PROTOTYPE RESEARCH BUILDINGS
Utilizing Precast Concrete Construction

by

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June 25, 1963

Dean Pietro Belluschi
School of Architecture and Planning
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Dear Dean Belluschi:

In partial fulfillment of the requirements for the degree of Master of Architecture, we hereby submit these projects entitled, "Prototype Research Buildings."

Respectfully,

John R. Frazier, Jr.

Carl Inoway

Dwayne C. Nuzum

Frederick A. Preiss

ACKNOWLEDGEMENTS

The authors wish to thank the folowing whose assistance and advice contributed substantially to the included thesis projects.

1. Mr. William Connolly, Boston, Massachusetts
2. Mr. Charles A. Crowley, Marion, Massachusetts
3. Mr. John Eberhard, Cambridge, Massachusetts
4. Dr. Howard Simpson, Cambridge, Massachusetts
5. Members of the M.I.T. Faculty who participated in the preliminary thesis jury, May, 1963.
6. Professor Eduardo F. Catalano, Thesis Advisor

ABSTRACT OF THESIS

The objective of the following thesis reports was 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.

The following reports are five individual efforts and approaches to the solution of research and development buildings as a system. Each report contains: the author's objectives, the program to which he designed and an explanation of his proposal in that order.

The major emphasis of the thesis by John R. Frazier is on a building designed to be adaptable to both horizontal and vertical work space requirements.

The proposal by Carl Inoway is for a building system with an emphasis on providing ease of expansion of the total building as well as maximum interior space changeability.

The primary emphasis of the thesis by Dwayne C. Nuzum is the solution of a system of dynamic and static spaces for a research and development building in an urban environment.

The proposal by Frederick A. Preiss is the design of a flexible architectural frame to meet the activity of research - not only today's requirement of space but future requirements and experimentation of space to work.

The introduction to these thesis reports covers the common research done by the authors in preparation of their individual approaches and is a summary and history of research and development buildings previously built.

The appendix contains the complete report submitted to the School of Industrial Management, Massachusetts Institute of Technology, to fulfill the requirements of a graduate research project sponsored by the National Aeronautics and Space Administration (NASA) studying the criteria presently being used in the design of research and development buildings. The members of the research team were Carl Inoway, Dwayne C. Nuzum and Frederick A. Preiss. This work was done under Professor Eduardo F. Catalano of the Department of Architecture and Mr. John A. Eberhard of the School of Industrial Management, Massachusetts Institute of Technology.

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INTRODUCTION AND

HISTORY AND BACKGROUND OF RESEARCH AND DEVELOPMENT BUILDINGS

A. Historical Introduction

In 1606 Andreas Libavius in "Alchymia" published a project for a complete chemical institute which, though never executed, is of particular interest as the earliest record of laboratory planning. On the ground floor, rooms opening off a central hall included a main laboratory, an analytical laboratory and a private laboratory for the director. There was a chemical store, a preparation room with benches and fittings, a crystallizing room with vats, storerooms and a room for assistants. The laboratory was to be supplied with water, and charcoal stoves were to be used for heating. Outside the building were areas for making saltpetre, vitriol, and alum. The upper story contained living quarters, a study, and a library.

Towards the end of the seventeenth century, scientific advance was accelerated. With this accleration, laboratories and lecture rooms began to appear in universities.

In 1824, Liebig organized the first real school of practical chemistry at the University of Liessen. His

Fig. 3. Plans for a chemical institute by Libavius, 1606.

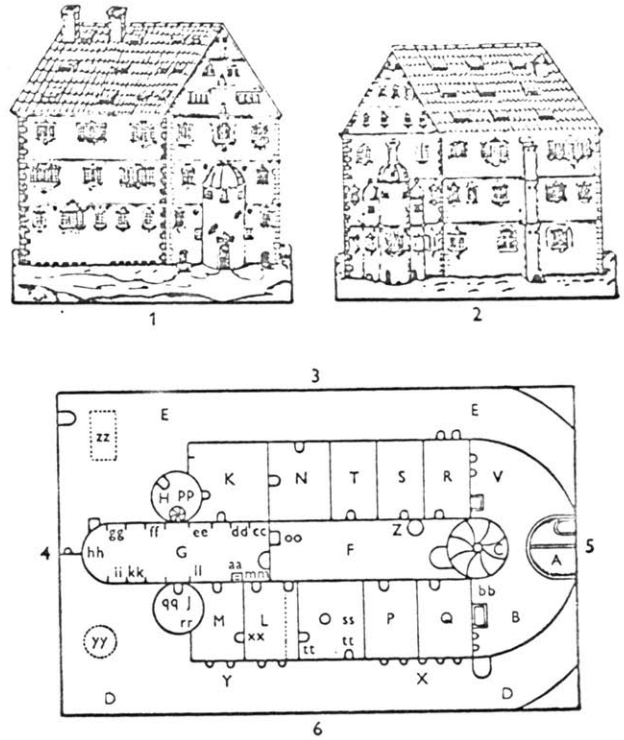
1. South-east front.

2. North-east front (with the chimney-stack of the main laboratory).

3. North. 4. West. 5. East. 6. South.

A. East entrance with small door. B. Main room with galleries. C. Spiral staircase. D. Garden. E. Drive. F. Vestibule of the laboratory. G. Chemical laboratory. H. Private laboratory with spiral stairs to the study. J. Small analytical laboratory. K. Chemical pharmacy. L. Preparation room. M. Bedroom for the laboratory assistant. N. Store room. O. Crystallization room. P. Wood store. Q. South store room. R. Fruit store. S. Bathroom. T. Aphodeuterium (closet). V. Vegetable cellar. X. Wine cellar. Y. Laboratory cellar. Z. Water-supply.

aa. Doors to the laboratory cellar. bb. Entrance to the wine cellar. cc. Steam-bath. dd. Ashbath furnace. ee. Waterbath. ff. Distillation apparatus for upward distillation. gg. Sublimation apparatus. hh. Ordinary fireplace. ii. Reverberatory furnace. kk. Distillation apparatus. ll. Distillation apparatus with spiral condenser. mm. Dung-bath. oo. Coal store. pp. Philosopher's furnace in the private laboratory. qq. Assay furnaces. rr. Analytical balances in cases. ss. Tubs and vats. tt. Distillation 'per lacinias' (table with vessels). xx. Equipment and benches for preparations. yy. Water tanks. zz. Space for preparing saltpetre, alum, and vitriol.



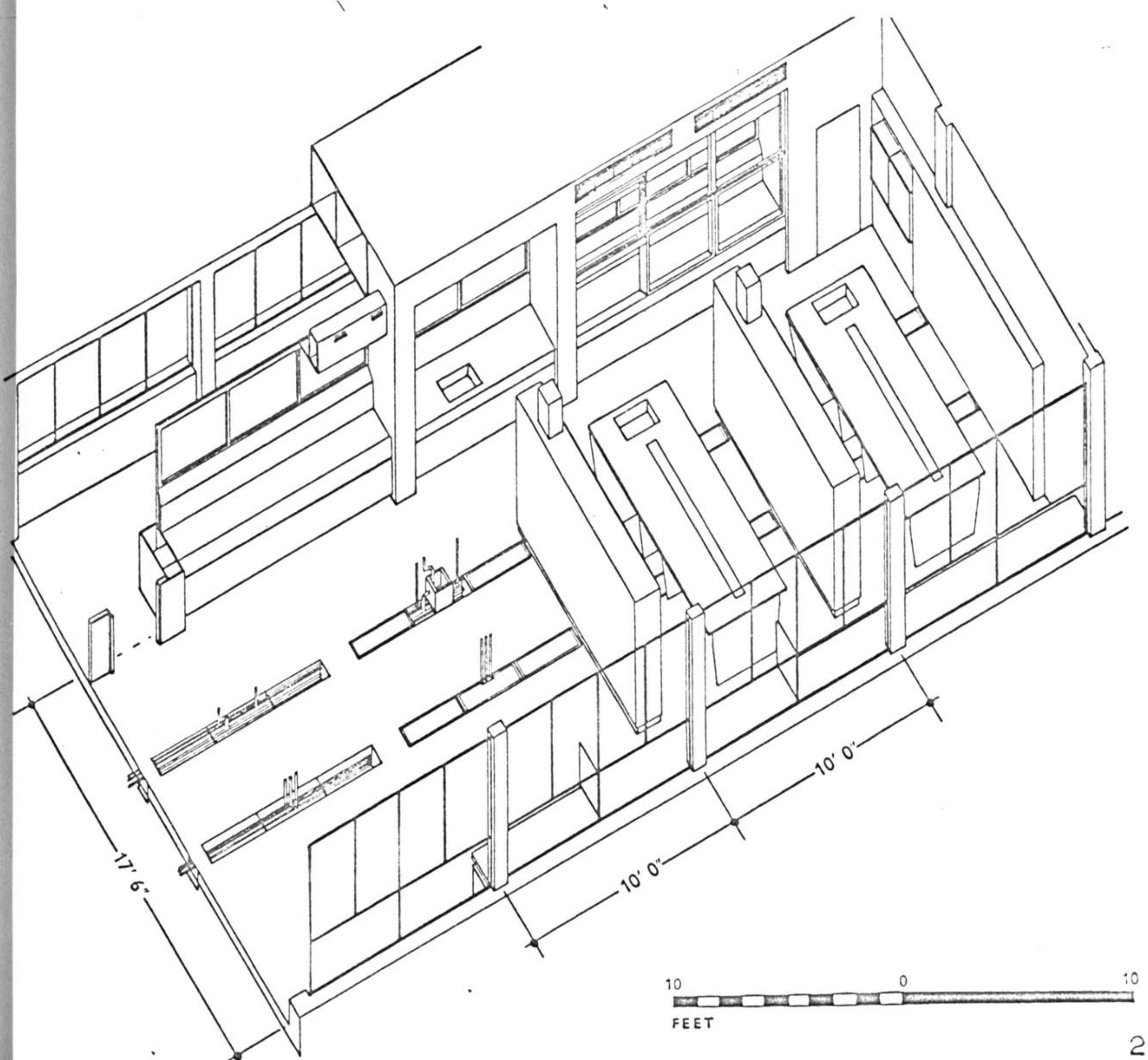


Fig. 19. The standard laboratory unit at the research laboratories of the Dyestuffs Division, Imperial Chemical Industries Ltd., Blackley, 1938.

laboratory comprised a workroom with sufficient space for twelve workers at benches under the windows. Behind the workroom was a room crammed full of equipment and supplies; behind this a room in which apparatus for glass-blowing was kept, and where anvils and balances were set up. The most striking feature of the main laboratory is the appearance for the first time of benches provided with cupboards, drawers, and shelves for regent bottles. The bench tops were removable and were fitted with sinks with piped water. As far as is known, this was the first laboratory so equipped.

In 1868, Pasteur wrote an article for Moniteur. "I implore you, take some interest in those sacred dwellings meaningly described as laboratories. Ask that they be multiplied and completed. They are the temples of the future, of riches and of comfort. There humanity grows greater, better, stronger; there she can learn to read the works of nature, works of progress and universal harmony, while humanity's own works are too often those of barbarism, of fanaticism and of destruction."

Parallel with the rapid development of science in the universities came the new idea of industrial research. Among the oldest industrial research laboratories in England are those of the Nobel Division of Imperial

Chemical Industries Limited founded by Alfred Nobel in 1873 at Ardeer. The first laboratory consisted of one large room which served also as a drawing office.

Until 1920, although laboratories had been built for universities, few new buildings were being erected for research, either by government or private firms. After 1920, the inconvenience of converted buildings into laboratories for highly specialized work was realized, and the research laboratory began to emerge as a distinct building type.

B. Research Buildings after 1920

1. British Laboratories

The general pattern of design for research buildings in England consisted of research rooms with serviced benches, offices, special rooms of various kinds and the usual ancillary accommodations are planned in shallow units (14 feet to 16 feet from window wall to back of room) on either side of a central corridor. Laboratories vary in size from the one-man room to large open laboratories. They are normally separated by permanent structural partitions. Service pipes are usually embedded in or attached to structural walls and floors.

In 1922, the British Cotton Industry Research Association Laboratory incorporated new ideas in design which were not utilized until very much later. A 5 foot deep service duct was placed under the corridor and a 3 ft. 6 in. void formed below the floor, so that service lines could be carried to any point and taken up through the floor where required.

In the late thirties, the first attempt was made to rationalize laboratory planning. Serge Chermayeff's design for the research laboratory of the Dyestuffs Division of Imperial Chemical Industries at Blackley was an important development in this respect. To fit the building to the work Chermayeff designed a repetitive unit to accommodate one worker, and built up laboratories of various sizes by combining different numbers of units.

The original building is two stories high and has two wings designed on different dimensional modules and placed at right angles to each other. One wing contains offices, and the other a series of research rooms on one side only of a connecting corridor. The laboratories were artificially ventilated from ducting in the corridor ceilings, and the corridor walls carried fume cupboard ducts and services to sinks. Shallow floor ducts with removable covers ran longitudinally along the middle of the laboratories carrying sub-mains to the bench positions.

The Blackley building contained the germ of certain ideas in laboratory planning which have been the guide lines for many laboratories in the United States. The ideas developed by Chermayeff can be summarized as follows:

"1. Overall planning was based on a structural module derived from an assessment of the space needed by each individual worker, i.e. bench length, bench width, and the clearance between benches.

2. Laboratory benches were placed at right angles to the window wall for ease of servicing and access from a longitudinal corridor.

3. Straight unimpeded runs of benching were provided for each worker.

4. Attention was given to the problem of lighting rooms greater in depth from window wall to corridor wall than had been used hitherto.

5. Office accommodation was provided in a separate wing, the office winge being based on a different dimensional module, thus avoiding the use of expensive serviced laboratory space." Nuffield Foundation.

The earliest attempt to provide flexibility of space was in the London, Midland and Scottish Railways' Research Laboratories at Derby in 1935.

"In recent laboratory buildings there are two main trends in design both of which reflect the need for adaptable buildings. First, there is the trend towards open serviced floor areas which can be divided up with demountable partitions, the aim being to give each scientist or group of scientists a serviced area which may be divided up to provide any combination of rooms as and when required. Secondly, there is the trend towards a simplified, functional arrangement of benches in long unimpeded lengths, spaced and arranged in such a way to rationalize bench servicing."

In 1953, the laboratories for Imperial Chemical Industries Plastics Division at Welwyn provided overall flexibility by providing demountable partitioning. The buildings module was a 4 ft. grid on which the panels could be put anywhere. The services were supplied at grid points from floor ducts carried within deep floors constructed on lattice beams.

2. American Laboratories

Recent American research buildings have placed the emphasis on planning of the utilities to achieve maximum room flexibility over overall flexibility.

The Bell Telephone Company Laboratories built in 1941 and designed by Voorhees, Walker, Smith and Haines has become the prototype of research and development buildings up to the present. See typical plans. The accepted practice in America is to plan the building of the basis of a dimensional module related to the space needed for an individual worker or teams of known size. The modules used vary in width from 10 ft. to 13 ft. depending on the space allotted between benches. Most research and development buildings in the U.S. since 1939 have rooms from 20 ft. to 30 ft. deep, with vertical sub-mains placed at each grid point. In deep rooms of this kind it is uneconomical to service benches under windows, and it may be essential to provide access between rooms near the outside walls as a safety measure in some cases. In multi-story buildings, lighting at the back of deep rooms was supplemented by artificial means, and artificial ventilation and air-conditioning are common.

(This section is to be expanded when survey of criteria of existing laboratories is completed.)

3. Recent European Laboratories

Again in Europe there is a broad acceptance of the principle of limited but adequate flexibility based on

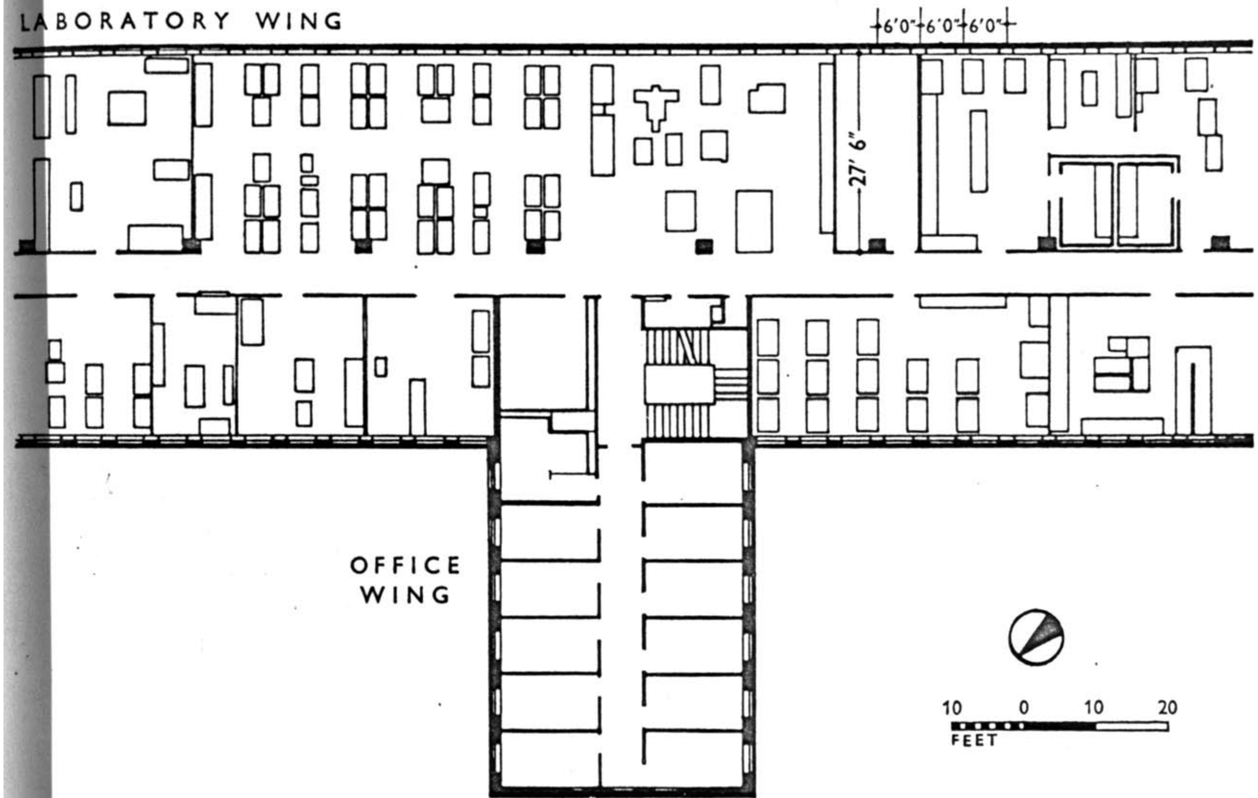


Fig. 25. Part plan of the laboratory wing and office wing at the Bell Telephone Company research laboratories, New Jersey, 1941.

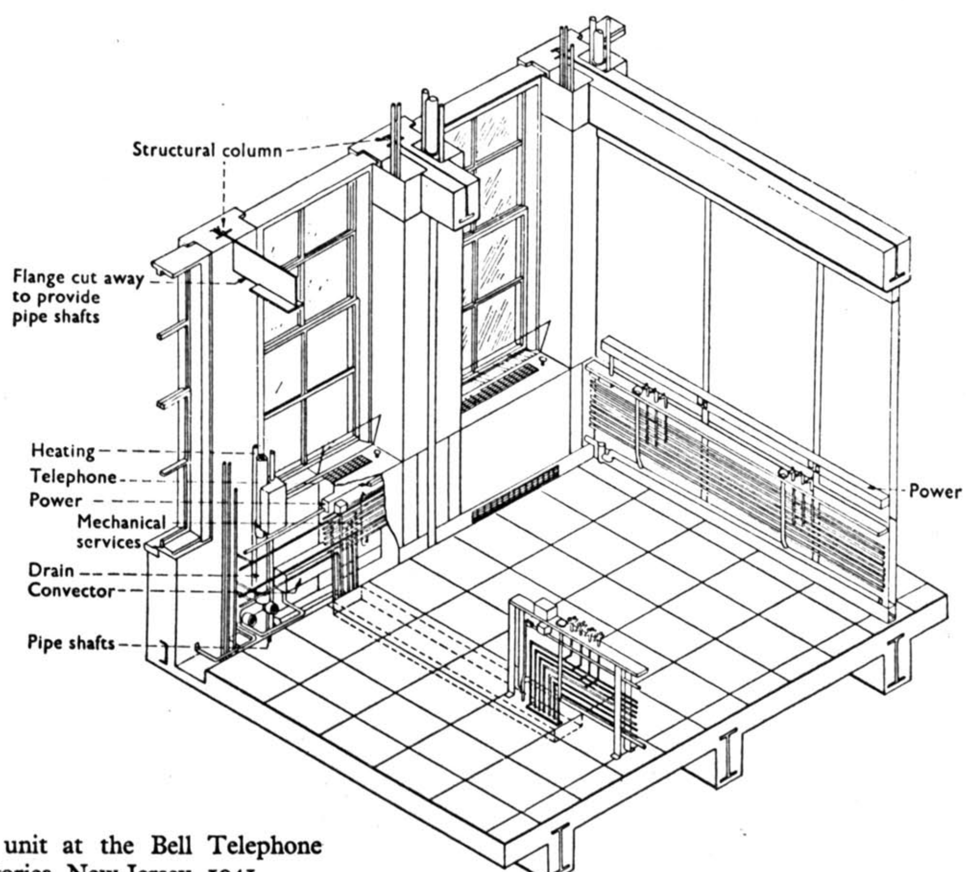


Fig. 26. A laboratory unit at the Bell Telephone Company research laboratories, New Jersey, 1941.

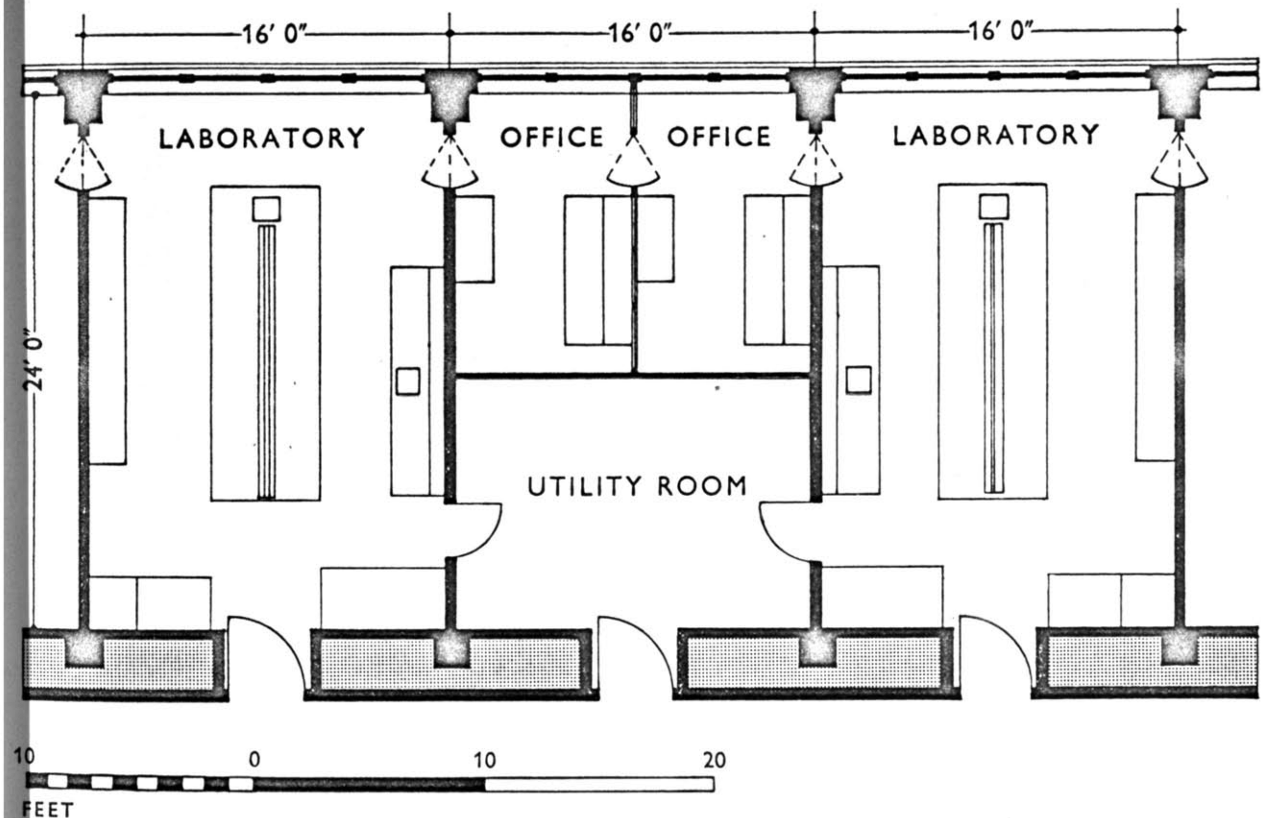


Fig. 28. Plan of the standard laboratory unit adopted in the regional research laboratories of the United States Department of Agriculture.

