

A PROTOTYPE RESEARCH BUILDING
Utilizing Precast Concrete Construction

by

WILLIAM E. PEDERSEN, JR.
B. Arch., University of Minnesota, 1962

SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF ARCHITECTURE

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MAY 1964

Cambridge 39, Massachusetts
May 29, 1964

Dean Pietro Belluschi
School of Architecture and Planning
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge 39, Massachusetts

Dear Dean Belluschi:

In partial fulfillment of the requirements for the degree of
Master of Architecture, I hereby submit this project entitled,
"A Prototype Research Building."

Respectfully,

William E. Pederson, Jr.

Signature of Department Head:

Lawrence B. Anderson

ACKNOWLEDGMENTS

The author wishes to thank the following whose assistance and advice contributed substantially to the included thesis project:

1. Mr. William Connolly, Boston, Massachusetts
2. Mr. Charles A. Crowley, Marian, Massachusetts
3. Mr. John Eberhard, Cambridge, Massachusetts
4. Dr. Howard Simpson, Cambridge, Massachusetts
5. Professor Eduardo F. Catalano, Thesis Advisor

ABSTRACT OF THESIS

The objective of the following thesis report is to study the research and development building type as a system of required spaces, their mutual relationships, building structure and mechanical services.

The general building program was first analyzed and the building's constants determined. The emphasis was then on studying integration of the building's structural and mechanical components into an all encompassing system for this particular building type. Precast and prestressed concrete were chosen as the construction materials to be studied for their design procedures and proper usage.

This thesis is intended as a continuation of the projects submitted by Frazier, Inoway, Nuzum and Priess, in June of 1963, with whom the author collaborated. All introductory material, bibliography and appendix are similar in content.

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THESIS PREPARED BY WILLIAM E. PEDERSEN, Jr.

OBJECTIVE

The objective of this thesis is to design a prototype facility for industrial research and development. The study is maintained at a level to contain only a vocabulary of architectural constants common to this building type. Precast, prestressed concrete will be the basic structural material, employing the capabilities and limitations of our present technology. The synthesis of structure and mechanical services must result in a spacial flexibility capable of satisfying the continually changing demands of research.

Similarly, psychological factors effecting human needs in the research environment combined with purely physical needs of the work space are to be visually reflected in the proposal.

These factors, plus the clarity of articulation demanded by precast concrete construction form the basis for an architectural expression.

APPROACH

The design of a prototype structure is possible if the building type selected contains elements present under all conditions. If these exist, the proposal will be applicable to specific use. Consequently, the research and development building group has been chosen for study. Past solutions have proven inadequate to meet the changing needs. These needs must be re-evaluated to clarify the conditions upon which future proposals may be erected.

Analyzation, in detail, of the specific requirements common to research facilities shall initiate the proposal. The requirements must then be reduced to contain only the most basic elements, forming the framework upon which a complete program may be developed.

Within the research facility there are two major categories; they are static space and dynamic space. In turn, these may be broken down into their specific components.

Static spaces are those which "serve" the basic needs of the building. Examples of such needs are: vertical and horizontal pedestrian circulation; vertical and horizontal mechanical services; electrical and plumbing supply; wash rooms and maintenance storage areas. Static spaces may also be expanded to include ancillary functions such as: reception areas; administrative offices; lecture halls; lounges; cafeteria; library and parking facilities. These spaces do require a degree of flexibility not common to the true definition of "static space," previously described; however, for clarity of design, they have been grouped into this category.

Dynamic spaces are those which contain the working areas of the research facility. Requirements in this category parallel the structure of research activity. The hierarchy of which is as follows: theoretical research; applied research; and pilot research. The following paragraph will examine the spacial demands of each category.

The area of theoretical research involves a limited number of "blue chip" personnel. The space required to house this phase, although small in comparison to the other areas within the category, must be tailored to meet the psychological needs of its occupant. Work performed here is highly creative in nature and spacial requirements involve little more than a small laboratory area and office.

It is at this point that the project idea is born. Ideal conditions would require a remote location accessible to exterior light.

Little flexibility for spacial change is desired, resulting in a semi-permanent environment.

The laboratory-office combination will not exceed 400 sq. ft. in area. Mechanical services required include: in the ceiling; comfort cooling, heating, lighting, in the floor; electricity, plumbing, gas, hot and cold water, etc..

Within the area of applied research, the widest range of spacial requirements exist. It is at this stage, where the idea is made a reality.

Personnel involved would include a representative of the theoretical group, from which the project has stemmed, down to laboratory technicians and assistants, whose duties consist of assembling apparatus and other related functions. Spatial conditions are stable only for the length of the project. Upon completion, the needs dissolve and new conditions take over. Consequently, any conceivable combination of spaces must be possible both in the horizontal and vertical plane. Area requirements might vary from a small office for the storage of apparatus, to a laboratory of 7,500 sq. ft. with a potential ceiling height of three stories. Mechanical services must be accessible from any point within the area designated to applied research. A complete list of the services required include the following: in the ceiling; heating, air-conditioning, florescent lighting, in the floor; electricity (110V, 220V, 440V,) hot and cold water, waste lines, telephone, gas, oxygen, etc..

The area requirements for pilot research are confined basically to the testing and application of developed systems. Spacial requirements within this group vary widely with the type of testing performed. A typical example might change from the testing of space capsules within a simulated environment to wind tunnel experimentation. Generally, the areas required demand large spaces both in the horizontal and vertical directions. Services to such areas often require movement of large scale equipment into and out of the building. Mechanical services to the space are similar to those required in the applied research area. Special equipment, such as cranes for lifting and moving heavy apparatus must also be accomodated within these spaces. The maximum horizontal floor area need be limited only by the dimensions of the building, while vertical height might extend up three stories.

The area of a building, which is capable of including the diversities of a complete research facility, must range between 500,000 sq. ft. and 1,000,000 sq. ft.. Inherent economies are present in a structure

of this scale. Duplication of facilities, common when many smaller structures are used to house specific functions, may be eliminated; moreover, tremendous flexibility is achieved when adapting to changing conditions. Considerations for such flexibility will be discussed later in the section entitled, PROPOSAL.

After a detailed analysis of the requirements for research facilities has been completed, it is necessary to extract the basic elements. These elements may be listed according to space usage and area requirements, upon which a concrete proposal may be based.

I. Static Spaces

A. Building Constants

1. Fire stairs
2. Elevators
3. Washrooms
4. Maintenance
5. Mail chutes
6. Mechanical ducts (vertical and horizontal)
7. Plumbing ducts " "
8. Electrical " "

B. Common Facilities

1. Reception areas
2. Cafeteria
3. Lecture halls
4. Libraries
5. Parking
6. Service areas

II. Dynamic Spaces

A. Small Offices

1. Area: 200 sq. ft. maximum (one story)
2. Services: Heating, cooling, lighting electrical and telephone outlets

B. Large Offices

1. Area: 1,000 sq. ft. maximum (one story)
2. Services: same as preceeding

C. Small Laboratory

1. Area: 600 sq. ft. maximum (one story)
2. Services: a full compliment of mechanical and electrical services (see below)

D. Large Laboratory

1. Area: 7,500 sq. ft. maximum (one, two, or three stories)
2. Services: full compliment of accessible at any point (see below)

E. Testing Area

1. Area: unlimited (one, two or three stories)
2. Services: full compliment accessible at any point (see below)

III. Services

A. Air Handling

1. Heating (ceiling supply)
2. Cooling (ceiling supply)

B. Electrical Supply

1. Telephone outlets (floor supply)
2. Electricity (110V, 220V, 440V of floor supply)

C. Lighting

1. Florescent (ceiling)
2. Incandescent (ceiling)

D. Plumbing

1. Hot and cold water (floor supply)
2. Waste lines (floor supply)
3. Gases (floor supply)
4. Distilled water (floor supply)

PROPOSAL

There are four major factors, which have rendered inadequate, many present day solutions to the research and development building: an inability to expand the structure; a lack of flexibility in the horizontal plane due to insufficient dimensions between supports; a lack of flexibility

to form vertical spaces without imposing unusual conditions upon the structure; a random organization of mechanical services, limiting the structure's ability to absorb increasing needs.

A proposal which neglects any of these four points severely limits its potential to act as a prototype structure. The morphology of a system must dictate a solution without denying its inherent identity. It is a system which contains within its members, the balance necessary to form a marriage between structure and mechanical services; there is an organic concept paralleling the bone and vessel relationship within the human body.

General Building Description

Before undertaking a detailed analysis of the basic system introduced in this solution, a general description of the building is necessary. The proposed ten story, industrial research building has a total gross square foot area of

approximately 800,000. The vertical organization of the facilities is as follows. The lowest three levels of the building are devoted to pilot testing areas and parking. Public entrance is gained above those levels by the automobile access; therefore, the fourth floor is devoted entirely to reception facilities, including parking for visitors and key personnel. The upper four levels house the common facilities: cafeteria; four lecture halls and library, while also providing the majority of space for research activities. Finally, the last two levels contain the mechanical equipment.

