

BUILDING SYSTEM, STRUCTURALLY AND MECHANICALLY INTEGRATED,
CAPABLE OF MAXIMUM INTERNAL REARRANGEMENT AND LATERAL GROWTH

Submitted in partial fulfillment of the requirements for
the degree Master in Architecture at the Massachusetts
Institute of Technology

Kenneth Walter Schwarz

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Signature of Author
Department of Architecture, 15 August 1966

Certified by
Thesis Supervisor

Accepted by
Chairman, Departmental Committee
on Graduate Students

15 August 1966

Lawrence B. Anderson, Dean
School of Architecture and Planning
Massachusetts Institute of Technology

Dear Dean Anderson:

In partial fulfillment of the requirements for the degree
Master in Architecture, I hereby submit this thesis entitled
Building System, Structurally and Mechanically Integrated,
Capable of Maximum Internal Rearrangement and Lateral Growth.

Respectfully,

Kenneth Walter Schwarz
6 Bennett Street
Cambridge, Massachusetts

ACKNOWLEDGMENTS

THESIS SUPERVISOR

Eduardo F. Catalano

STRUCTURE

Waclaw Zalewsky

MECHANICAL EQUIPMENT

Sidney Greenleaf

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1.0 THE SYSTEM

1.1 General Description

The project attempts to develop a series of components from which various buildings of a given type can be constructed. These buildings will share a common range of structural spans, mechanical equipment, required exit distances, degree of fireproofing and ability to resist loads. The buildings will differ in size, shape and specific mechanical services.

The group of components, or system, developed for this project fulfills the specific needs of the new school of architecture, planning and visual arts proposed for M.I.T. The system, however, could be similarly used for other academic buildings, research laboratories and some office facilities. The system provides space, mechanically serviced with air supply, air return, lighting, piped services and vertical circulation.

1.2 Division of Space in the Horizontal Plane

Space in the horizontal plane is limited by 4'-2" square columns occurring on centers of 37'-6" x 48'-2" and fire stair housings which occur on centers of 192'-8" x 187'-6". When necessary, toilets and additional vertical circulation are clustered around the fire stairs. Space can be subdivided by movable partitions placed anywhere along a grid

of 4'-2" x 8'-4". The smallest horizontal area which can be created and reached by all the mechanical services is 8'-4" x 12'-6".

The system is infinitely extendable in the horizontal plane and can grow in alternating increments of 16'-8" and 33'-4" in one direction and 12'-8" and 21'-0" in the other. Each increment is structurally and mechanically resolved. The structure of the perimeter zone is identical to the structure of the interior zone. The system of air distribution differs only slightly between the perimeter and interior zones and can be readily changed to serve one or the other. A given building may be extended past its original boundaries with only minimal changes in its structure and mechanical system.

1.3 Division of Space in the Vertical Plane

In the vertical plane, space is divided by floors which can be placed at intervals of 12'-7½". The floor structure is 2'-7½" thick, thus creating normal floor-to-ceiling heights of 10'-0". Large areas of the floor system can be omitted without affecting the integrity of the overall structure. This allows considerable freedom in the initial planning of auditoriums, lounges, ceremonial stairways, etc. and in subsequent remodeling of the building to add or modify high spaces. The system allows a maximum building height of five stories or 63'-1½".

2.0 STRUCTURE

2.1 General Description

One-way structural action is used. Columns rise on centers of 37'-6" x 48'-2". The short distance between them is spanned by channel-shaped girders. The long distance between the girders is spanned by tee-shaped beams. Both the girders and beams are normally simply supported but can be post-tensioned to be cantilevered beyond the line of support and to laterally stiffen the structure. The number of restrained joints required over any given area is dependent upon the height of structure, number of core walls, seismic conditions, etc., and cannot be accurately determined outside the context of a specific building design.

2.2 Description of Elements

All of the structural elements are made of pre-cast concrete. Shapes were chosen which yield high structural efficiency, efficient transport and easy erection.

Columns are cast in building-height lengths to eliminate joints and produce members similar in size and weight to the girders and beams. The columns are rectangular in section with identical, cubical protrusions occurring at 12'-7½" centers along the column length. Standard deformed reinforcing bar is used. No special casting techniques are required.

Both the beams and girders incorporate the floor surface as part of the structural member and utilize the floor material to resist compressive forces generated by the long span. The tee- and channel-shaped beam and girder are formed by standard adjustable steel forms of those shapes used in most pre-casting plants. Simply supported tee-beams are pre-stressed at the casting plant. (See drawing 2.) Cantilevered tee-beams or those used to provide lateral stiffening are minimally reinforced at the plant, to resist stresses resulting from temperature change, transit and erection. They are post-tensioned during erection. (See drawing 2.)

Girders are usually pre-stressed at the casting plant.* Girders to be cantilevered or used to provide lateral stiffening are minimally reinforced at the plant and are post-tensioned during erection.

2.3 Elements

Name	Section	Width	Height	Length	Weight
column	rectangular	0'-10"	3'-8"	63'-1½"	36.5 K
girder	channel	4'-6"	2'-5"	33'-4"	30.6 K
beam	tee	4'-2"	2'-5"	44'-0"	19.5 K

* Drawing 3, however, shows them reinforced with deformed reinforcing bar. This was done upon the advice of Ing^o. Zalewski. He suggested that because relatively few girders are used in a building, it might not always be feasible to use pre-stressing equipment and that it would be prudent to design the member to accommodate normal reinforcing steel.