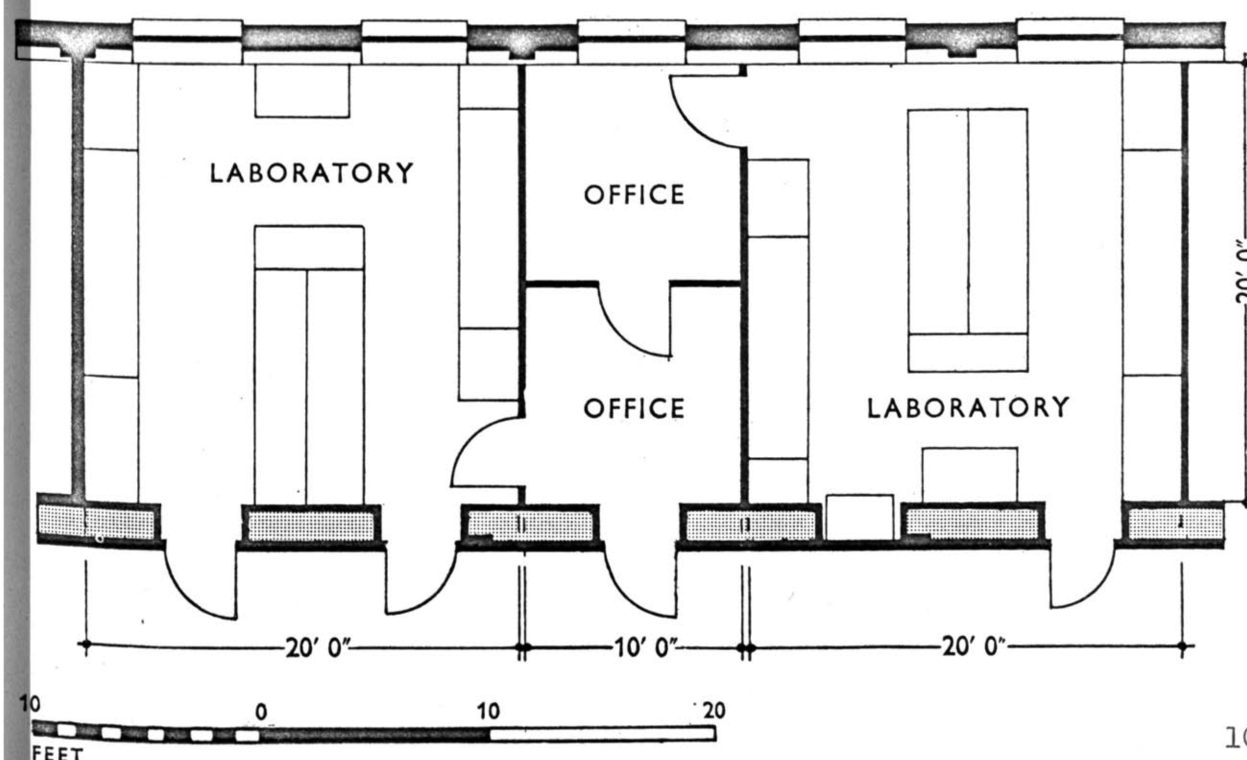


Fig. 29. Laboratory unit, Merck research laboratories, New Jersey.

a services grid. In some laboratories the partitions between the bays are demountable in order to allow rapid re-arrangement but only in multiples of one whole bay.

"In Europe there has also been an attempt to combine the idea of limited flexibility with some degree of adaptability based on possible combination of a fixed bay size. The preference amongst users and architects alike is to improve the systems of servicing rather than to spend money on excessive flexibility. It is of some interest that the Battelle Institute in Frankfurt which undertakes all kinds of research for private firms, has adopted a rather different approach to flexibility. The laboratory accommodation must be capable of changing over to an entirely different kind of work, possibly two or three times in the course of a year. Industrial finishes have been used throughout the building; internal walls are constructed of light weight concrete blocks that are left unplastered. All services are carried at high level, completely exposed and dropped wherever needed. The electrical services are carried in a plug-in trunking system in the corridors. Although many of the mechanical systems are expensive, they are considered essential to the flexibility of the use of Battelle Building." Nuffield Study.

C. Aspects of Design

From the research of existing laboratory buildings, three problems have become of special importance.

1. Office Accommodation

The provision of office space for laboratory workers has a marked effect upon building economy as well as working efficiency.

Serviced laboratory space is expensive and it must be used intensively, if it is used for office space, it cannot be economical in terms of building cost.

In many of the older laboratories no special provision was made for offices except perhaps a private office for the director. Recently, however, it has been realized that reading and writing take up a considerable amount of the scientist's time. It also is inevitable that an increasing amount of paper work is being done at all levels of research and development.

The Nuffield Foundation Study categorized systems of providing office space in three types:

a. Offices opening directly off the laboratory, usually occupied only by staff working in the adjacent laboratory.

b. Offices within the laboratory block, but separated by a hall or other boundary.

c. Offices in a separate wing of the building. This is less expensive since offices can be built with a lower ceiling and less mechanical services.

2. Mechanical Systems

Older laboratories had service lines which were inaccessible. The laboratories have failed to meet the changing needs of research associated with modern technology. The tendency today is to regard laboratories as workshops, in which service lines are an integral part of the equipment. Today, exposed services are not the problem they were 20 years ago when corrosion, dust and safety made them undesirable.

In the U.S., mechanical equipment systems have become the biggest cost item of the building. Recent laboratories have allotted up to 50 o/o of their volume to complete mechanical service system.

Lighting of laboratory space has become a problem as rooms of greater depth have appeared. Also the testing done in today's laboratories requires such high standards of precision that many new laboratories have supplied complete artificial systems. Saarinen's laboratories for I.B.M. and Bell Telephone use peripheral corridors. All the laboratories are interior spaces.

3. Structural Systems

Until recently, laboratories have been designed in two steps. One being the structural design based on such criteria as cost, work space, module and appearance. Two being the design of the mechanical system to fit around the structural system. Today the trend is toward solving the structural and mechanical systems integrally. This has been one of the main purposes of this thesis.

THESIS PREPARED BY JOHN R. FRAZIER, JR.

OBJECTIVE

The objective of this thesis is to design a prototype building for industrial research and development, utilizing precast and prestressed concrete construction. To attain a synthesis and continuity of spaces, structural and mechanical systems into a total working whole. To develop an environment uniquely suited to the life of the researcher in his work shop.

APPROACH

The approach to the design of this building is based upon the desirable requirements of the research worker. In general his requirements are most adequately met through a freedom to choose. Some of these choices would be a freedom of circulation; the size, shape, and adaptability of working space; environmental control including, hot and cold air regulation, and humidity control; and ease of access to electrical and plumbing services.

The solution to the design of this building to meet and satify the above choices is flexibility. In particular this means the flexibility of space, structure, air conditioning, electrical and plumbing services. By flexibility of space is meant large areas free from obstructions that can be subdivided by partitions into modular increments. Structural flexibility allows both major and minor revisions to occur within the building, and expansion vertically and horizontally. Flexibility of air conditioning is complete control of heating, cooling and humidification throughout the building in small modular increments. The maximum flexibility of plumbing and electrical services throughout the building would be total access.

PROPOSAL

Program

1. Site

a. Assumptions

open rural hill site with space for horizontal expansion

b. Requirements

parking areas, service areas and landscaping

2. Building

a. Requirements

1. Size of building

a. approximately 515,000 square feet in four floors and a basement

b. approximate horizontal expansion 525,000 square feet

c. accommodating approximately 1,800 persons

2. Functions

a. administrative offices

b. reception and lobby area auditorium or lecture hall

c. applied research and development laboratories and offices (small areas)

d. testing laboratories and offices (large areas)

3. Mechanical Services

a. Air conditioning

1. heating - provision for differential control
2. cooling - provision for differential control
3. humidity - provision for maintaining relative humidity at 45 o/o or lower in all areas
4. provision for total air change if required
5. provision for temperature differential of 20 degrees

b. Electrical

1. overhead supply for lighting fixtures, complete artificial lighting coverage
2. floor supply - 110W, 220W, 440W accessible throughout

c. Hot and cold water supply to be accessible throughout floor

d. Waste lines accessible throughout floor

e. Other supplies - natural gas, compressed air, oxygen, helium, hydrogen, nitrogen, etc. accessible throughout floor

Structural Components

In order to attain spatial and mechanical flexibility a one-way structural system has been chosen, which is to be constructed of as few different configuration of parts as possible. A breakdown and design criteria of these parts are as follows:

a. Bearing Walls

25'-0" x 10'-0" reinforced concrete spaced 20'-0" on center in two rows, 125'-0" apart, center to center.

Design Criteria

1. These walls can be precast at the concrete plant and trucked to the site for erection.

2. These walls will facilitate erection of the structure and future expansion, both horizontally and vertically.

3. When two walls are enclosed at either end with precast sections the space between can be used for several functions -

   a. vertical cores of circulation

   b. mechanical rooms

   c. toilet and storage facilities

   d. each bearing wall gives lateral bracing to the structure; longitudinal bracing is taken up in cross walls at each mechanical room and vertical core.

b. Girders (see photograph No. 1)
2'-0" x 5'-0" x 220'-0" long constructed of three major members. Two of these members, 80'-0" in length, are post-tensioned to opposite bearing walls and cantilever over each end of the walls. The interior and exterior cantilevers are 20'-0" and 35'-0" long respectively.

The third member, or center span, is constructed of three 20'-0" verendeel sections, post-tensioned together and simply supported between the two interior cantilevers.

Design Criteria

1. By dividing the main girder into three members each member can be precast and pretensioned at the concrete plant and transported to the site for erection.
2. The 35'-0" exterior cantilevers allow a 10'-0" corridor and laboratories or private offices of 25'-0" in depth.
3. The free end of the exterior cantilever enables the expansion of the existing building by receiving one end of a 20'-0" center span that would connect it with the exterior cantilever of an adjacent building, similar in structure. (See photograph No. 2)
4. The simply supported center member can be removed without disturbing

the main structure, the post-tensioning removed, and the three sections stored or taken out of the building. One end of this center span would be seated on a neoprene pad and act as an expansion joint.

c. Double Tee Floor System

The floor system is composed of 5'-0" x 18'-0" double tee sections which span between the main girders. A 2" light weight concrete topping is then poured over the tee sections.

Design Criteria

1. The double tees can be precast and pre-tensioned at the concrete plant and transported to the site for erection.
2. These double tees are removable in any part of the building.
3. Expansion joint located near the center of the building is taken up in the double tee-girder connection.

d. Ceiling Members

The ceiling members are composed of 6" x 12" x 18'-0" and 9'-0" long precast concrete members that form with the soffit of the main girders a 10'-0" grid.

Design Criteria

1. These members allow each floor to be divided into large and small spaces by 10'-0" increments.
2. The underside of each ceiling member is notched to receive partitions.

e. Partitioning and Space

The ability to adapt sizes of spaces for particular work programs is a desirable requirement of research. In this building the maximum unobstructed space possible on a typical floor is 100'-0" x 200'-0". This larger space can then be broken down into areas as small as ten square feet by movable partitions. The height of any space in the building can be increased to one, two, or three stories by the removal of the double tee floor sections and girders. The maximum height area space that could be attained, within reasonable limits considering structural stability, can be 60'-0" x 150'-0" x 45'-0" high.

The partitions can be of any material, wood, metal, masonry, etc., their only requirement being a tpyical ceiling connection. This connection would be adapted to the groves in the ceiling members and in the soffit of the main girders.

f. Spandrell Members

The spandrell members are 5'-0" x 20'-0" long, precast and pre-tensioned. These members span between the exterior ends of the main cantilever girders.

Design Criteria

1. To stabilize the free ends of the main girders.
2. To carry the window walls and sun screens.

3. To cap the girder ends in order to protect them for future expansion.

4. When expansion occurs these would be removed and relocated.

g. Window Walls

The window walls are 20'-0" x 10'-0" section divided by mullions 5'-0" on centers. The materials are black anodized aluminum and tinted thermopane.

Design Criteria

1. To reduce the load on the cantilever a light wieght material is desirable.

2. When expansion occurs the light weight window sections would be easily removed and relocated.

Mechanical

The air conditioning is a low velocity, hot and cold duct system. It is decentralized throughout the building with sixteen air handling units per floor. Each unit is located in a mechanical room which covers a zone of approximately 6,600 square feet. These zones are further broken down into 10'-0" square foot areas which can be completely controlled by a hot and cold air mixing box, a supply diffuser and a return air grille.

Design Criteria

1. A decentralized system has the following advantages in such a large building:
   a. mechanical rooms are within a reasonable distance of each work space.
   b. smaller ducts
   c. without a decentralized system maximum control could not be attained.

Electrical

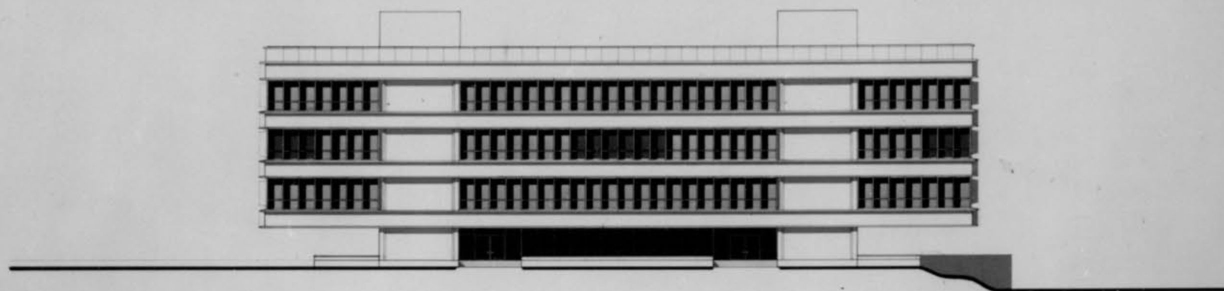
Both day and artificial lighting are important considerations to the general well-being of men at work. In this building the disposition of the larger areas of work, which are difficult to illuminate adequately by daylight, are located on the interior between the two rows of bearing walls and lighted artificially. The smaller areas of private offices and laboratories, which can be easily illuminated by daylight are located on the perimiter of the building. The artificial lighting consists of 8'-0" double flourescent tube fixtures recessed in the ceiling grid and spaced on five foot centers throughout the building.

Construction Sequence

1. Foundation walls and footings poured in place
2. Basement floor poured
3. Bearing walls seated and post-tensioned in place
4. 80'-0" main girder members partially post-tensioned placed over extended post-tensioning rods of bearing walls, seated, leveled with metal shims, post-tensioned to bearing wall, and the joint grouted
5. The three sections of the center member post-tensioned together, dropped into

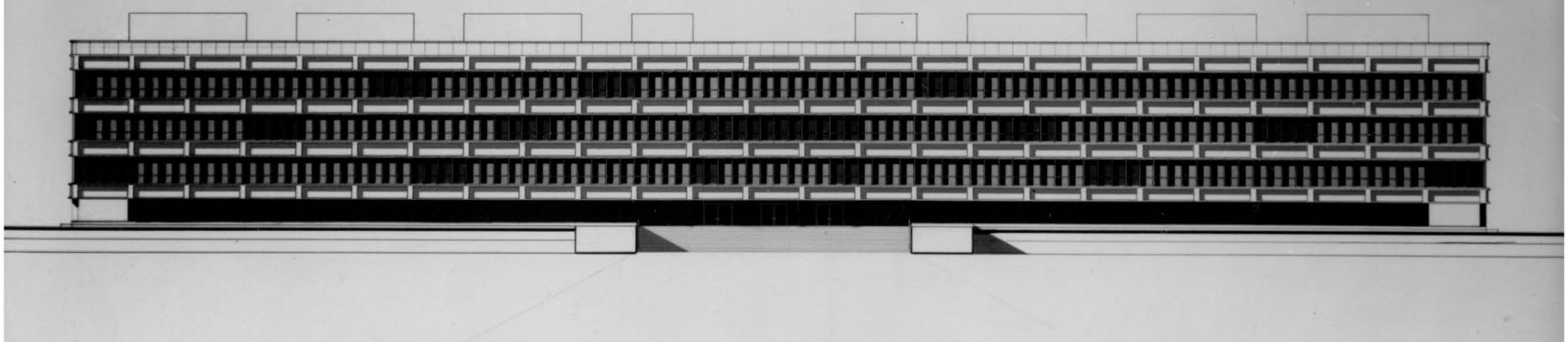
place between the interior cantilevers, seated, leveled with metal shims, post-tensioned to cantilevers and the joints grouted.

6. Complete post-tensioning of main girder
7. Bolt spandrell members into place
8. Lay double tee floor sections between girders and weld to girders
9. Using masonry precast units, block up between bearing walls used for mechanical and service cores.
10. Run ducts, piping and electrical wiring through and between main girders.
11. Bolt ceiling members into place
12. Pour concrete topping
13. Place window units and glaze



LEFT END ELEVATION

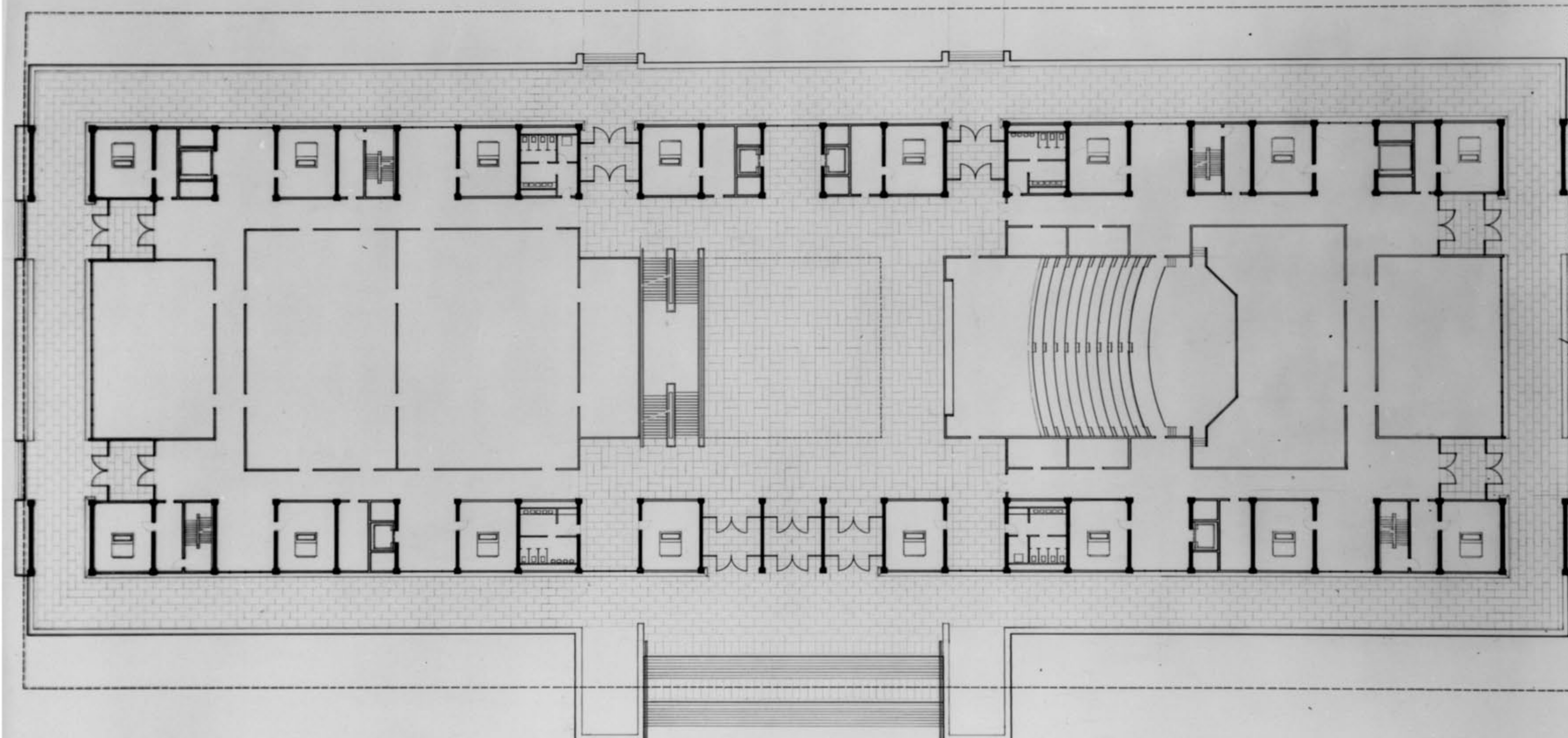
SCALE 1/16" = 1'-0"



FRONT ELEVATION

SCALE 1/16" = 1'-0"

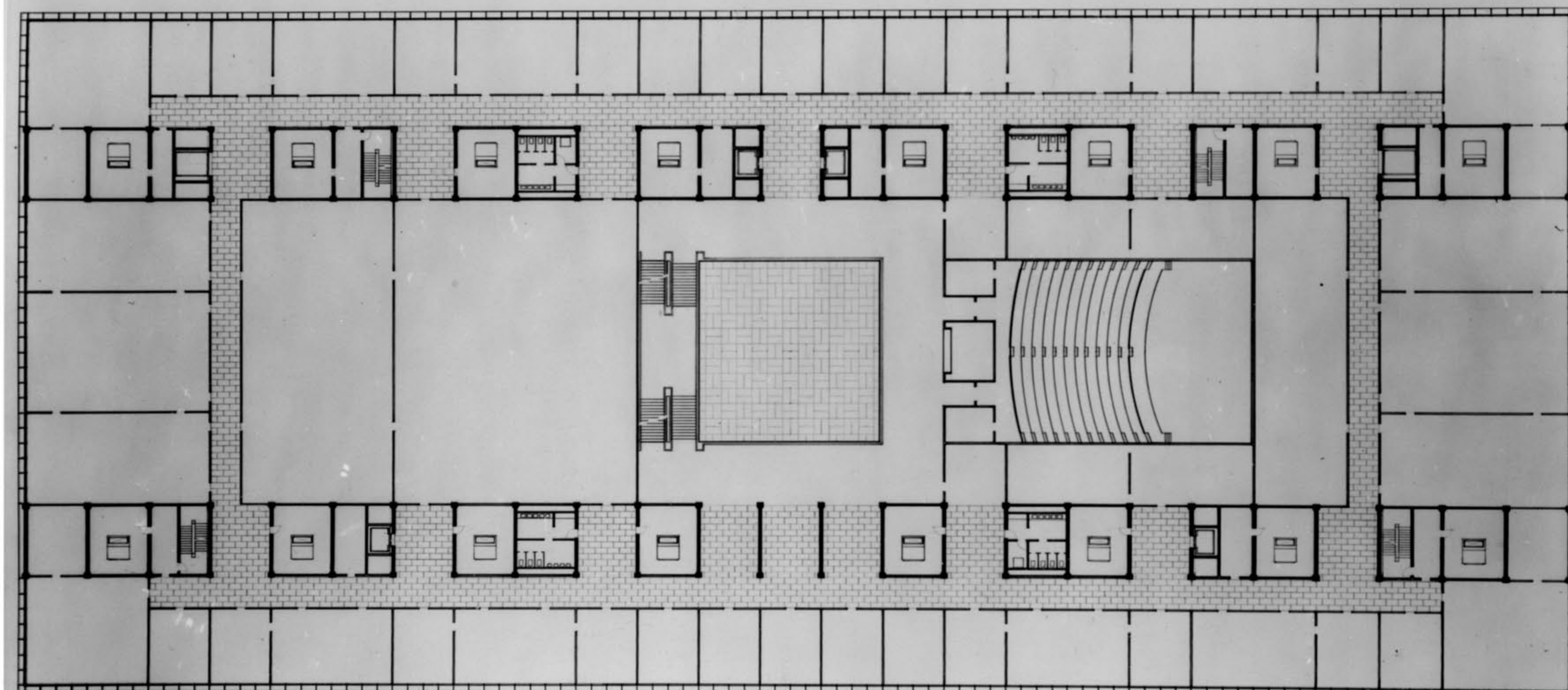
A PROTOTYPE RESEARCH BUILDING—THESIS FOR THE DEGREE OF MASTER IN ARCHITECTURE—M.I.T. 1963—JOHN R FRAZIER JR



FIRST FLOOR PLAN

SCALE 1/16" = 1'-0"

A PROTOTYPE RESEARCH BUILDING - THESIS FOR THE DEGREE OF MASTER IN ARCHITECTURE - M.I.T. 1963 - JOHN R FRAZIER JR.