The location of the static elements (four passenger elevators, two service elevators, fire stairs, toilets, and maintenance supply areas) are adjacent to the pedestrian gallery, which runs the entire length of the structure. This gallery is intended to act as a major gathering space for research workers, when out of their specific areas. A central core is located at the end point of the gallery. This court is initiated at the fourth level or

reception area and increases in dimension as it penetrates upward through the building. Unusual emphasis is placed upon this area. Not only will it serve to give orientation for the inhabitants, but it will afford a psychological relief from the "mechanical" nature of the research areas. Great importance is given to the scientist in our society. His environment must, then, reflect a balance between the technical requirements and his social responsibility.

Structural System

The basic structural bay, which is the backbone of the system, dictates the planning configuration. This bay is rectangular, sixty feet by forty-two feet; it is formed by column clusters (four per cluster) at each of its corners. At the sides of this bay, parallel to the sixty foot dimension, twin girders span between the column clusters. In turn, they are spanned by a series of channel beams. The channels may be omitted at any point within the bay to produce vertical penetration. Within each of the column clusters, all mechanical,

electrical, and plumbing services are transported vertically through the structure. At each level, these services leave the column group and penetrate horizontally into the bay. The void remaining between the two girders acts as a raceway for all the air supply ducts and major mechanical services. Likewise, the void within the girder itself, serves the waste lines and plumbing access. Subsupply lines may then leave the girders and penetrate transversely into the bay by means of the channel beams. The subsupply lines stand in a relationship to the major supply, as do the vessels to the arteries in the human body (a more detailed analysis of the structural-mechanical relationship will occur in a later section.) Hence, the resulting structure is simply formed by a repetition of bays. Expansion of the building can be achieved at any time by continuing this repetition. The maximum uninterrupted horizontal space is limited only in the sixty foot dimension. This dimension also corresponds to the upper limits prestressed concrete can span efficiently, using present technology. The achievement of a

balance between spacial flexibility and economy of structure was the criterion for its selection.

The span of the secondary members, forty-two feet, allows the designer to include vertical spaces of adequate dimension without imposing unique conditions upon the structure. Flexibility to provide these spaces must be considered at the initial planning stages. It is highly impractical to consider that they be formed after the structure has been completed, although it is possible. An additional consideration for choosing the forty-two foot span is the minimum distance at which prestressed concrete is effective. As was previously mentioned, the range of dimension between forty feet and sixty feet has proven most economical for prestressed concrete application. Such a consideration is vital to the design of a building, uniquely tailored to its construction material.

Because the major girders pass over the column clusters at the exterior of the structure, they possess the flexibility to cantilever past

their support. This flexibility has been utilized to form the semi-permanent spaces required for the theoretical research groups. In this position, they receive natural light and a psychological importance, visually expressive of the work performed. This cantilever imposes no unique conditions upon the structure other than forming the major girders to three varying dimensions. This condition is easily solved by constructing the initial mold to satisfy the longest condition. Shorter lengths are possible by using a lesser portion of the mold.

Each column cluster is composed of four individual columns. The space formed by the grouping provides a vertical shaft to the mechanical services. The separation between columns gives access into the shaft. The total cross-sectional area provided is in excess of one hundred and forty square feet. Of this area, one hundred and ten square feet are available to mechanical services; the remainder is devoted to the structure.

All the individual columns are ten and one half feet square in area. However, exactly one half of this area is devoted to a hollow core, within which all plumbing services are transported. The columns consist of two solid outer flanges; through these, access to the hollow core may be gained. All columns are to be precast to an eight foot length, with mild steel reinforcing placed at the time of casting. One inch steel shim plates are welded at the top and bottom of the column to the reinforcing. These plates will receive the major girders.

Each girder is supported at the column cluster, by two of the four columns. The girders are composed of two rectangular webs, connected near the bottom by a continuous concrete flange to absorb bend stresses. This flange is omitted over the column heads to allow passage of the plumbing services. Connections between the girders and columns are performed by welding the steel shim plates. This gives continuity to the vertical reinforcing and achieves a rigid connection. The major girders, which run

the width of the building, pass over three structural bays. Since it is impossible to transport a member covering the full width of the building, the girder is divided into two outer sections and one middle section. These sections are welded together to achieve continuity. Care has been taken to eliminate post-tensioning, whenever possible, to provide a more economical structure. The prestressing of members is done at the concrete plant.

The secondary members are a series of channel beams three feet on center and welded at their webs to give lateral continuity. The joinery between the webs provides a continuous groove against which moveable, partitions may be placed. These channels are seated on top of the girders, allowing mechanical services to pass unobstructed. Neoprene pads enable movement of the members at the connection seats.

Mechanical System

Due to the close integration between structural and mechanical systems, much of the material in this section has already been covered; nevertheless, a few detailed conditions need further clarification.

All of the air handling equipment is housed in the two story mechanical "bridge," located in the upper floors of the building. This equipment carries fresh air from the intake heads, at the perimeter of the structure. Used air is exhausted at high velocity, directly above the machines. Each unit services one structural bay through the entire height of the structure. A total of twenty-two units are present during the initial stage of construction. Decentralization of these units allows great flexibility and economy. Peak loads may be accommodated at specific points within the building without requiring total output of the system. Major air supply arteries feed directly from these machines down into the structure within the column clusters. The air supply arteries are hot and cold dual-duct,

high velocity systems. This artery is "tapped" at each floor by horizontal supply ducts traveling between the girder pairs. These supply ducts then feed subsupply ducts, which enter the bay at nine foot intervals. These subsupply ducts are terminated by mixing boxes located in the ceiling and again on nine foot centers. The nine foot interval corresponds to every third channel of the structural system. The second channel then carries the return air ducts, while plumbing, electrical, and water supplies are transported in the third. Due to the frequent occurrence of vertical shafts, horizontal supply runs are reduced. The efficiency of organization promotes maximum flexibility by minimal means.

While all air supply is carried within the ceiling of a space, the other services must be reached from the floor. This is facilitated by regular openings in the channels. These openings are cast into the beams during fabrication.

Special services such as fume hood exhausts may also be carried within the ceiling structure. This exhaust is also carried up the column clusters, between a column pair, and released with the return air exhaust.

Lighting

All lighting elements will be fitted into the channel beams. Placed at the lower edge, space is still available for overhead ducts. These will be two feet six inches by five foot six inch florescent units. Air diffusers are incorporated within these at necessary points.

Building Module

Choice of a building module rests upon providing optimum flexibility. The conventional square module of five feet was thought inadequate and unnecessary. Its selection has usually been determined by standard market fixtures such as lighting elements and moveable partitions.

This criterion does not apply to a building with close to one million square feet. Repetition of parts is numerous, affording economy in specialty design. This proposal has selected a rectangular module of three feet by six feet. Combinations of this module are double that of the five foot module. This fact is particularly convenient for laboratory benches, using a three foot width and a three foot or six foot aisle. Minimal spaces such as nine feet by twelve feet may be provided for storage areas or write-up offices, while interior partitions and door widths adjust easily to the three foot dimension.

Interior Partitions

Partitions are solid up to a level eight feet above the floor. From this point glass extends to the underside of the channel members. Criterion for this choice rests on the desire to attain visual continuity of the structural system. The solid elements may be any material (wood, metal, masonry, etc.) controlled only by a typical connection to the glass. Connections between

glass and structure occur in the groves formed by two channel beams. This grove is sealed by neoprene rope.

Acoustics

Acoustical control is far easier within the one way structure. Sound transmission, therefore, is possible only in one direction. Since mechanical services must run only to the center of the bay, an acoustical baffle may be introduced at this point. Also, by introducing an acoustical baffle between the girder pairs, it is possible to isolate any transmission of sound within a twenty-one foot strip. Additional baffles may be added in this dimension but must be designed so as to allow for passage of ducts through them. This will rarely be necessary for a structure comprised mainly of large spaces.

Exterior Wall Elements

All exterior wall elements are of precast concrete. The concrete is poured about a core of rigid insulation. This acts to lighten the weight of the individual members, while still

retaining the desired dimensions for visual consideration. These elements are of four basic types. One piece combines to form the solid end walls of the building. Another combines to form parapit walls for roof drainage control. The third acts to form a window unit, which is then welded to the floor deck, while the fourth forms the window sill. All such units are non structural and their surface is scored with vertical groves three inches on center, to reflect this fact. The surface of all structural members is of a smooth texture.