2.4 Erection Procedure

The erection procedure is shown in plate 7.

- (Step 1) Columns are erected in building-height lengths. Each half of the double column is erected independently and stabilized by guy wires.
- (Step 2) Transverse elements link the two halves of the column and are secured by high strength steel bolts. The column becomes internally stable. Guy wires are removed.
- (Step 3) Girders are placed between the columns. Normally these are simply supported and require no scaffolding or additional fastening. The photographs show the more critical condition, however, where post-tensioning is used. This can take two forms. If the member is cantilevered, it is positioned upon scaffolding, the compressive area of the joint grouted, and the tendon placed, stressed and grouted. When the grout has hardened, the imposed stress is released and the scaffolding removed. If the member is not cantilevered, it can be placed as a simple beam without the aid of scaffolding. Grout is placed in the compressive area of the joint and the tendon is placed, stressed and secured as described above.
- (Step 4) Tee-beams are placed between the girders. Normally these are simply supported and require no scaffold-

ing. The flanges of the tees are welded to stabilize the beams before the topping is placed and to minimize the effects of differential loading on adjoining beams. The photographs show the condition where post-tensioning is used. This, as in the case of the girder, can take two forms: that of the cantilever condition which requires scaffolding, and that of the simple span which later is made continuous. The post-tensioning process in each case is the same as that used in the corresponding case for the girder.

Floor topping is placed.

The structure is now complete. Additional erection steps involve placement of mechanical equipment and are described in the next section.

3.0 MECHANICAL EQUIPMENT

3.1 General Description

Mechanical services rise within the structural columns on centers of 37'-6" x 48'-2". (See plate 1.) Main horizontal distributors are contained within the channel-shaped girders and are 33'-0" long. Supply and return air is fed from the columns into opposite ends of each main distributor. Secondary horizontal distributors are contained between the webs of adjoining pairs of tee-beams. They occur on centers of 4'-2" and are 22'-0" long. Secondary distributors are arranged in groups of three and contain, alternately, supply air, return air and piped services. For a full complement of mechanical services, a space must cut across a group of three distributors and must therefore have a minimum dimension of 12'-6" measured perpendicular to the distributors.

The mechanical module is the same as that of the structure and follows a similar pattern of growth. Thus, whatever extensions or voids are possible within structural limits can be mechanically serviced without special conditions or awkward patterns of distribution.

3.2 Air Supply

Hot and cold air rise at high velocity through separate vertical ducts.* At each floor level air is taken off into

* Duct sizes and air velocities are summarized in the table which follows.

a mixing box in which the sound is attenuated, the velocity lowered, and the air mixed to the coldest condition required within the area served. A main horizontal distributor extends directly from the mixing box and serves six secondary distributors, each of which can be fitted with electric reheat coils to provide individual temperature control to areas as small as 275 square feet. The secondary distributors serve the double function of air duct and strip diffuser. Where they meet an exterior wall, these distributors supply induction units which further heat and cool the air by passing it over coils containing hot or cold water.

3.3 Air Return

Air is returned vertically at high velocity. At each floor level an attenuator is placed which eliminates the sound and reduces the velocity of the air. From each attenuator extends the main horizontal return duct to which are connected four secondary ducts.*

* The pattern of horizontal distribution suggests that a fifth and sixth secondary return duct should occur on either side of the vertical riser. To do this, however, would require a direct connection between each secondary duct and the riser, including a separate attenuator at the juncture. When one considers the relative closeness of the return inlets possible with four ducts, it becomes apparent that the inclusion of a fifth and sixth duct is only an academic issue and would not be important in actual practice.

3.4 Air Velocity and Duct Size for Typical Bay

Name	Velocity	Duct Size
Supply:		
vertical hot	4000 fpm	1'-0" x 1'-5"
vertical cold	4000	1'-3" x 1'-5"
take-off hot	4000	0'-5" dia. round
take-off cold	4000	0'-6" dia. round
main horizontal	1200	0'-11" x 2'-5"
secondary horizontal	1000	0'-5" x 0'-11"
Return:		
vertical	3600 fpm	2'-5" x 1'-2"
take-off	3600	0'-10" dia. round
main horizontal	1000	0'-11" x 1'-9"
secondary horizontal	800	0'-5" x 0'-11"

3.5 Piped Services

Piped services include electrical conduit, communication lines and roof drains, as well as hot and cold water supply and return for random sinks and reheat-recool coils of the perimeter air system. These services rise within the structural columns and are distributed on each floor in a pattern identical to that of the air system. The main horizontal distributors are 14'-8" long. Secondary distributors consist of 0'-6" x 1'-0" channel sections in which pipes are placed. These sections are 22'-0" long. From there, pipes pass through small holes cut into the flange-edge of the tee-beams to the floor above, where the services are ultimately

used. (See plate 2.) Slope provided by this arrangement allows a 3" drain a slope of 1" in 10'-0".

All of the vertical and horizontal pipes are accessible and may be readily serviced and replaced.

3.6 Lighting

Lighting is provided in each 4'-2" x 8'-4" module in one of three ways: a) by exposed fluorescent bulbs placed to either side of the mechanical ducts, b) by fluorescent bulbs placed in a diffuser which attaches to the bottom of the mechanical ducts, c) by fluorescent bulbs placed above the mechanical ducts and providing indirect illumination to the space below. The drawings show the first possibility. Though the bulbs are exposed, they are placed so that from any given point at eye level only four bulbs can be directly seen. Within the normal cone of vision, centered horizontally, no bulbs are seen.

