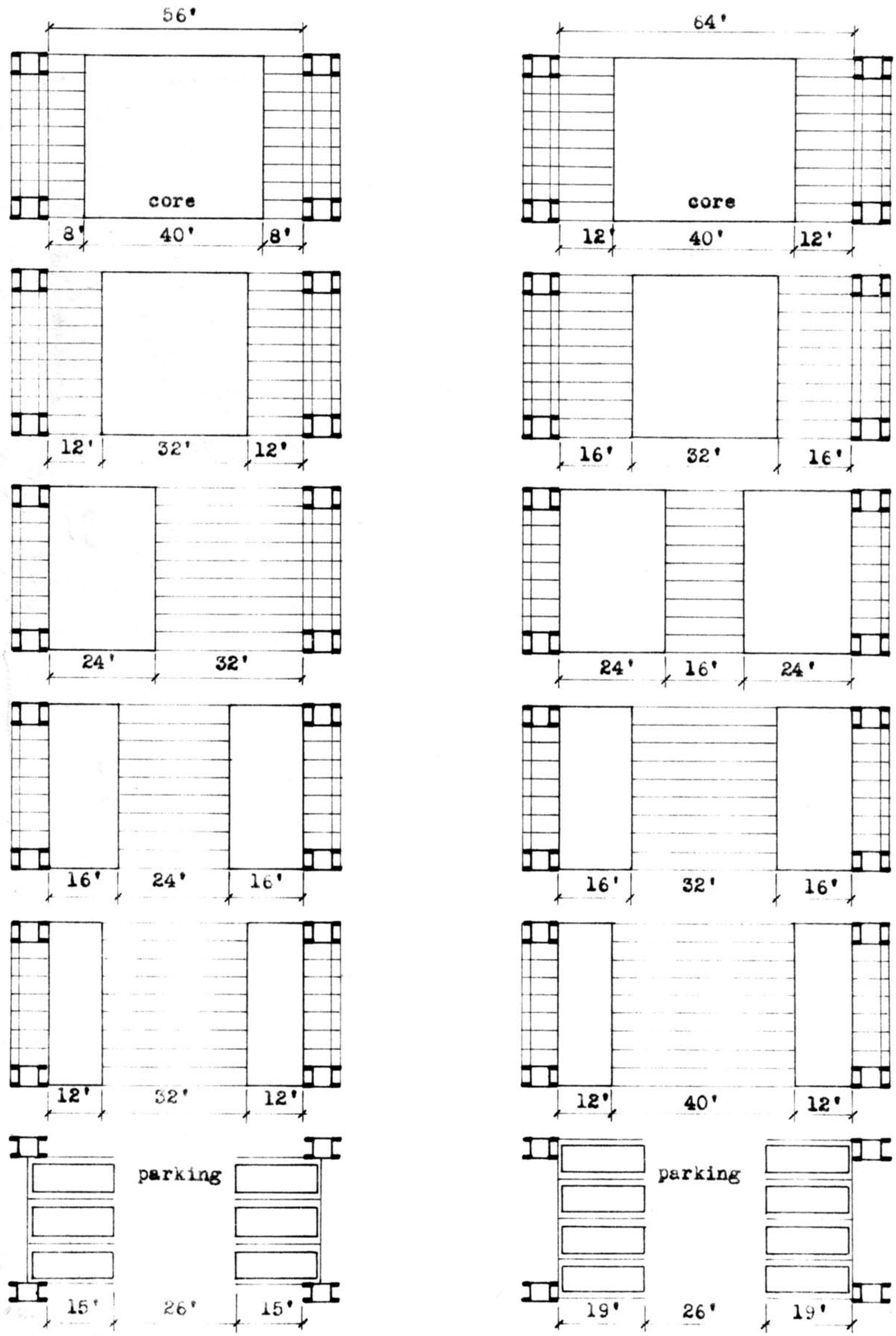
The geometry of linear cores lends itself to bearing wall construction which is directly incorporated into the structural system proposed in Section Two of this report. The relationship of core elements to columns and girders within structural bays of 56 and 64-feet clearspan is diagrammed on page 69. In some of these examples, the girder has been replaced with a bearing wall.