Basic Construction Sequence

1. Ground cleared and graded
2. Excavation for levels below grade
3. Foundation walls and footings poured in place
4. Basement floor poured
5. Column clusters seated and welded in place
6. Major girders seated, leveled, and welded in place; Joints grouted
7. Center span 30'-0", positioned, leveled, and welded in place
8. Lay channel beams between girders and bolt to neoprene pad on girder

9. Begin ducts, electrical wiring and piping in column cluster
Horizontal runs may be positioned at any point during construction
10. Bolt precast diaphragms to channel members
11. Pour concrete topping
12. Weld precast window unit to floor slab
Add sill units
13. Weld precast end wall units to floor slab
14. Repeat 5-13
15. At upper floor weld parapet units
16. Lay roof insulation and build up roof surface
17. Construct intake hoods and mechanical "bridge"
18. Install all horizontal mechanical services
19. Interior spaces completed

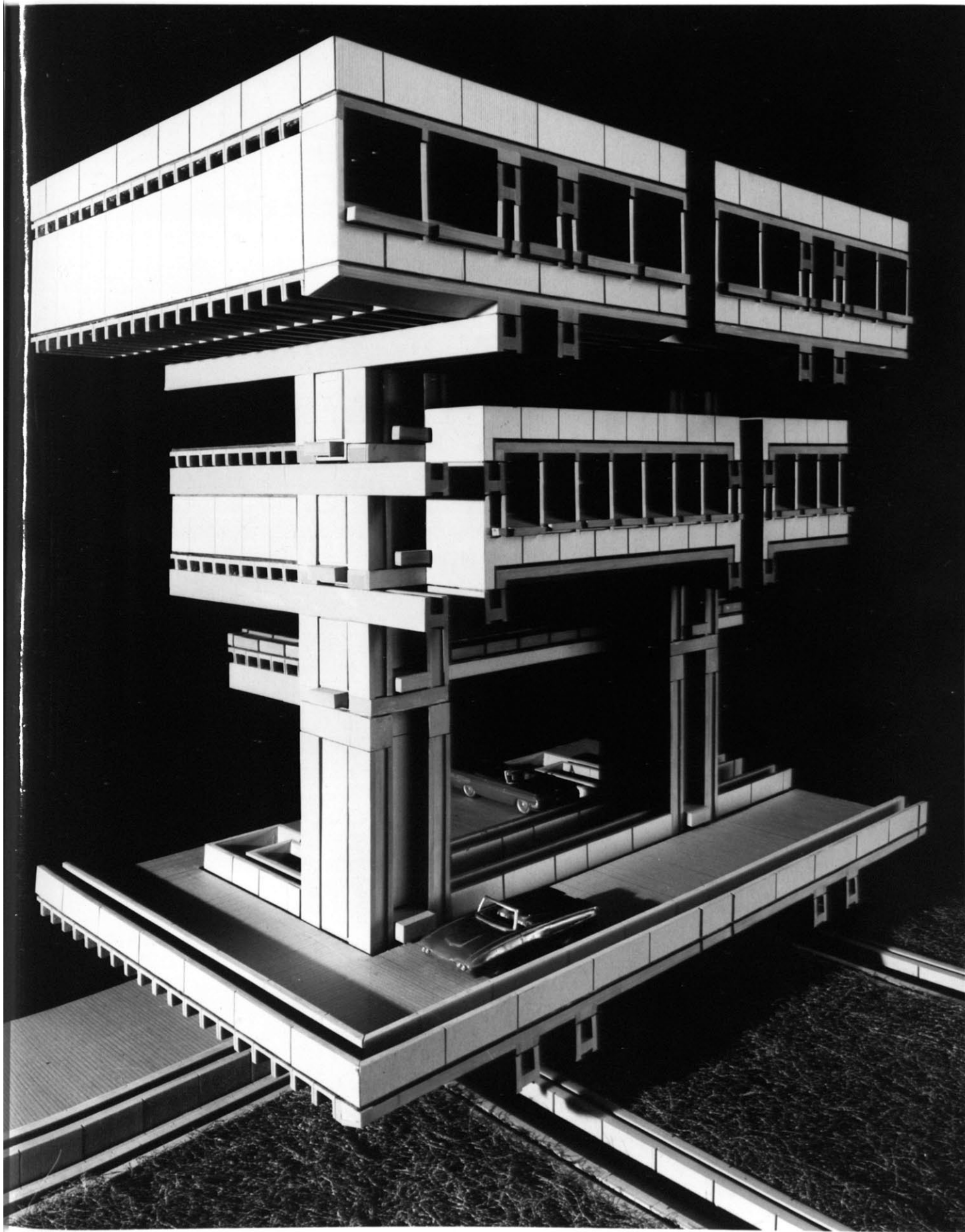
Conclusion

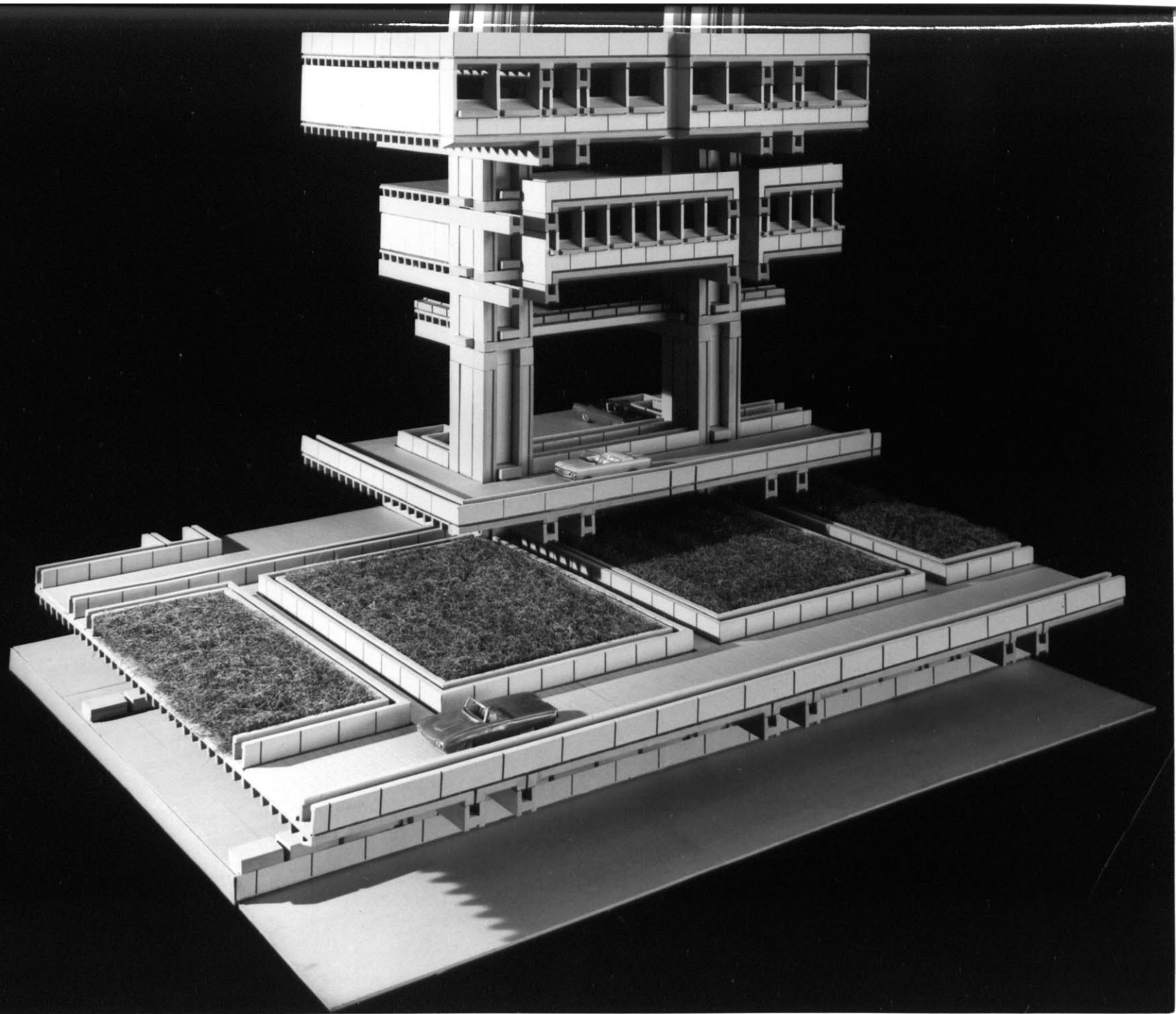
What does this proposal offer as a contribution to the design of research facilities?