Incandescent lighting is used in the 4'-2" strip under the girder.

3.7 Diaphragms, Acoustical Treatment, Sound Isolation

Diaphragms are located on 8'-4" centers, perpendicular to the web of the tee-beams. They serve three main functions: a) to provide acoustical baffles for large open spaces, b) to provide effective sound barriers across the top of walls which separate rooms, c) to provide hangers and

junctions for the horizontal elements of the mechanical system. The diaphragms are non-structural and are made of an acoustically absorbent material. In the face of each diaphragm is a 0'-7" x 1'-8" hole which receives an element containing the sockets, ballasts and starters for the fluorescent lamps as well as connecting pieces for the eight-foot lengths of air supply and return ducts and pipe channels.

3.8 Erection Procedure

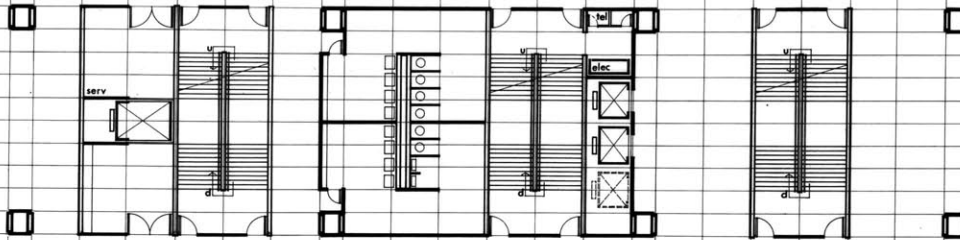
The erection procedure is shown in plate 7. Steps 1 through 4 involve the erection of structural elements and are described in the preceding section.

(Step 5) Diaphragms are inserted between the webs of adjoining tee-beams.

(Step 6) Vertical ducts are inserted into the space within the columns. Main horizontal ducts are placed in sections of 4'-2" length and glued along interlocking flange-edges. Secondary ducts are placed in sections of 8'-4" and secured to the connecting element within the diaphragm. Dimensional inconsistencies are adjusted within the connecting element.

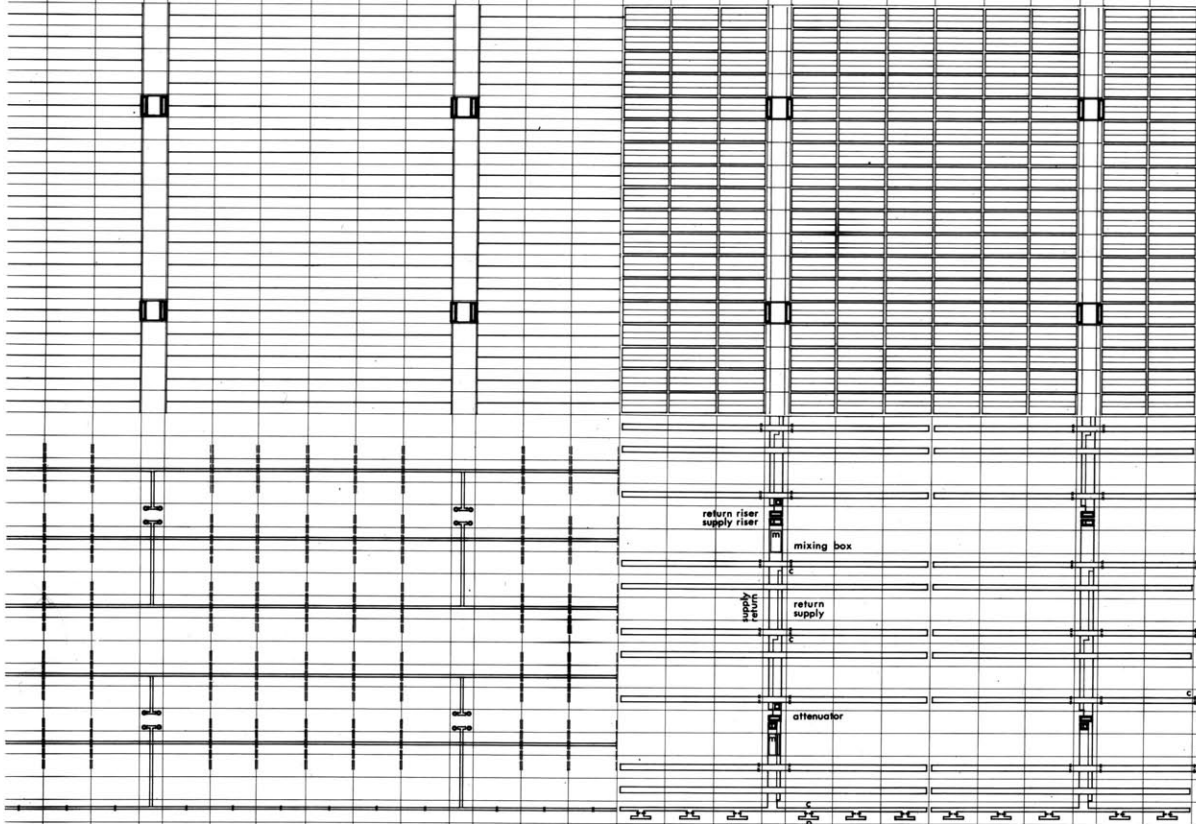
(Step 7) Vertical and horizontal pipes are placed. Small holes are cut, where necessary, through flange-edges of the tee-beams to allow pipes to connect to fixtures above.

