

A BUILDING SYSTEM WITH EMPHASIS ON FLEXIBILITY,
USING PRECAST CONCRETE ELEMENTS


by

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June 25, 1965

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Dear Dean Belluschi:

In partial fulfillment of the requirement for the degree of Master of Architecture, I hereby submit this project entitled, "A Building System with Emphasis on Flexibility."

Respectfully,

Hans J. Huber^u

ACKNOWLEDGEMENTS

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

1. Professor Wacław Zalewski, Warsaw, Poland
2. Professor Eduardo F. Catalano, Thesis Advisor

ABSTRACT OF THESIS

This thesis is concerned with the design of a prototype building for industrial research and development, utilizing precast and prestressed concrete construction.

The objective is to design an integrated system of structural and mechanical components in a way which allows growth in small increments and flexibility of dynamic spaces, as well as interchangeability of its components and spaces.

Specially emphasized is the maximum continuity of spaces, horizontally and vertically, combined with a maximum of vertical flexibility of dynamic spaces, as it might be required in this type of building to achieve great freedom for its working space.

Another objective is to arrive at a solution, which allows for growth of the building system in an easy and efficient way regarding the fact that the current research can be carried out without much interference during construction time of the expansion.

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DEFINITIONS

1. Building System

Building System means a building as a integrated total system of life, growth, circulation, services and construction on modular base. The Building System consists of self-sufficient minimum units of growth.

2. Growth

Growth means expansion of a building, not just in form of adding a new building to an existing one, but expansion of a building in an organic, integrated procedure, where the growing building preserves its character and main components in all stages.

3. Static Spaces

Static Spaces are mechanical rooms, fire stairs, elevator shafts, toilets and closets for electrical and telephone supply. Their size and location can be predicted and designed for each special building type as a part of constant requirements.

4. Dynamic Spaces

The terminus Dynamic Spaces is used in juxtaposition to Static Spaces. Dynamic Spaces are office and laboratory spaces. Their location and three-dimensional size may change many times during the existence of the building.

I. A. Introduction.

There is a basic difference between present-day plannings for applied research buildings and future designs.

Up to now many types of office, laboratory buildings and similar types were designed for a specific program, where the structure, size, shape, mechanical and electrical equipment was laid out following a fixed program. Very often, specially in industrial architecture, the architect had nothing to do but to design the envelop and interior decorations. The responsibility of creative engineering is that the architect is acquainted and concerned with the buildings as a total of many functions and systems such as: structure, mechanical equipment, static and dynamic spaces, size, shape, life, growth, circulation and all services.

The future architect has the important and difficult task to coordinate and integrate all the complex systems and functions mentioned above to a total system. This is his chance and challenge.

The architect cannot be engineer for everything, but he has to be aware and to recognize the basic needs of future technology in buildings.

This will be necessary in the future in many more types of buildings, since technology and the use of buildings will change their programs very often, influenced by new methods of work, equipment

and production. Building systems have to be living, very flexible units in order to be economic and usefull for a long time and wide range of work.

I. B. Approach.

According to the requirements of a research worker, the design criteria was to develop a building system, which allows a maximum of freedom to choose, a freedom of size, circulation, shape and adaptability of working space, environmental control and ease of access to electrical and mechanical services. The problem can be solved only by analyzing the static requirements such as fire stairs, elevators, toilets and mechanical layout. All of these components have to be integrated and designed in a simple and repetitive way, fixing only the basic requirements and leaving everything else as flexible as possible without loosing control over the functioning and character of the building system. The main target of this thesis was to find an adequate solution, which provides a maximum of unobstructed horizontal and vertical space flexibility.

The system proposed originates in the following ideas:

A one-way system provides vertical flexibility easier than a two-way system.

Maximum continuity of spaces can be achieved only by minimizing the columns and by coordinating the cores and columns in size as well as location, following a modular grid.

By analyzing the permanent and the temporary systems the author arrived at a solution, where the columns contain air shafts and pipe space, because these two have to occur in a strong repetitive spacing to be efficient and economic.

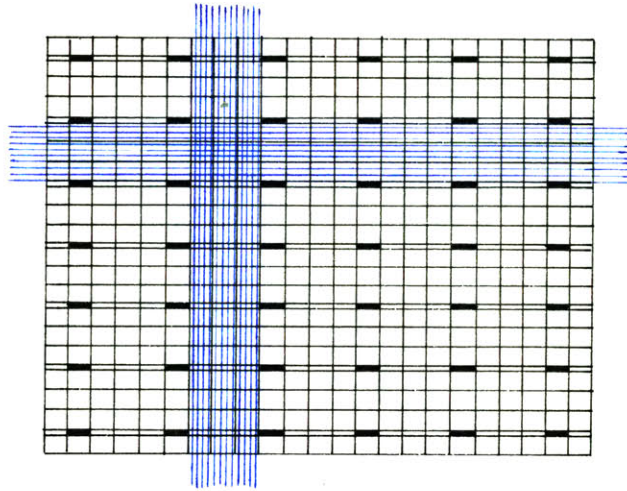
This is not the case for stairs, elevators, freight hoists, toilets and electrical closets, which can be more flexible. They have to be related to special conditions such as main entrance, main lobby as a center of gravity, maximum height of the vertical growing building. A one-storied building as a stage of growth may not need a fire stair or an elevator. So the author tried to design two types of cores, one containing the elevators and stairs, the other one containing the toilets, janitor closets and telephone booths. Both cores have shafts and closets for electrical and telephone supply.

Following the idea of maximum continuity of spaces these cores are designed to fit in the grid of the vertical supports, the core-columns, in order to minimize horizontal obstructions.

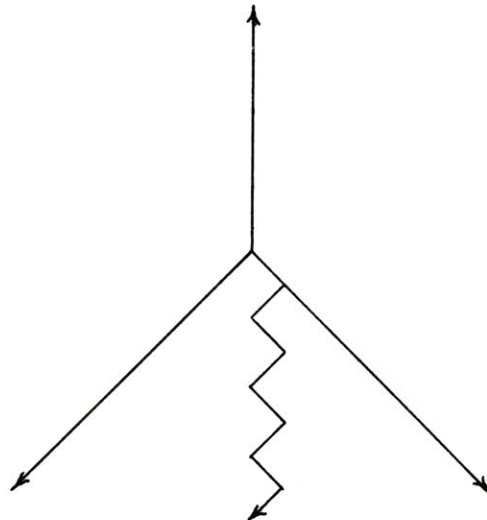
The cores are designed for a self-sufficient minimum unit of growth of about 20 000 sq. ft.

The author analyzed different spacings of columns. In all cases the span between the columns is a multiple of the cantilevers, regarding the fact that twenty to twenty five feet of cantilever are necessary for a continuous peripherie zone of working space.

Combining all considerations mentioned above, the author arrived at a structural grid of twenty feet in one direction, twenty five in the other. The units are joined by a fill-in which fits in the structural grid.



Scheme showing main structural grid and continuity of spaces



Directions of growth

II. A. The Building System.

To achieve this degree of flexibility a one-way-system was chosen. The building is composed of self-sustained increments of growth of 20 000 sq. ft. of floor area. The whole first stage of this prototype building for 600 000 sq. ft. is laid out for a maximum of five stories with two basements underneath for parking and mechanical equipment. The minimum floor area is 40 000 sq. ft.

Using a five by five foot module for all services the working space can be divided by flexible wall partitions in any reasonable size for office and laboratory space.

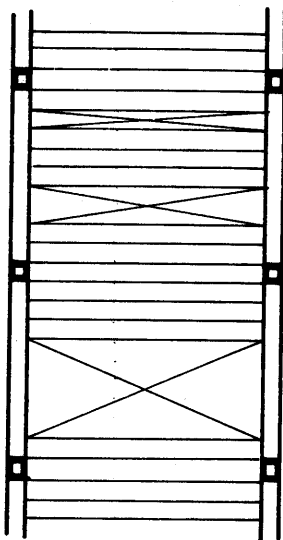
It was felt that a low building with few stories has more advantages for research buildings than high towers. This was one main reason to separate the vertical services in two parts: (see drawing No. 6).