SECOND FLOOR PLAN

SCALE 1/16"=1'-0"

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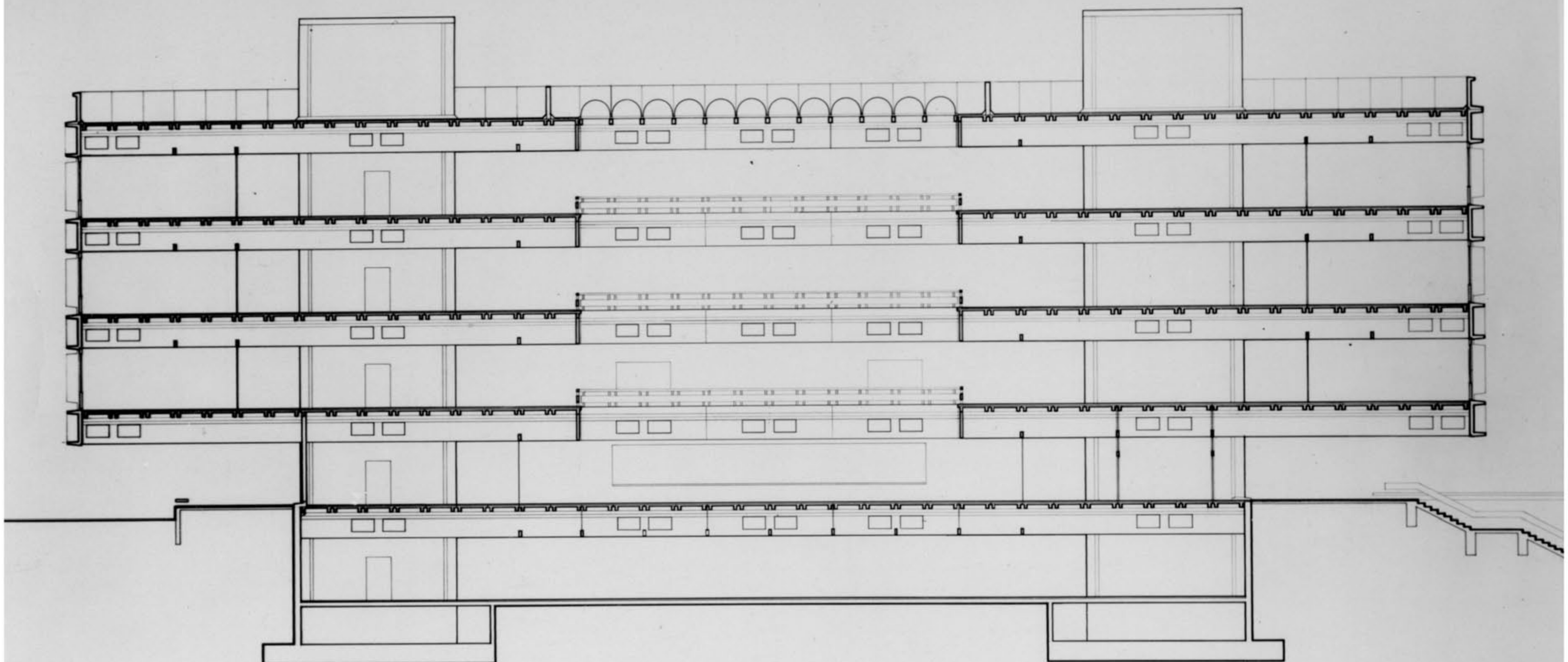

CROSS SECTION

SCALE 1/8" = 1'-0"

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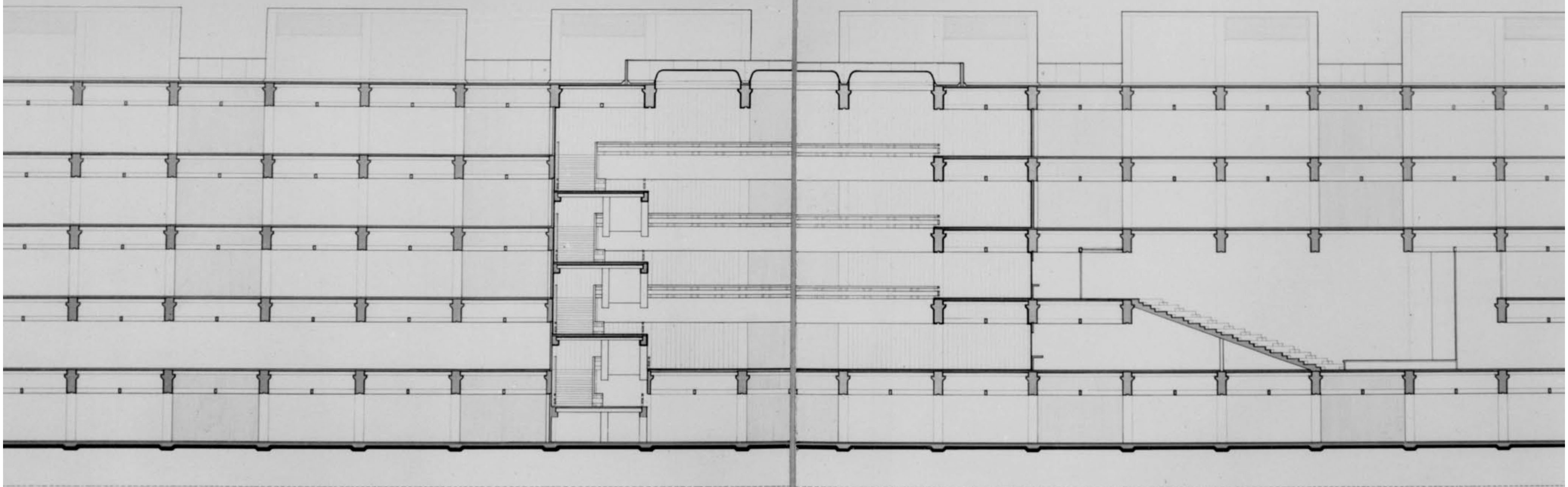

LONGITUDINAL SECTION

SCALE 1/8"=1'-0"

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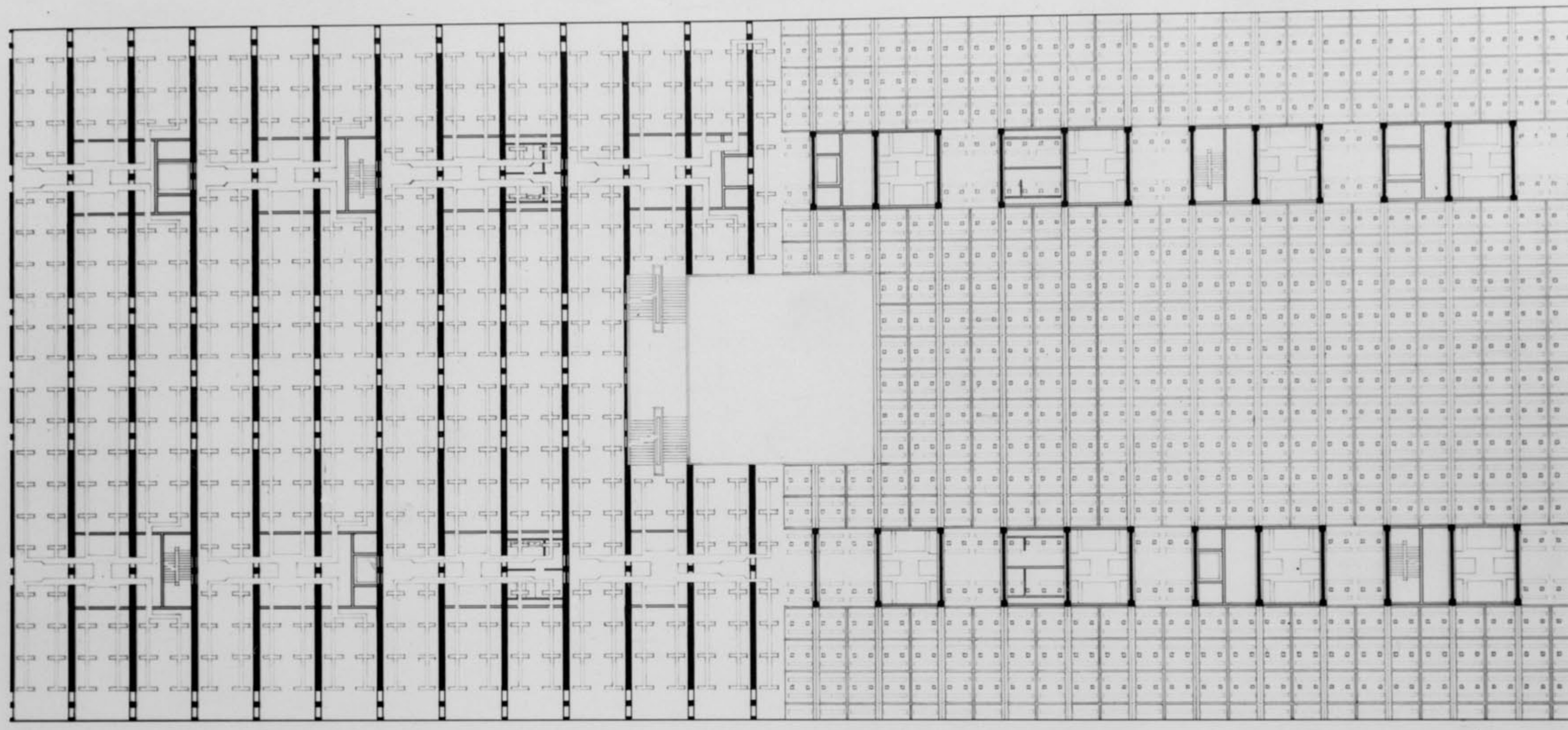
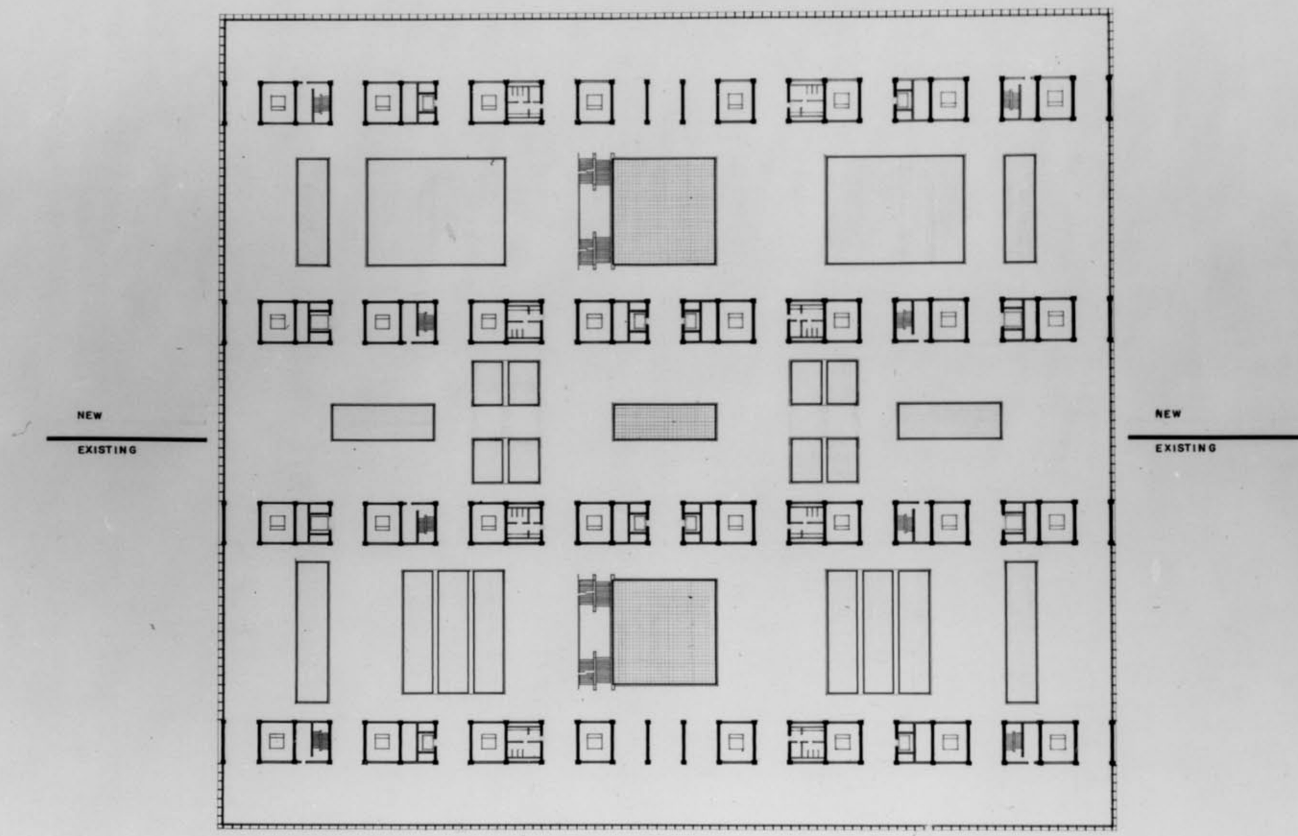


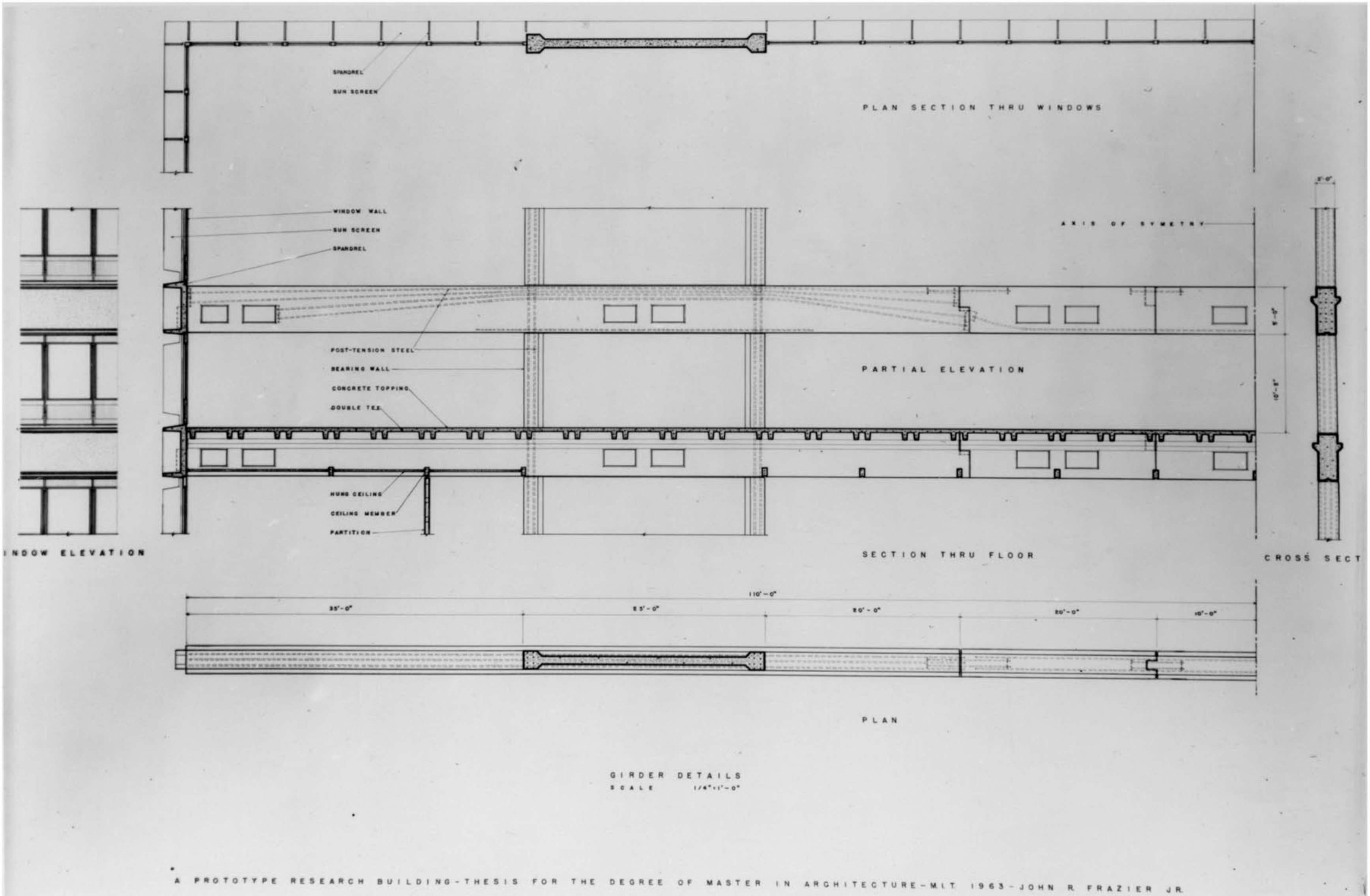
PARTIAL DUCT LAYOUT
SCALE 1/16"=1'-0"

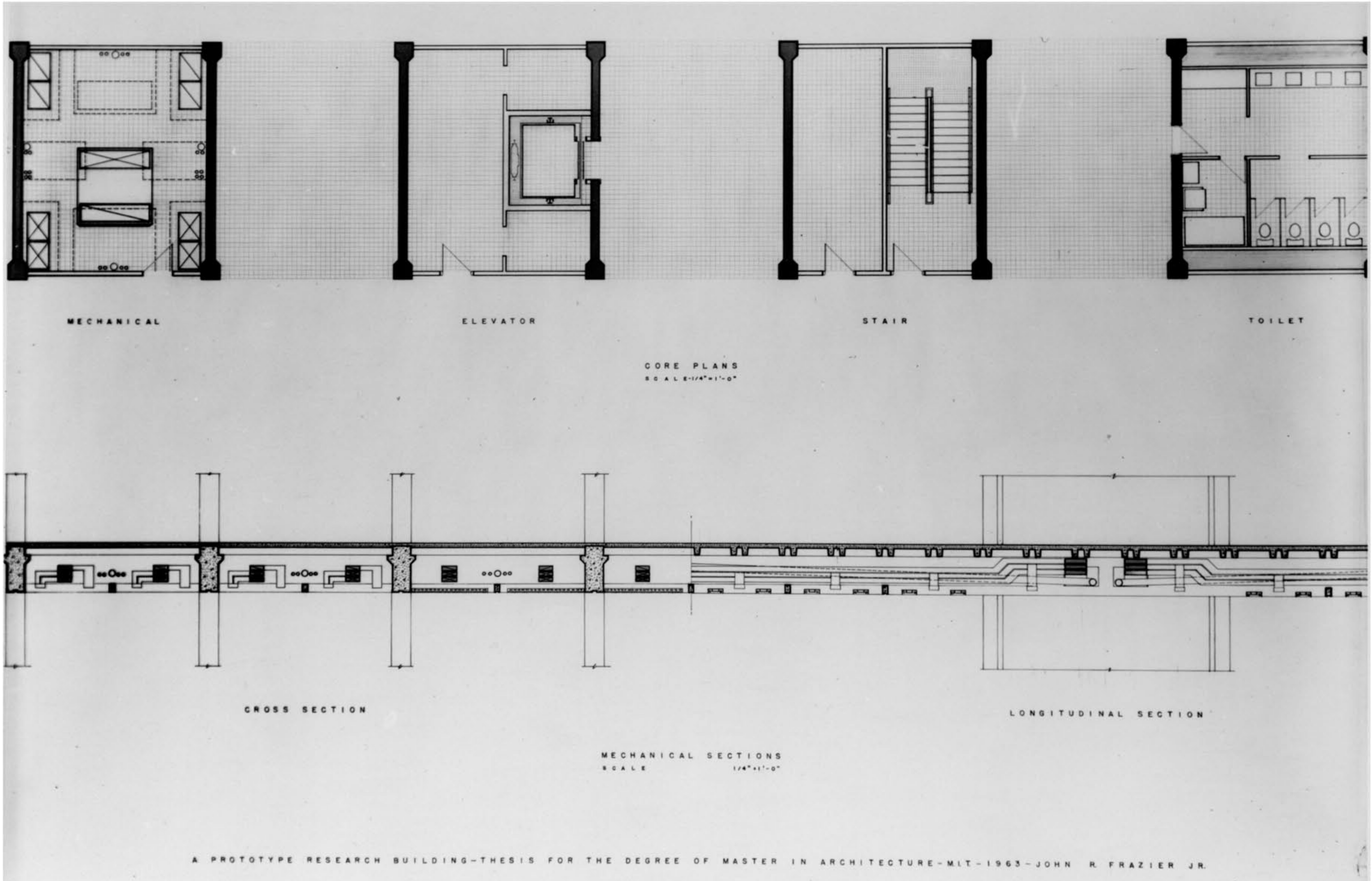
PARTIAL REFLECTED CEILING PLAN
SCALE 1/16"=1'-0"

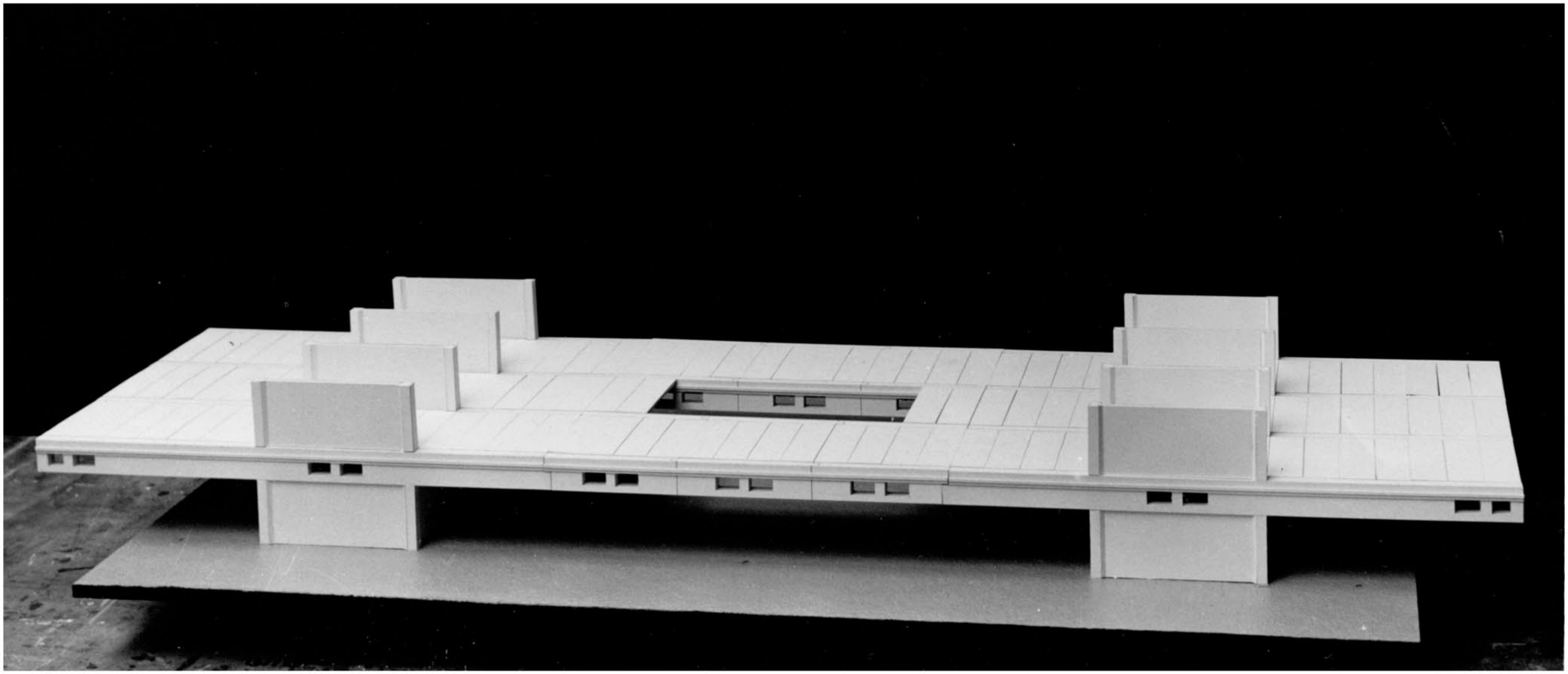


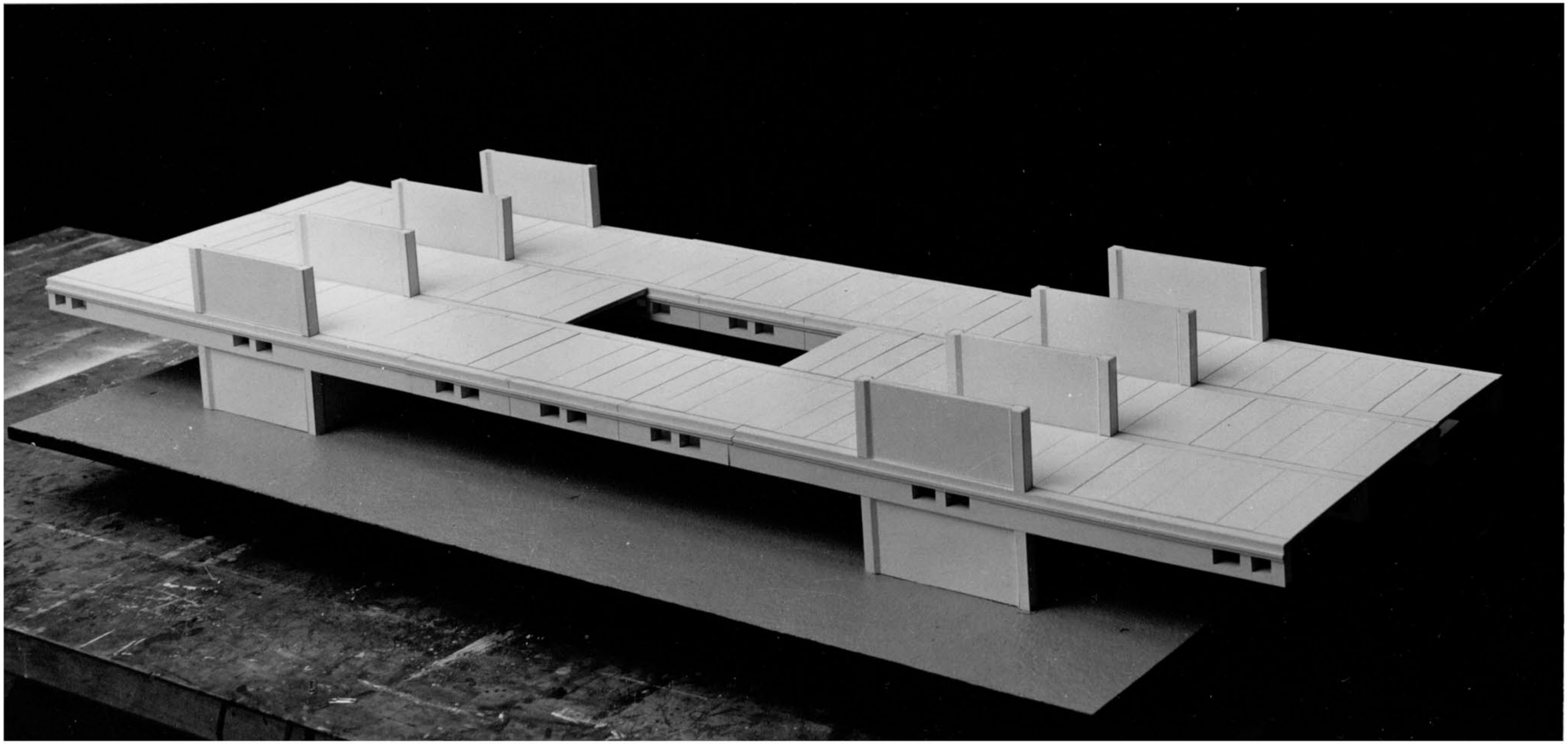
EXPANDED TYPICAL FLOOR PLAN
SCALE 1"=50'-0"