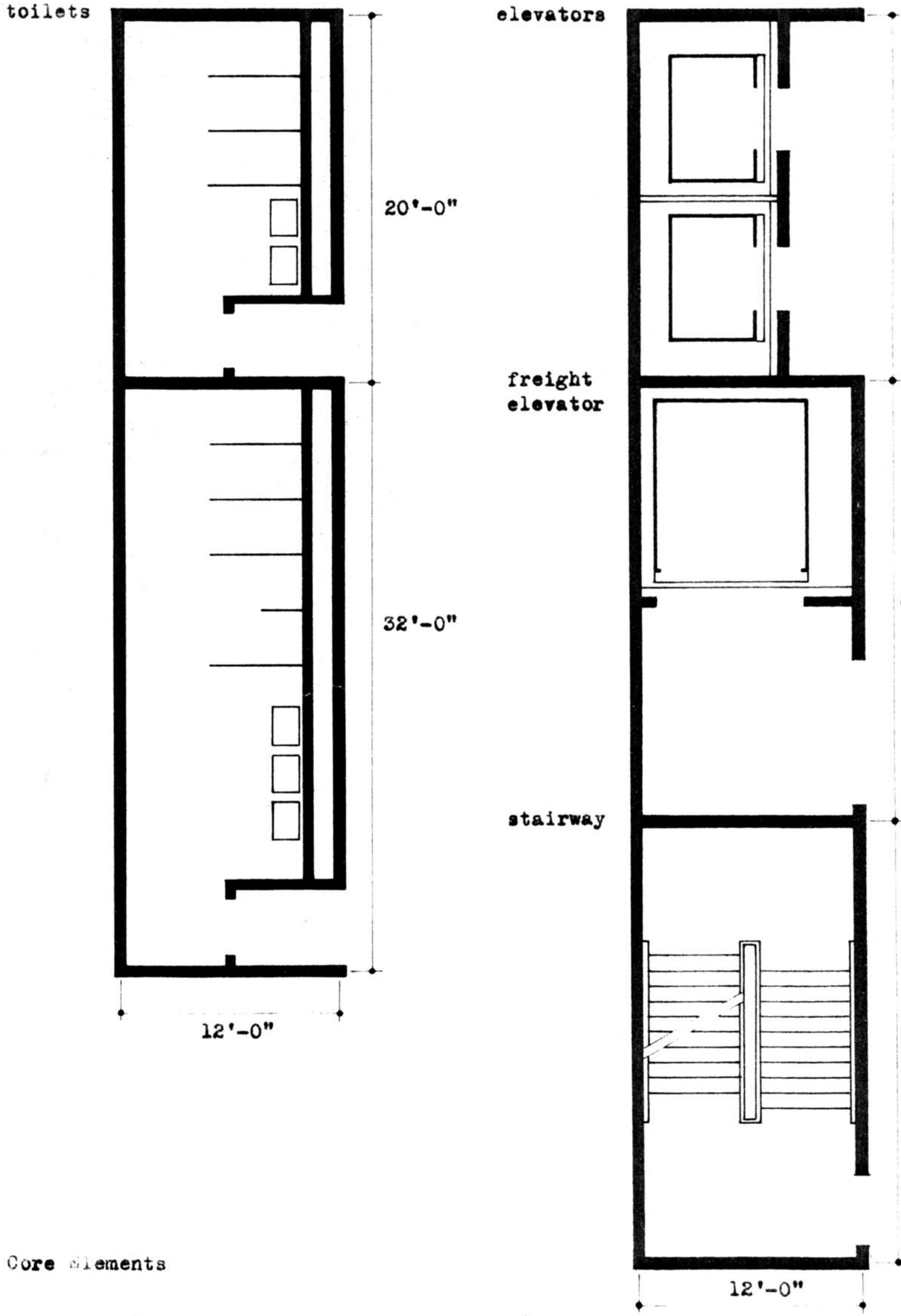
Superimposed Geometry of Maximum Distances to Exit Stairway