The static parts such as air ducts and pipe space occur in the grid of the structural supports 60' - 0" in one, 75' - 0" in the other direction, thus allowing large working spaces between the core-columns. The elevators, freight hoists, stairs and toilets are joined into non-structural cores, but integrated with the structure, wherever they are required. So this multi-cores can be flexible and efficient.

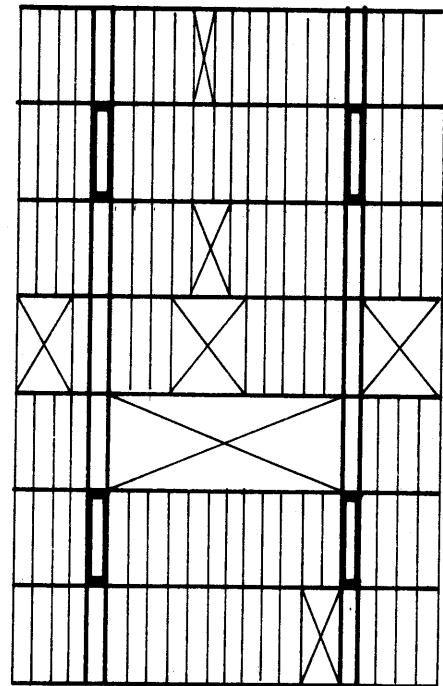
The mechanical rooms are located in the lower basement in order to minimize sound transmission, vibration, waterproofing and dead load on the structure.

Furthermore the author felt that the basement is the most natural location for mechanical rooms considering vertical growth of the building. The proposed building shows the different possibilities of growth and their visual expression in the diagrams: (see drawing No. 1 and No. 2).

II. B. Flexibility.



Sketch No. 1



Sketch No. 2

The author tried to create life in the building by emphasizing flexibility of continuous spaces and three-dimensional change of the building.

While sketch No. 1 shows a structural system with two kinds of girders only, the scale of voids is in many cases unnecessary large and does not allow the minimum size of required vertical flexibility.

Scheme No. 2 was chosen to provide this minimum of required vertical flexibility, which can occur in all parts of the building and provides voids from 5' - 0" / 25' - 0" up to 60' - 0" / 25' - 0" by 5' - 0" increments without touching the main structural girders type No. 1 and No. 2.

The girder type No. 2 allows for voids with the sizes:

20' - 0" /	50' - 0"	or	75' - 0"
40' - 0" /	50' - 0"	or	75' - 0"
60' - 0" /	50' - 0"	or	75' - 0"

The small scale flexibility is almost 100 % without disturbing the basic structure and the basic mechanical equipment, thus avoiding expensive time wasting site work.

The vertical flexibility is illustrated in the enclosed photographs of the model.

II. C. Character and Expression.

In designing the plans for this building an attempt has been made to express the flexibility of the system and the different possibilities of growth by using one basic unit. So each floor area is different in the first building stage, but it was attempted to retain and express a sense of visual order by using similar physical units and expressing the structural spans, floor heights, core-columns and the basic 5' - 0" module in the curtain walls.

A system of growth has to provide and to show this characteristics mentioned above. While growing, the building cannot have the same compact, strong expression as a building, which is designed for one defined program.

(See drawings No. 2 and No. 4).

III. A. Structural System.

(See drawings No. 3 and No. 5 and photographs of the structural model.)

Precast concrete provides both structure and finished surface and is fireproof. No maintenance costs occur. This is due also to the structure, which is exposed at the ceiling as well as to the envelope of the building, i. e. to the precast concrete curtain walls.

Using prestressing and posttensioning methods long spans and a high degree of precision and economy can be achieved by simplification of a minimum of repetitive structural components.

Another factor with increasing importance in building technology are the methods of forming, transportation and erection of the structural components.

Reuse of forms, preassembling of structural members in order to avoid expensive scaffolding, in other words, standardization and industrialization are essential for future buildings of this scope and scale.

All structural components are prefabricated and designed for an erection method, which makes expensive scaffolding unnecessary.

The total structure is composed of four different types of components. They are:

1. Core-Columns

Each vertical support has the grid dimension of 5' - 0" / 25' - 0". The non-structural cores are designed so that they fit into the 25' - 0" module of the core-columns, which allow unobstructed spaces between the columns of 60' - 0" / 75' - 0". No other columns are necessary. The core-columns are prefabricated in two equal parts (12 tons each). They are joined together after erection by additional reinforcement inserted in openings between the parts, which are filled with concrete, when the steel is placed.

2. Girder Type No. 1

The double-girders are prefabricated in three parts per unit. The two parts resting on the core-columns are 5' - 0" wide, 5' - 0" high, 75' - 0" long, 65' - 0" on center. They are connected with the third part by posttensioning. The third part consists of two T-beams, each 25' - 0" long.

3. Girder Type No. 2

Precast poststressed girders 1' - 0" wide, 5' - 0" high, consisting of five members, each 20' - 0" long. Joined together with the girder type No. 1, they define the width of one unit of growth (110' - 0"). The girder type No. 2 is spaced 25' - 0" on center. The girder type No. 2 serves as support of the T-beams No. 3.

4. T-Beam Type No. 3

All type No. 1 and type No. 2 girders are post-stressed throughout the building system, except where expansion joints are required.

Type No. 3 T-beams are 5' - 0" wide (vertical part 4 " wide), 5' - 0" high, 25' - 0" long, placed 5' - 0" on center.

The T-beams are welded together with steel plates in both directions and supported by the girders type No. 2. The welding connection provides continuity of the floor slab and allows easy demountability. The components can be reused again without repair. Since they are short and light weight, it is no problem to demount and to transport the T-beams inside the building without special equipment or disturbance of the work.

III. B. Curtain Walls.

The enclosure of the building system consists of precast concrete panels. They are divided vertically in two parts per floor, one has the height of the floor structure, the other one has the height of the clear opening of the floor.

The idea of this division is to preserve the full use of the existing building during construction time for growth.

The spandrel panel is designed in a way, which allows its removing and joining of the new girders and T-beams for expansion.

When the expansion is finished and the new part of the building is air-conditioned, the curtain wall in the existing floor will be removed.

The division of the panels in two parts per floor has some minor disadvantages such as complication of the attachments of the panels to the structure. Furthermore, more joints resulting in additional risk of weatherproofing have to be taken in account. Despite these facts the author feels very strongly that especially in such a flexible building system, where growth has to be made possible in a very efficient undisturbing method, this design of the panels is a precondition.

III. C. Construction Procedure.

The total structure is assembled on the site in the following order. Special scaffolding can be omitted.

1. Excavate and place footings.
2. Place service trenches and connect with site utilities.
3. Place lower level slab and retaining walls.
4. Place core-columns.
5. Join together girder type No. 1 (75' - 0") and girder type No. 2 (20' - 0") by post-tensioning in field, but on the ground.
6. Lift up this preassembled structural unit (75' - 0" / 45' - 0") and connect with core-column.
7. Repeat procedure 4., 5., 6.
8. Place connecting unit between cantilevers of girder type No. 1 and posttension to get continuity.
9. Place connecting unit between cantilevers of girder type No. 2 and posttension.
10. Place T-beams and weld to each other and to girder type No. 2.
11. Place floating floor together with electrical raceways.

12. After finishing one floor the procedure starts again at step 4.
Meanwhile ductwork and pipe installation can be done in the preceding floor.
13. Curtain wall panels have to be placed as soon as possible after the erection of each floor to allow moderate temperature for inside work.

IV. Mechanical System.

The mechanical services are extensive, in order to provide maximum flexibility in meeting the variety of work to be performed.

Each unit has its own air-conditioning center located in the lower basement. It occupies the area between the four core-columns of the unit (8 % of the cross area of a unit). This decentralized system allows maximum control and provides each working space with air in a short efficient way.

The cooling towers and the cold generator are on the roof of the main entrance building, since this is already designed for the maximum height of five floors.

The air-conditioning system is a low velocity system integrated with the structure with supply and return air shafts in each bearing column. From these core-columns round ducts, which are placed in the ceiling structure 10' - 0" o. c., distribute the air so that it serves all five by five foot bays alternatively to provide a

maximum of flexibility of sizes and partitioning of the rooms. Each room has the same amount and the same sizes of supply diffusers and return air grilles.