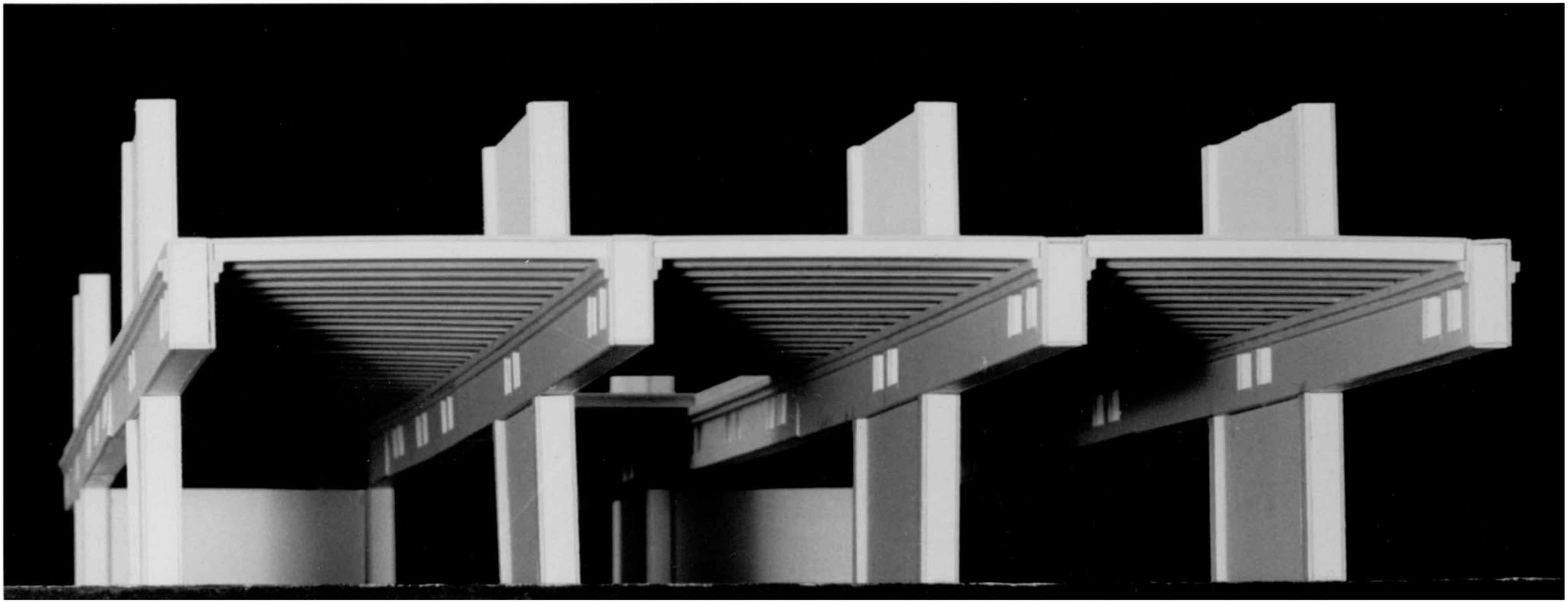
A PROTOTYPE RESEARCH BUILDING-THESIS FOR THE DEGREE OF MASTER IN ARCHITECTURE-M.I.T. 1963-JOHN R FRAZIER JR.

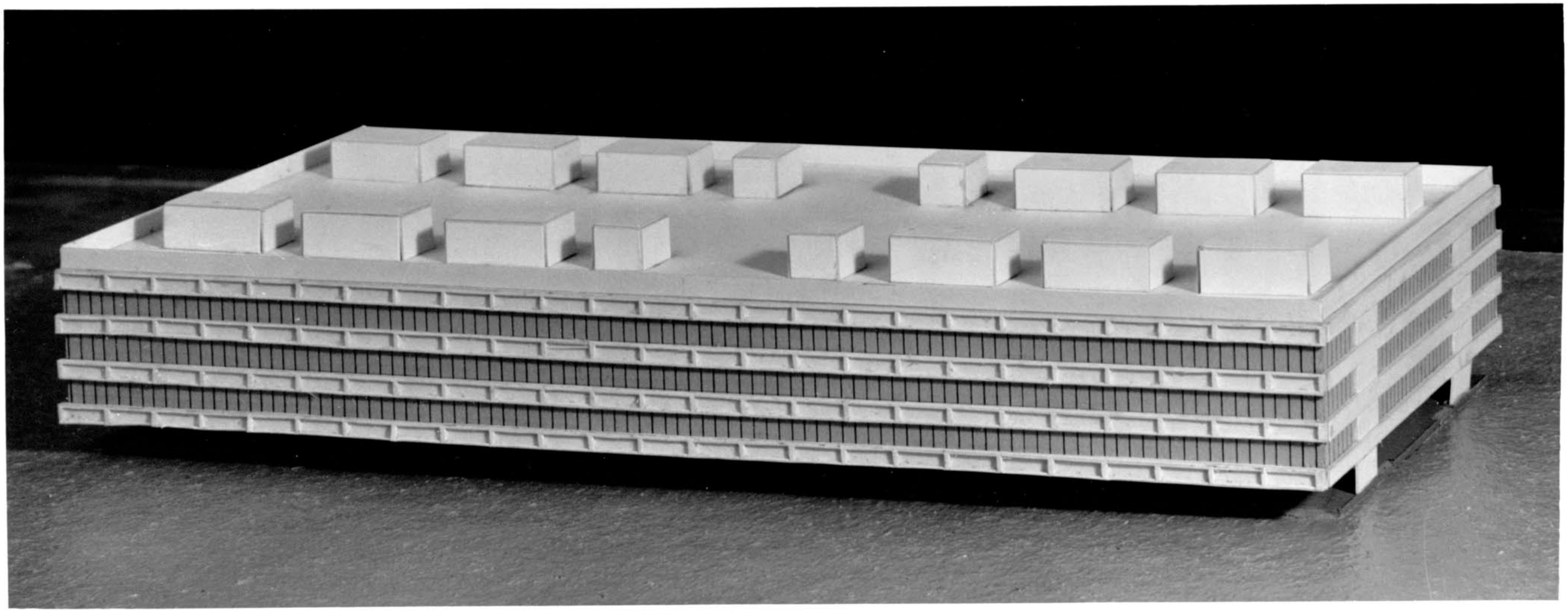

SPANDREL
SUN SCREEN
PLAN SECTION THRU WINDOWS
WINDOW WALL
SUN SCREEN
SPANDREL
AXIS OF SYMETRY
POST-TENSION STEEL
BEARING WALL
CONCRETE TOPPING
DOUBLE TEE
PARTIAL ELEVATION
HUNG CEILING
CEILING MEMBER
PARTITION
INDOW ELEVATION
SECTION THRU FLOOR
CROSS SECT
110'-0"
35'-0"
25'-0"
20'-0"
20'-0"
10'-0"
PLAN
GIRDER DETAILS
SCALE 1/4"=1'-0"
A PROTOTYPE RESEARCH BUILDING-THESIS FOR THE DEGREE OF MASTER IN ARCHITECTURE-M.I.T. 1963-JOHN R. FRAZIER JR.

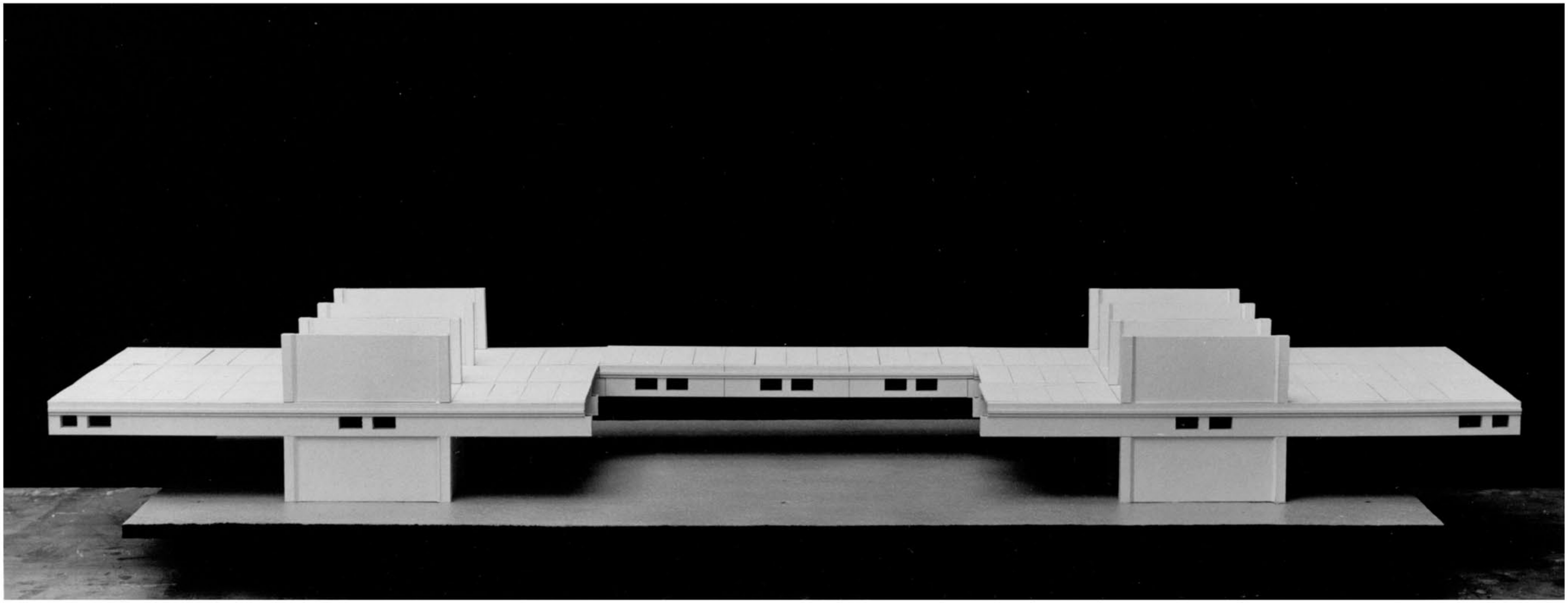

MECHANICAL
ELEVATOR
STAIR
TOILET
CORE PLANS
SCALE 1/4"=1'-0"
CROSS SECTION
LONGITUDINAL SECTION
MECHANICAL SECTIONS
SCALE 1/4"=1'-0"
A PROTOTYPE RESEARCH BUILDING—THESIS FOR THE DEGREE OF MASTER IN ARCHITECTURE—MIT—1963—JOHN R. FRAZIER JR.











THESIS PREPARED BY CARL INOWAY

OBJECTIVES

The objective of this approach to the design of a prototype research and development building is to arrive at a solution which will provide for expansion of the building in an easier and more efficient manner than is presently being used and also to provide a solution to the problem of changing interior space requirements both horizontally and vertically.

PROGRAM

Because of the wide range of kinds of research being done today and their varying spatial requirements, the category of research type which this prototype program covers will be limited generally to electronics, physics and directly related fields for both government and private industry and will exclude facilities housing chemical, pharmacutical, medical research and ordinary educational institution facilities.

Function

Within this general category there are five main groups of functions: administrative, ancillary, pure or theoretical research, applied research and development, and testing.

The area needs of the first group are primarily office spaces which range in size from a minimum of 100 square feet to 400 square feet according to staff hierarchy and status. There is need also of larger areas for secretarial and clerical sections either open or semi-divided into smaller cubicals. Their physical needs include air conditioning, mechanical and electrical services such as drinking fountains, light and power, and telephones. In room height a minimum of eight feet is required.

The ancillary spaces include possibly: dining area, auditorium, library(ies), lounges, common electronic computer rooms, graphic reproduction rooms, rest rooms, maintenance facilities, and public reception areas. Areas such as the kitchen and restrooms will require fairly extensive mechanical and electrical services. The remainder need primarily air conditioning and electricity. Height requirements vary with the size of these areas.

The pure research group's needs are generally office space only. These become cubicals for scientists to do mostly desk work. Their sizes will be in the range of 250-400 square feet with a minimum of eight feet in height. These spaces require only air conditioning and electricity.

The needs of the applied research and development group vary widely. There is need of small spaces ranging in size from 70 square feet for instrument rooms, 100 square feet and larger for offices, laboratory and work spaces from 150 square feet up to 7500 square feet. Height requirements vary according to the area of the room and the needs of the particular work being done. These needs are constantly changing. Mechanical and electrical services to be provided to these areas must be sufficient for any forseeable need with the possibility of adding additional service beyond even this if necessary.

The testing group has need of office spaces sized from 100 square feet to 250 square feet and large work spaces for apparatus and test models. These spaces should be able to be as large as 15,000 square feet and three stories in height.

Investigation into present research facilities seems to indicate a preference for no windows in the laboratory and testing areas due to the precise environmental control required. However, some visual relationship to the outside must be provided in areas such as lounges, dining rooms, major corridors and for personnel doing clerical and desk work at one place all day.

The manner in which these five groups are physically located and relate to each other has been found to be generally this way:

the administrative and ancillary groups centrally located, the remaining three groups divided into physical project groups according to their participation in a particular program. In other words, one physical project group might include a nucleus of theoretical scientists, with small laboratories near them surrounded by larger laboratory and shops where technicians are assembling apparatus. These areas are surrounded by large testing rooms and pilot plant areas. This would be the physical make up of one part of the building, and there would be several such project groups throughout the building. These project groups would increase in physical size as additional area is required and at the termination of the project these people might disburse to another proejct area and a new project would take over this space and adapt it to their specific needs.

PROPOSAL

In consideration of the unpredictable nature of much of today's research industries, with respect to the work being performed, there are two principal shortcomings in the design of present research and development buildings. One is that the work being performed in these buildings must adapt itself to the space available rather than the space adapting itself to the work to be performed as it should be for most efficient functioning. The type of work taking place in research and development facilities is constantly changing and the requirements for these spaces change as the work taking place within them changes. It would be ideal if the space envelope could adapt itself both horizontally and vertically as the need arises.

The second shortcoming is that as additional space is added to the building, it is usually added in large increments. This creates a situation in which there is a lack of adequate space before the expansion takes place and usually superfluous space after the expansion until that amount of additional space is required.

This, then, is the primary problem in the design of research and development buildings: to provide for their changing spatial needs. These changes are of two kinds: one kind is the change in size (horizontally and vertically) and use of interior spaces, and the other is change in the building size through expansion.

One solution to this problem is to design a unit which can adequately serve as work space for many kinds of functions once these various functions are reduced to their essential needs and also be a unit which is small enough to be relatively quickly added to the existing structure. Such a unit can be designed to be self sustaining with respect to its structural system and mechanical services, at least for its essential items (i.e. floor, walls, roof, air conditioning, electricity) that all spaces will require. Additional services may then be brought in as they are needed and only where they are needed.

The advantages to this kind of design are that in effect, every space is a possible laboratory, office, testing room, library, etc., and as the need arises for a changing of the work taking place in a particular space, that space can easily and quickly be converted to the needs of the new function. Also, as additional space is required to facilitate the nature of the work and its operation, additional units of adaptable space can be added in the amounts required.

The disadvantages to such a building system are that few of these spaces are designed for one specific kind of work and thus are not able to take advantage structurally and mechanically for an exact required need (e.g. short spans for office areas, comfort cooling only in offices where there is no equipment load on the heating and cooling system). In the duplication of mechanical and structural parts due to each unit being self sustained, there is additional cost for many small items rather than the savings in larger units. It is assumed that these disadvantages can be balanced by the possible saving in production and operation time to accomplish a given amount of work through a more efficient operation. In addition, in such a design with relatively high flexibility, the building never becomes obsolete since it has greater possibilities for varied use.

Application of this design concept will be most appropriate today for only certain parts of research buildings, that is in those areas of the building in which such flexibility justifies the additional initial cost. The more stable parts can be designed in a conventional manner. The goal of this thesis, however, is to illustrate that such a concept for a flexible kind of building system is possibly a worthwhile consideration in designing for research and development buildings.

The approach of this thesis is to design a prototype research and development building utilizing precast concrete as a part of its construction. The building is designed to be a horizontal building studying the advantages and disadvantages of this kind of scheme. It attempts to reduce the functions of the research operation to its essential parts, to analyze the spatial needs of these parts, and to arrive at a design which will possibly be a better solution to this new and vital architectural problem.

In consideration of these varying needs of the total building, it has been decided that a single, large, one story building might be an ideal solution to this problem. Such a solution has these advantages: the area of many separate one story buildings but tied together so that horizontal expansion can go in any direction, with the possibility of vertical expansion at any point. Communication lines become longer, but investigation has indicated that the majority of personal contact is between project members and not between projects. The length between common facilities such as library, dining room, administration, etc. and project areas is reduced by centrally locating these facilities with respect to the various projects. As these project areas grow physically and the geographic center of the building changes, these ancillary and administrative functions can then also move in order to be always centrally located.

The solution provides for the main entrance to be at the center of the building thus minimizing the distance to all points. In order to achieve this the building has been raised on its columns one story so that entry to the building is under and up into the reception area. This raising of the building also allows for parking under the building and in proximity which is a major problem to be solved in such a large horizontal scheme in a rural area where most workers drive to work. In addition to the main entry in the center of the building, there are provided six minor entrances regularly spaced throughout the building. These entrances and exits are in a core unit which includes also rest rooms, mechanical service distribution center, lounge and an open court. All of these common facilities regularly spaced throughout the building then give a sense of orientation both from within and outside of the building. Employees can park under the immediate area where they are working and enter at the nearest entrance. This solution eliminates a long walk from automobile to entrance and shelters the pedestrian and automobile as well.

This building as designed has an area of approximately 250,000 square feet, but has the possibility to double or triple this area if it is necessary or desired.

Structural System

Part of the purpose of this thesis is to study the use of precast and prestressed concrete construction. As a construction material and type of construction, precast and prestressed concrete have both advantages and disadvantages for use in the solution to a prototype research building. In keeping with the concept of relatively short construction time and repetitious use of many similar elements, the use of precast concrete is advantageous. Also as a relatively massive material compared to steel, concrete will transfer less high frequency vibration from laboratory to laboratory. In the category of research concerned, the majority of vibrations are of high frequency which steel would transfer more easily. In consideration of the desired changeability of the structure, steel would probably be more easily assembled and disassembled.

Since interior flexibility of space arrangements is required, prestressed concrete makes possible longer spands and more efficient use of the material than in standard reinforced concrete construction. These advantages have helped determine the design of this building.

The structural bay size of this building was decided upon after these considerations: required laboratory size according to equipment and amount of work space around them; possible combinations of offices, and offices and laboratories; parking below work spaces. The size of bay chosen was 52'-0" x 52'-0" clear to inside of column. At this span, prestressing could then become helpful in making a more efficient structural system. Also, an interspace of 8'-0" between the larger squares was chosen. The advantages to this are that then each structural bay can be relatively independent and self supporting. Superfluous sizing of the structural members in anticipation of maximum uneven loading is omitted. Also, the additional eight feet provides space for corridors and other projections such as storage closets, toilets and stairs which otherwise would project into the larger clear space.

In determining the kind of floor system to be used, the requirements of it were analyzed. It would have to allow for mechanical services to pass either through it or under it. If these services were under the floor system then some kind of hung ceiling would be required. It would be desirable if the floor could be perforated regularly in order to allow easy access to the mechanical equipment. Also, since units were to be added to each other in any direction, a standard edge connection would be desirable.

The roof system had several requirements made of it. It had to carry the roof loads, be a solid element to attach movable partitions to, provide for some means of acoustical control between spaces and allow mechanical and electrical services to pass through, under or over it.

It was decided that a two-way, concrete, post-tensioned, Virendel truss system with a 4'-0" grid spacing both ways would allow partition placement at 4'-0" centers in either direction for reasonable flexibility. This module was chosen to best accomodate present furniture and equipment size. The mechanical services would pass through the structure and be left exposed. Some acoustical material would be incorporated in the underside of the top slab. This solution seemed to satisfy best all the requirements.

It was decided to use a similar system for the floor but making the grid spacing 6'-0". This larger spacing caused the members to be deeper, but allowed larger openings in the beams and structural system to carry the floor loads.

This two-way system is supported by a continuous edge beam on all sides and the loads are transferred to four corner columns and carried to the ground where they rest on concrete piers and spot footings.

It was then decided that if, in the construction process, the roof were poured on the ground and lifted into position by hydraulic jacks mounted on the columns, then the roof could be placed at any height required. In addition, if later, a higher space were desirable, the columns could be lengthened and the hydraulic jacks reapplied to raise the roof to a new height. The other advantages to this type of construction procedure is that if both the roof and the floor are constructed on the ground there would be no scaffolding required and much of the mechanical and electrical services, roofing, etc., could be installed easily while at ground level then the whole lifted into place and final connections made.

The columns, which are all identical, would be concrete precast in a plant as would the members of the eight foot interspace, exterior wall panels, and penthouse. Also, the edge beams of the roof and floor system would be precast and prestressed in a plant and brought to the site. These members would be used as the outside formwork as the floor and roof grids were poured.

The erection process would be thus:

ground cleared and graded
excavation for footings made
footings formed and poured
piers (either precast or cast in place) placed
columns erected
ground back filled and leveled
edge beams for floor positioned
formwork for floor grid positioned
reinforcing rods and post tensioning conduit placed
floor poured
floor cured
bond breaker applied

edge beam for roof positioned on top
of floor

formwork for roof grid positioned

reinforcing rods and post tensioning
conduit placed

roof poured

roof cured

mechanical equipment installed on roof

mechanical penthouse assembled on roof

roof system post tensioned

roofing applied

roof lifted to floor level position

ceiling fixtures for air conditioning
and electricity installed

roof lifted to final position

floor system post tensioned

floor lifted into position

exterior wall panels installed

mechanical services installed in floor

interior spaces furnished and finished

Mechanical and Electrical Services

In keeping with the concept of making each 52 feet square spatial increment self sustaining for its basic requirements, it was decided to provide separate "forced warm air" air conditioning equipment for each unit of space. Since air for cooling must be distributed from above, this equipment was placed on the roof. This solution works well with the structural system chosen, since the holes through the grid beams are largest in the center of the span and this is where the large ducts enter the structural system from above. As the large holes in the beam become smaller, the ducts also diminish in size as they near the ends of their runs.

The roof carries all of the air conditioning ducts integrated with its structure thus freeing the spaces in the floor system for the many special mechanical services it must contain. Electricity will run in the exposed roof structure for both lighting and power source. The lighting fixtures chosen are short lengths (3'-6") in order to be able to be placed to serve any arrangement of interior partitions.

The air conditioning unit on the roof is all electric powered and therefore has no need of water supply to it. An air supply diffuser is placed at 8'-0" intervals in the ceiling near the outside wall where the load is greatest and at 8'-0" centers around an inner ring. Return air is drawn directly into the penthouse through grilles located in the ceiling in the center of the bay.

The mechanical and electrical services in the floor will vary. In office areas there may be only electricity and telephone lines. In the laboratory and testing areas, there may be an almost solid maze of pipes, conduits, and ducts. In order to make access to this equipment as easy and simple as possible there are 12" holes at 6'-6" centers both ways throughout the floor system. These holes have cover plates in them when not in use and adapters to close off open areas when there are pipes etc. coming up through them. In addition, the total floor mechanical space is accessible from below by removing the insulation panels on the bottom side.

Service to each units of space comes from a mechanical core centrally located to the units it serves. Each core serves 12 to 15 units. In these mechanical rooms, equipment would be located which would provide compressed air, natural gas, nitrogen, hot water, etc. The main lines of supply run below the eight foot interspace strips then feed into each unit through holes in the edge beam into the floor grid system. In the event that special high quantity service is required for a work process, the area immediately below that work area could be cleared of automobile parking and special apparatus (such as a large liquid nitrogen tank) could be installed temporarily. The holes in the edge beams of outside walls open directly to the atmosphere. This enables exhaust fans pressure relief vents, special drain lines, etc. to have direct outside access. There are four waste drain shafts serving these 12 to 15 units spaced closer to the work units than the mechanical core. This was done to shorten the length of run and thus the depth required in the structual system to allow for the pitch of the drain lines. These drain shafts and the mechanical cores connect underground to mechanical service tunnels through which services are connected to the outside street lines.