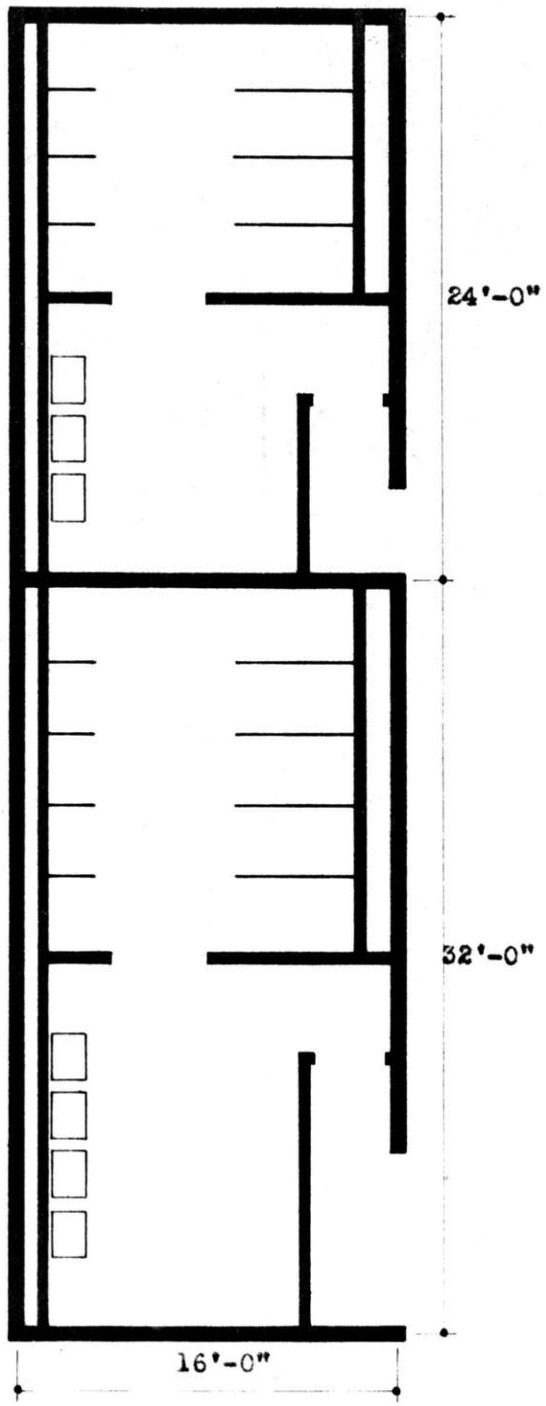
Comparative Dimensions of Linear Cores

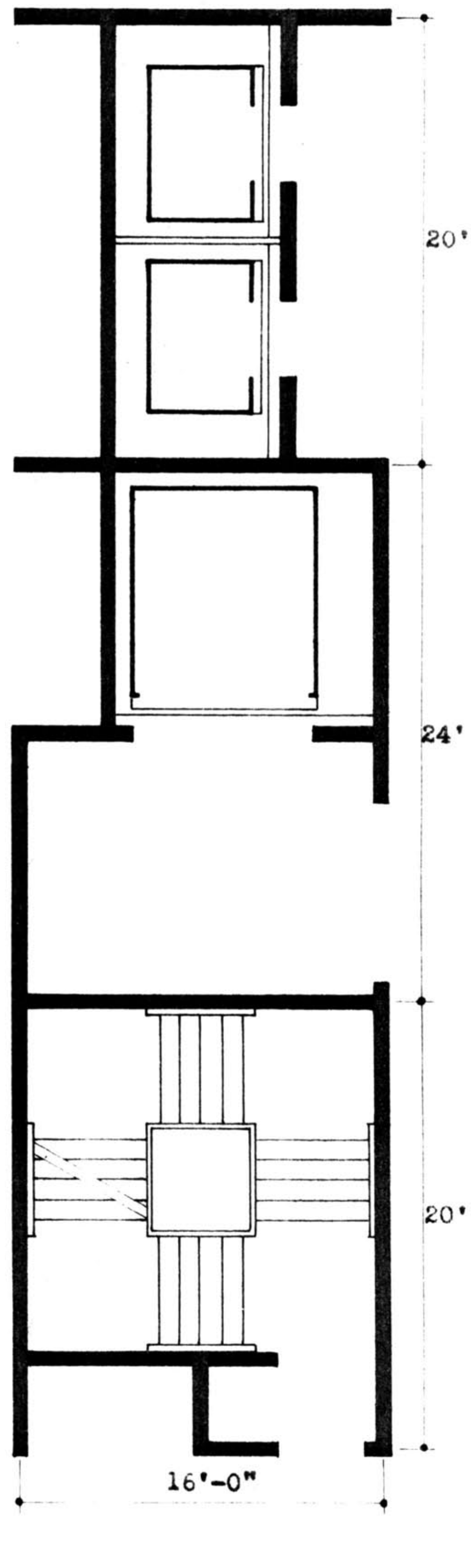


Positions of Core Elements Within Bay