BASIC ELEMENTS



STRUCTURAL FRAMING

REFLECTED CEILING PLAN



PIPED SERVICES

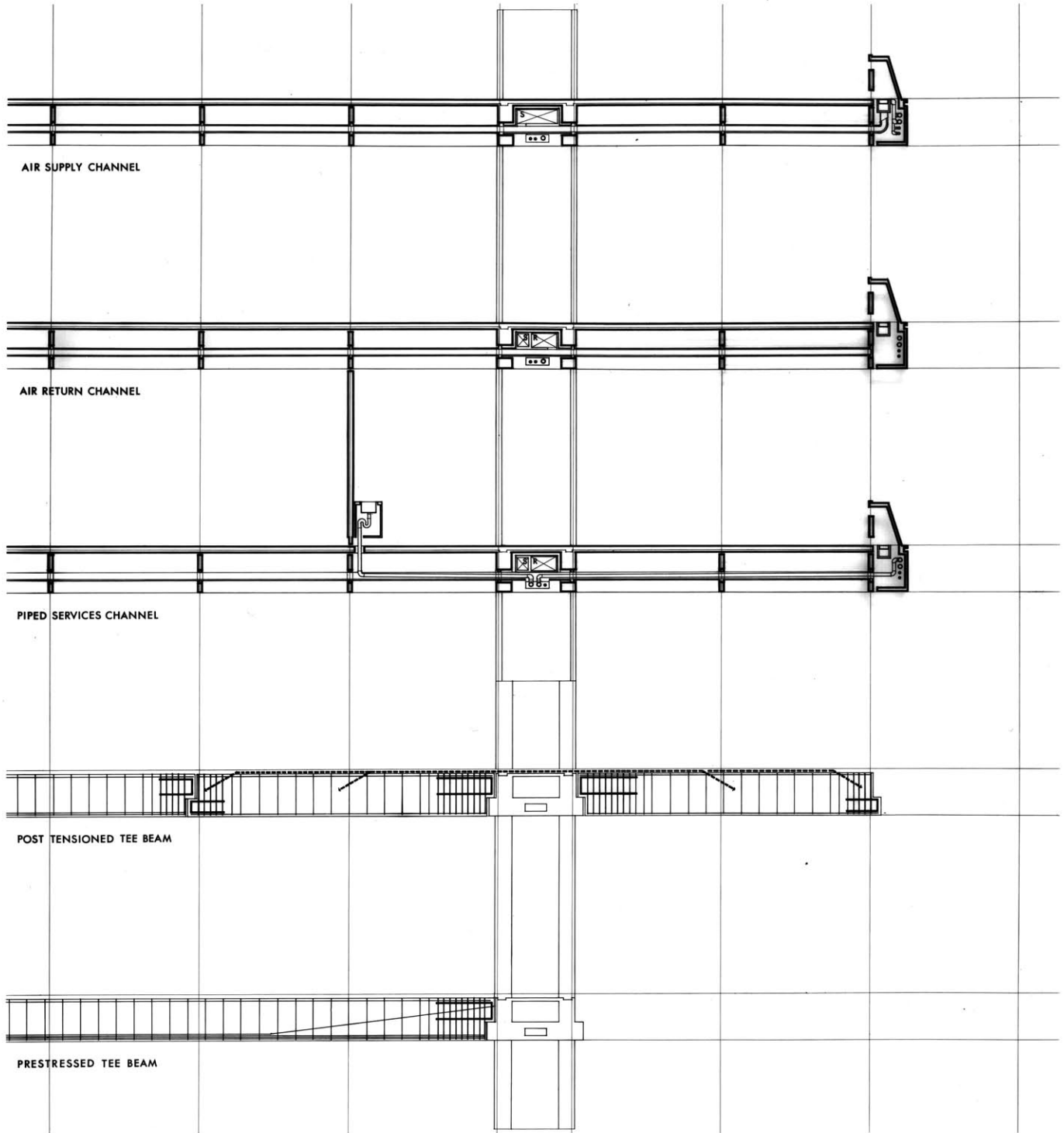
AIR DISTRIBUTION

0 4-0 FT

INTEGRATED BUILDING SYSTEM DEVELOPMENT

MASTER IN ARCHITECTURE THESIS
ADVISOR EDUARDO CATALANO
M.I.T. 1966 KENNETH W. SCHWARZ