It is unfortunate that the level of technology in mechanical services, especially air conditioning, is so low and thus determines so much of the design of building. Though this design is a prototype building and it necessarily had to be designed for present day equipment, it is hoped that more efficient equipment and new methods could be utilized to make better total structures.

Other Materials

The only non-structural elements considered in this design are the mechanical equipment penthouse and the exterior wall panels. Since both are exposed to the weather and since there are many of each, it was decided to use precast concrete for these.

The penthouse is made up of four pieces and has an opening to exhaust heat, take in fresh air, and an opening for servicing and equipment changing.

The exterior wall panels are of four kinds. One piece covers the roof edge beams and shelters its openings as well as provides a low parapet wall for roof draining control. Another piece covers the floor edge beam and shelters its openings. There is a solid wall panel consisting of a layer of insulation sandwiched between two layers of protective concrete. The fourth piece is a window wall panel. The initial solid wall panel would come in the standard eight foot height, after which increments of two feet could be added in order to enclose any height that might be required for the unit. These exterior pieces would be removed from a unit as expansion occurred and reapplied to the new exterior walls.

Character and Expression

With regard to the character that this building should express, it was felt that somehow the unpredictable nature of research and development work taking place inside should be expressed, somewhat like a plant that can change its size and configuration as the inner workings change and yet retain some kind of visual order and coherence.

In designing this building, to be able to adapt itself to its inner workings and yet retain a sense or order through use of a similar physical unit and expressing the character of this unit was a work space between two supporting mechanical service areas, an attempt has been made to obtain this character and expression.

CONDENSED BUILDING PROGRAM

Problem

To design a prototype research and development building as a system providing maximum ease of expansion and interior changeability.

I. Site

A. Assumptions

open suburban or rural area

a level site with adequate room for horizontal expansion and development.

B. Requirements

development

building at ground level

parking facilities for 500 cars

immediate area ladnscaping

II. Building

A. Requirements

size of building

approximately 250,00 square feet

accommodating 1,000 persons

function

administrative group

offices 100-400 square feet

clerical sections

ancillary group

reception area

library 7200 square feet

dining rooms for 500 persons

kitchen

auditorium for 500 persons

theoretical research group

offices 250-400 square feet

applied research and development group

offices 100-250 square feet

laboratories and other work spaces 100-7500 square feet

testing and pilot plant group

offices 100-250 square feet

laboratories and other work spaces 100-15,000 square feet

III. Mechanical Services

A. Air conditioning

1. heating-- provide for differential control within reasonable area increments $75^{o}F \pm 1/2^{o}F$

2. cooling - provide for differential control within reasonable increments; supply from above

3. humidity - provide for equipment sized to maintain relative humidity of 45 o/o or lower in all areas with provisions for additional equipment for control in special areas to $\pm$ 3 o/o relative humidity.

4. filtration - provide for equipment to filter air

5. air changes - provide for optimum required

6. reliability - provide space for possibility of deuplexing equipment in those special areas which may require it.

B. Electricity

1. overhead supply for lighting fixtures

   type - incadescent, flourescent

   occurrence - regular, frequent throughout ceiling

2. floor supply

   110v, 220v, 440v

   any amount necessary anywhere in floor

C. Hot and cold water

1. supply through floor at any location

2. in any amount required

D. Telephone

1. floor connections located anywhere necessary

2. as many as required

E. Waste lines

1. through floor at any location

2. as many as required

F. Other special services

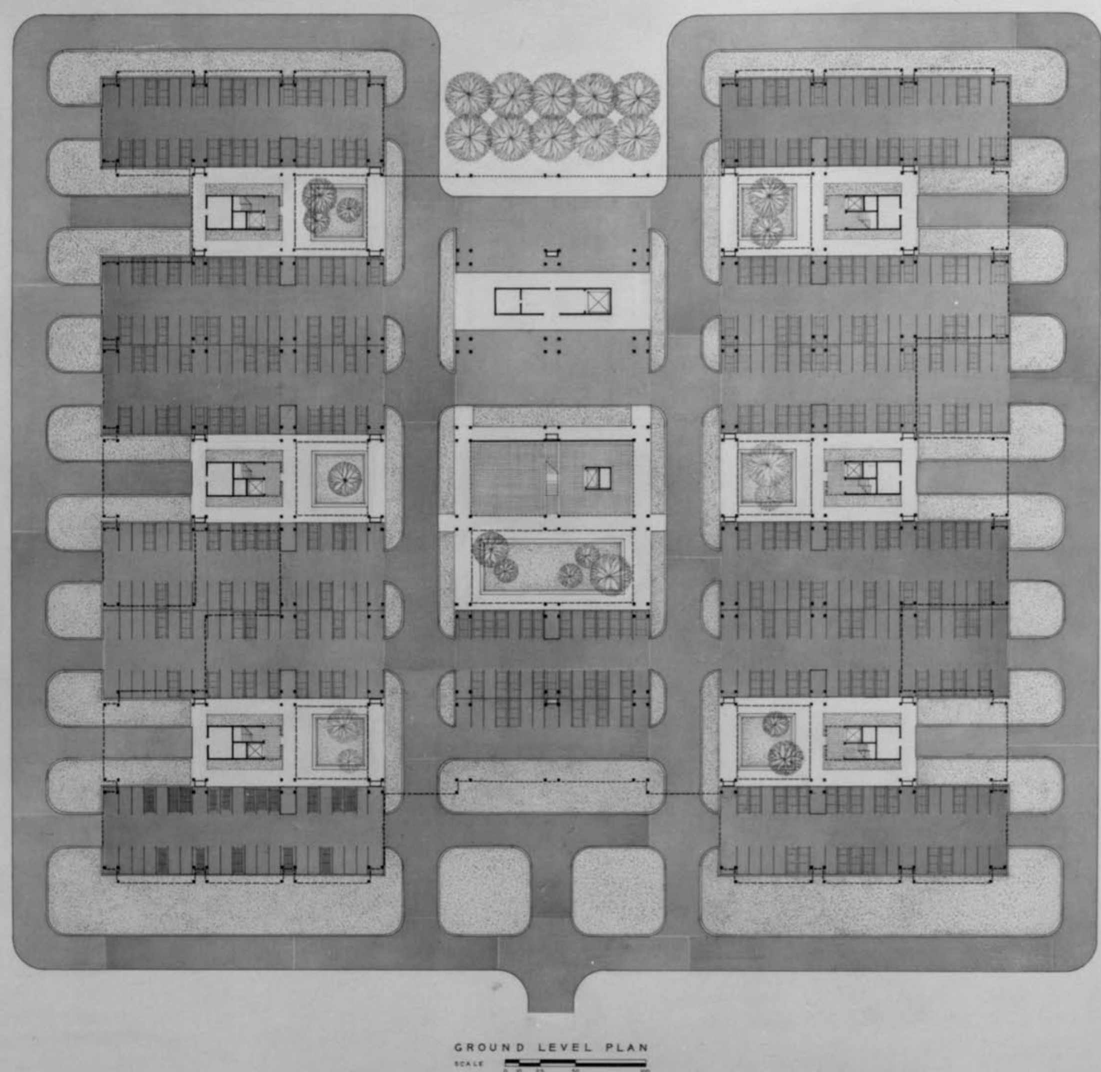
1. natrual gas, compressed air, oxygen, helium, hydrogen, nitrogen, etc.

2. supply through floor at any location

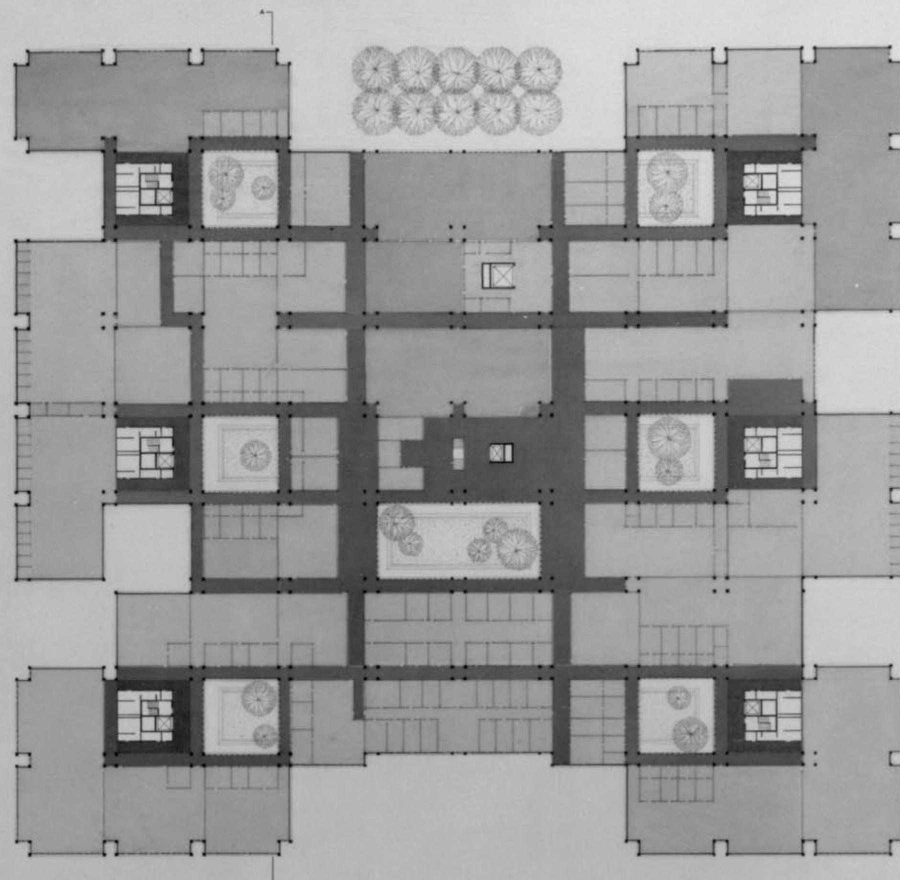
3. in any amount required

IV. Structural System

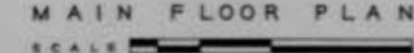
Use of precast and prestressed concrete construction where applicable and according to its nature and best use as a building material and study of the design procedures and techniques of its use.



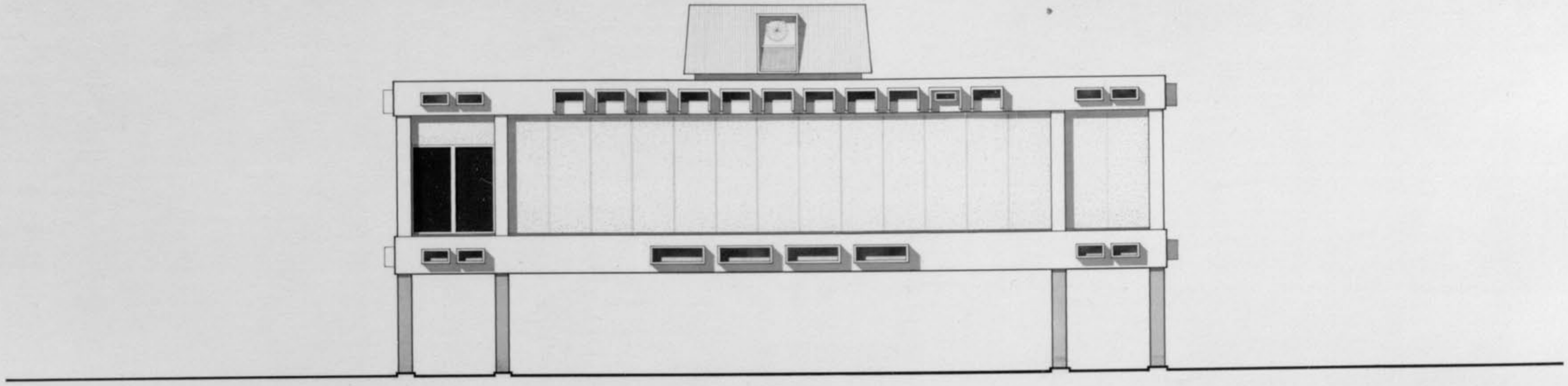
GROUND LEVEL PLAN



MAIN FLOOR PLAN

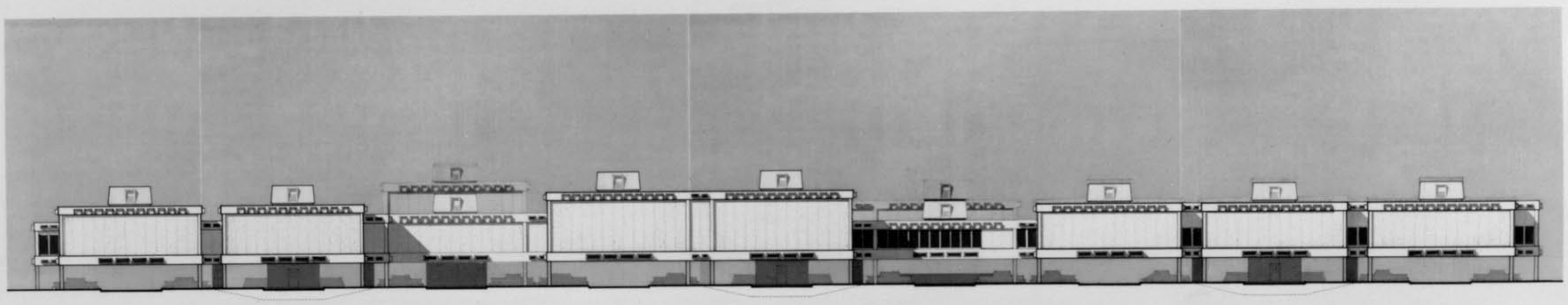


A PROTOTYPE RESEARCH AND DEVELOPMENT BUILDING   MASTER OF ARCHITECTURE THESIS   MASSACHUSETTS INSTITUTE OF TECHNOLOGY   1963   CARL INOWAY



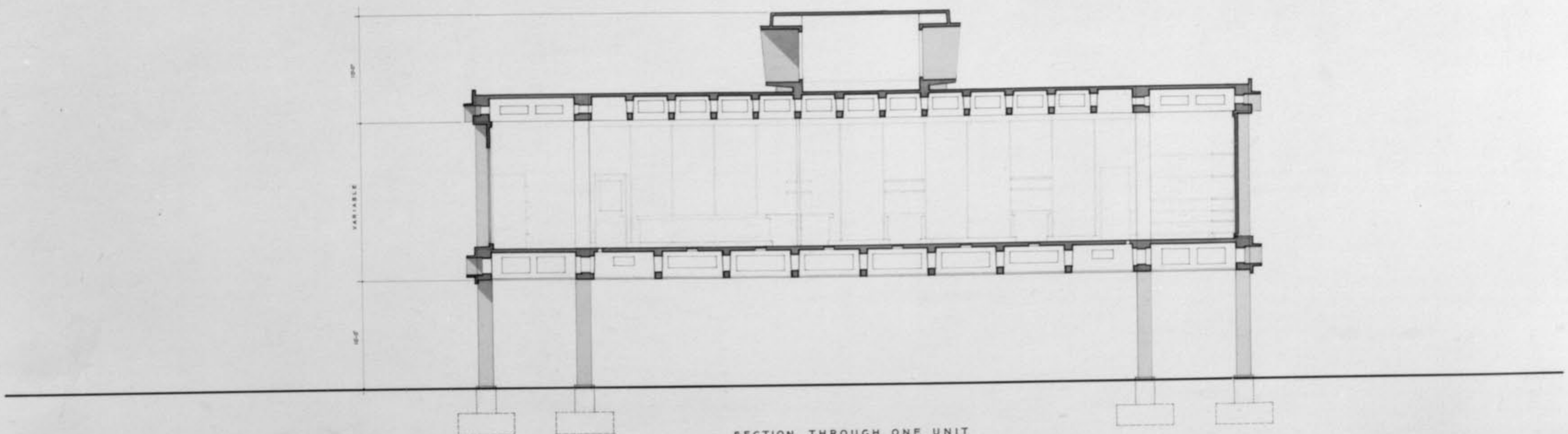
ELEVATION OF ONE UNIT

SCALE 0 1 2 3 4 5 10 15



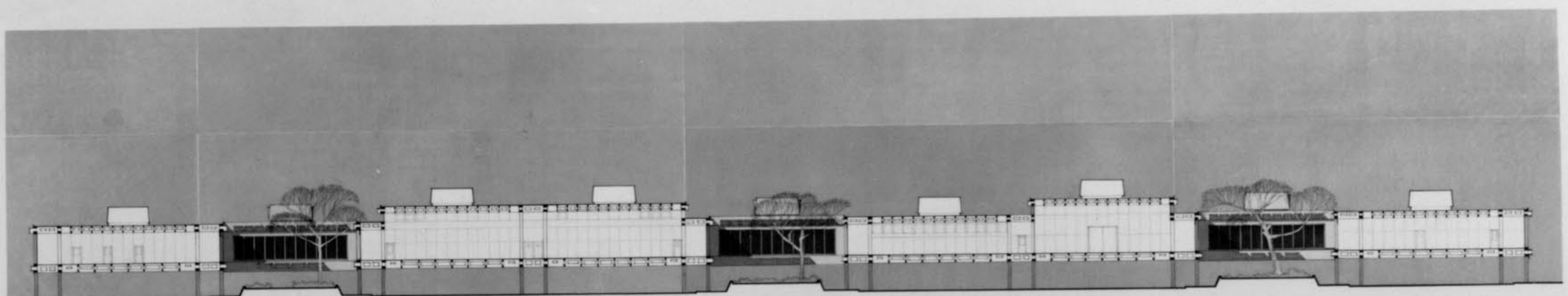
ELEVATION OF BUILDING

SCALE 0 5 10 25 50



SECTION THROUGH ONE UNIT

SCALE



SECTION THROUGH BUILDING

SCALE

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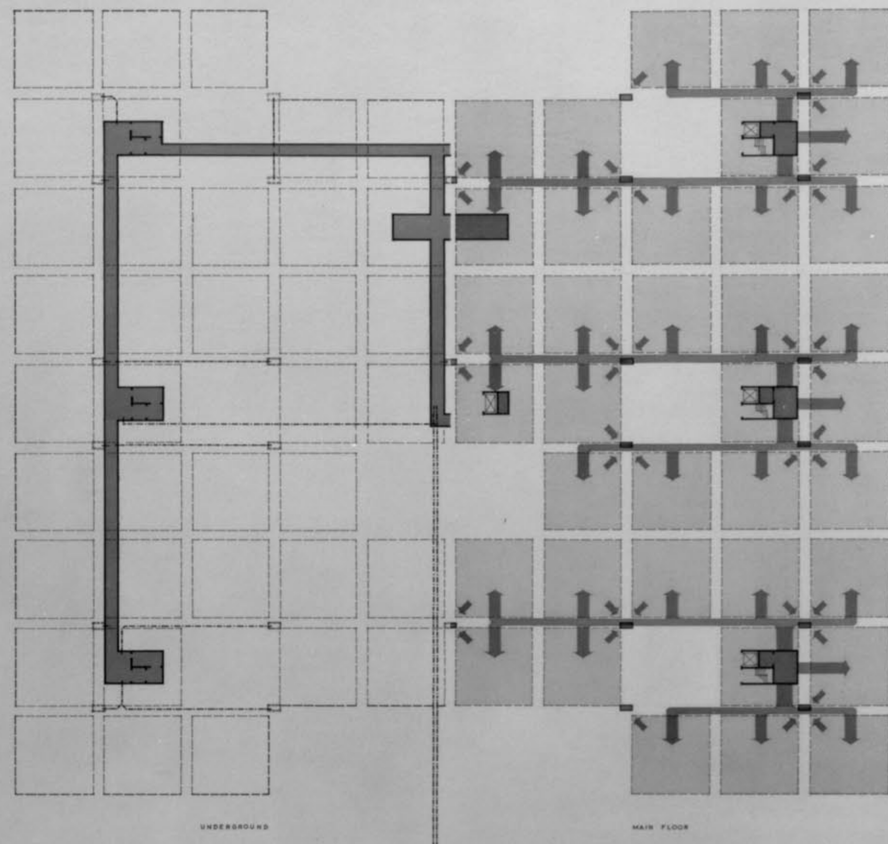
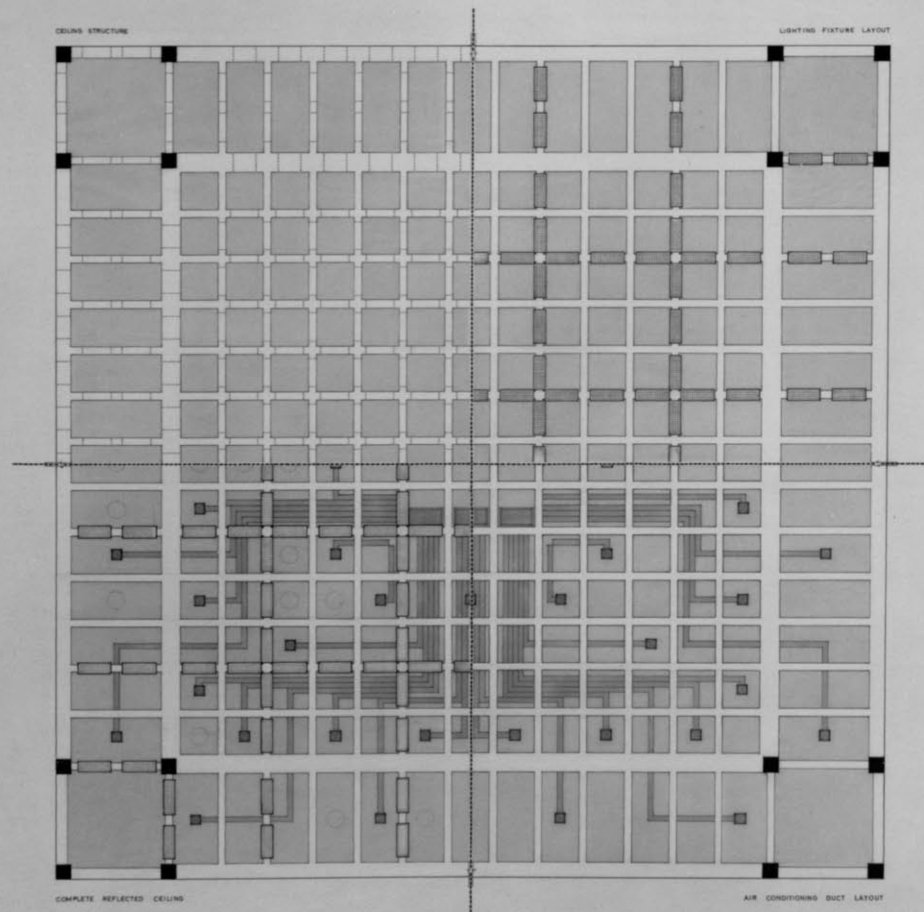