Special ducts lead fresh air from the roof down to the mechanical rooms.

The layout of the distribution ducts takes in account the vertical flexibility, i. e. no ducts have to be rearranged no matter where voids for vertical dynamic space occurs. Each supply diffuser contains an electric heating advice, which allows change of temperature and humidity due to the different requirements of the spaces.

A fan coil system was chosen as a secondary heating and cooling system for the peripherie zone with individual control according to the exposure and the personal needs.

This secondary system is laid out for 15' - 0" depth of the peripherie zone.

V. Electrical System.

High and low currenncy raceways are placed in a 4" high floating floor. Supply is possible through the floor at each 5' - 0" bay.

The wiring for telephones is run in the same divided underfloor ducts.

Telephone and electrical services originate from special closets located in the service cores on each floor, easily accessible through fireproof steel doors.

VI. Lighting System.

Since in future research buildings laboratory work will continue even in the night and considering the fact that exterior space might turn into interior space while the building system expands, it seems to be necessary to design the layout for artificial lighting unique for the total working space.

The intensity of the light can be changed according to the varies needs in interior and exterior or specially used space.

Each five by five foot ceiling unit contains two 4' - 0" fluorescent tube fixtures behind a luminous grid, which is recessed to show the structural ceiling.

The conduits for the lighting fixtures run in the open space of the structure to electrical closets.

VII. Acoustics.

The ceiling panels are designed so that sound absorbing material can be added where required, predominantly in office space.

The exact placement of ducts has to be done so that they can be isolated to avoid sound transmission from room to room via ceiling.

The wall partitions are divided into two parts, one going from finished floor to underside of structure, another one as a filler between the floor slab soffit and the underside of the girders.

The wall partitions have to be designed for an average of a transmission loss of 40 decibels. The floor is isolated from the structure by a precompressed layer of fiber glass, rockwool, cork or equal. This floating floor avoids impact noise as well as vibration.

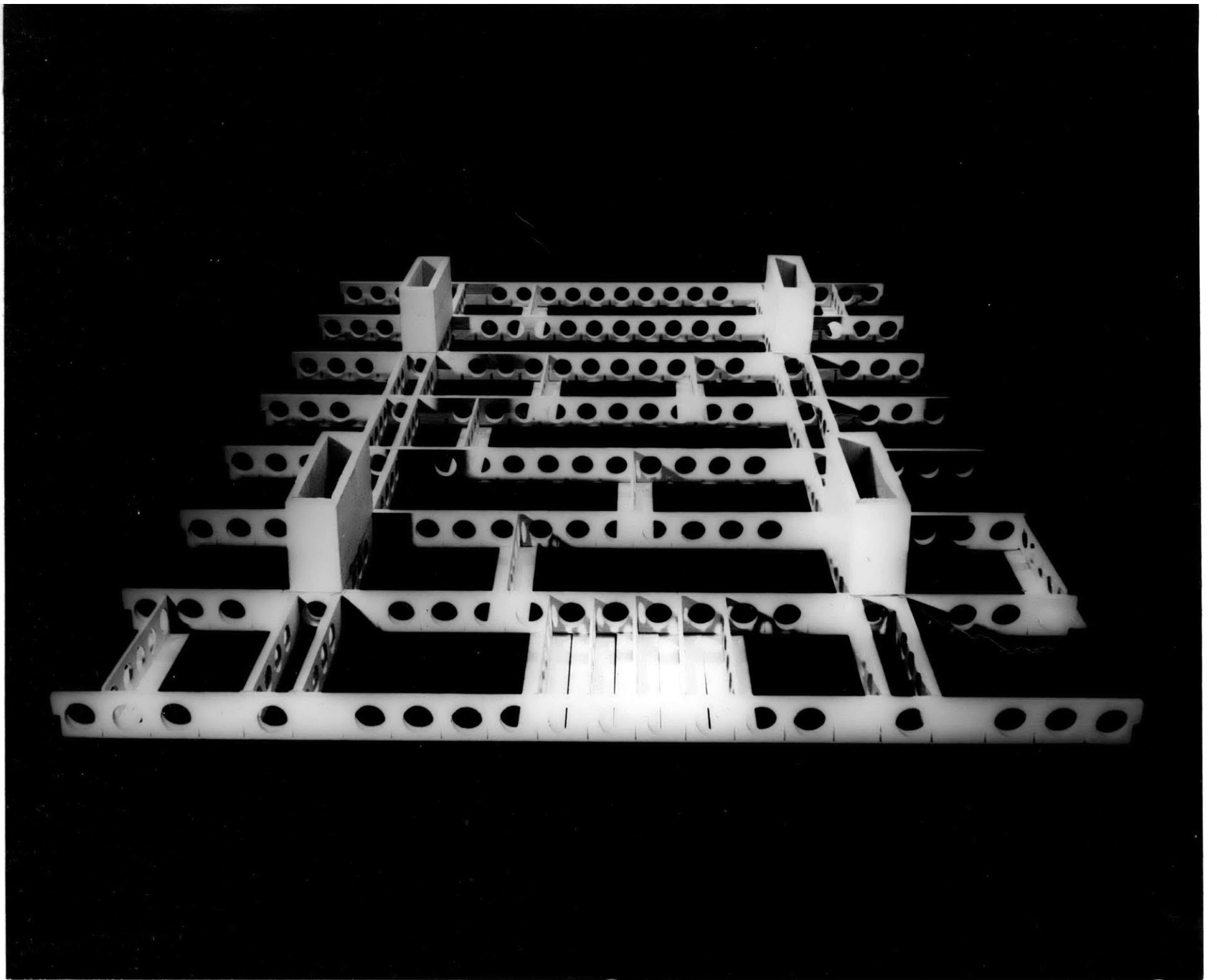
Since the windows are fixed and sealed to the precast concrete curtain wall panels the noise from outside the building will drop considerably.

VIII. Photographies of the Model and of
the Drawings.

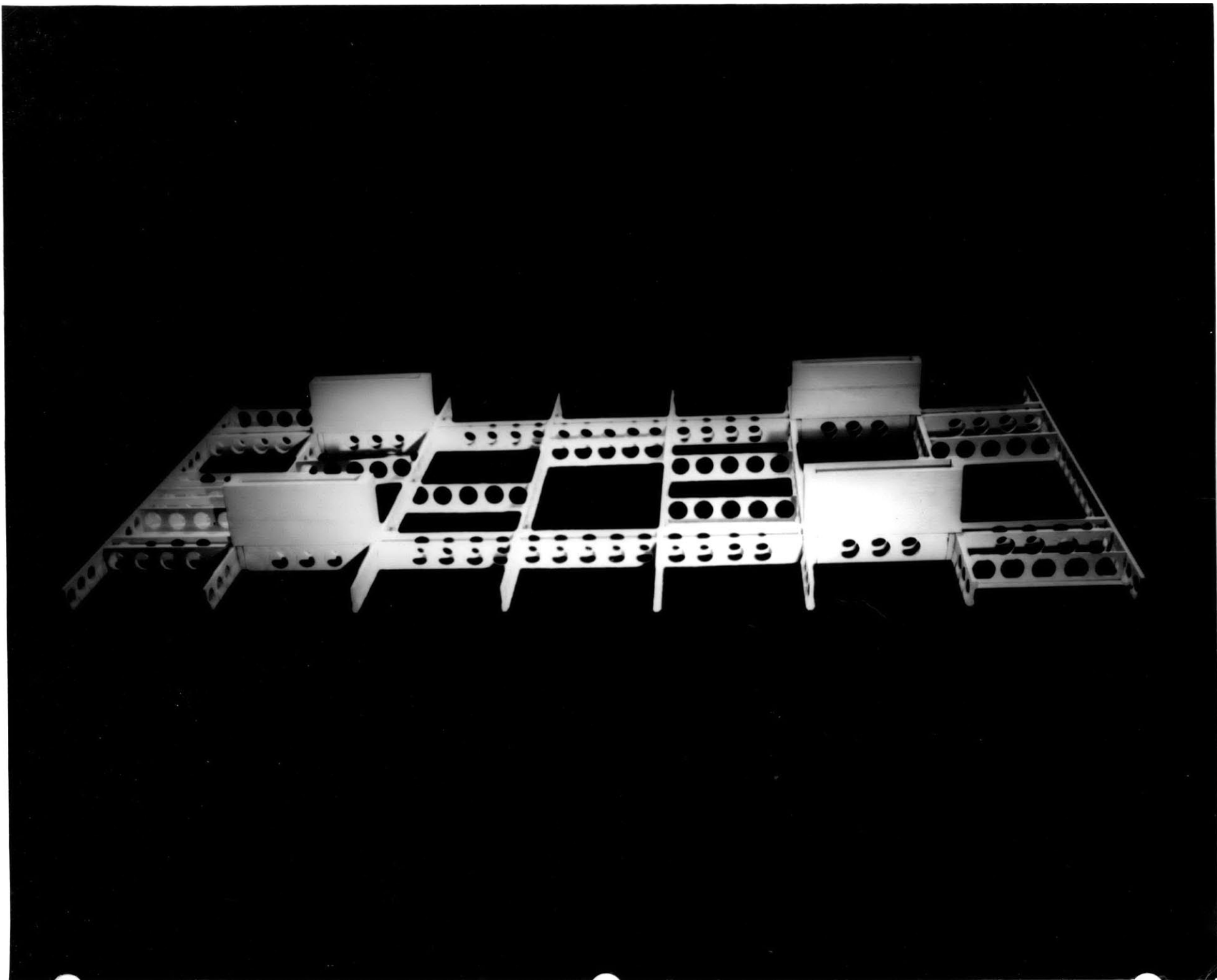
Photographies of the structural model
showing the vertical flexibility of
dynamic spaces.