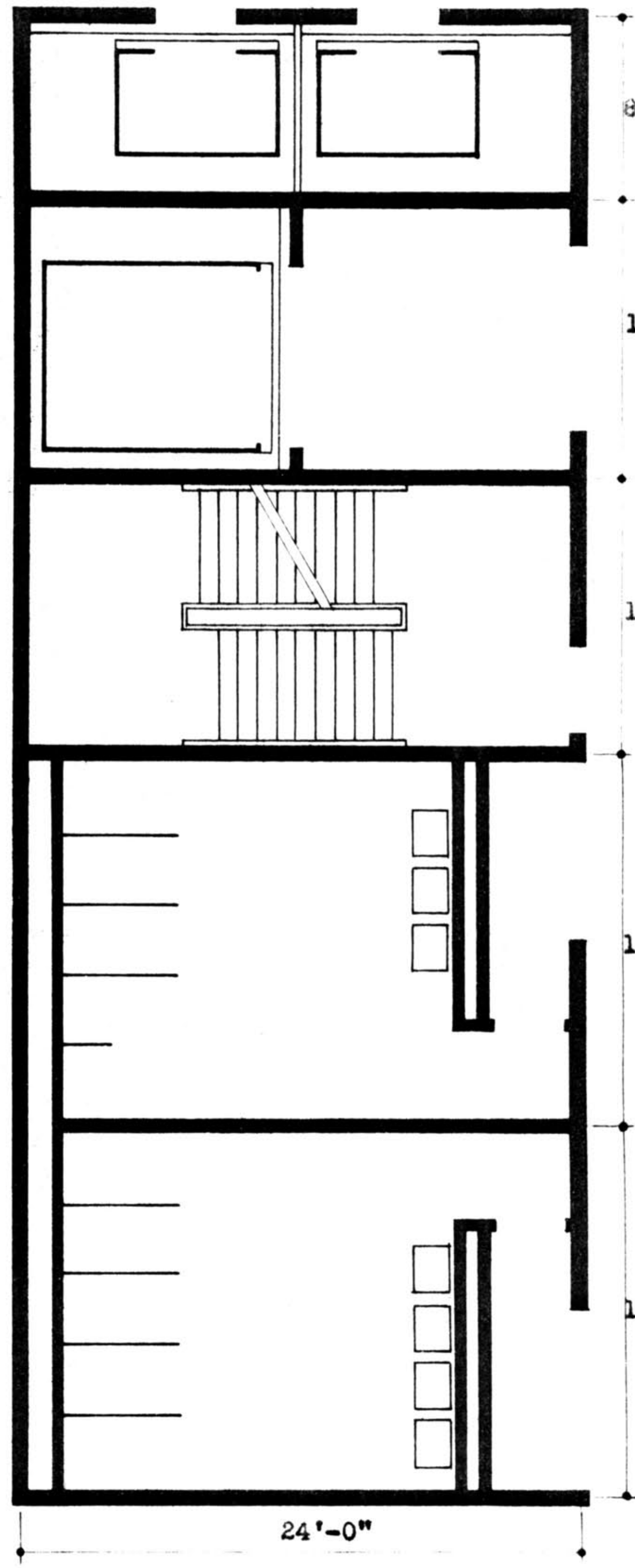


Core elements

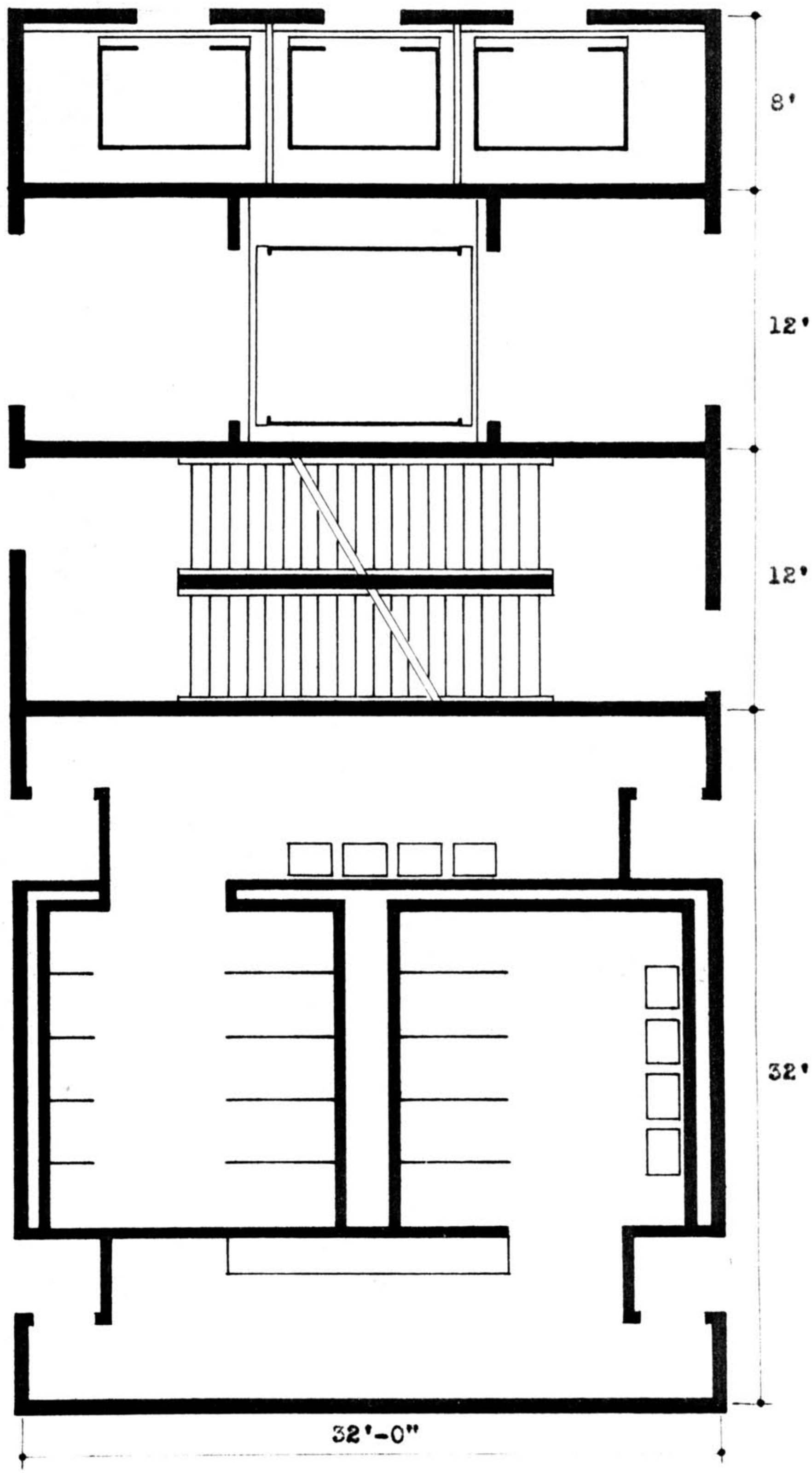




Core Elements



Core Elements



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