ELECTRICAL & MECHANICAL SERVICE DISTRIBUTION DIAGRAM

SCALE



REFLECTED CEILING PLAN

SCALE

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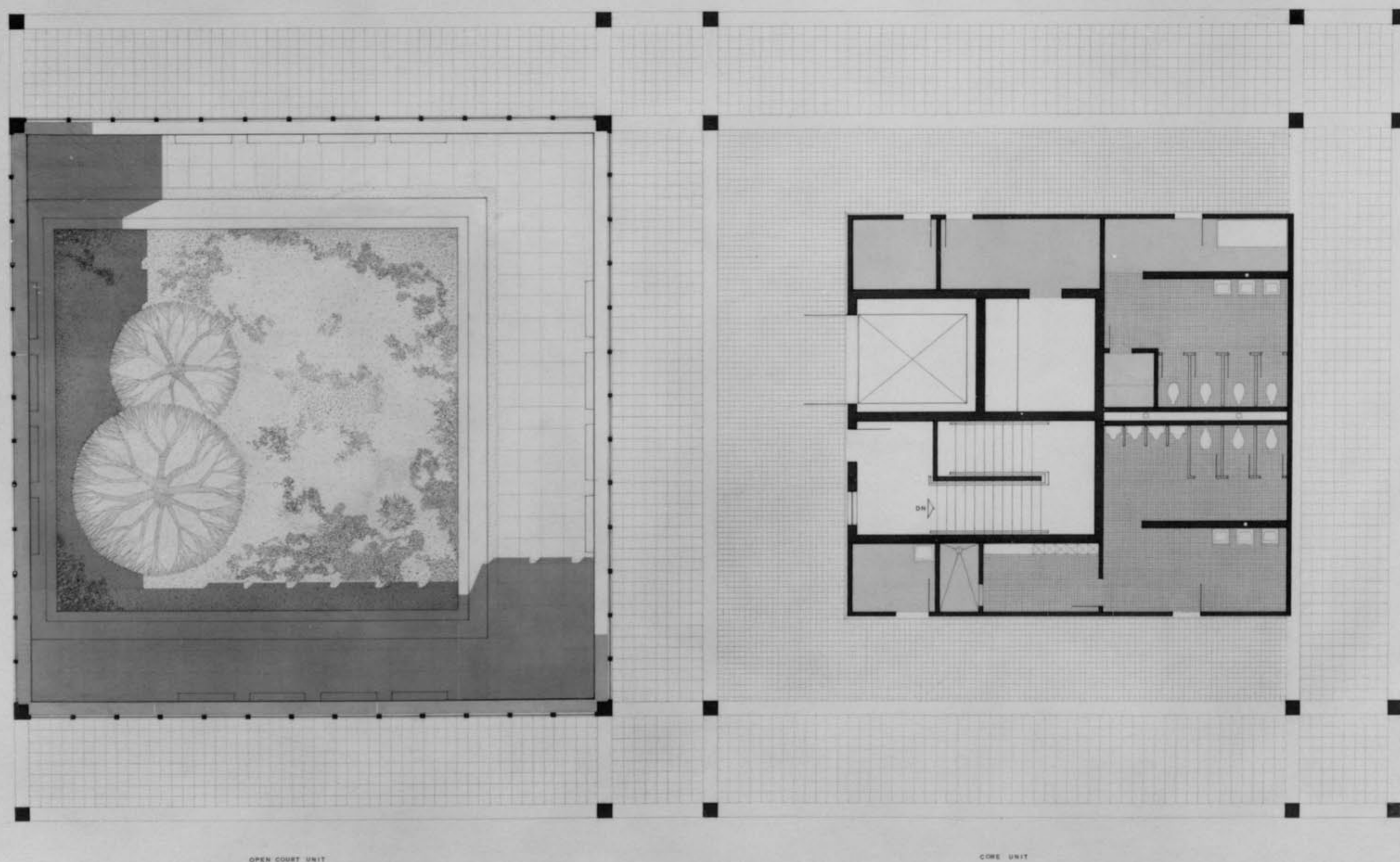
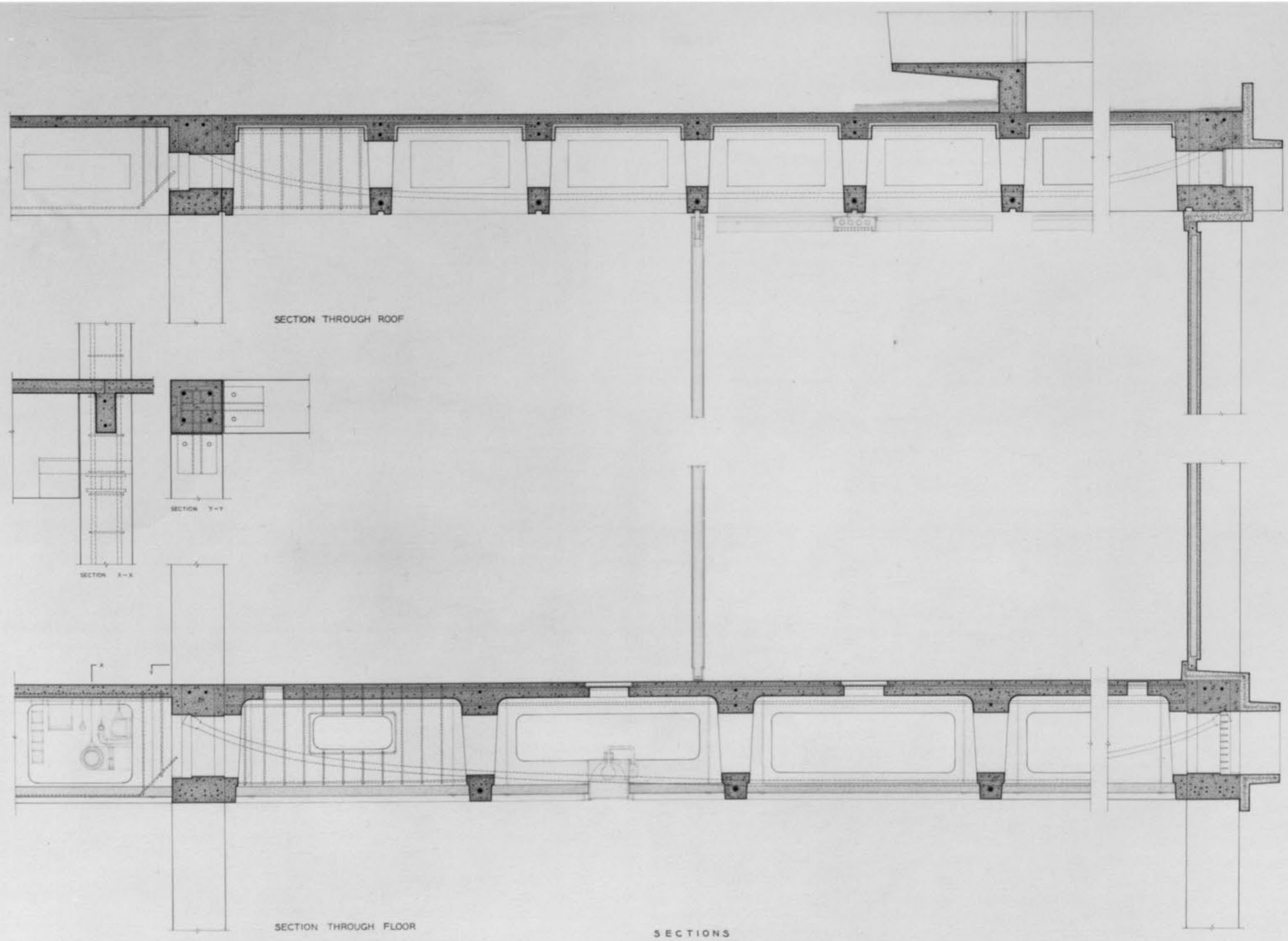


PLAN DETAIL

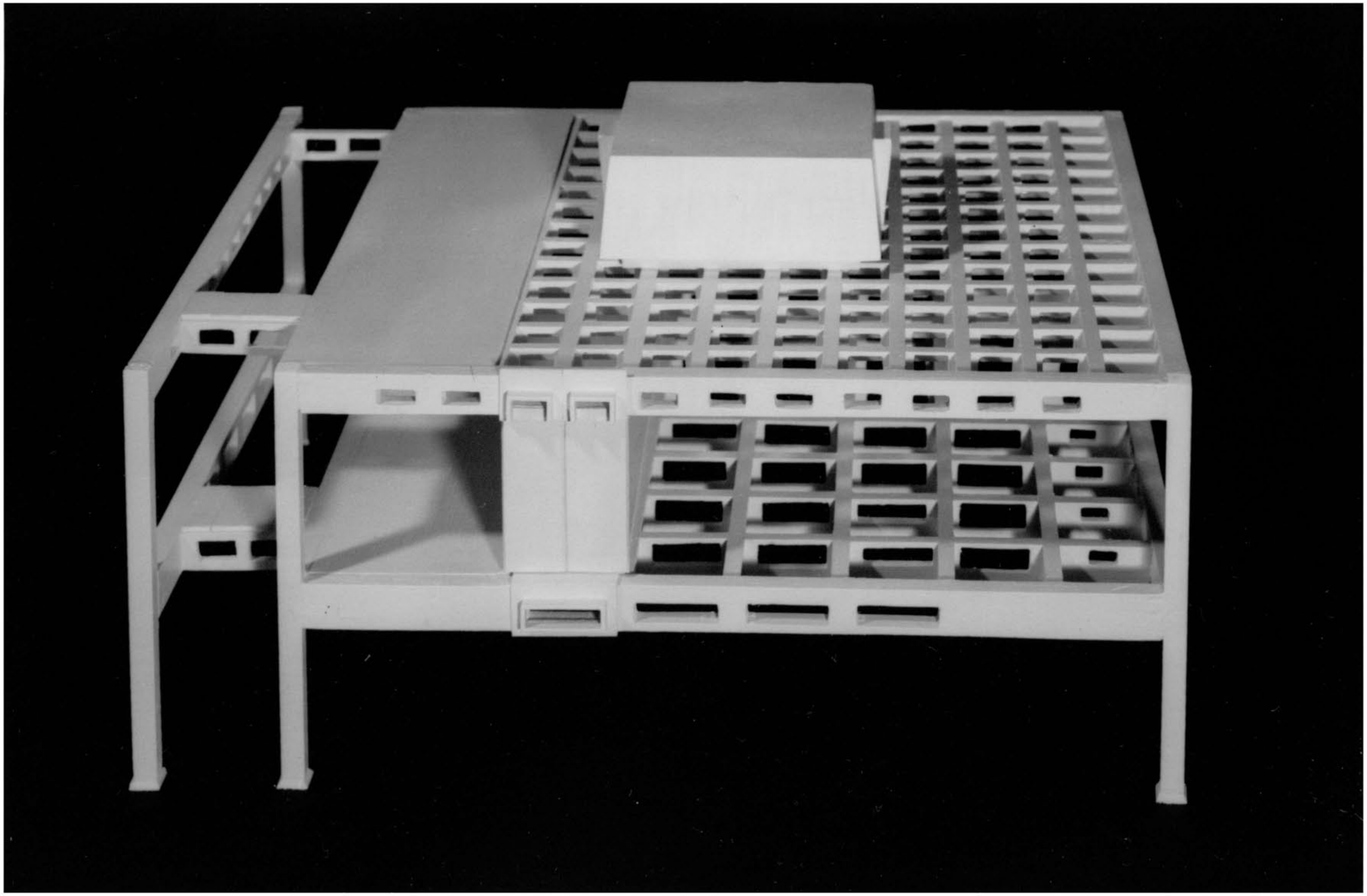
SCALE

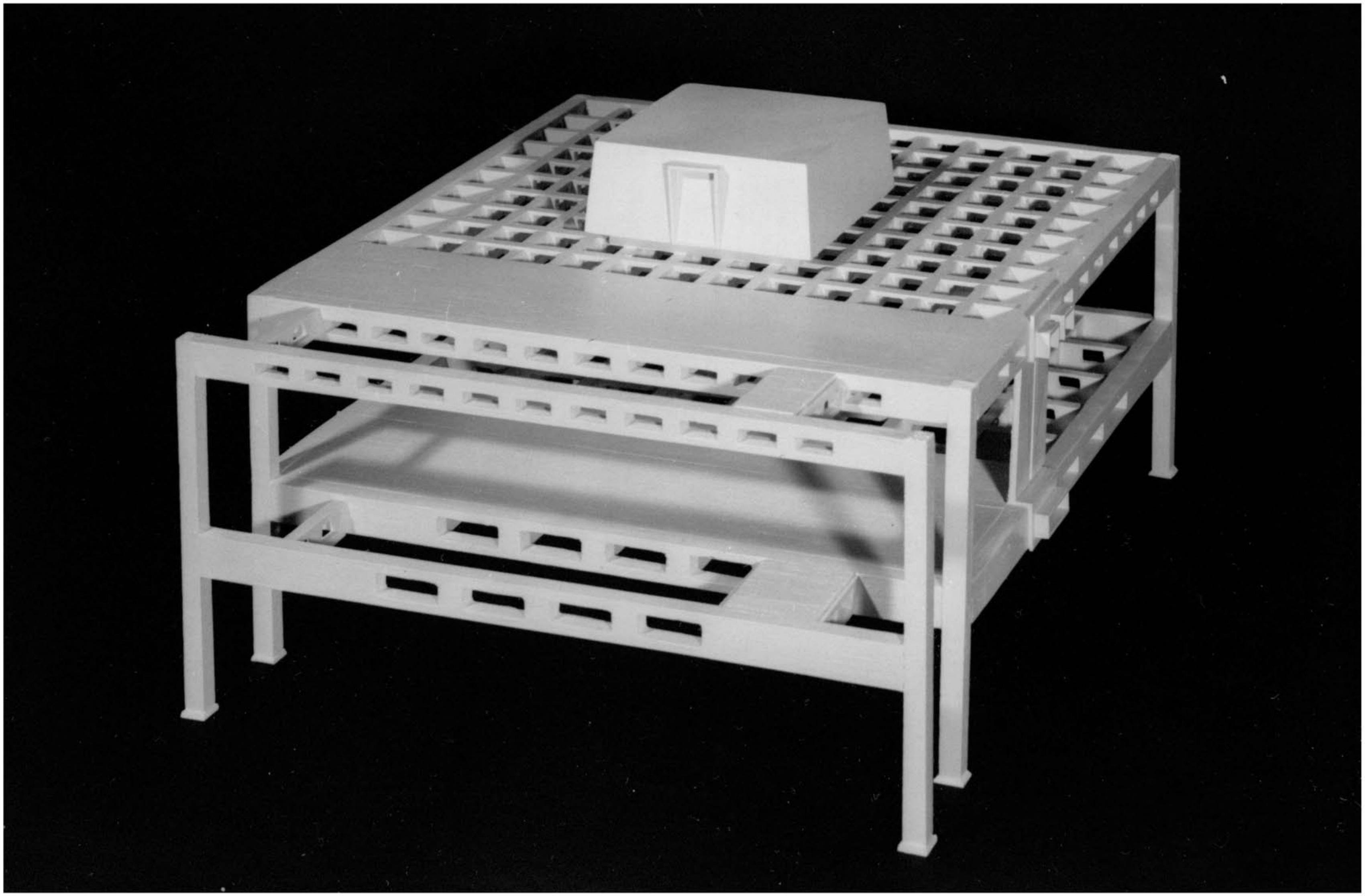
A PROTOTYPE RESEARCH AND DEVELOPMENT BUILDING MASTER OF ARCHITECTURE THESIS MASSACHUSETTS INSTITUTE OF TECHNOLOGY 1963 CARL INOWAY

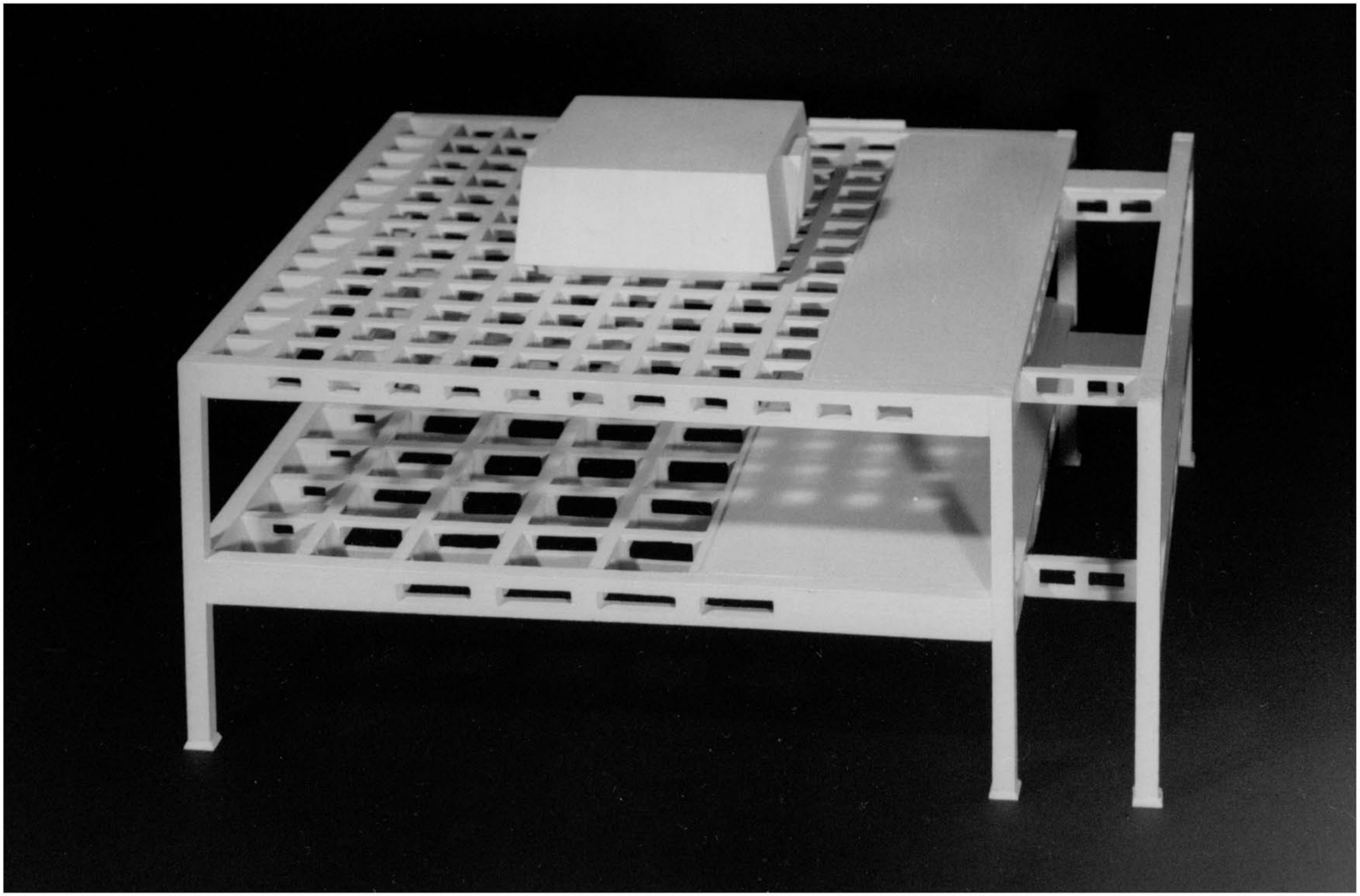


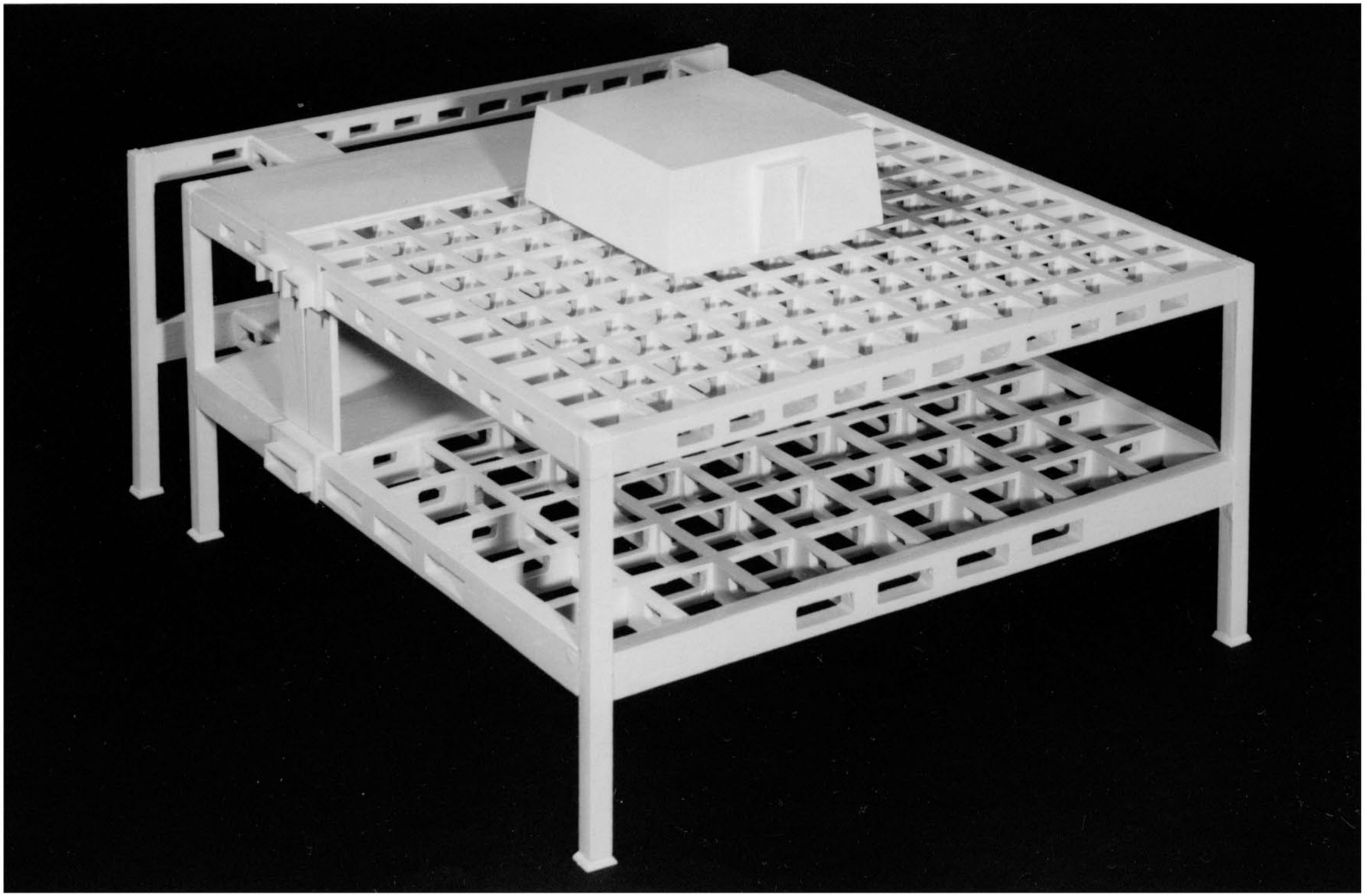
SECTIONS

A PROTOTYPE RESEARCH AND DEVELOPMENT BUILDING MASTER OF ARCHITECTURE THESIS MASSACHUSETTS INSTITUTE OF TECHNOLOGY 1963 CARL INOWAY









THESIS PREPARED BY DWAYNE C. NUZUM

OBJECTIVE

The objective of this thesis is to design a prototype highrise research and development building utilizing precast concrete. The main emphasis is towards a solution for an urban area, and the design of a dynamic space in the sense of adapting the building to the work to be done, rather than adapting the work to a building composed of static spaces with limited flexibility.

APPROACH

Research and development buildings became a building type after 1935. But as a building type they have not kept up with the changing functional demands.

The design of a prototype building requires a different approach than the design of a building which has a site, definite requirements, orientation, a known budget, and a specific client. A prototype building requires the designer to design optimums.

These optimums, being conditions most conductive to the realization of research work, are not only for present standards but should contain some reflection of future standards.

In America at the present time concrete has proven to be one of the least expensive methods of enclosing a space. The reasons for this include the following:

1. Fireproof
2. Weather resistant surface
3. Minimum sound transmission
4. Formed into a multitude of shapes
5. Minimum construction time

Precast concrete offers the further advantages over poured in place concrete:

1. Mass produced
2. Higher precision
3. Longer spans

Therefore, in this thesis precast reinforced concrete was chosen as the principal building material.

What should a precast concrete building be? Today its form is the result of the assembly of precast units made in a factory. The results are similar to buildings made of wood and steel. Precast concrete buildings should have an identity which wood has to dwellings and steel has to skyscrapers. Part of this thesis will be an effort to discover the true potential of precast concrete. Concrete's unique properties are the key to the true use of concrete. The architect can become the fuse to ignite technology to a better utilization of concrete.

What is the nature of research work today and tomorrow? Today in most, if not all, research buildings the work is adapted to the space of the building. However, today's research and development buildings need a dynamic space, a space which is always changing as the project moves from conception to completion. Desirable spaces in a research and development building include monastic cells, high sensitive testing areas, large secretary pools, and every other conceivable work space associated with creative technology. Expressed optimums of research space seek minimums of waste in time, work, and energy.

The existing electrical and television wiring loads are a minimum today. As computers and other objects that do work become more numerous, more and more man hours will be spent in the servicing and housing of these machines. The future research and development building should encompass these trends.

Abstractions of the problem which an effort was made to solve include:

1. An expression of life compatible with research.
2. The quantity and quality of flexibility desired.
3. An expression of a hierarchy of elements.
4. Aesthetic questions
    a. The relation of the automobile both functionally and

visually to a highrise research and development building.

b. The relationship of the building with the ground.

c. The termination of a building in space.

d. The expression of research and development using precast concrete elements.

All of these abstractions the author has tried to answer with this solution. Many of these abstractions do not have objective solutions, either they do or do not succeed. There are no all encompassing solutions. For each problem there is one solution that is better than all others at the time; but, the problem is always unique; thus, the solution is always unique.

The program for a prototype building is a program of optimums. Listed below are the design criteria, as defined before, which were imposed upon the problem:

1. Site

The site is to be in an urban area where land costs are high and quantity of available land is minimal. All utilities are available at the property line. No orientation is given. It is assumed that pedestrian traffic will exist at least on one side of the building and that service access will be available on the opposite side.

Due to the urban location one building was proposed without the possibility of expansion. Expansion would occur only by adding a completely new entity, if the land could be made available.

Urban renewal agencies throughout the country are seeking types of employment which can be housed in high density building types. Research and development buildings which employ the technician as well as the scientist could help alleviate part of the planners problem of trying to achieve a finer grain of employment opportunities within our present cities.

2. Building

a. Size

A minimum of 200,000 square feet and a maximum of one million square feet were found to be the limits of function and physical dimension. The maximum number of floors seems unknown, except the more floors per total quantity the poorer the utilization of the utilities. The larger the floor area, the better the utilization of utilities, until a physical dimension constants is reached and "sub station" units are desirable. A value judgement exists as to what the optimum floor area should be. 22,500 square feet per floor was found to be the optimum floor area based on the structural module, height limitations and the ratio of usable space to mechanical and utility space.

b. Structural System

The structural meterial is to be precast concrete. Factors which will effect the structural system will include:

- integration of mechanical and structural systems including light and air conditioning
- integration of a structural system with a module which is based upon research work requirements (see appendix)
- integration of structure with the vertical shafts
- integration of precast concrete with cast in place concrete or other structural material
- acoustical considerations

In the selection of the structural system, consideration was to the construction process of the precast units. Studies were also made to find the relationships between bays, cores, voids, supports, and economic modules.

c. Mechanical System

The mechanical system must be capable of providing optimums, being conditions most conducive to the realization of research work at any point within the space. The mechanical systems to be available in this building area;

air conditioning (heating, cooling and humidification)

electric cables

telephone lines

television and computer facilities

drains

piping for various forms of gases and liquids

flues for contaminated air

Another aspect of the mechanical system is a study of lighting levels and the type of light source to be used. Incandescent bulbs and fluorescent tubes both have their advantages and disadvantages in research and development buildings.