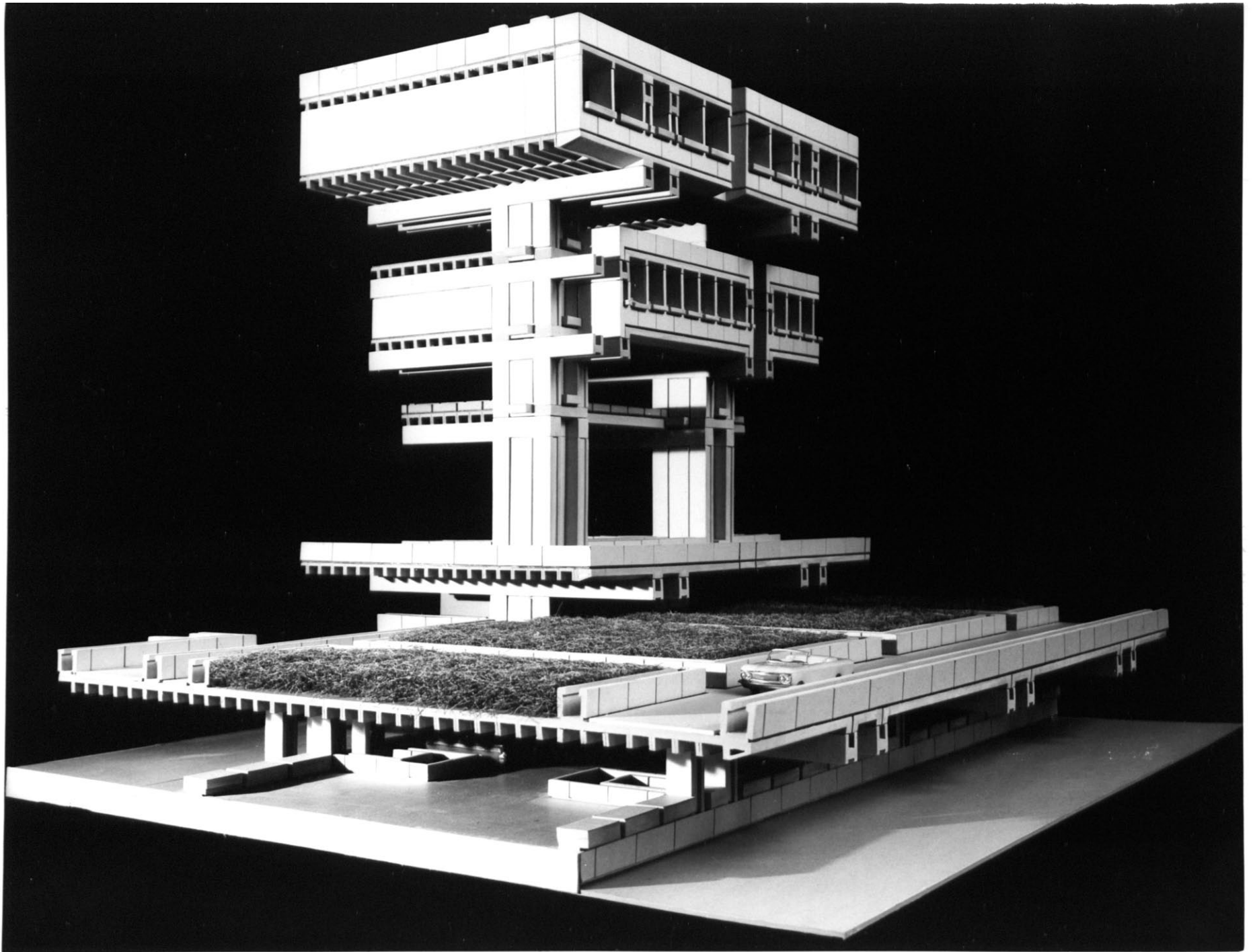
- A. A structural system of elemental simplicity, dictated by the demands of precast and prestressed concrete
- B. The systematization and integration of structure and mechanical services
- C. A structure capable of unlimited expansion

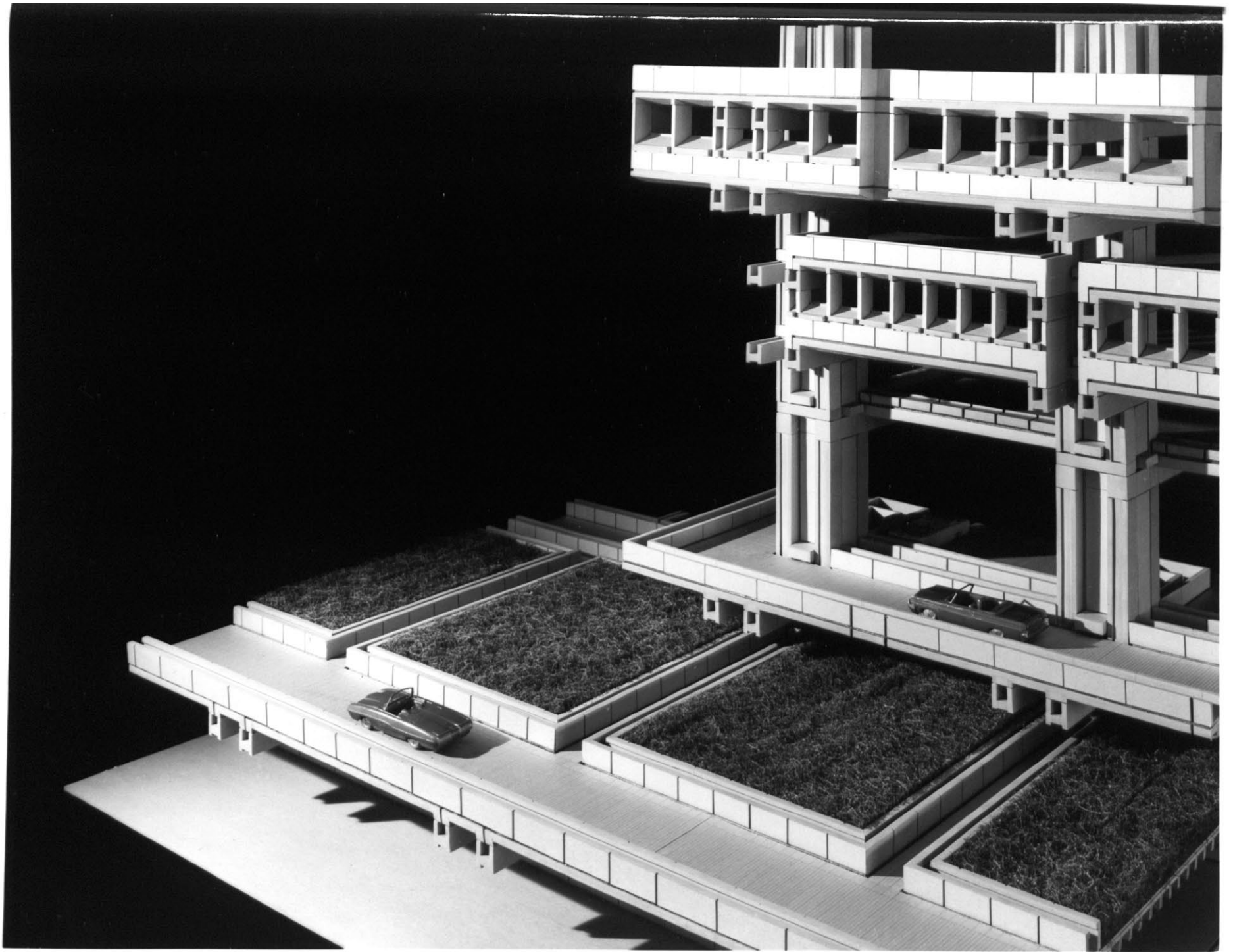
- D. A system of spaces providing horizontal and vertical flexibility

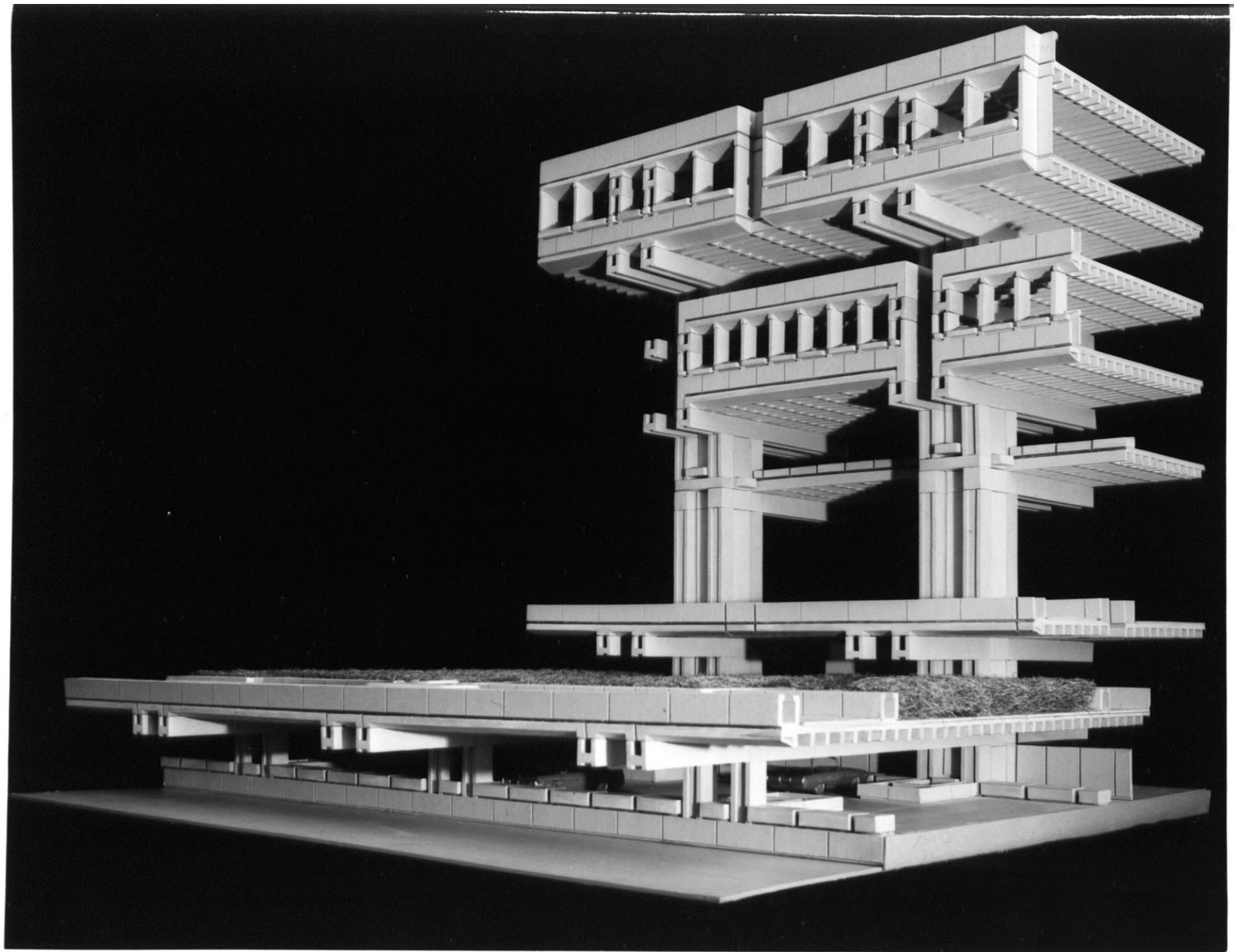
- E. An architectural expression of structure, uniquely tailored to precast concrete construction, while providing a visual richness with the breakdown of mass and scale appropriate to a building of large dimensions.