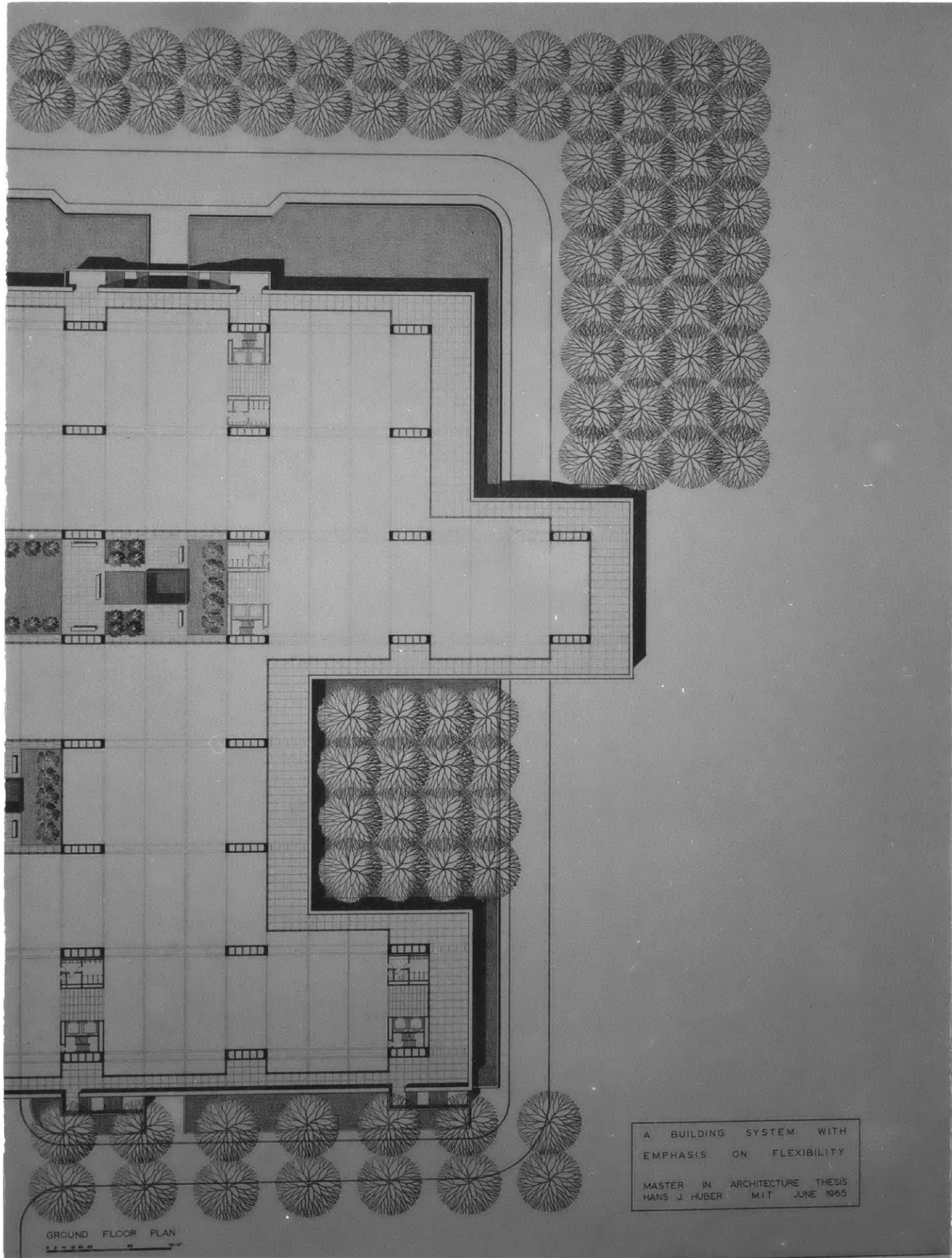
Photographies of the drawings.

1. First floor plan with landscaping.
2. Diagrams of the floors and
wall partition layout.
3. Longitudinal section.
4. Main entrance elevation.
5. Structural components,
minimum unit of growth.
6. Detail of the cores,
lighting and duct distribution layout.