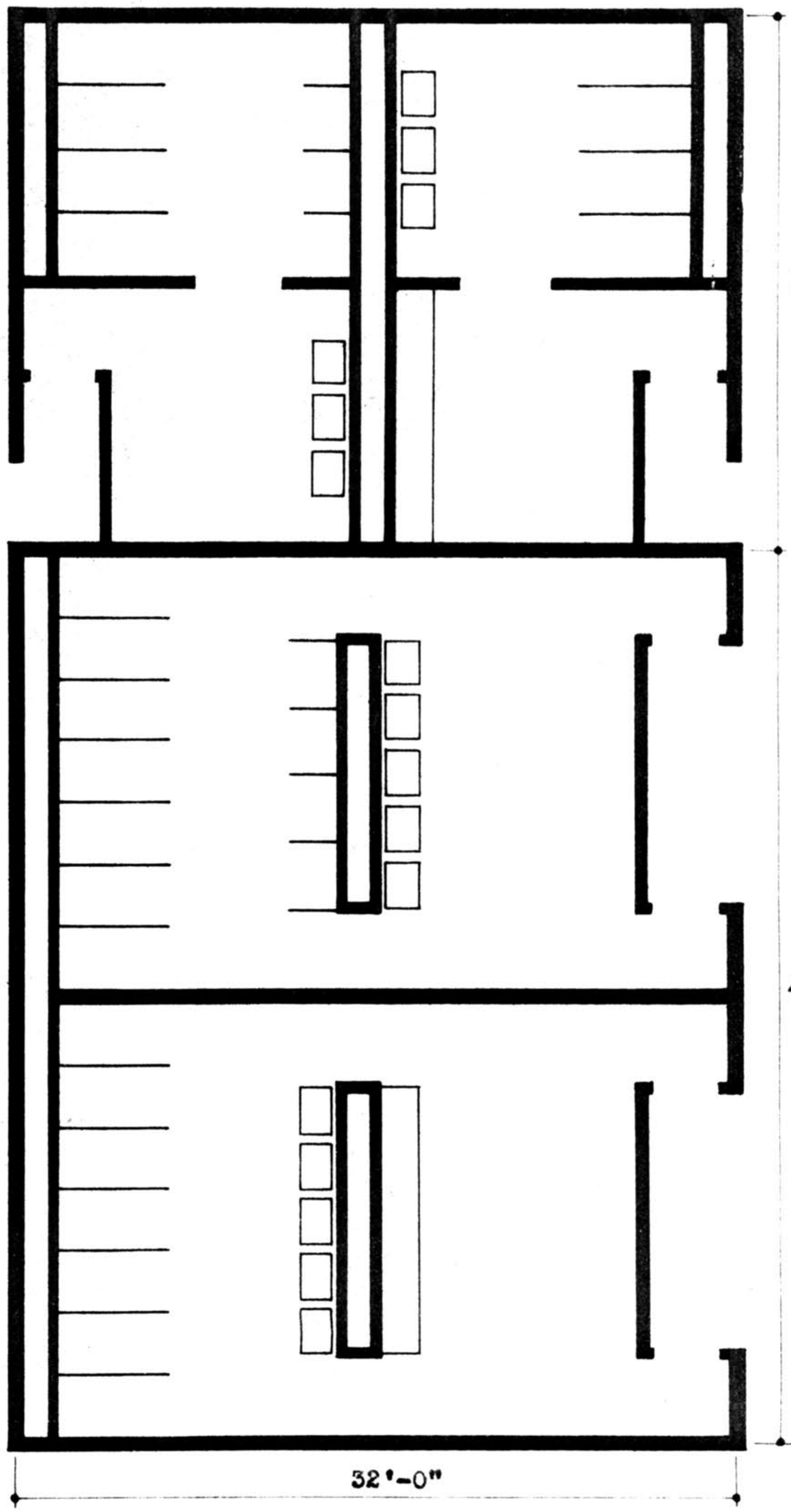

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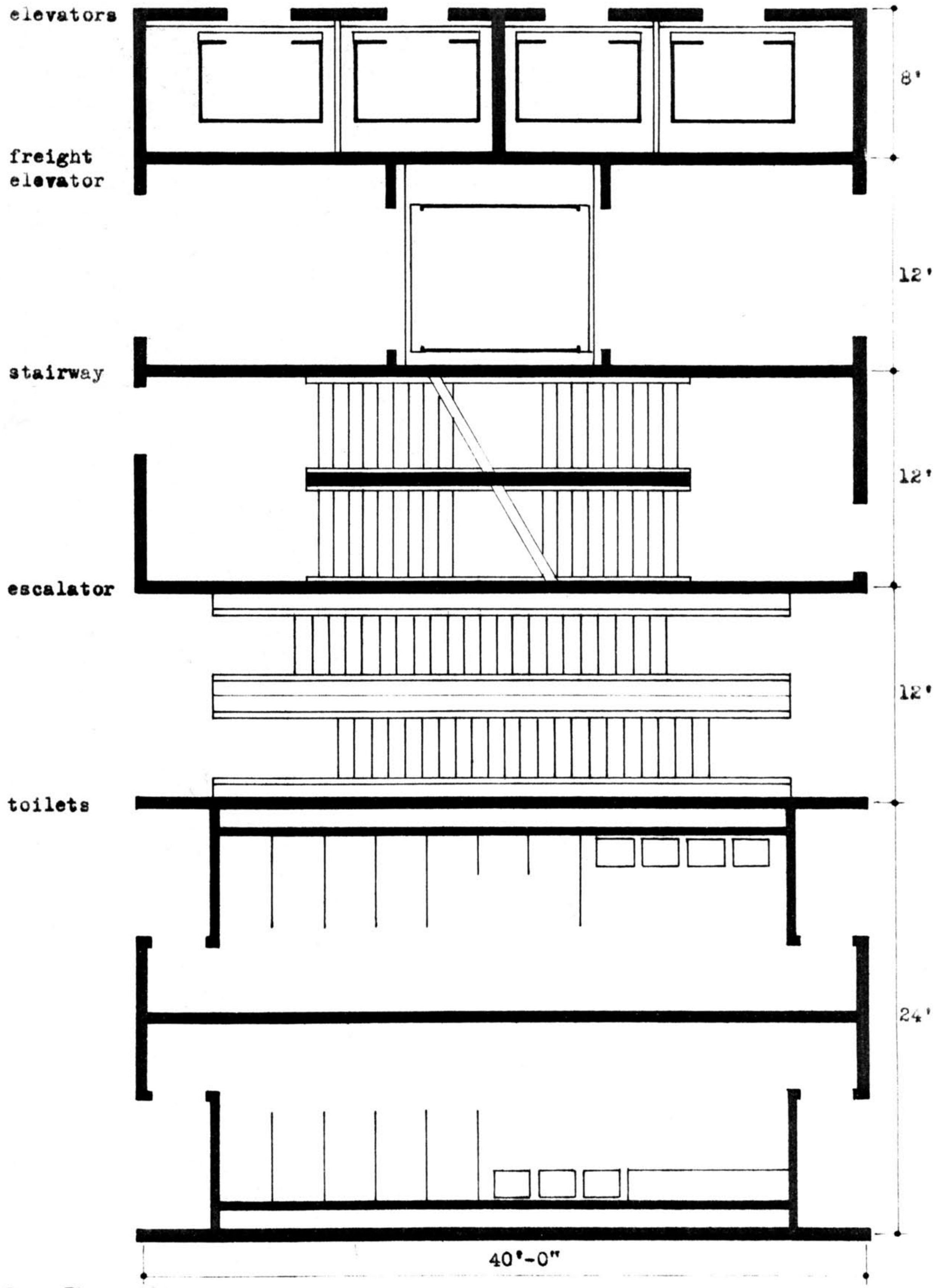