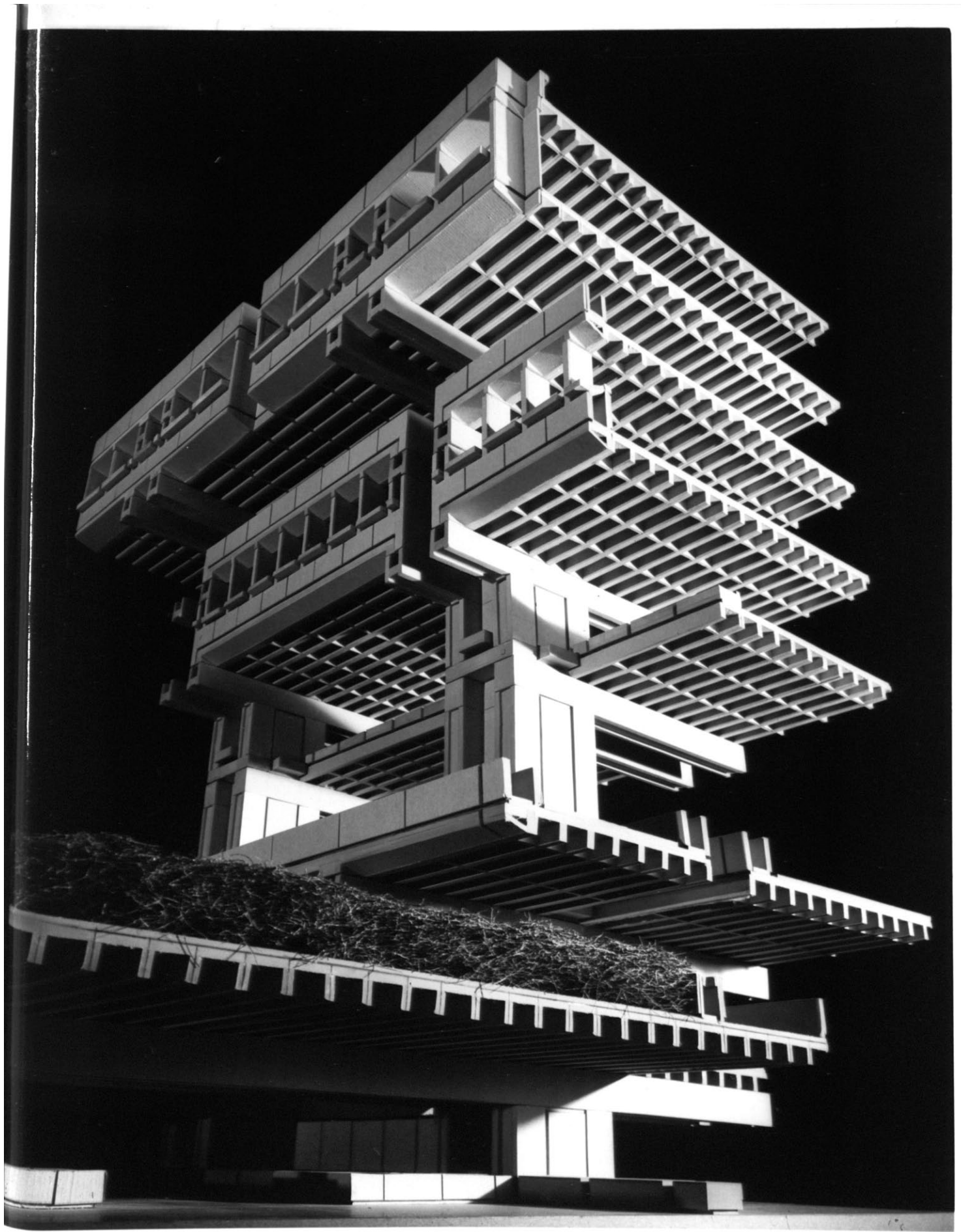


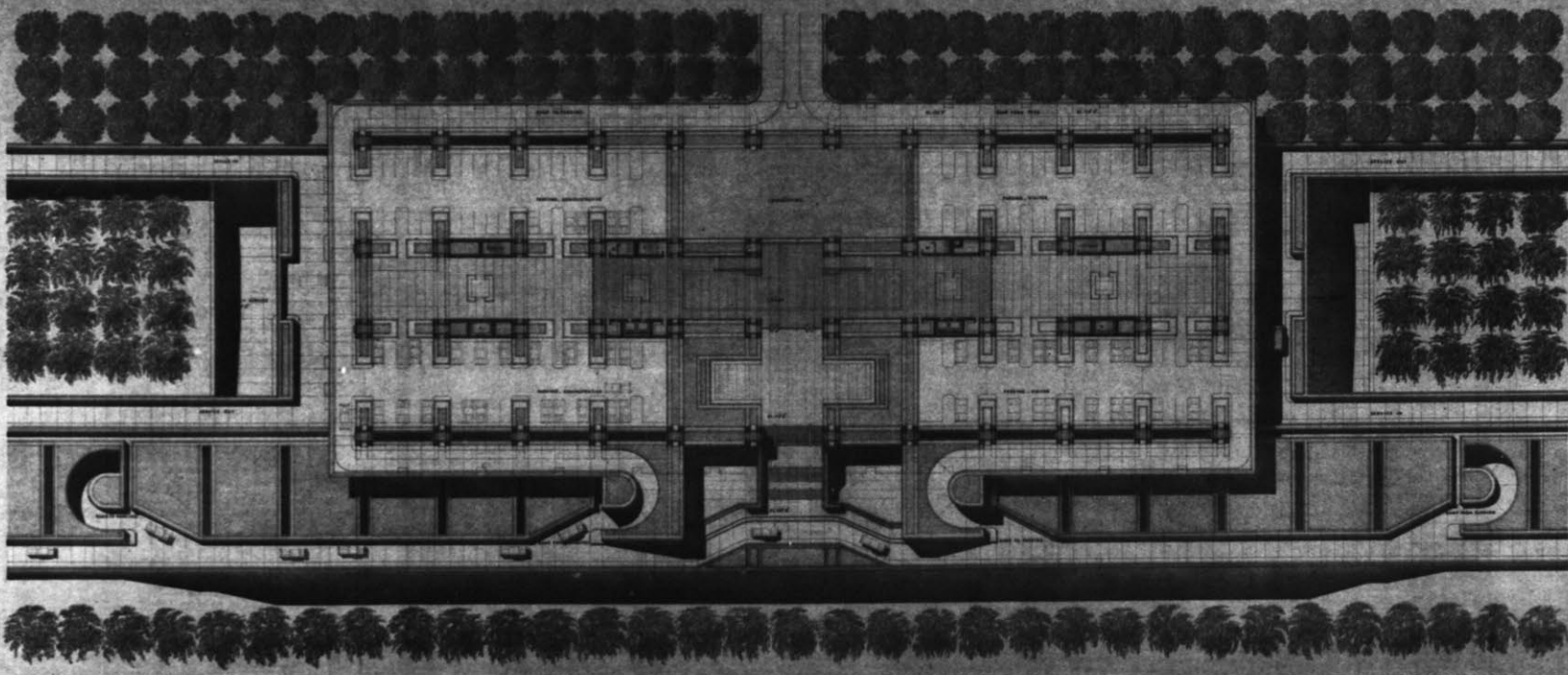






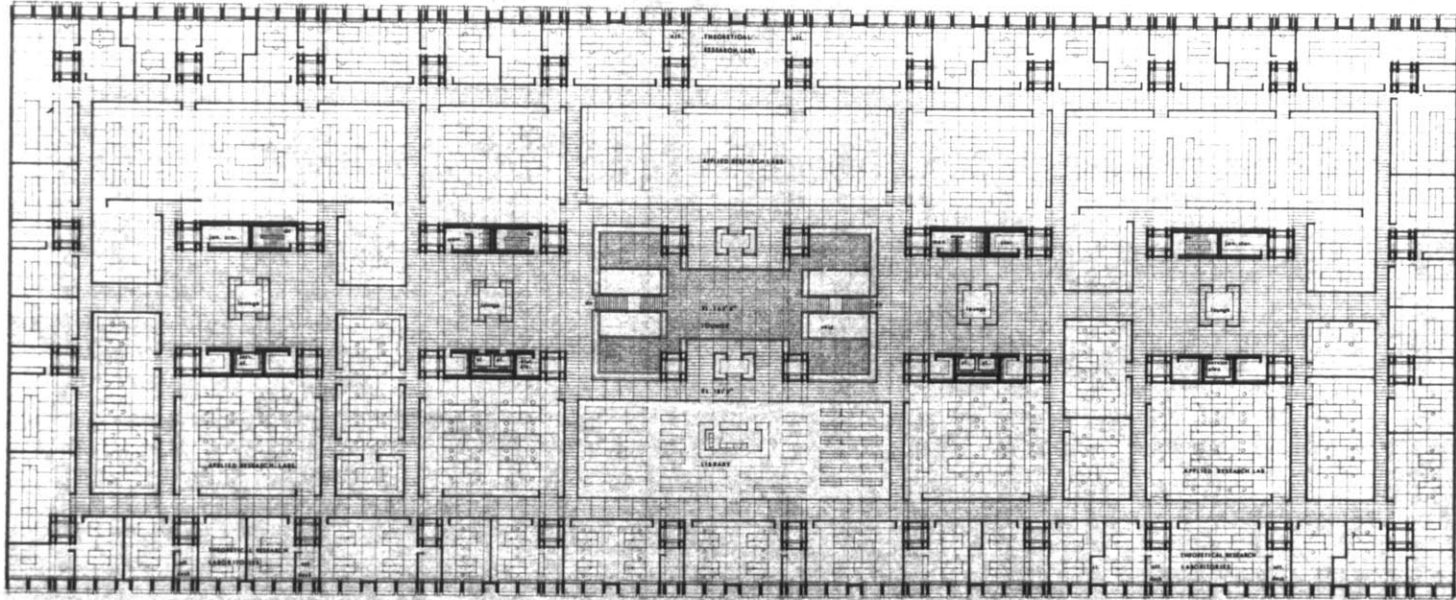






A PROTOTYPE STRUCTURE
for
RESEARCH; DEVELOPMENT
A. HAYES YOUNG ARCHITECTS
INCORPORATED
WILLIAM E. PEDERSEN
DALLAS, TEXAS
MAIN FLOOR PLAN