2



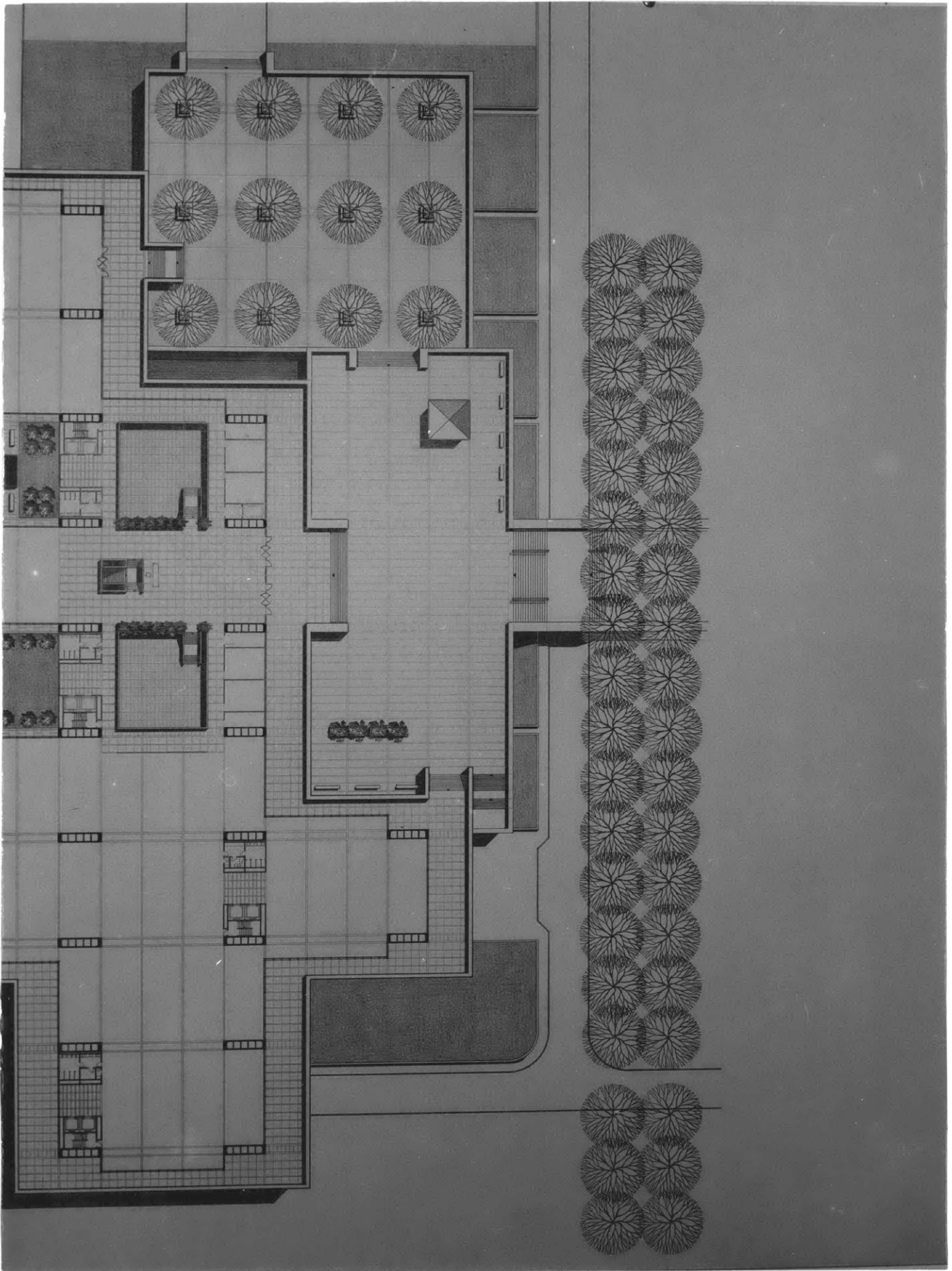


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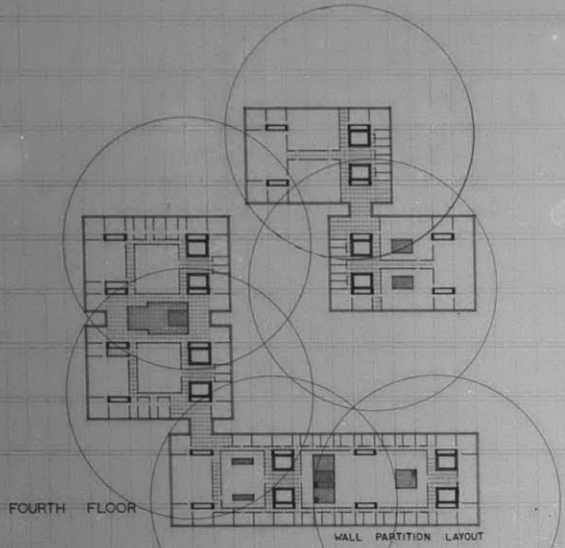
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GROUND FLOOR PLAN

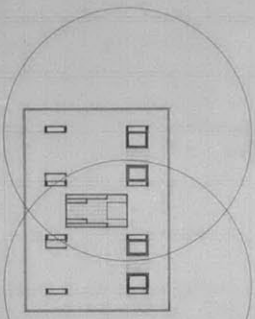




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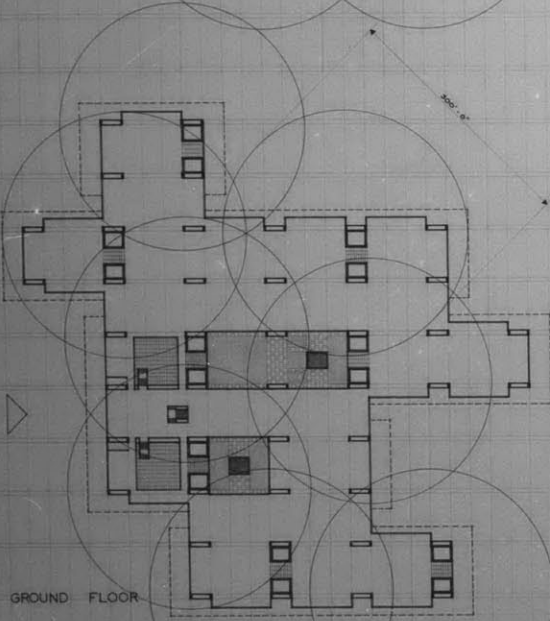
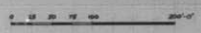
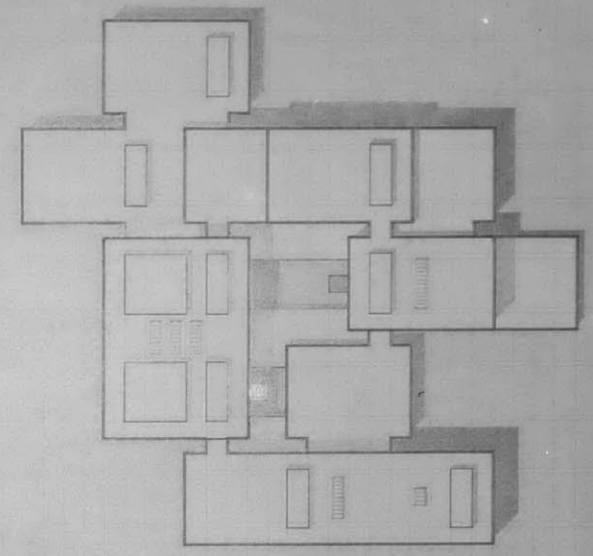