As mechanical systems become a larger and larger part of research and development buildings, maintenance of such systems increases in cost due to increases in time and materials. The mechanical system chosen should reflect some consideration of maintenance.

d. Flexibility

To justify a high rise structure, the enclosed space must be utilized at all times. The solution must solve the problem of changing the interior space monthly if not weekly, as the research project devèlops from an idea into a reality. Also such constants as storage, computer memory systems, and mechanical equipment systems must be located in a position that will not impeded the flexibility of the space. Included in this report are some of the preferred relationships of office and laboratory for different types of work.

Today, dimensional modules are the vehicle to set up a system of control of flexibility. Here the problem is to select a module which can be utilized by offices, laboratories, building materials, structural systems and mechanical systems.

Since this is a prototype building the main emphasis will be directed towards the solution of an integrated structural and mechanical system.

There are two types of spaces necessary for a research and development building. They are the spaces for static elements such as mechanical services, stairs, elevators, rest rooms, computers and storage systems; and the spaces for dynamic elements, such as workers, solids to separate workers, and machines to be used by workers. The static space is a function of the dynamic space.

The object of this thesis is to supply over 200,000 square feet of dynamic research and development space with its ancillary space in an urban area.

PROPOSAL

Description

The solution is a 14 story high rise building. Each story consists of a dynamic space (10'-6" high) and a static space (7'-6" high) with exception of the first floor where the ceiling height is 18'-0". The lower floor level contains dining facilities (vending machines), a small lecture area and permanent testing apparatus areas. The first floor is divdied into an interior space for displays and information and an exterior plaza where people may enjoy the life of the city and the sun. The other twelve floors are designed to be adaptable to any foreseen research and development work that can be done in the given space within the height and span limitation.

The static work space is the space which houses the mechanical services, the computer and memory systems, the television, telephone and electronic equipment, and the space from which the workers maintain all services. All machinery will be hung from the ceiling of the space so that the workers can service it without bending over. Many systems (i.e. air conditioning, electrical, drainage) must function as a system of spaces. Therefore, certain volumes within the static space have been alloted for certain systems.

The dynamic work space is an uninterrupted space in the shape of a square doughnut with the mechanical services and utilities in the core. The clear span is 50'-0". The outside dimension is 152'-6". The total usable space is a little more than 20,000 square feet per floor. The dynamic space can be divided into smaller units on a 5'-0" module in both directions. Each 5'-0" module will have an air diffuser and light.

The 5'0" module was chosen for the following reasons:

1. Studies of existing offices and laboratory spaces showed that 5'-0" was an acceptable module. 10'-0" seems to be a minimal office dimension and 15'-0" a minimal laboratory dimension, under present conditions.
2. Lighting units work very well within a 5'-0" module.
3. 5'-0" is a convenient module to use when precasting and hauling concrete units.
4. A 5'-0" x 10'-6" movable wall partition is the largest unit that can be handled by two men and carried in the freight elevator.

Structural Concept

The structural concept is a form of a Vierendeel truss which contains within it the static space and supports the dynamic space. The spacing of the cruciform columns is

75'-0" center to center. The major truss members bear on the columns or the utility core. Lateral bracing for wind loads is achieved by the cruciform column and the utility core. The columns and utility core will be poured in place concrete using slip forms.

The joint between the major truss and the column is designed to accommodate the horizontal temperature expansion problem. Vertical temperature expansion problems are solved by designing joints such that the structure can move.

Many studies were made to try and evolve a logical structural system, keeping in mind the concept of spaces. Floors need to be at least 4 inches in depth to cover the steel and work as a structure. This 4 inch depth will span a 5 foot module. An 8 inch to 10 inch deep beam 5 foot on center with a 4 inch concrete web will span 20-25 feet. Therefore, the solution was to put trusses 25'-0" on center with 25'-0" x 5'-0" beams spanning between them. The minimum required height in the static space including the structure is 7'-6". Working with a structural engineer it was found that a 75'-0" span with a design load of 400 lbs. per square foot for two floors dead and live load required a depth of 7 feet if the width was 2'-6". Therefore, the structural system as shown in the accompanying drawings was used.

The floor of the dynamic space is composed of a 6 inch deep web with a 2 inch topping poured on top. The 2 inch topping works with the web to form an 8 inch slab upon which the main loads are supported.

The resulting structural system is a result of functional needs and of a study of the relationships between bays, cores, voids, and supports of precast concrete.

The primary truss members are poured into two flat channels then post-tensioned to form a box-beam truss. In the calculations, 6000 p.s.i. concrete was used. This will require all the precasting to be done in a plant so that the finished product will be precise and have adequate strength.

The exterior concrete surface will be bush-hammered.

The construction process will be the following:

1. Excavation
2. Placing of footings or piers
3. Slip form core elements and columns one level high
4. Place precast truss and top floor members and pour 2 inch topping
5. Slip form core elements and columns one more level
6. Place precast members and repeat the process until the top is reached
7. The precast units to be used at the top are different but should be placed in the same method as the lower units

8. Mechanical equipment is placed throughout the construction period

9. The bottom floor of the static space can be placed at anytime since it is bolted into place

10. Windows and partitions are placed, and equipment is moved in.

Mechanical Equipment

The air conditioning system consists of water cooling units on the top floor, water heating units in the basement, and air handling equipment in each static space. The heated and cooled water is pumped to four air conditioning units on each floor. Fresh air is brought to the air conditioner from vents at each floor level and mixed with return air and delivered to diffusers placed 5'-0" on center in the ceiling. Flexible ducts connect to mixing boxes along a central plenum. Diffusers which are not delivering air are used as return ducts into the static space which is used as a return plenum.

The air conditioner is capable of developing a room temperature within one-half degree temperature and a humidity within one percent of the required amount. It can deliver from 100 per cent fresh air to 100 per cent re-circulated air.

All equipment will be sound damped by using leaded plastic coating at the noise source.

Movable partitions are 2 1/4 inch panels composed of an exterior veneer and 2 inch gypsum and coreboard center.

The lighting fixtures are designed to be serviced from above. They are an integral unit which functions as an air diffuser, acoustical panel and light reflector beside containing fluorescent or incandesent lights.

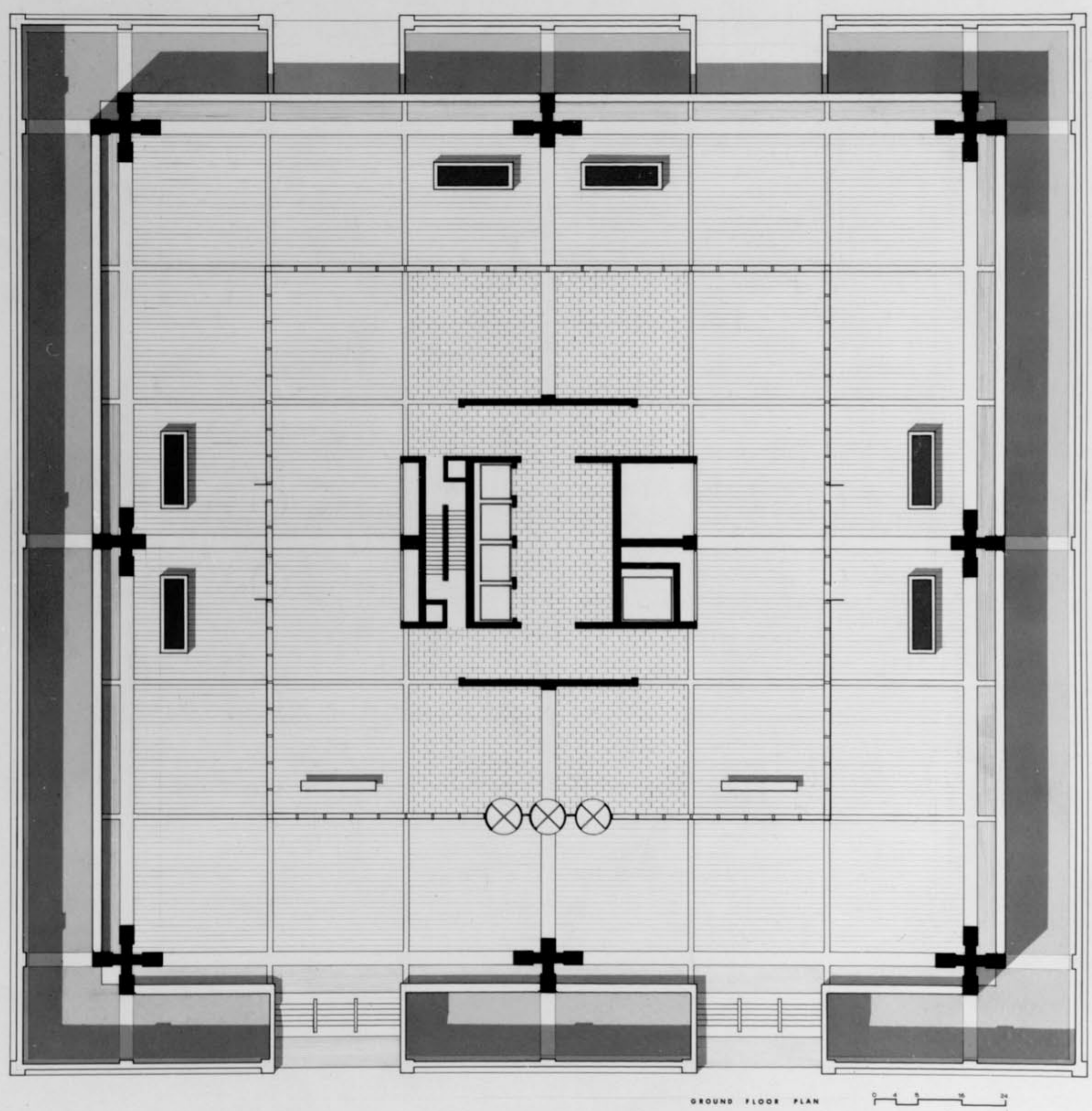
This explanation of a research and development building as a system gives the basic ideas that went into the prototype building shown in the following photographs.

Drawings

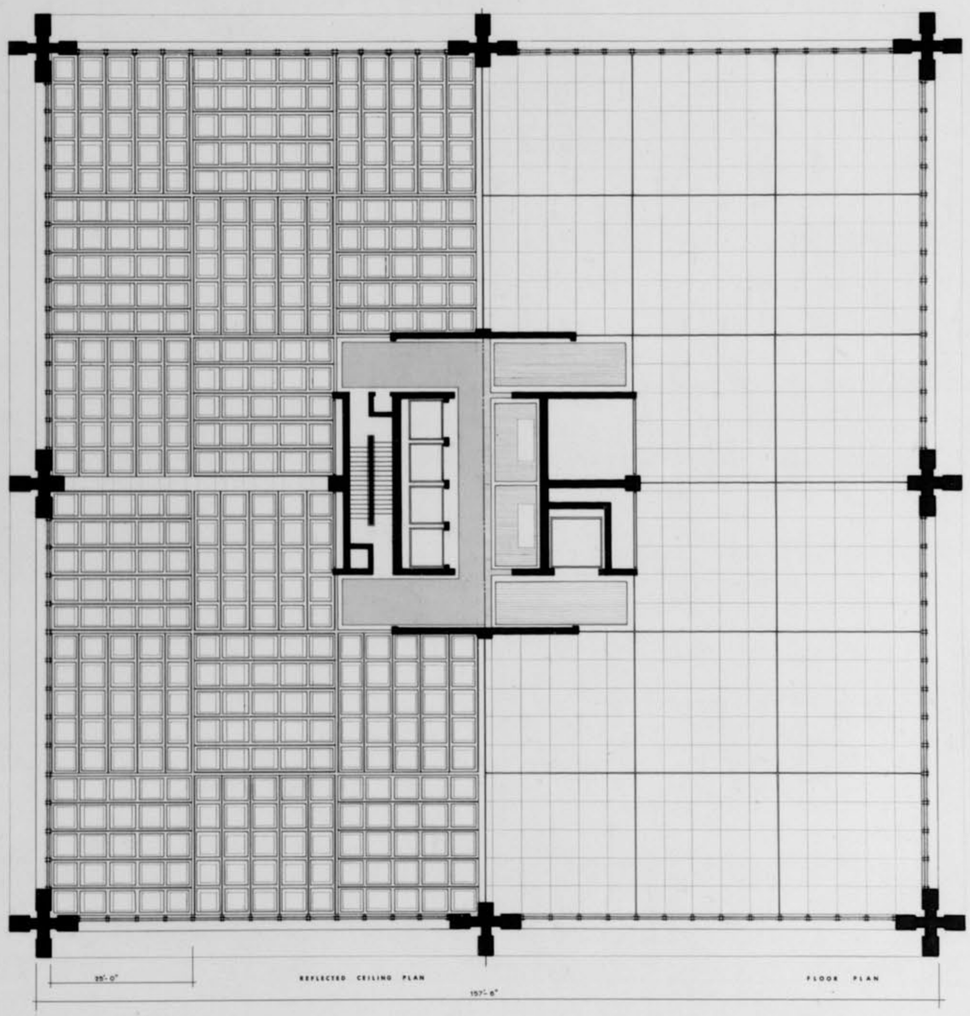
1. Plot plan (1st level) 1/8"
2. Typical floor plan (reflected ceiling and floor plan) 1/8"
3. Typical floor plan showing - mechanical systems (air conditioning, electrical and systems storage) 1/8"
4. Cross section of building 1/8"
5. Elevation 1/8"
6. Details 1/2"

Models

1. Overall model of building at 1/16"
2. Detail model of system

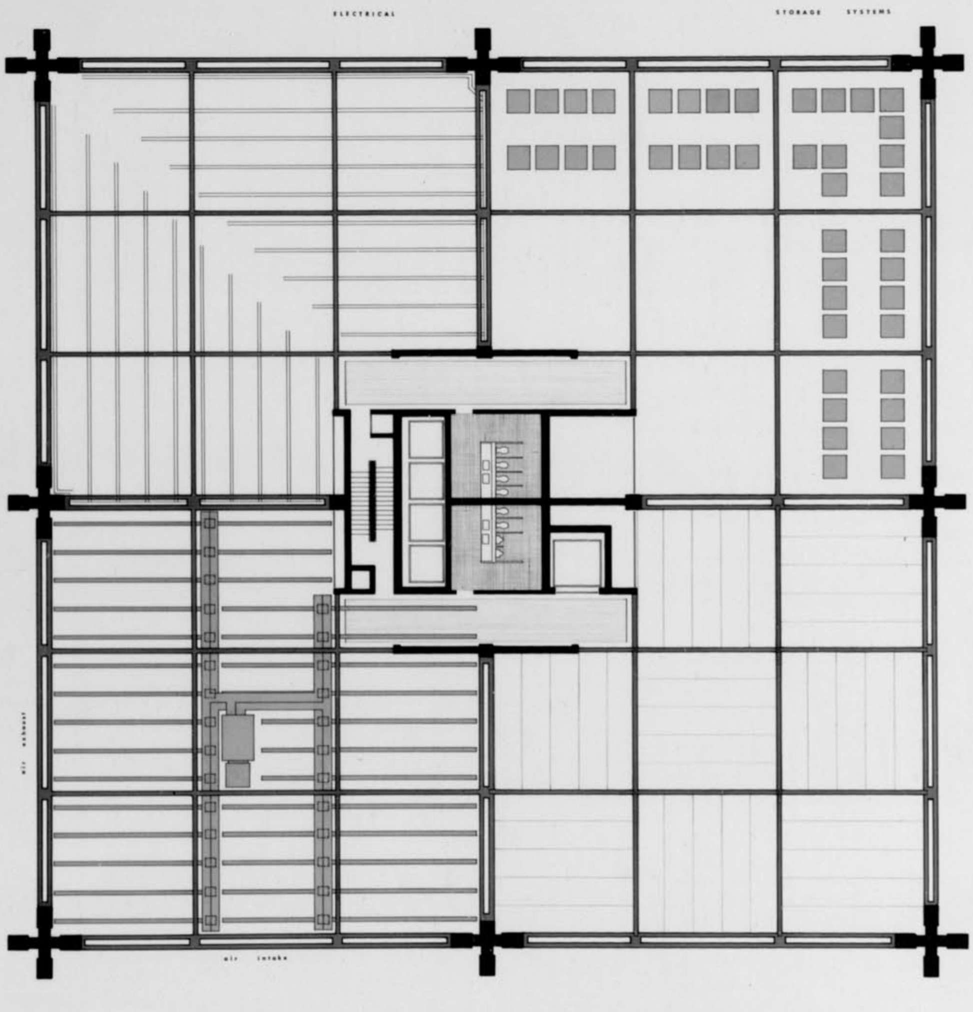


A PROTOTYPE RESEARCH BUILDING M ARCH THESIS M I T 1963 DWAYNE C NUZUM

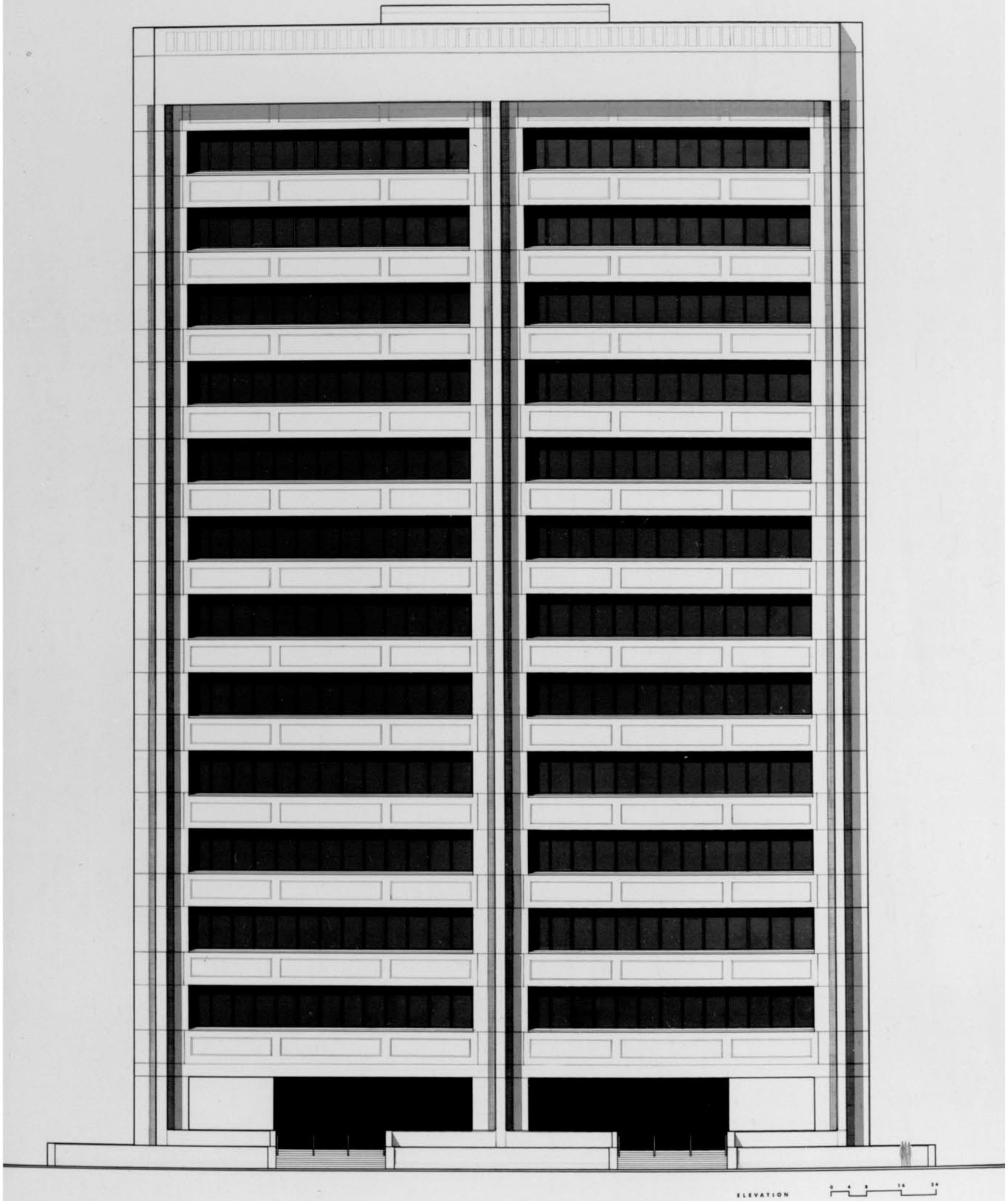


TYPICAL FLOOR PLAN

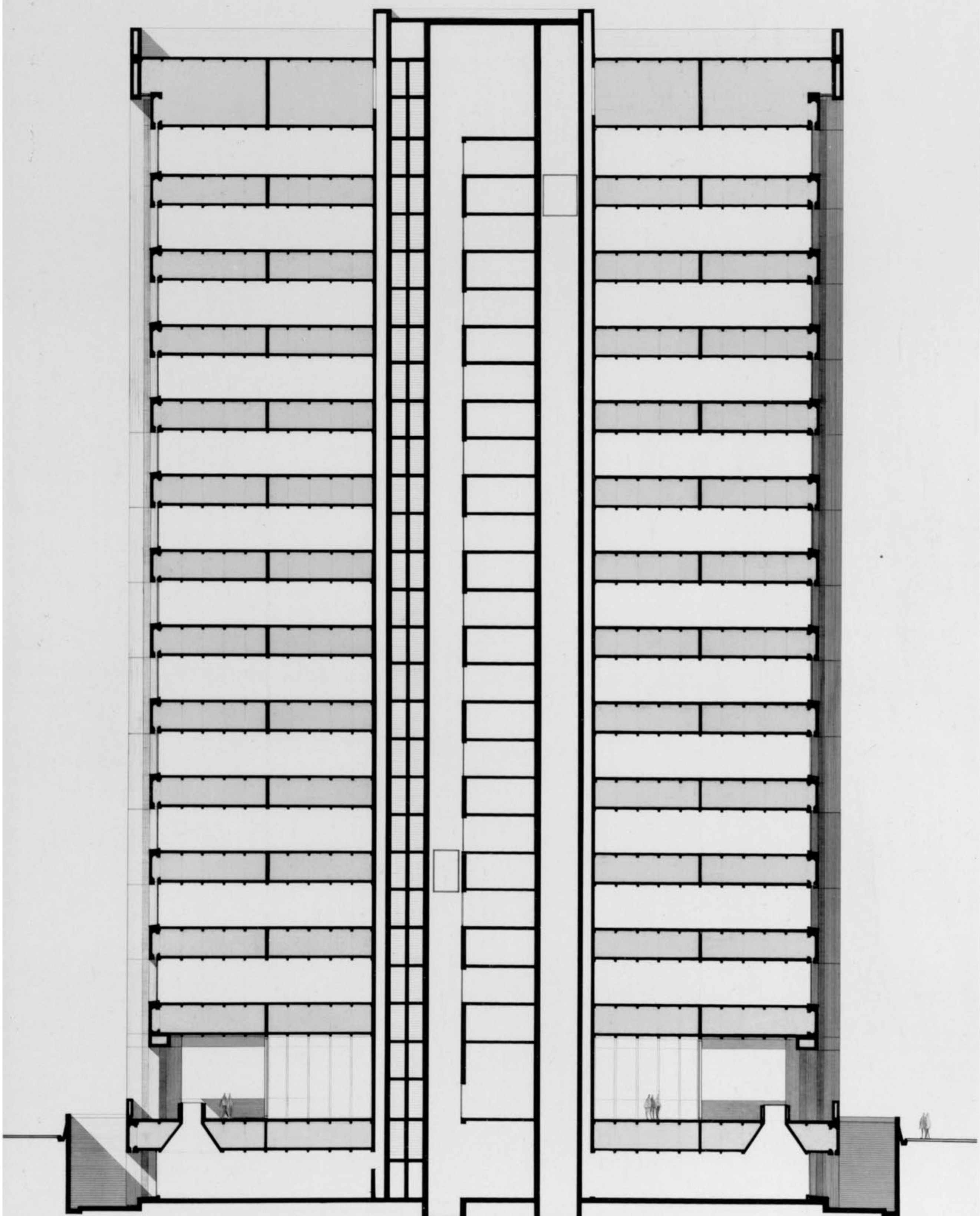
0 4 8 16 24



MECHANICAL FLOOR



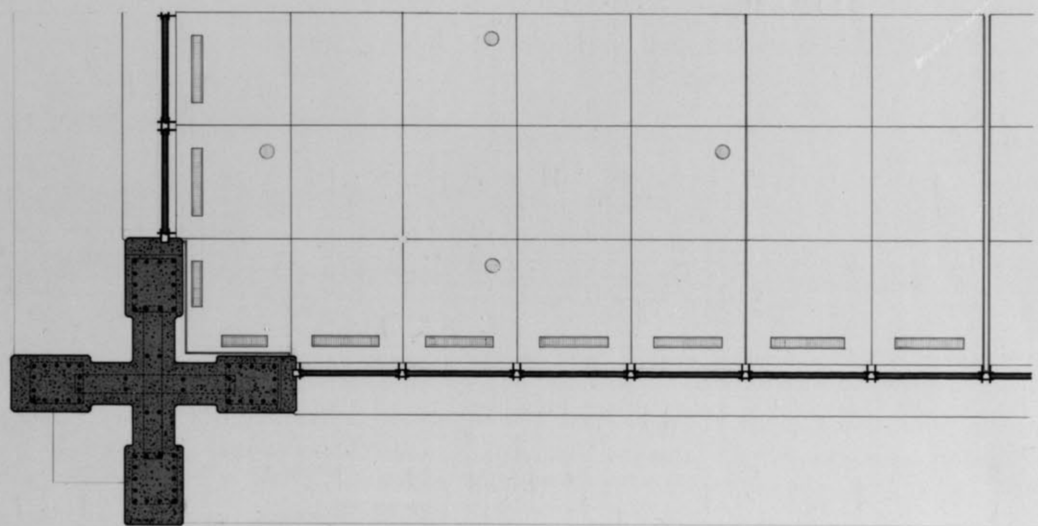
A PROTOTYPE RESEARCH BUILDING · M. ARCH THESIS · M. I. T. · 1963 · DWAYNE C. NUZUM