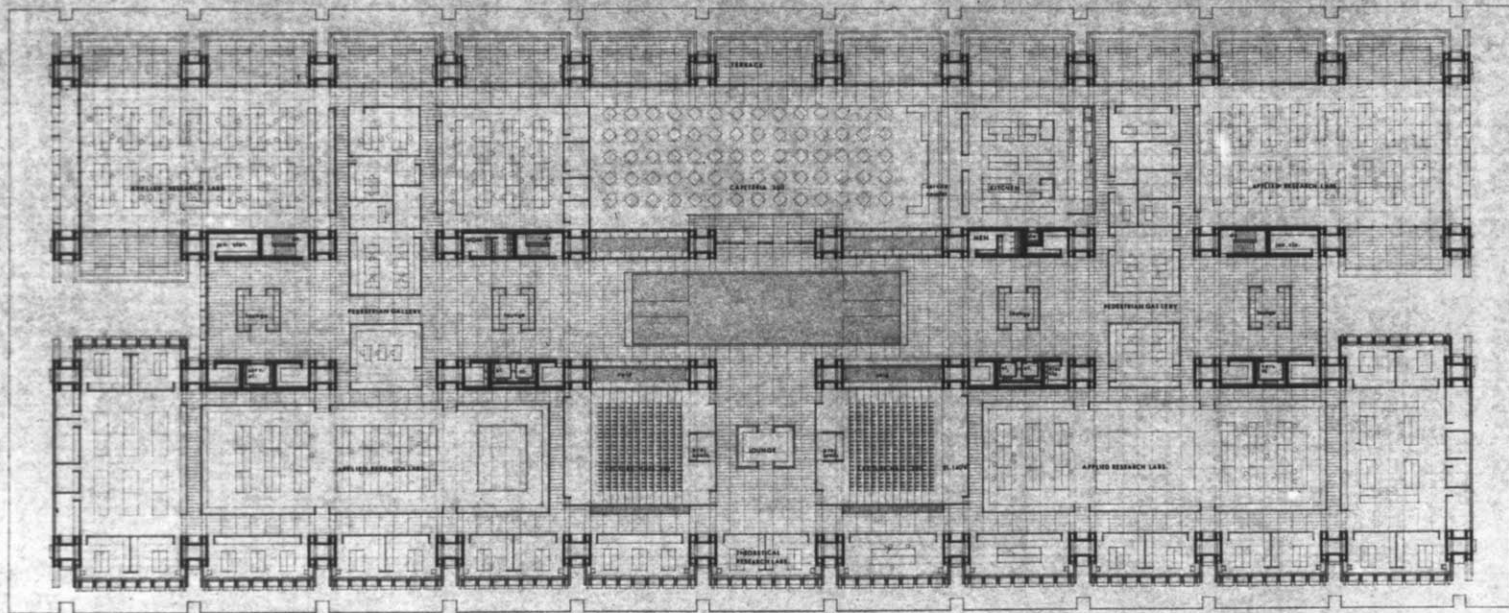


**A PROTOTYPE STRUCTURE
FOR
RESEARCH : DEVELOPMENT**

A MASTER'S THESIS IN ARCHITECTURE
SPRING SEMESTER 1964
WILLIAM E. PEDERSEN
M.A.C.

UPPER FLOOR PLAN 2



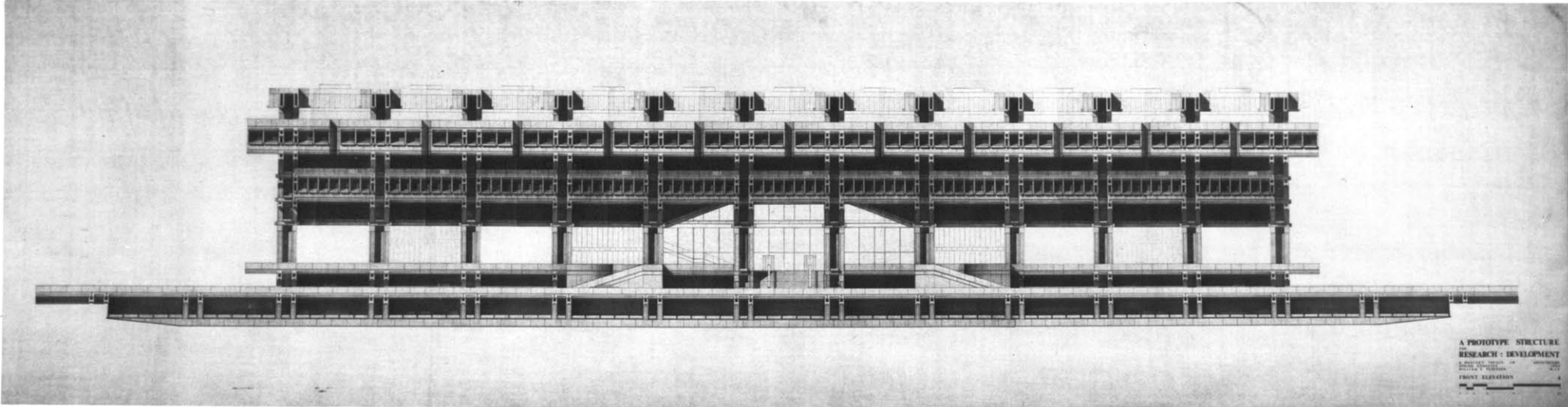


NOTE: UPPER HALF OF THIS
PLAN SHOWS FLOOR AT
EL. 142.7'