FIFTH FLOOR

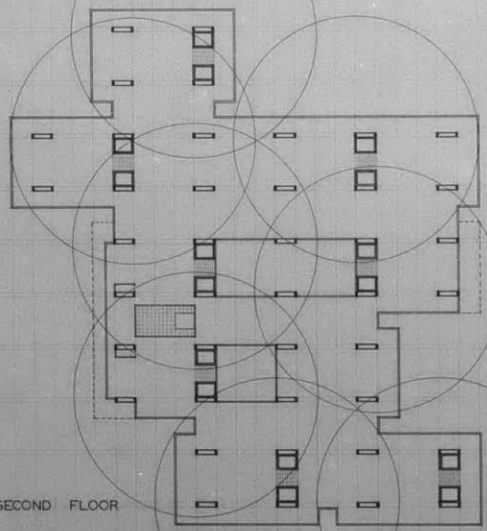


- ELEVATORS, STAIRS
- LOBBY
- TOILETS
- FREIGHT ELEVATOR
- CORE - COLUMN WITH AIR SHAFTS

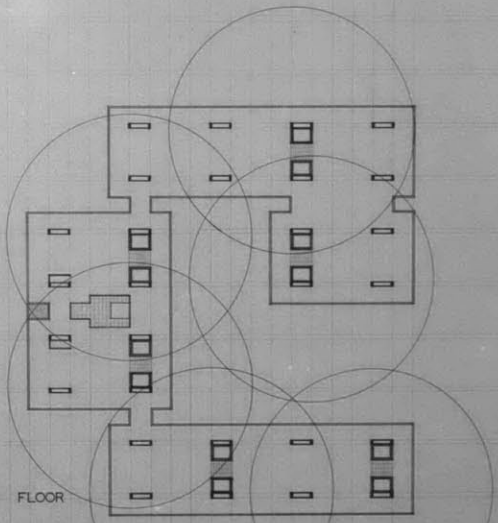
SITE PLAN

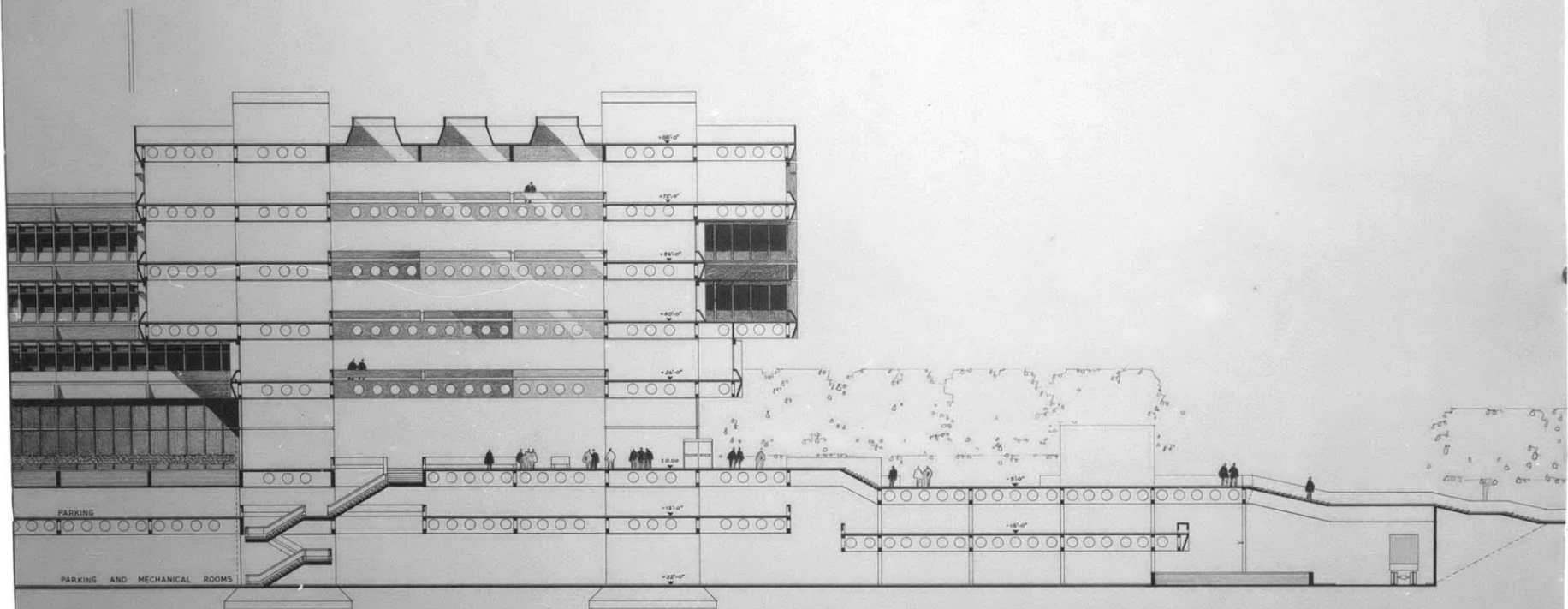


SECOND FLOOR



THIRD FLOOR





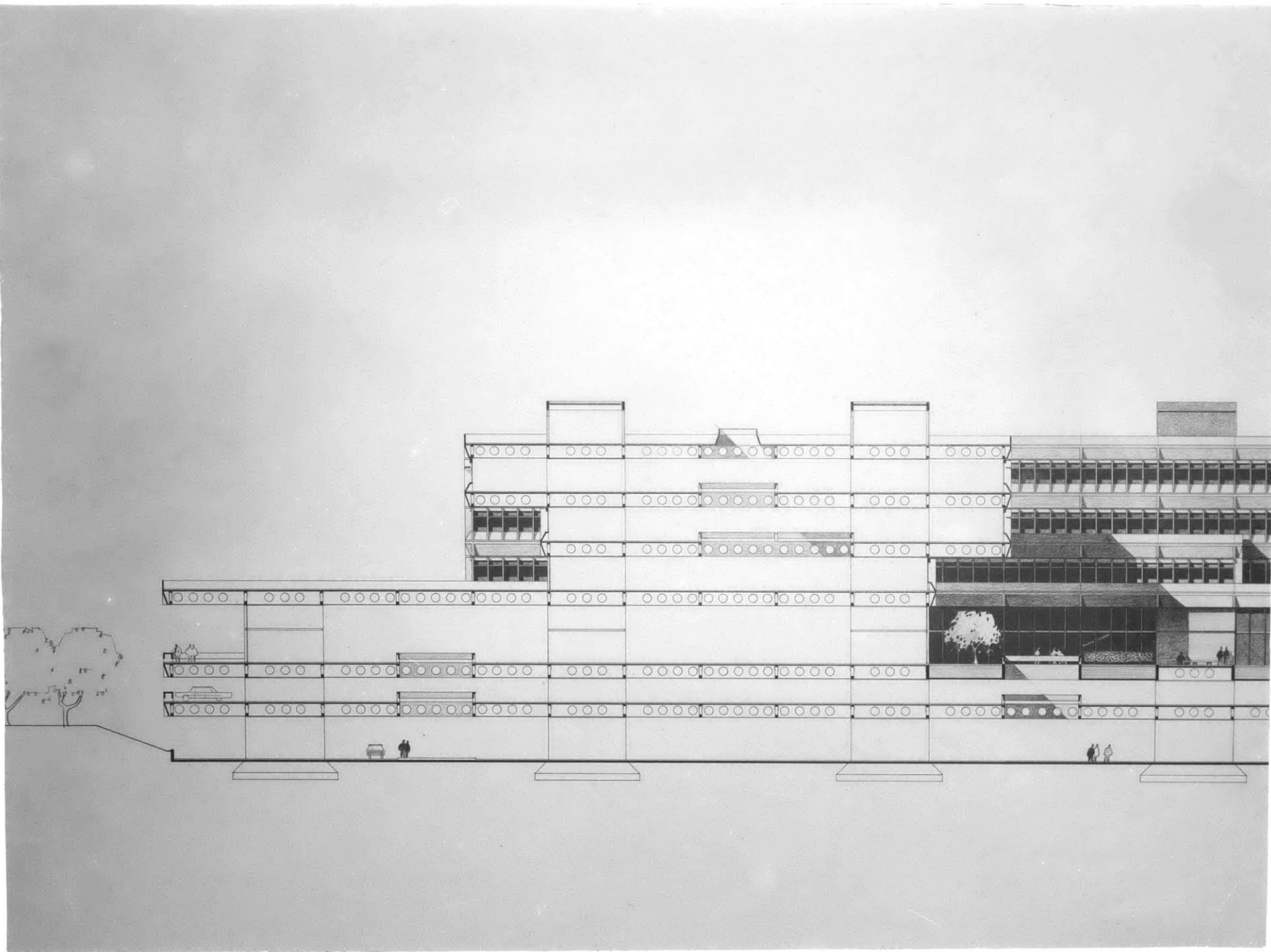
LONGITUDINAL SECTION



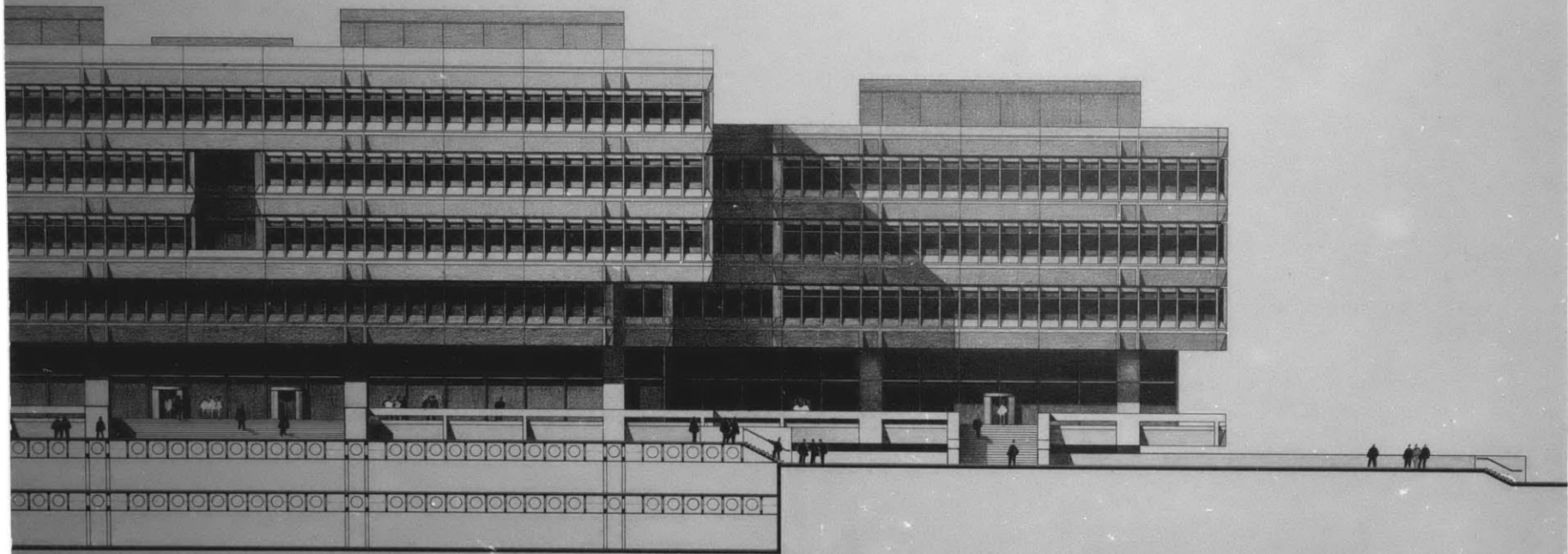