LONGITUDINAL SECTION



AIR SUPPLY CHANNEL

AIR RETURN CHANNEL

PIPED SERVICES CHANNEL

POST TENSIONED TEE BEAM

PRESTRESSED TEE BEAM

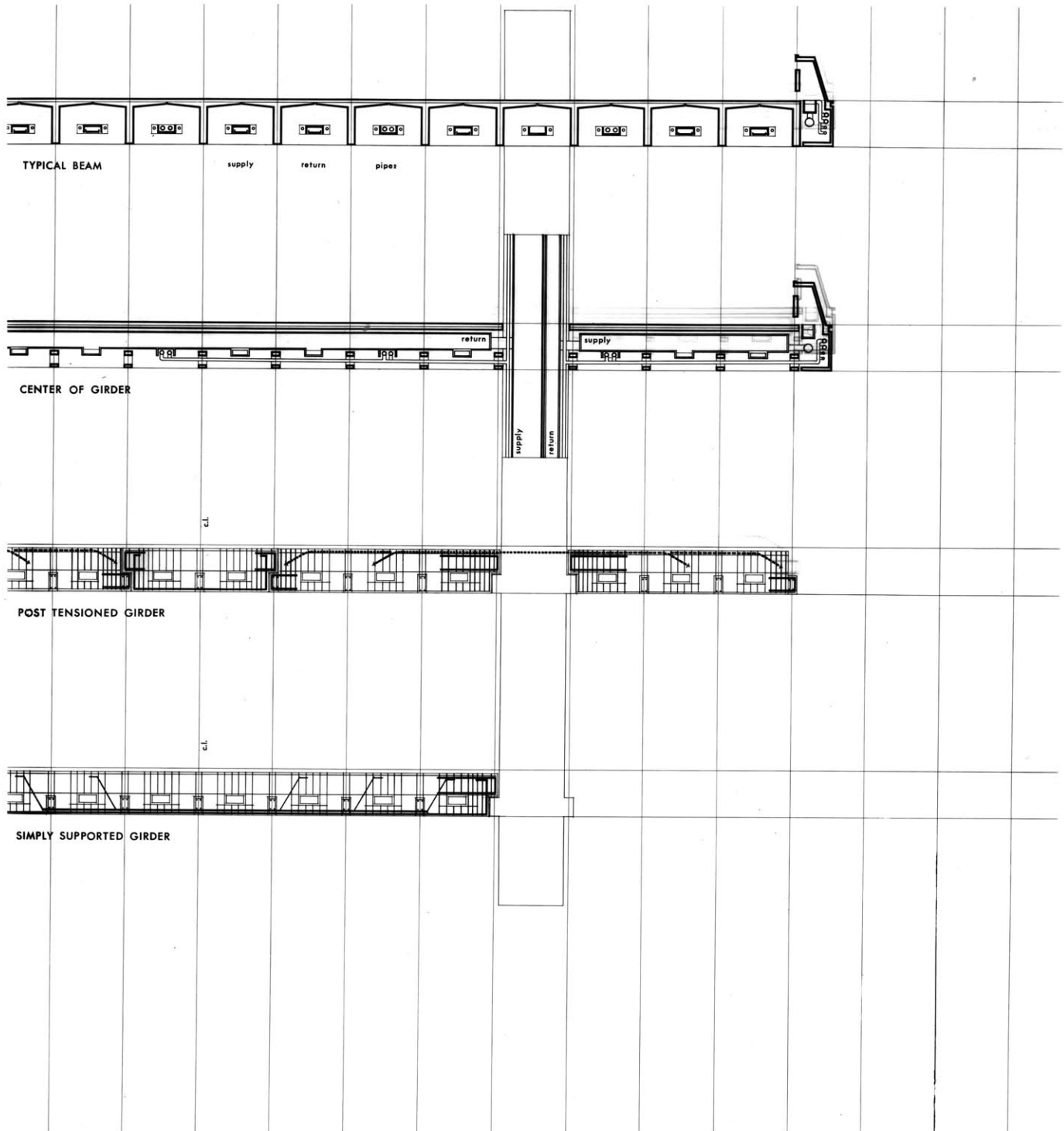
0 1'-0 FT

2

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SYSTEM DEVELOPMENT