Core Elements

APPENDIX ONE

Graduate Class
February 1966
Professor Catalano

Buildings as Systems

Aim of the Project:

To design a footprint of structural, vertical circulation and mechanical components from which different sizes of buildings, with different spatial qualities and character can be defined.

The system to be created can be approached as an orderly organization of components to achieve "a finished product" for each case, or as a system of growth, for which it is required to establish the geometrical, structural and mechanical self-sufficiency of each unit. It is advisable to design a structural and mechanical system where the vital components become permanent elements of the systems (columns, girders, main mechanical service branches) while the secondary components can change or be removed to achieve flexibility in use or spatial changes, (beams, joists, secondary mechanical service branches), thus becoming temporary elements of the system.

An initial step of work could be the simultaneous study of a typical structural and mechanical bay, with such behavior and geometry as to allow several organization patterns to form a system of growth.

Study of different one and two way structural systems is necessary to see which one offers more freedom in the relation between the structural and mechanical permanent and temporary elements of the system.

APPENDIX TWO

Graduate Class
February 1966
Professor Catalano

Buildings as Systems

The following work will be presented on Friday, February 11.

1. Study of uses of columns for mechanical services. Draw showing in a simplified way the connection between slabs, beams, and columns and how the duct work and pipes are distributed in vertical and horizontal runs. See thesis reports, available in my office, of following students:

Witcomb, Hook, Soetrisno, Huber, Hoskins, Hoover, Bonar, Brunon, Vitols, Hershdorfer, Torsuwan.

Draw columns, in plan and elevation, slabs, and plan of complete duct work (supply and return) within a bay.

2. Same for shafts in cores, used for mechanical services.

3. Same for cores used as mechanical rooms: Frazer, Preiss.

4. Draw in sheets 8 1/2 x 11 basic construction systems of the following thesis reports: Burns, Kulpritz, Rudquist, Vitols, Torsuwan, Brunon, Frazer, Hershdorfer, Hook, Hoskins, Swanney, Zellmer, describing units, plan, section, elevation, and erection procedure, plus connection of units to columns -- shape of columns.

5. Draw different poststressing anchorage systems and hydraulic jacks, indicating minimum dimensions available related to stresses. Consult: Prestress Concrete, by T. C. Lin, and Prestress Concrete for Architects and Engineers. Draw cranes, types, reach and loading capacity: McGraw Hill "Construction Techniques." See information on European cranes.

6. Study of module dimensions considering: uses of rooms (especially the very small ones); width of main and secondary horizontal circulation; stair openings (single and double flight); dimensions of lighting fixtures taken in consideration a width of ribs no less than 6"; width of doors; relationship of area -- number of lighting fixtures to obtain 60 FC at working level; study of location of fixtures to achieve even illumination per room (any size) in an economical manner; location of diffusers, and return grills to achieve flexibility to move partitions without moving diffusers. Combination of lighting fixtures and diffusers. In all cases, fluorescent lighting should be considered. Although there are 2, 3, 4, and 8 feet tubes, the larger the tube is the more economical the system becomes. Modules could be square, rectangular or combined, for two and one way construction.

7. Draw plan and section of 4 passenger elevators 5 x 7, indicating car dimensions, clearances, width of doors, walls, pit, overhead run and machine room for 350 F/M 500 F/M, 700 F/M. Same for service elevator with front and back door. Car dimensions 6 x 8 -- speed 250 F/M.

8. Draw different ways to build single and double set of fire stairs, based on minimum width of 66", for a minimum height (floor to floor) of 14 feet, paying attention to construction and comfort.

9. Draw sheet metal work, indicating transition of duct work for variable sections; connection of vertical and horizontal ducts; connection of ducts and diffusers -- systems of diffusers available in the market.