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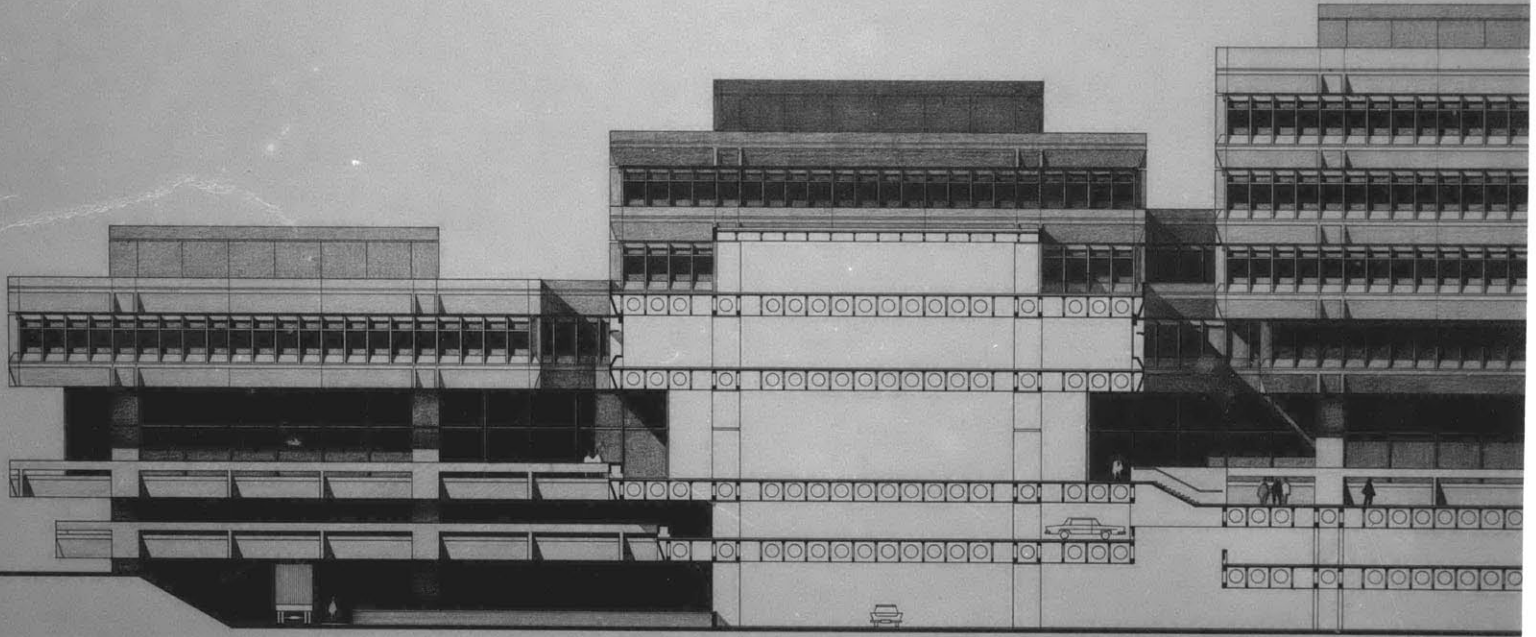
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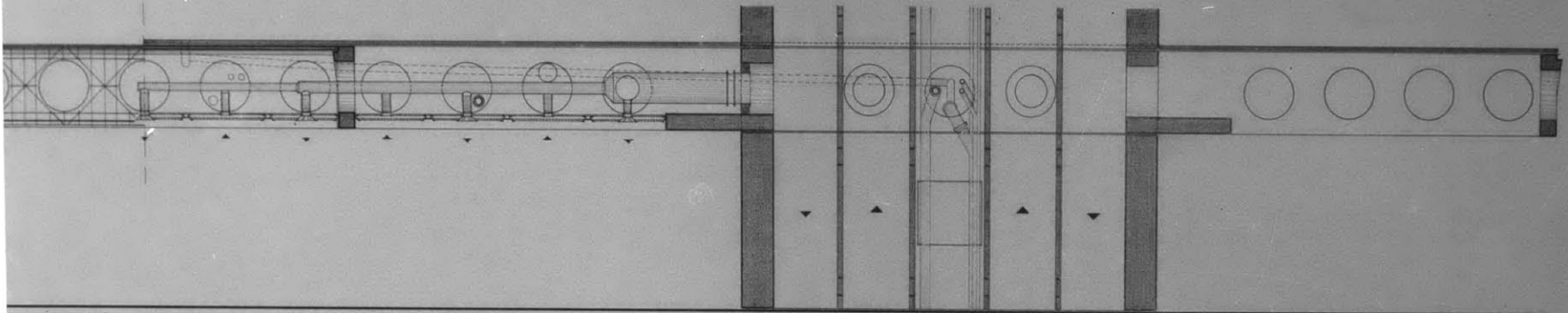
MAIN ENTRANCE ELEVATION



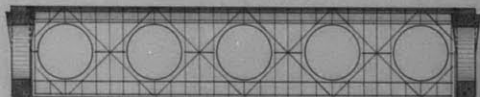
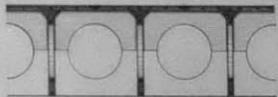
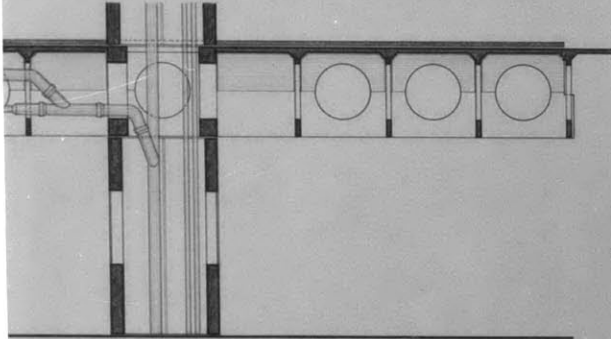
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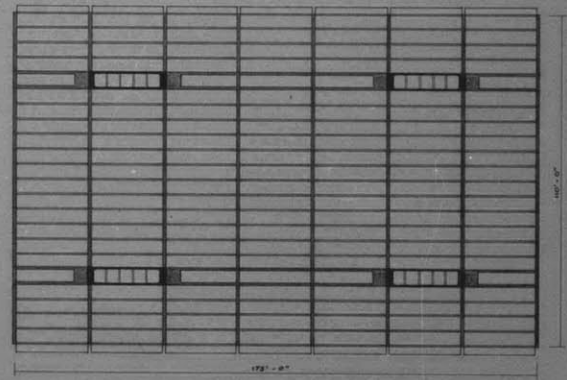
10