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TRANSVERSE SECTION



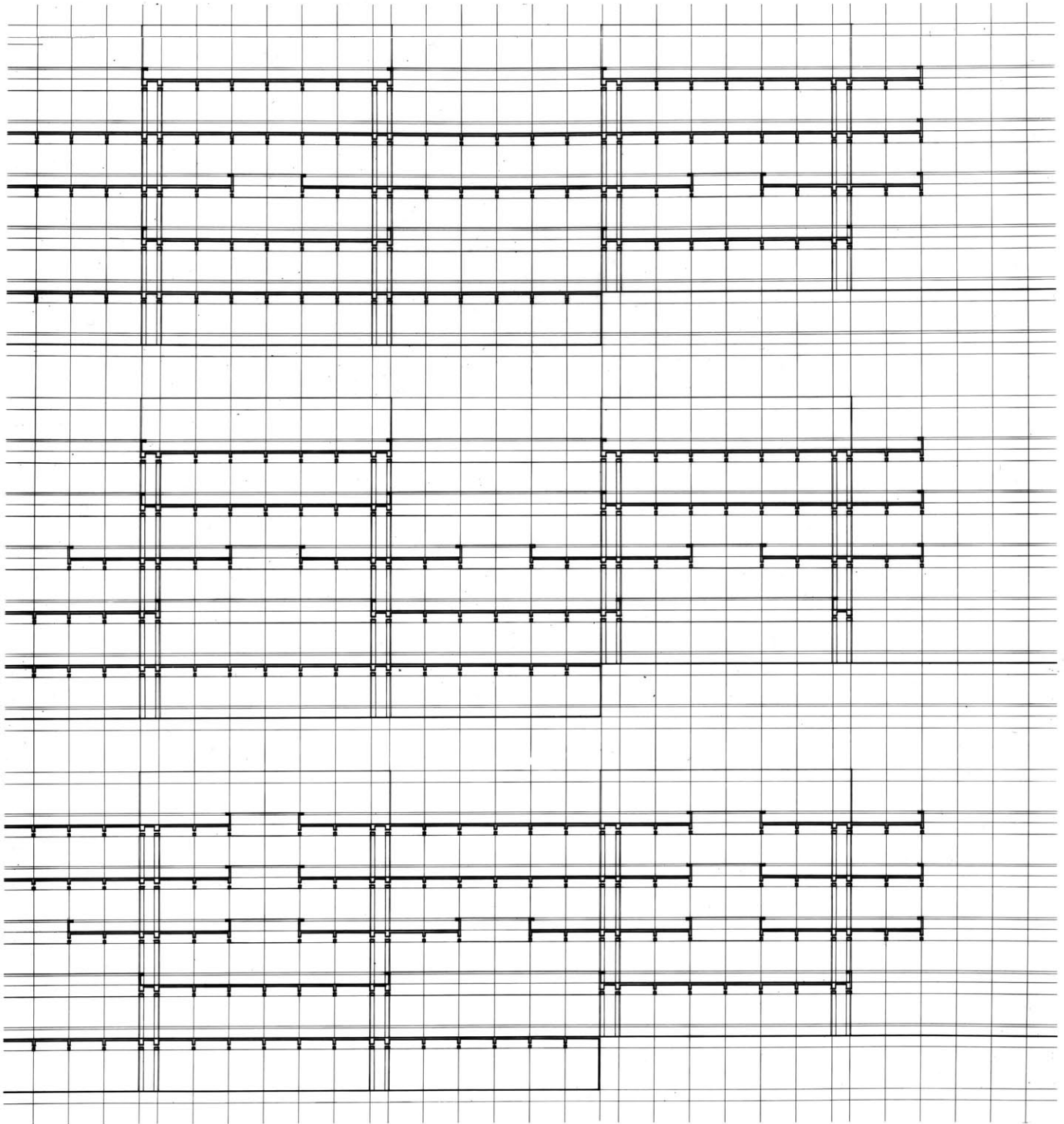
0 1'-0"

3

INTEGRATED BUILDING
SYSTEM DEVELOPMENT

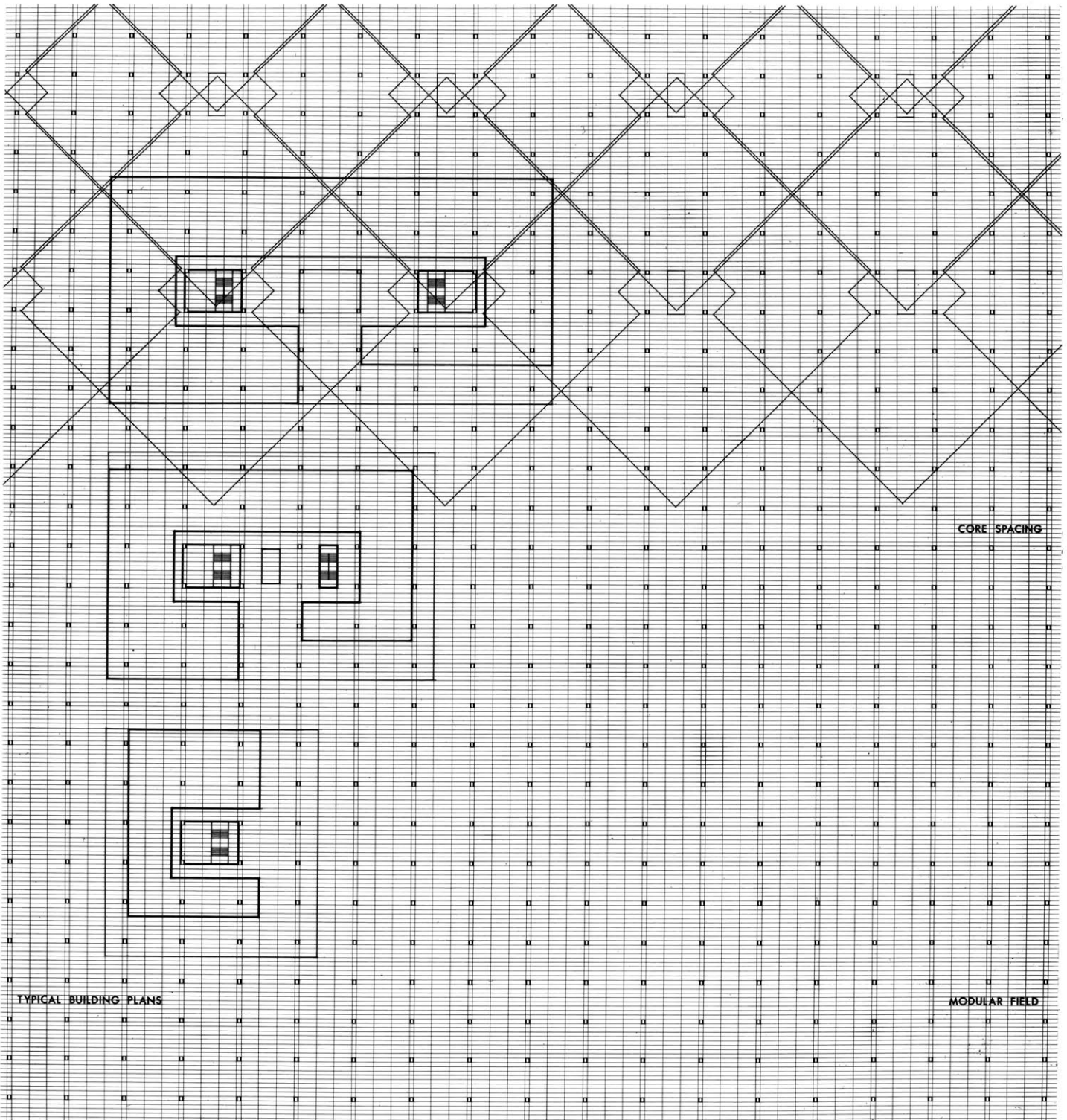
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LONGITUDINAL BUILDING SECTION