10. Draw in accepted standard dimensions toilets with metal partitions, lavatories, urinals, and vertical plenum necessary for plumbing for each type of fixture. Design not less than 5 solutions of well arranged toilet rooms for each sex, with fixtures distributed in such a way as to allow increase of number of fixtures without change in design concept, and providing privacy from outside view. Study location of entrance door to provide flexibility in the use of any solution for a given core condition. Use 5 foot module increments for each solution.

All the drawings will be drawn on a translucent sheet 8 1/2 x 11", in pencil, with very strong lines or ink, and with clear lettering about 1/8" high. Indicate source where information was obtained. All drawings will be done in scale, and each group will keep same scale for comparison of dimensions.

APPENDIX THREE

Graduate class 1965-66
Starts 5 January 1966
Due 30 March 1966

Building as a System

M.I.T. is planning the construction of a common building for the School of Architecture and Planning and for the Visual Arts Center. The building to be located on the East Campus will have to be designed to achieve the maximum flexibility of use and growth, and building in reinforced concrete with the most advanced technological means available.

Program:

Total space allocation:

School of Architecture and Planning:

architectural design	17,400	s.f.
visual design	10,240	s.f.
other arch. teaching space	5,760	
administration	6,430	
building construction	15,000	
city planning	15,500	
common space	10,400	
library	25,000	
net area	105,730	s.f.

Visual Arts Center:

Museum	29,000	s.f.
administration	2,250	
support areas	10,500	
educational program	16,700	
studio and activity areas	22,400	
net area	80,850	s.f.
Total net area	186,580	s.f.
Total gross area including 10% of net area for mechanical rooms	280,000	s.f.

APPENDIX THREE (continued)

Program Breakdown

ARCHITECTURAL DESIGN

Proposed Use	Comments	Area	Dimensions
2nd yr. Drafting Room	@30 students	2880	40 x 72 or 60 x 48
2nd Seminar & Storage	class room (1)	600	20 x 30 or 40 x 15
3rd yr. Drafting Room	30 students @96 sq ft	2880	40 x 72 or 60 x 48
3rd yr. Seminar & Storage	class room (2)	600	20 x 30 or 40 x 15
4th yr. Drafting Room	30 students @96 sq ft	2880	40 x 72 or 60 x 48
4th yr. Seminar & Storage	class room (3)	600	20 x 30 or 40 x 15
5th yr. Drafting Room	30 students @96 sq ft	2880	40 x 72 or 60 x 48
5th yr. Seminar & Storage	class room (4)	600	20 x 30 or 40 x 15
Grad. Drafting Room	30 students @96 sq ft	2880	40 x 72 or 60 x 48
Grad. Seminar & Storage	class room (5)	600	20 x 30 or 40 x 15
	TOTAL	17,400	

VISUAL DESIGN

Proposed Use	Comments	Area	Dimensions
Form & Design (Filipowski)	15 students@100 sq ft	1500	30 x 50
Photography Total	dark rooms - studio	1500	30 x 50
Light and Color	studio	1080	30 x 36
Painting Studio	studio	1080	30 x 36
Drawing Studio	studio	1080	30 x 36
Resident Artists	5 studios @800	4000	30 x 134 (@20 x 40)
	TOTAL	10,240	

APPENDIX THREE (continued)

OTHER TEACHING SPACES

Proposed Use	Comments	Area	Dimensions
History & Criticism	class room (6) (H.M.)	720	24 x 30
Structures	class room (7) (L.M.)	720	24 x 30
Structures	storage	360	24 x 15
Student Lounge	student coffee	360	24 x 15
Shop & Lab.	wood-plaster-metal	3600	30 x 120
	TOTAL	5760	

ADMINISTRATION AND STAFF

Proposed Use	Comments	Area	Dimensions
Head of Department	office & meetings	500	15 x 34
Professor Arch.	office & meetings	320	15 x 21-6
Professor Arch.	office & meetings	320	15 x 21-6
Professor Arch.	office & meetings	320	15 x 21-6
Professor V.D.	office & meetings	320	15 x 21-6
Professor (Structures)	office & meetings	180	12 x 15
Professor (Structures)	office & meetings	180	12 x 15
Professor (V.D.)	office & display	320	15 x 21-6
Professor (V.D.)	office & display	320	15 x 21-6
Professor Arch.	office	180	12 x 15
Professor Arch.	office & library	180	12 x 15
Professor Arch.	limited office & conf.	180	12 x 15
Professor Illumination	office	180	12 x 15

APPENDIX THREE (continued)

Proposed Use	Comments	Area	Dimensions
Professor Landscaping	office	180	12 x 15
Professor Acoustics	desk	100 - 120	10 x 12
Professor Arch.	office	120	10 x 12
Professor Arch.	office	120	10 x 12
Professor Arch.	office	120	10 x 12
Assistant	desk & storage	120	10 x 12
Assistants	two desks total	160	15 x 10-6
4 Visiting Critics	desk space @100	400	15 x 26-9
1 Chairman secretary	counter-desk-storage	200	10 x 20
1 Department secretary	desk-storage	150	15 x 10
1 Visual Design secretary	desk-storage	120	10 x 12
1 Faculty secretary	desk-storage	100	10 x 10
4 Researchers	@80	320	15 x 21-6
Departmental Conf.	faculty grade meetings	300	15 x 20
	TOTAL	6030	