DOUBLE GIRDER TYPE NO. 1



T - BEAM

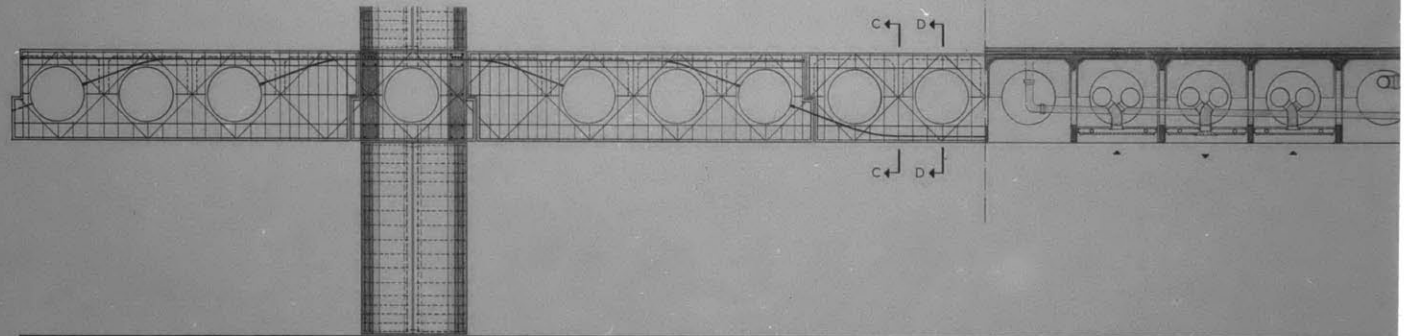
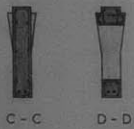
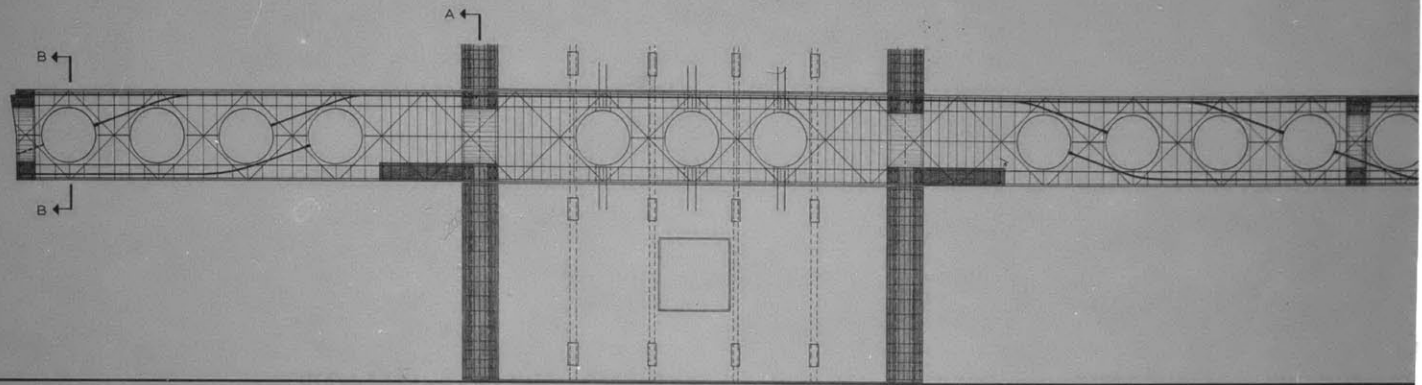
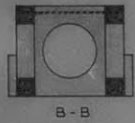


MINIMUM UNIT OF GROWTH

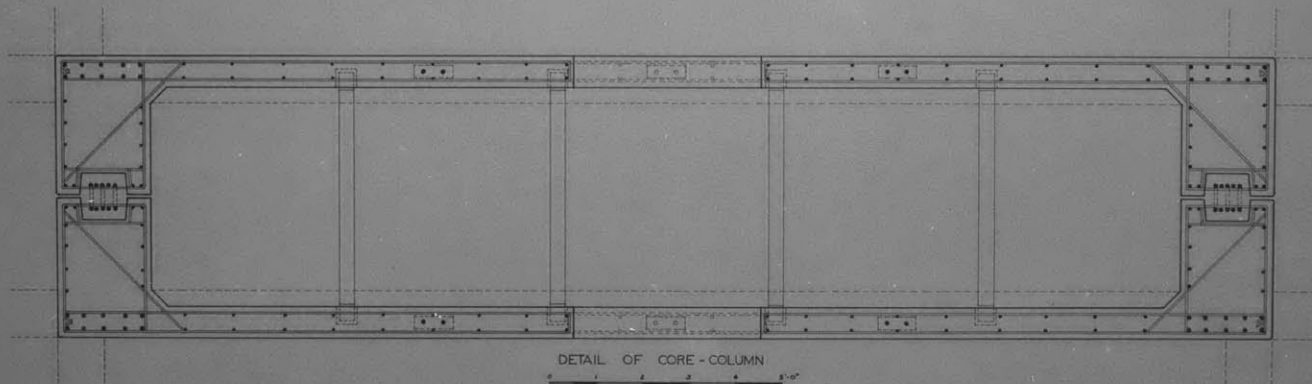
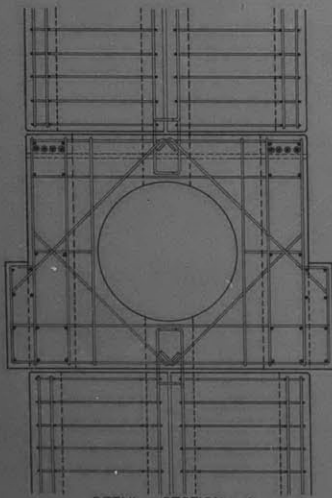


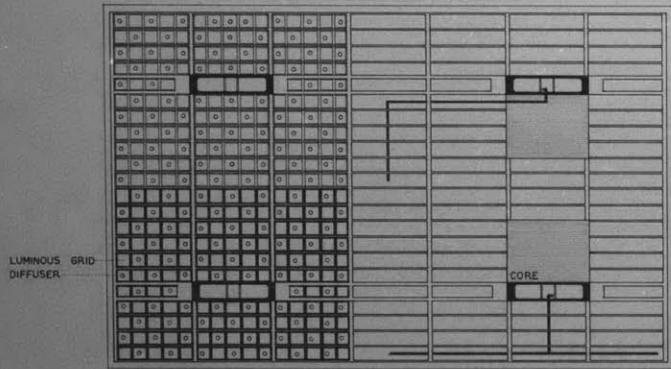
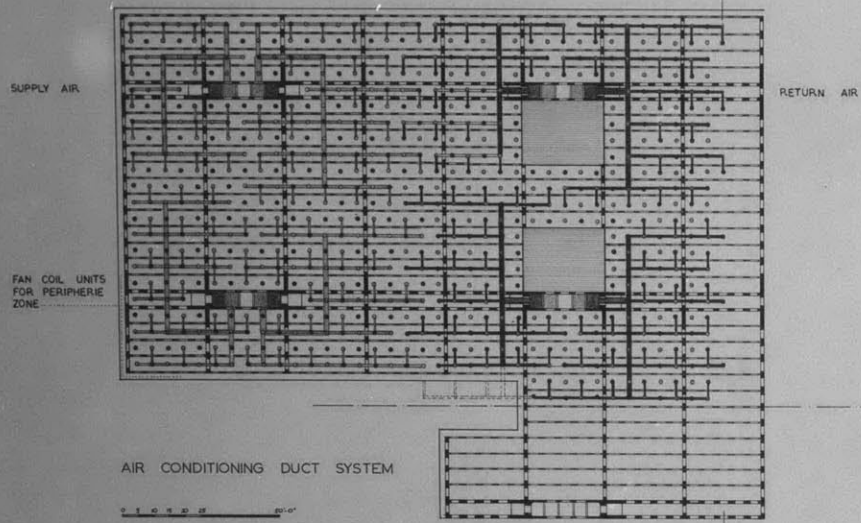
STRUCTURAL SYSTEM

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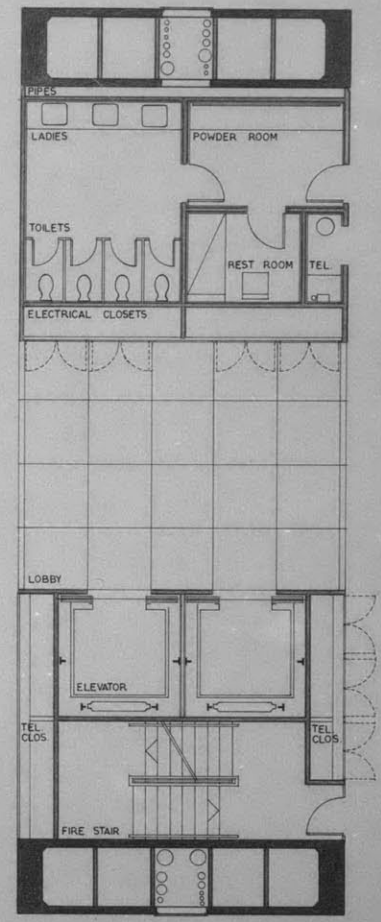
GIRDER TYPE NO. 2





REFLECTED CEILING - LIGHTING SYSTEM

PLUMBING



CORE DETAIL

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