0 4'-0" FT

HORIZONTAL GROWTH



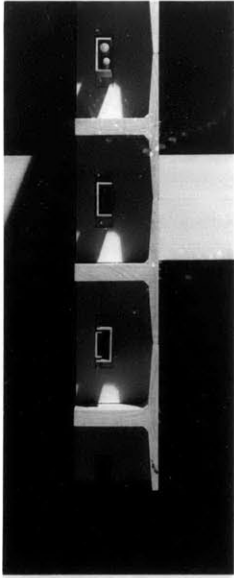
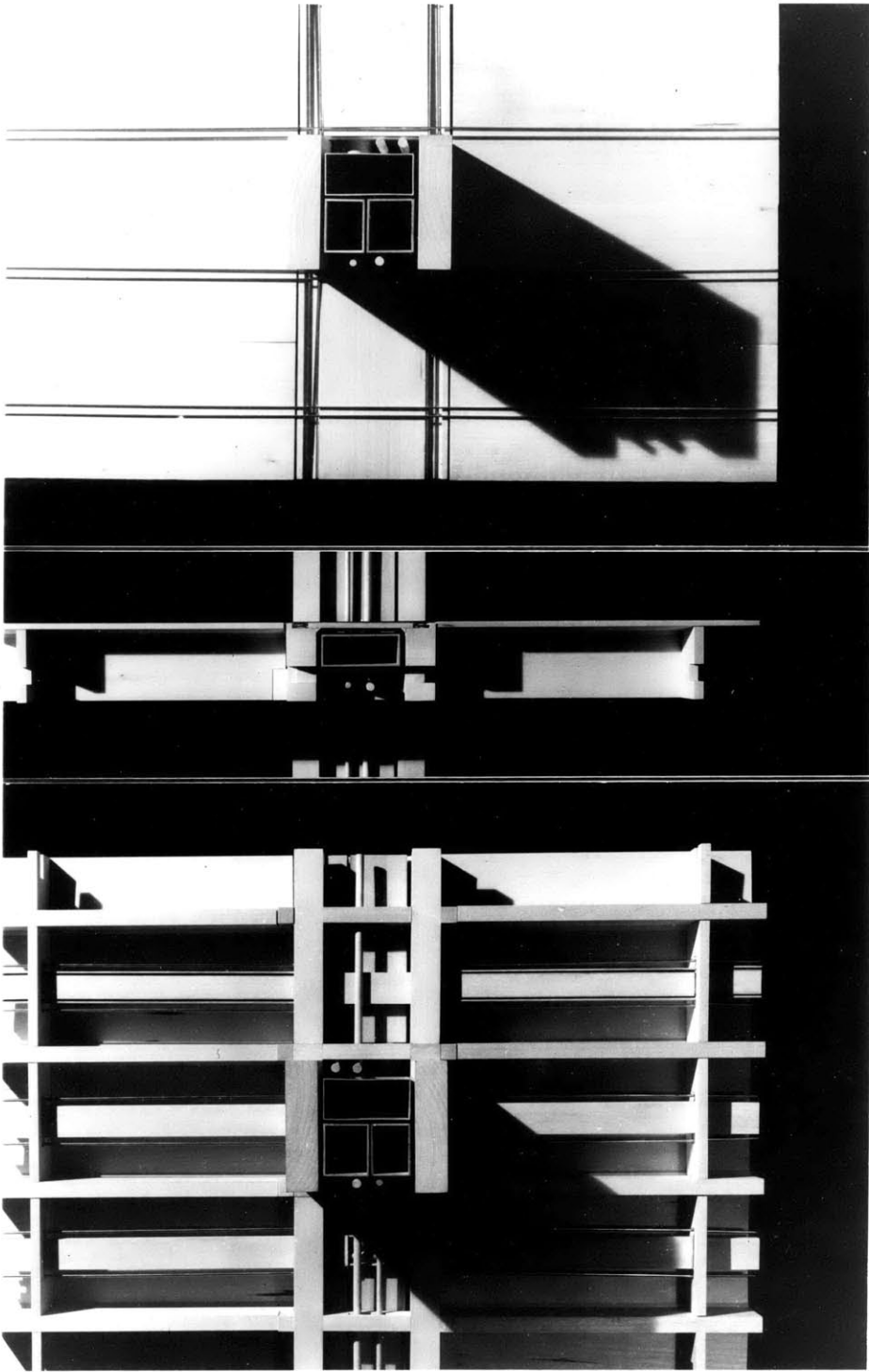
TYPICAL BUILDING PLANS