DEPARTMENT OF BUILDING CONSTRUCTION

Proposed	Comments	Area	Dimensions
1 Class Room	lectures (11)	720	24 x 30
Professor	office & meetings	320	15 x 21-6
Professor-Testing	office (in Lab.?)	180	12 x 15
Professor-Materials	office	180	12 x 15
Professor	office	120	10 x 12
Professor	office	120	10 x 12
Models Laboratory	structures testing	5000	50 x 100

APPENDIX THREE (continued)

Proposed	Comments	Area	Dimensions
Illumination Laboratory		2000	50 x 40
Lab. Storage		320	15 x 21-6
4 Researchers	desks @80	320	15 x 21-6
2 Technical people	desks @80	160	10 x 16
2 Secretaries	desks @80	160	10 x 16
	TOTAL	9600	

CITY PLANNING DEPARTMENT

Proposed	Comments	Area	Dimensions
1st yr. drafting room	25 students @96 sq ft	2400	30 x 80
1st yr. seminar	class room (8)	600	30 x 20
2nd yr. drafting room	29 students @96 sq ft	2400	30 x 80
2nd yr. seminar	class room (9)	600	30 x 20
Student Lounge		360	20 x 18
1 class room	lecture-slides (10)	720	30 x 24
Administration office & staff	Total	3200	30 x 107
Joint Center for Urban Studies		5220	
	TOTAL	15,500	

COMMON SPACE FOR ALL DEPARTMENTS

Proposed	Comments	Area	Dimensions
Exhibition Room-Jury	student work	1440	30 x 48
Jury Room	student discussions	1080	24 x 45

APPENDIX THREE (continued)

Proposed	Comments	Area	Dimensions
Lecture Room	large-public	2400	240 x 10 sq ft
Drawing Storage		2160	30 x 72
Museum Exhibition	public exhibitions	1440	30 x 48 (might be circulation space)
Museum Storage	library-arch-inst	720	
2 Secretaries		200	10 x 20
Library (Including 1 librarian & 2 assoc librarians)	Total	12000	50 x 240 or 40 x 300
Dean's Office	includes 1 secretary	960	30 x 32
	TOTAL	22,400	

VISUAL ARTS CENTER

I. MUSEUM	Net Footage	Dimensions
Exhibitions and Public Areas		
1) Permanent Exhibitions - Interior	4,000	100 x 40
2) Permanent Exhibitions - Exterior	2,000	100 x 20
3) Changing Exhibitions	14,000	100 x 140
4) Combination Studio-Gallery	3,000	
5) Visual Library	3,500	
6) Study Exhibitions	2,500	
TOTAL	29,000	
Administrative Areas		
1) Director's Office	250	12 x 21^{6}
2) Director's Conference Room	250	12 x 21^{6}
3) Curator's Office	150	10 x 15

APPENDIX THREE (continued)

4)	Exhibition Manager's Office	150	10 x 15
5)	Administrative Assistant's Offices (2)	200	10 x 20
6)	Visual Library Office	150	10 x 15
7)	Registrar's Office	150	10 x 15
8)	Secretarial Office	400	20 x 20
9)	Curatorial Conference Room	200	10 x 20
10)	Miscellaneous Office Storage	150	10 x 15
	TOTAL	2,250	

Support Areas

1)	Lobby	1,800	45 x 40
2)	Guard's Room	150	10 x 15
3)	Coat Room	200	10 x 20
4)	Maintenance Office and Store Room	300	10 x 30
5)	Shipping and Receiving	2,000	40 x 50
6)	Storage of Art Objects	2,000	40 x 50
7)	Small Object Vault	150	10 x 15
8)	Examination and Conservation	1,000	40 x 25
9)	Installation Equipment Storage	1,000	40 x 25
10)	Electrical Shop	150	10 x 15
11)	Carpenter Shop	800	20 x 40
12)	Paint Shop	200	10 x 20
13)	Kitchen	100	10 x 10
14)	Public Lounge and Toilets	650	20 x 32
	TOTAL	10,500	

APPENDIX THREE (continued)

II. EDUCATION PROGRAM

Classroom and Administration Areas	Net Footage	Dimensions
1) Auditorium and Cinema Theatre	6,000	100 x 60
2) Backstage and Projection Room	1,000	60 x 15
3) Lecture Rooms, 3 @ 1500	4,500	30 x 50 x 3
4) Seminar Rooms, 1 @ 400, 1 @ 600	1,000	20 x 20/20 x 30
5) Faculty Offices, 10 @ 200	2,000	20 x 10 (10)
6) Conference Rooms, 2 @ 250	300	12 x 20
7) Secretarial Offices, 2 @ 250	500	12 x 20
8) Lounge	300	15 x 20
9) Storage	700	20 x 35
10) Toilets	400	20 x 20
TOTAL	16,700	

Studio and Activity Areas		
1) Visual Design, Painting, Sculpture, Graphic Arts Studios	10,000	100 x 100
2) Photography Studios	5,000	100 x 50
3) Dark Rooms	1,000	100 x 10
4) Faculty Studios, 6 @ 400	2,400	20 x 20 x 6
5) Carpentry, Electrical, and Metals Workshops	1,800	20 x 90
6) Equipment and Supply Rooms	2,200	20 x 110
7) Sink Rooms and Toilets	400	20 x 20
TOTAL	22,800	

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