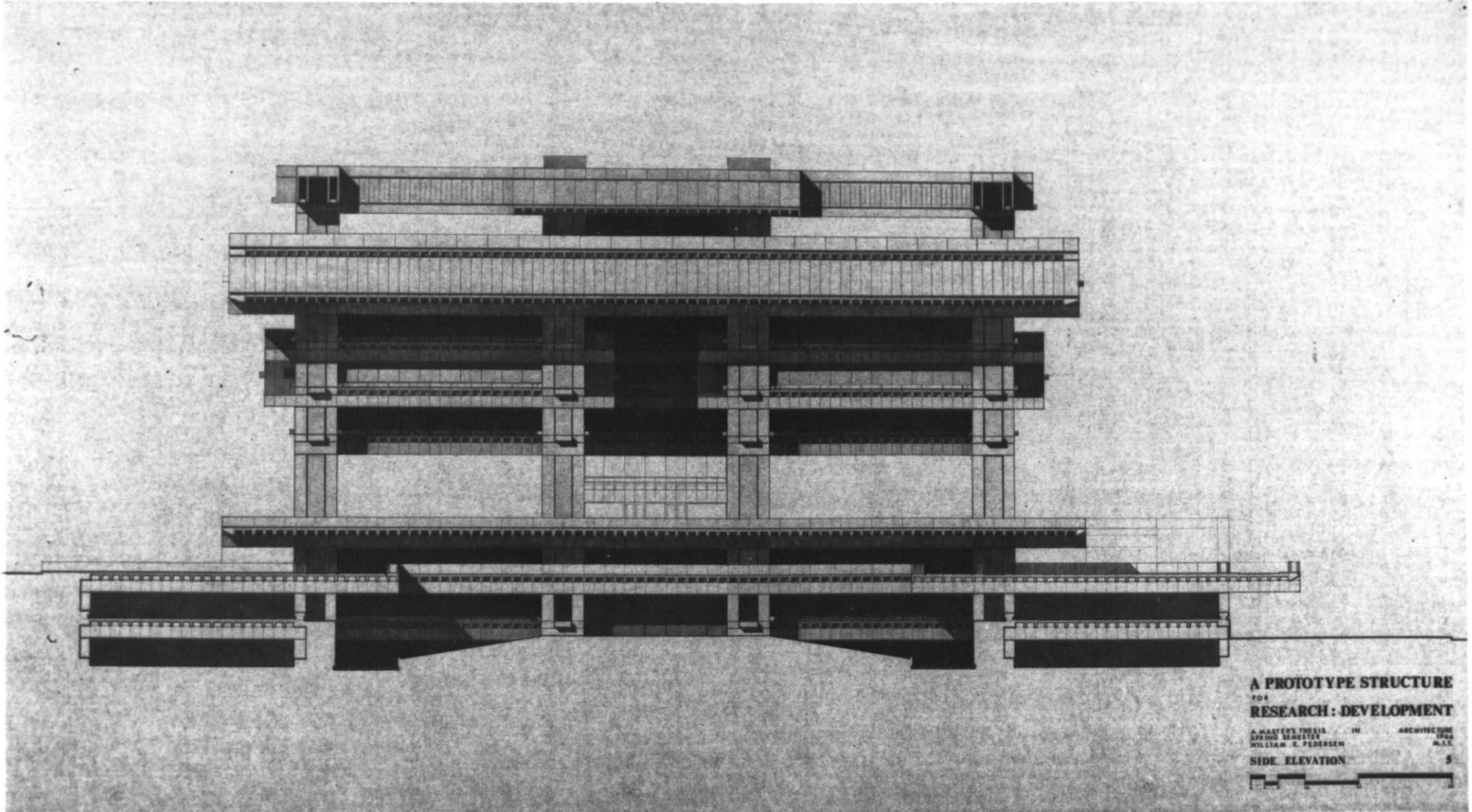
NOTE: LOWER HALF OF THIS
PLAN SHOWS FLOOR AT
EL. 142.0'

A PROTOTYPE STRUCTURE
FOR
RESEARCH : DEVELOPMENT
A MASTER'S THESIS IN ARCHITECTURE
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A PROTOTYPE STRUCTURE
RESEARCH - DEVELOPMENT
FRONT ELEVATION

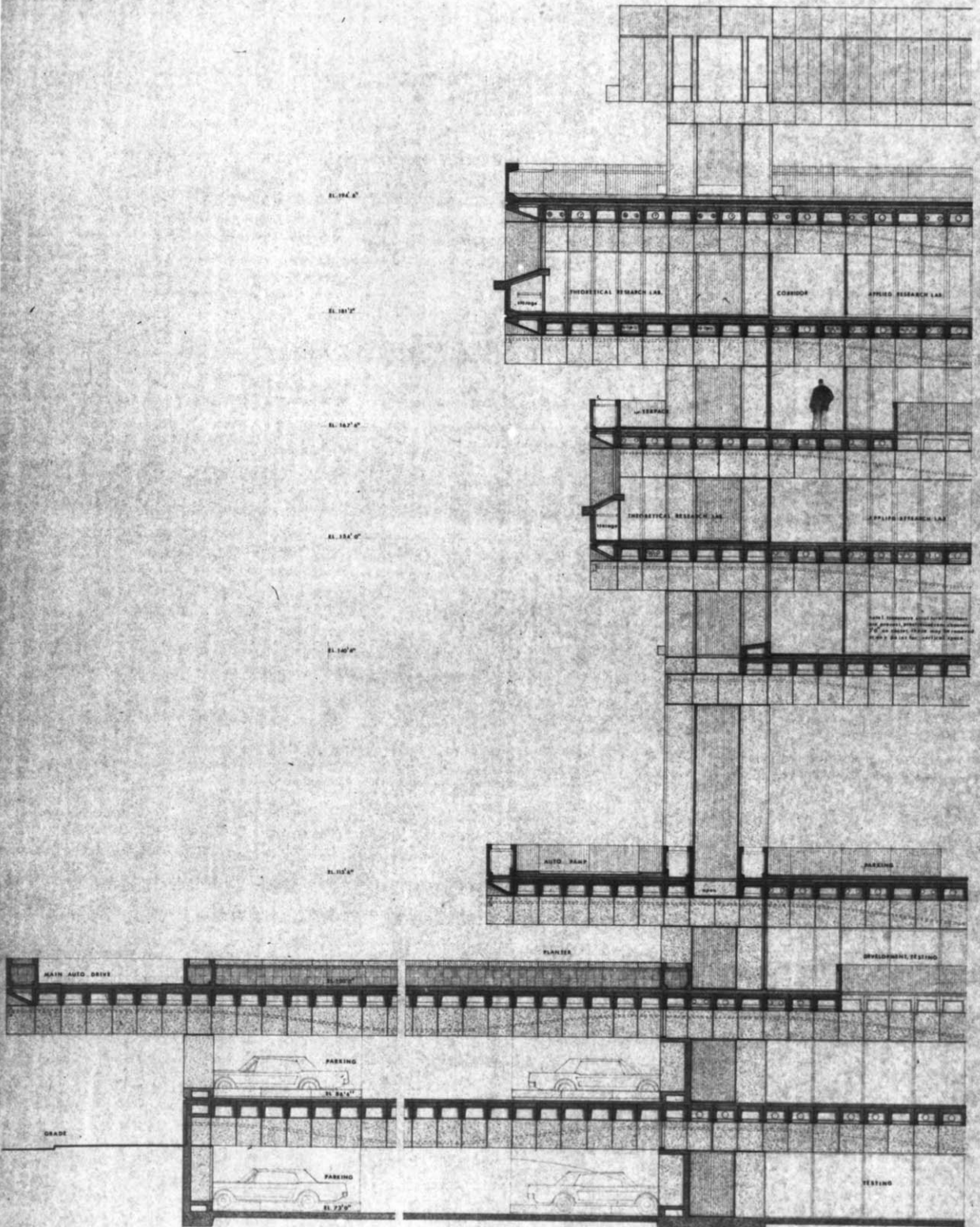


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RESEARCH : DEVELOPMENT**

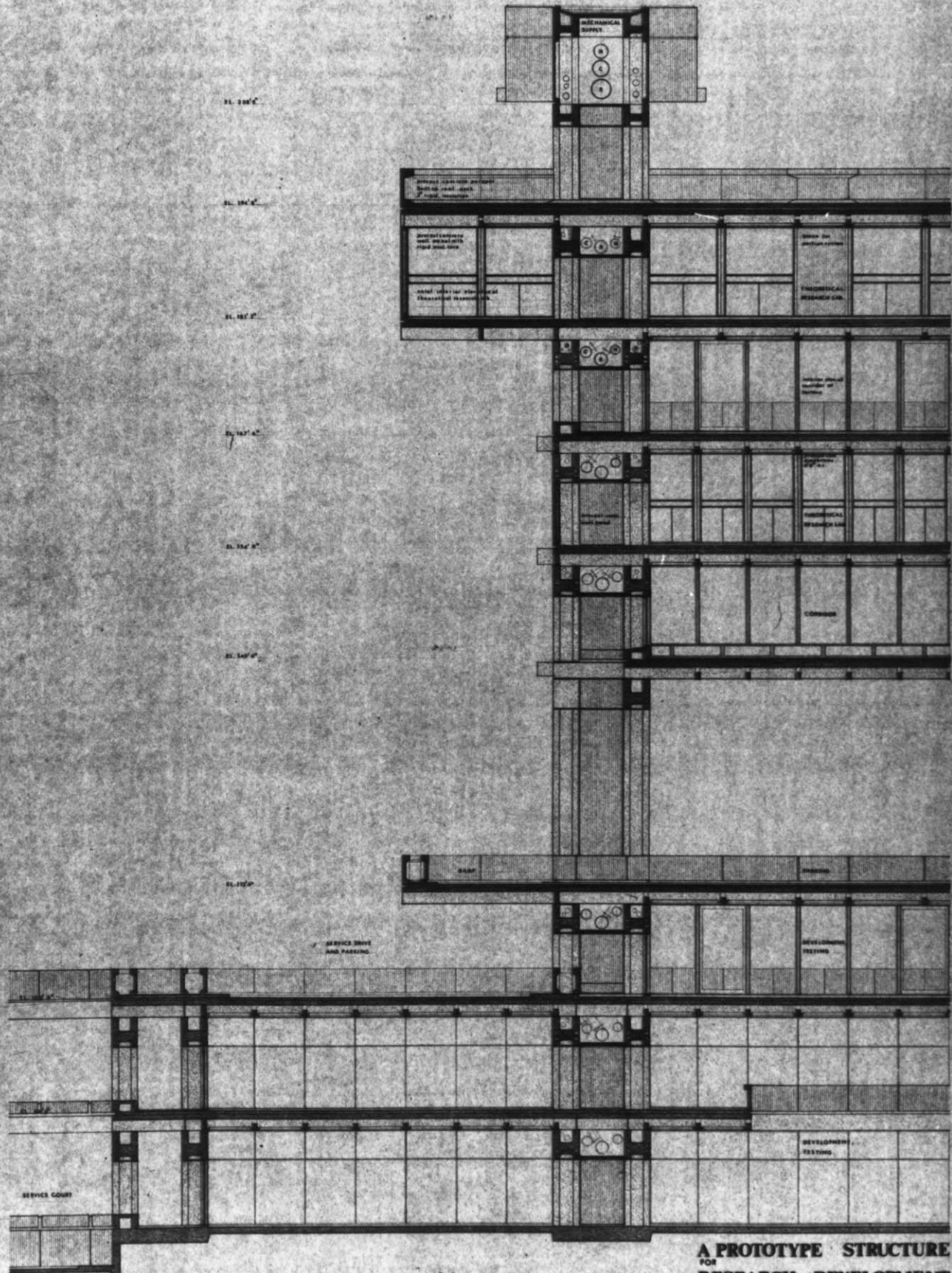
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SIDE ELEVATION 5