CORE SPACING

MODULAR FIELD

0 16'-0" FT

COLUMN FLOOR INTERSECTION



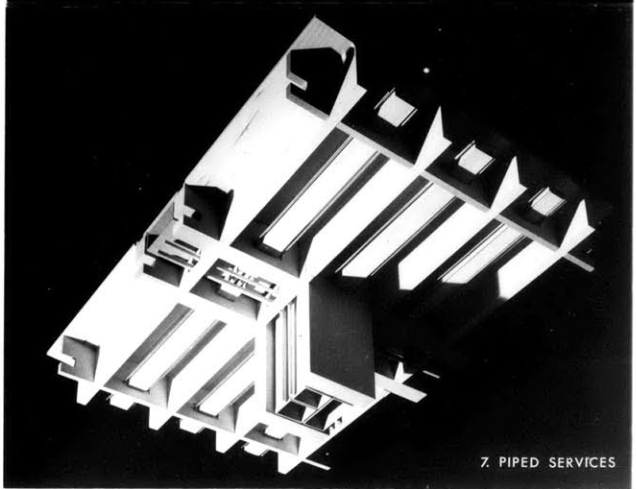
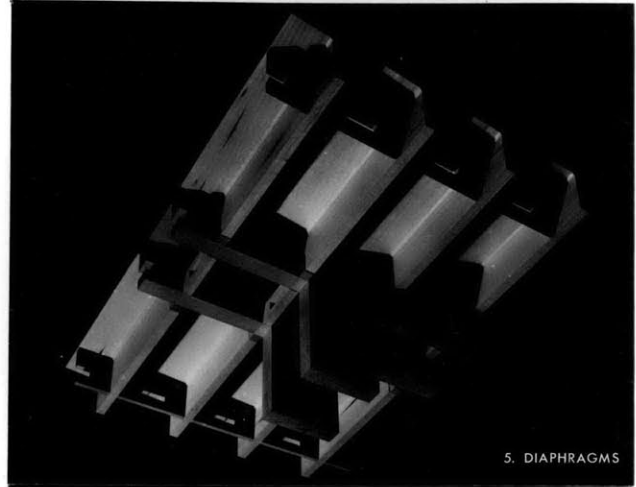
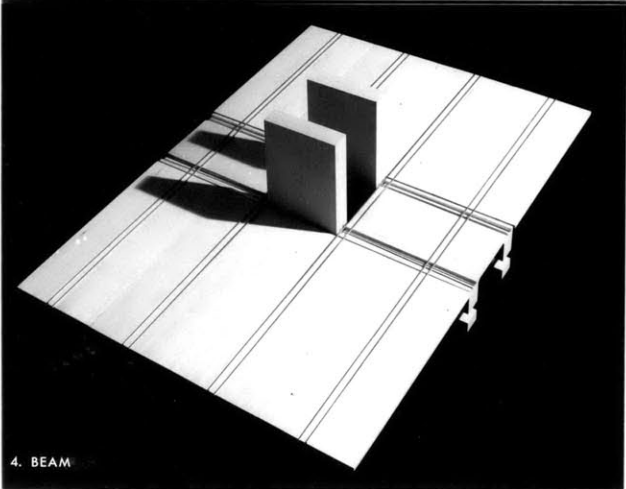
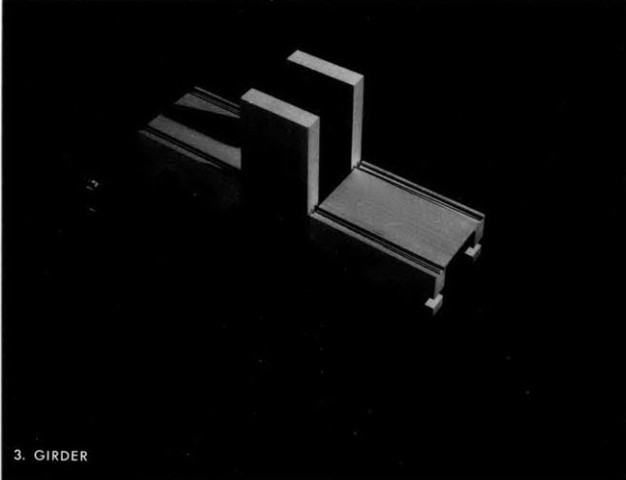
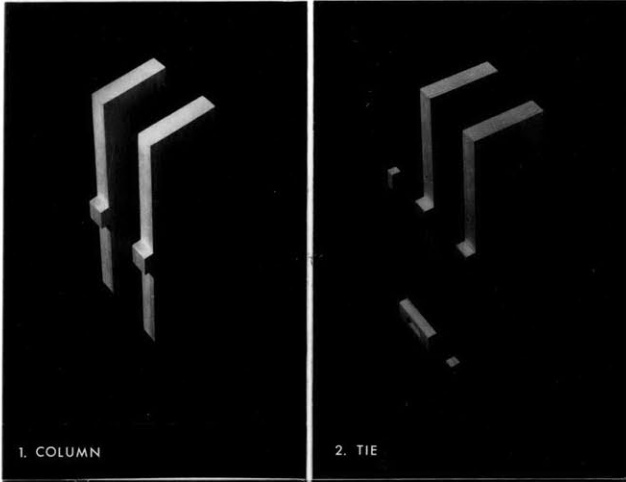
0 1'-0 FT

6

INTEGRATED BUILDING SYSTEM DEVELOPMENT

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CONSTRUCTION SEQUENCE



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