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FOR
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 SPRING SEMESTER 1964
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PARTIAL TRANSVERSE SECTION 8
 0 5 10 15 20 25



EL. 106' 0"

EL. 106' 0"

EL. 107' 0"

EL. 107' 0"

EL. 108' 0"

EL. 109' 0"

EL. 110' 0"

EL. 110' 0"

SERVICE DRIVE AND PARKING

SERVICE COURT

MECHANICAL SUPPLY

GENERAL OFFICES

LABORATORY

LABORATORY

THEORETICAL RESEARCH LAB

THEORETICAL RESEARCH LAB

COMMONS

COMMONS

COMMONS

COMMONS

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COMMONS

DEVELOPING TESTING

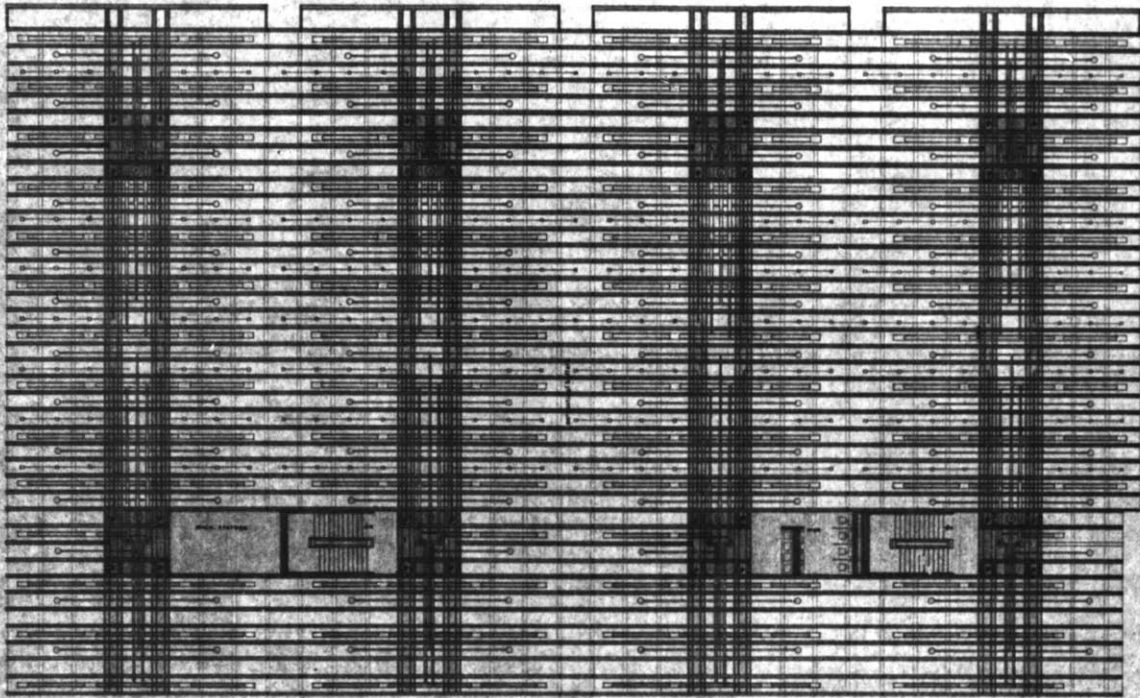
DEVELOPING TESTING

A PROTOTYPE STRUCTURE FOR RESEARCH : DEVELOPMENT

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PARTIAL LONGITUDINAL SECTION ' 9

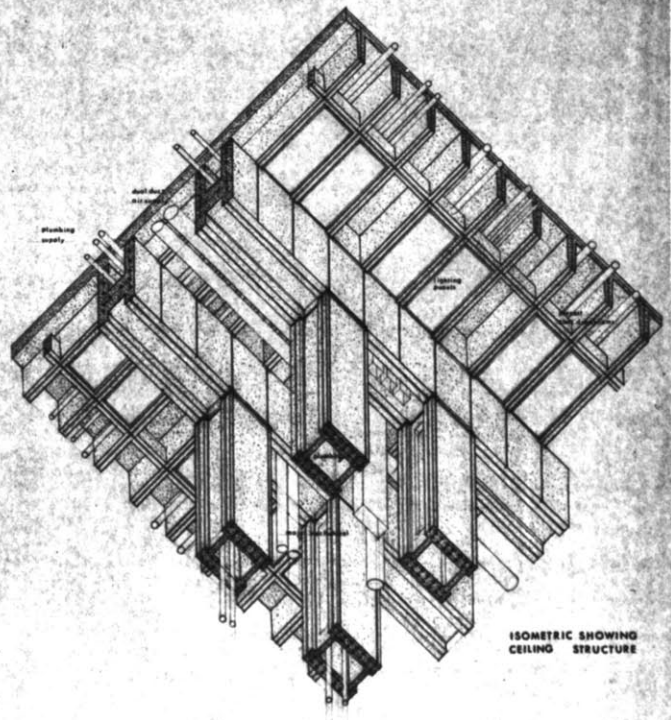
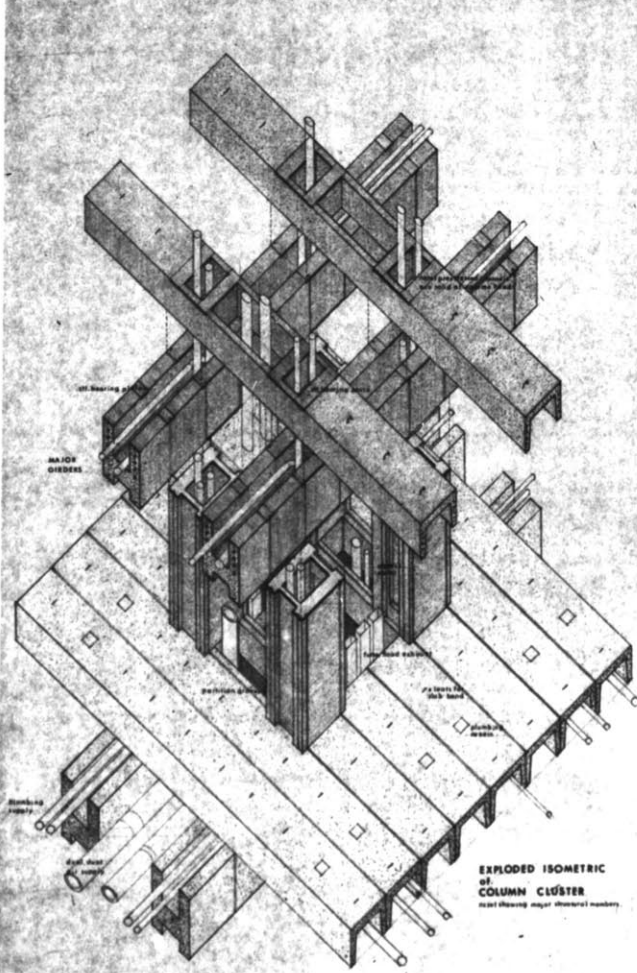




MECHANICAL & PLUMBING DIAGRAM

0' 6" 9" 12" 15" 18" 21" 24" 27" 30"

Overall mechanical system is composed of 24 galvanized steel ducts surrounding an existing steel ductwork system. All ductwork, vents and plumbing are to be in the structure shown at the boundary element number.



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STRUCTURAL & MECHANICAL 10