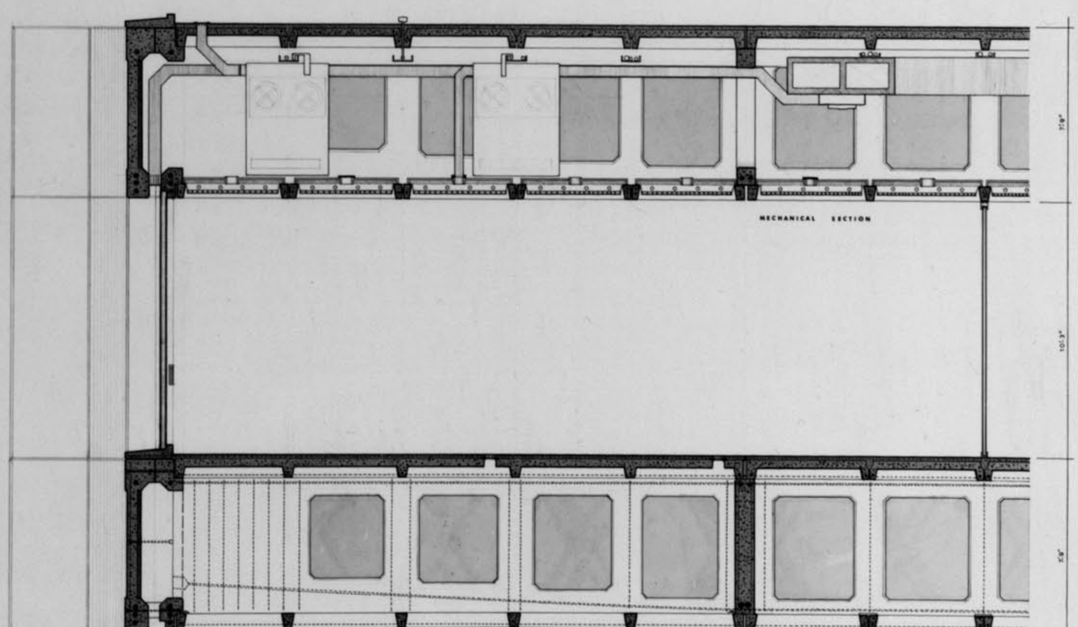
SECTION

A PROTOTYPE RESEARCH BUILDING · M. ARCH THESIS · M. I. T. · 1963 · DWAYNE C. NUZUM

5



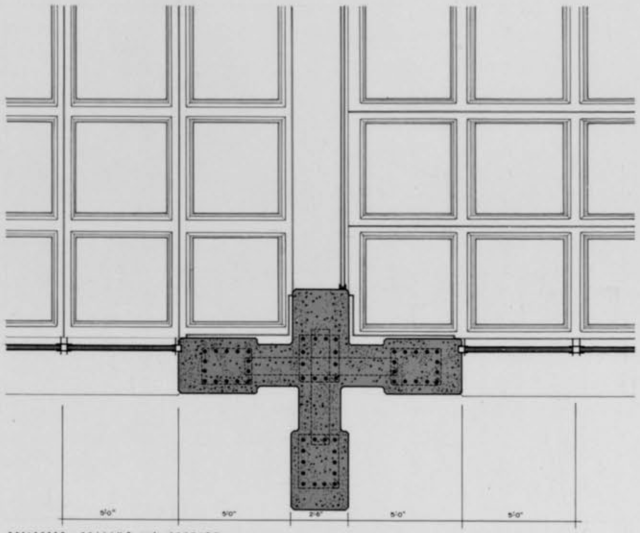
HORIZONTAL SECTION



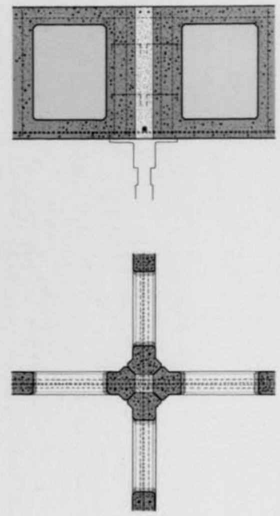
MECHANICAL SECTION

STRUCTURAL SECTION

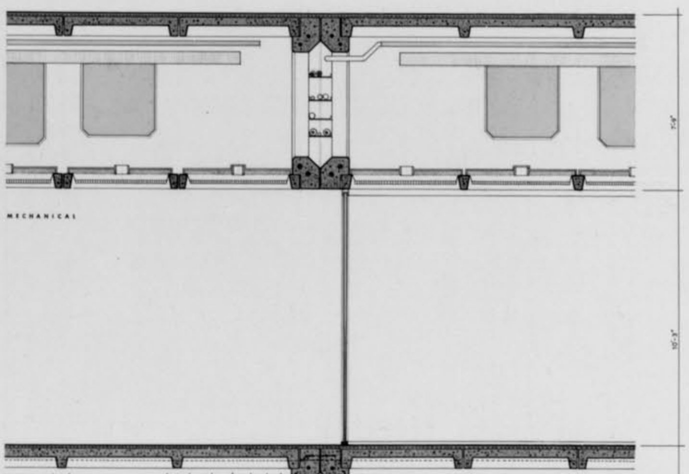
DETAILS



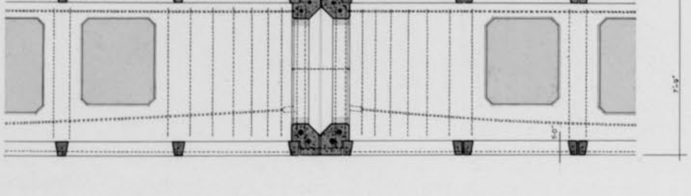
REFLECTED CEILING and SECTION



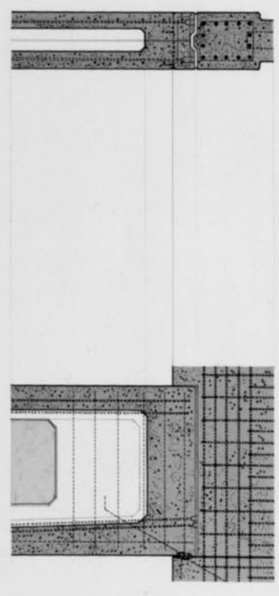
BEAM CONNECTION



MECHANICAL

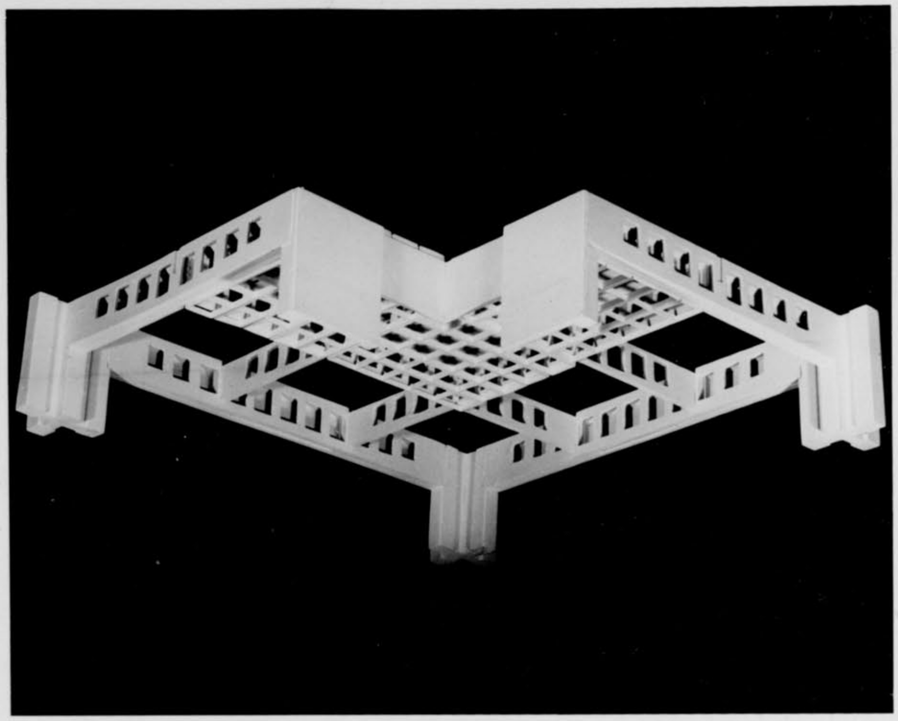


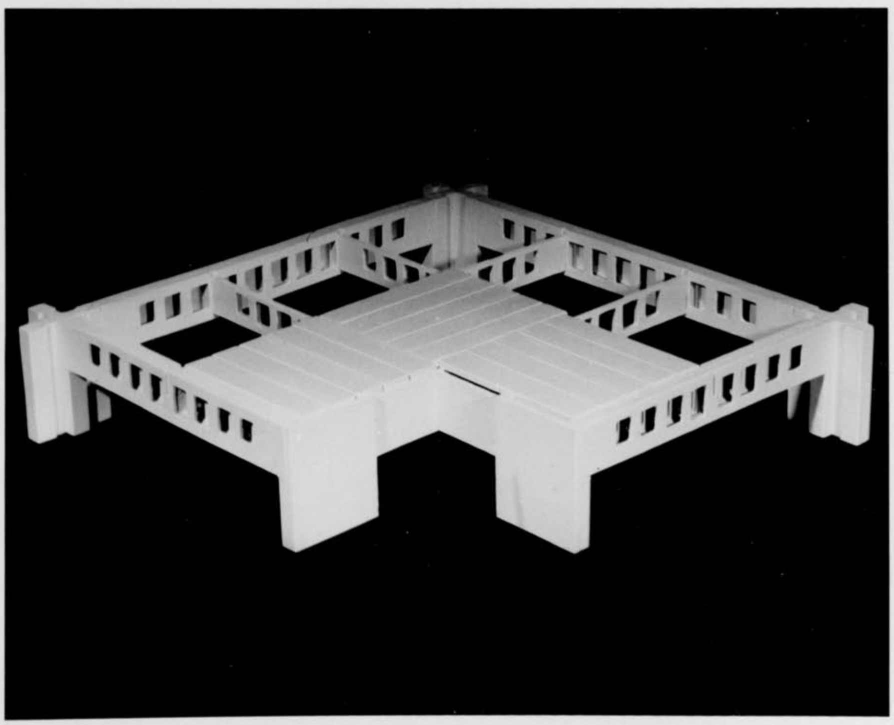
STRUCTURAL SECTION



BEAM TO COLUMN CONNECTION

DETAILS 0 1 2 3 4 5





THESIS PREPARED BY FREDERICK A. PREISS

OBJECTIVE

The development of a prototype research building utilizing precast concrete construction. The prototype building by elimination of specific site conditions, specific dimensional requirements, and budget, allows a greater concentration on the problems of function and construction, giving answers of broader significance and application.

APPROACH

Since 1950 space in relation to research work has become one of the prime concerns of management and, therefore, architects, the providers of space. A whole new concept has evolved--that of thinking of space as it affects work. The fundamental processes of research are problem solving and decision making. It is a sequence of subactivities each of which is essential to the ultimate accomplishment of a useful goal. They may be carried out by one person or many different people. The concept of research as a planned, organized approach by technically trained people to the solving of certain sorts of problems is a development of the last decade, but the essence of the research process is as old as Archimedes.

It will be noted that the author has specifically refrained from today's assumptions utilizing present day terminology (such as office space and laboratory space) in order to allow a new definition of space. A detailed program indicating dimensions of spaces and percentages of space types to one another has been omitted as well. Nevertheless, as a point of departure a working hypothesis was formulated. Those two hypotheses are the function and the square footage requirement.

Research today falls into the following categories:

Pure Research

Applied Research

Development

Testing

Since the activity of pure and applied research occupies the majority of spaces in todays research facilities, comprises the majority of time and effort put forth by research personnel, and requires a constant vertical space dimension with maximum flexibility in the horizontal dimension, the building's design focuses on these categories of research.

Study has shown that today's most complete research facility has between two hundred fifty thousand square feet and one million square feet. This is line with a trend towards buildings with large dimensions housing a multiplicity of functions. The author has chosen five hundred thousand square feet as a requirement.

The current problem is to provide an architectural frame within which spaces can be organized to meet this activity of research--not only to meet todays requirements but to be able to meet future requirements and experimentation of space to work. One large building with allowance for the proper balance of spaces provides a solution to this problem giving greater flexibility in meeting the need of research. Centralization of activities shortens lines of physical and mechanical communication, a key element to research, and increases personal contact opportunities and interchange of ideas and thoughts. There is a concentration and a more efficient use of services and a considerable savings in maintenance.

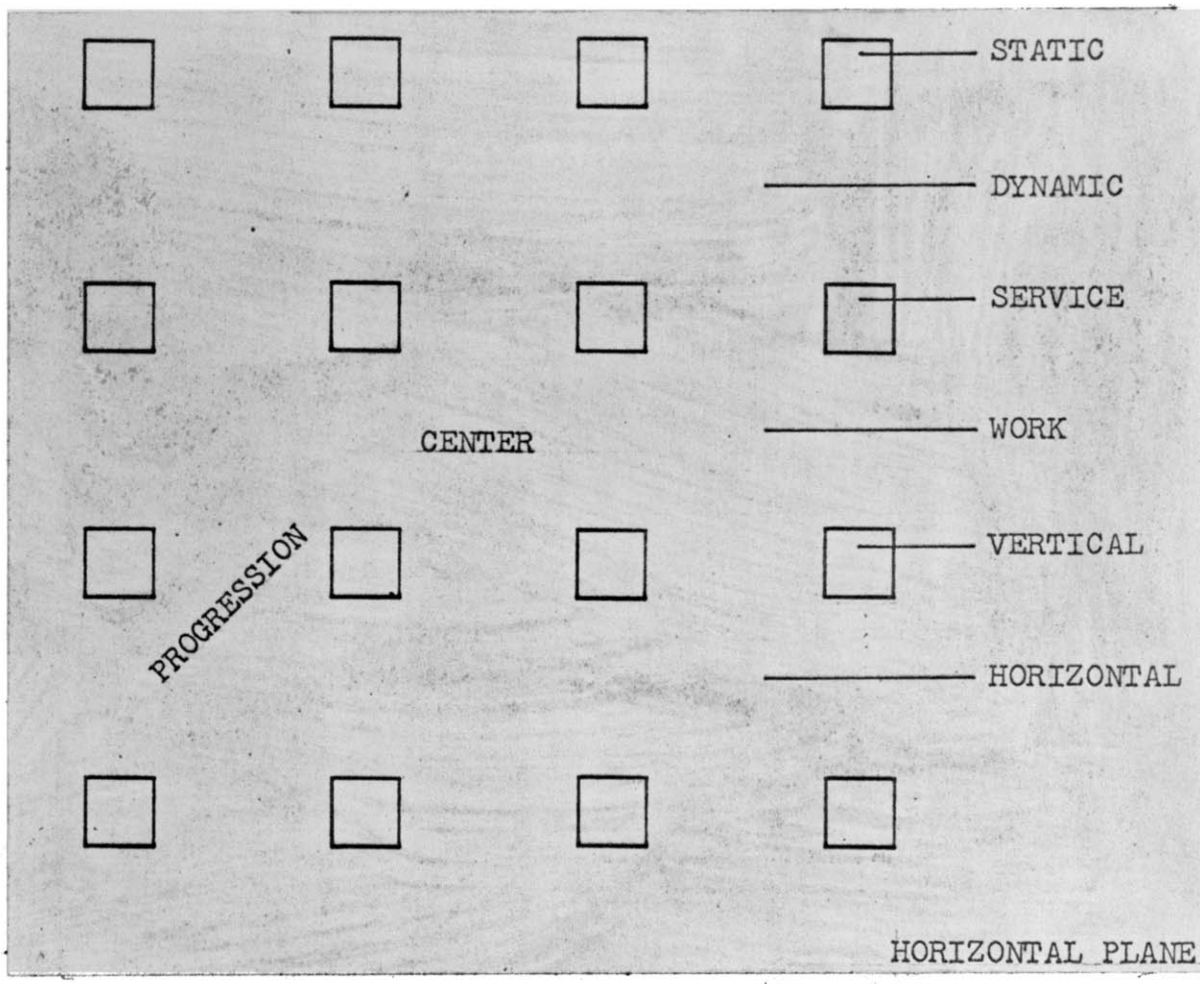
To attain the ultimate of space to work, space should have the ability to be broken down into a series of related space units with the possibility of future experimentation and programming by management aided by electronic computer-optimizing devices. The space created must be optimum in dimension, but also be evocative and non-distracting. It must be able to maintain the dignity and productivity of the individual, group, or project.

PROPOSAL

A dimension of five feet square is used as the organizing horizontal module and a dimension of ten feet is used as deck to overhead distance. This provides the frame in which the problems of structure, mechanical services, space division, and construction are solved. These dimensions were derived from the studies of human needs in relation to work and from studies of existing research facility spaces.

The building is conceived and organized according to the following:

Static space versus Dynamic space
Service space versus Work space
Vertical space versus Horizontal space



Structural System

Precast concrete has many advantages over other structural materials. Its main asset is that it provides both structure and finished surface and is fireproof. It lends itself with the use of prestress to long spans and it can easily be formed with high degree of precision and economy by used of repetitive forms under controlled conditions.

The horizontal structure is composed of precast elements and is a two way Vierendeel truss system on module. A two way system spanning a square bay has many inherent structural advantages in that stresses are more evenly distributed and each segment is dependent on one another for transfer of load. The span and depth are based on the optimum relationship of structure and mechanical services in regard to space function. A span of seventy foot is used with a structural slab depth of four foot-eight inches. The opening in each segment is three foot-two inches by two foot-ten inches in the majority of the truss system. The openings reduce as they near the support and at the support is a solid segment relating to and approximating the shear concentrations. The open dimension in each segement provides sufficient height for all horizontal services. The most critical is the drainage system run which requires a twenty inch drop from farthest horizontal distance to vertical return. The horizontal structure is composed of precast concrete long and short members tied together by prestressing in the bottom chord. Negative mild steel reinforcing is in the top slab which is placed monolithically with the precast elements. A concentration of negative moment occurs at the supports and requires additional steel reinforcement. The types of connections, segment openings, and special fastenings are kept to a minimum allowing for more efficient industrialized process in precasting.

The vertical support structure is in effect a large twenty-five foot square column. It is cast in place with vertical ribs corresponding to the horizontal structural system. The overall twenty-five foot square dimension was based on a requirement of services as well as providing sufficient bearing area for shear.

Mechanical Service System

The mechanical services are extensive in order to provide maximum flexibility in meeting the variety of work to be performed. The services are decentralized within the building, spread out and integrated with the structure to provide continuous services at any point.

Air conditioning is provided in the overhead plane to all areas of the building. The supply is a high velocity dual duct system providing hot and cold ducts originating from air handling equipment and terminating with the mixing boxes located on ten foot module. With mixing boxes on ten foot module, maximum control of the air environment is permissible. It is designed to provide this control in any area where there is a concentration of heat-emitting equipment or where there is a specific humidity requirement. Air handling equipment and vertical ducts are located within the vertical structure. The fresh air intake for the air handling equipment is located at the base of the vertical support and air exhaust is located at the top.

Telephone, electric, plumbing, and gas services are organized in the deck plane paralleling the air conditioning system supply lines and are small in dimension and occupy relatively little space. Drainage systems are required for both water and acid wastes. They are located in the deck plane paralleling the air conditioning return system. Service access in the deck plane is provided on three and two foot centers through ten inch diameter panels. This allows the connection of equipment and surfaces, required for work, to it. The equipment and work surfaces contain their own internal plumbing and electric systems.

Services related to a specific type of research can be added within the structure and access provided through service access panels in the deck plane. Access to overhead services is readily available.

Space Division System

Spaces are formed within the building by vertical space dividers on module between the deck and overhead planes. The dividers are the same dimension with a standard edge detail using a flexible gasket tying them into a metal supporting frame. The dividers have a variety of surfaces (such as formica, wood, metal) relating to the individual space requirement and are kept free from any mechanical services except electric light switches, allowing for maximum ease in movement. Deck to overhead dividers are designed to provide a forty decible transmission loss between spaces.

The deck is surfaced with a resiliant expoxy surface continusouly applied over the concrete slab.

The overhead is a continuous plane with chord elements intersecting on five foot module. Within each module a connection is provided to attach a standard metal frame. By use of flexible gaskets, panels with illuminating elements and acoustic enclosure can be attached. The air conditioning supply diffuser and return element is related to the illuminating and acoustical enclosure panels to form an integral unit.

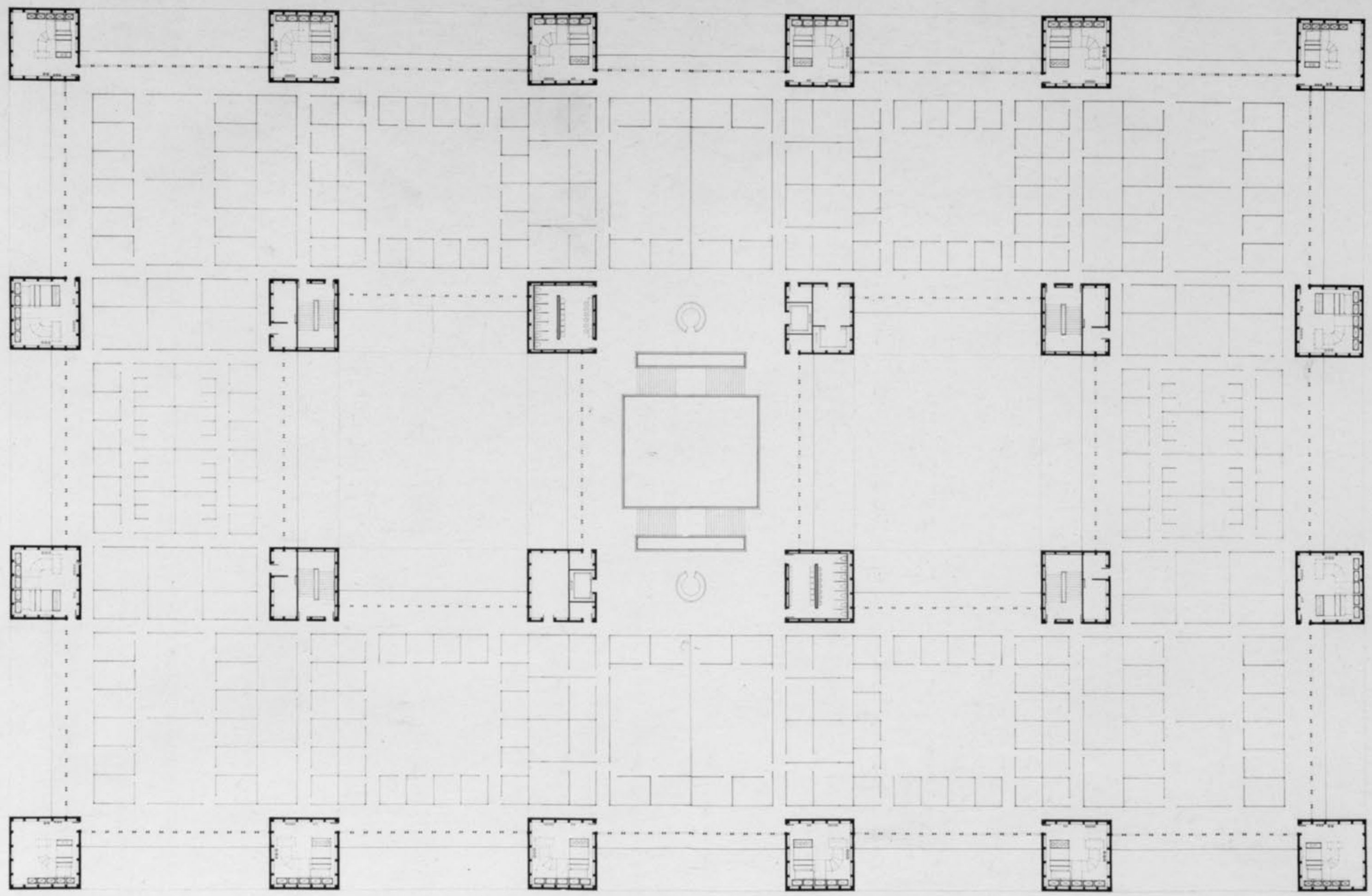
Construction

The most efficient procedure of construction involves the cooperative council and knowledge of the architect, engineer, and contractor. The following is a brief outline which could guide a more detailed investigation:

1. Excavate and place footings
2. Place service trenches and connect with site utilities
3. Place lower level slab and retaining walls
4. Erect form work and place vertical support to a level ten foot above deck
5. Place long precast elements on support; shore where required

7. Insert and pull through prestress steel in precast elements
8. Shim joints
9. Post tension bottom chord
10. Place cement-wood-fiber panels and top slab including slab over vertical support

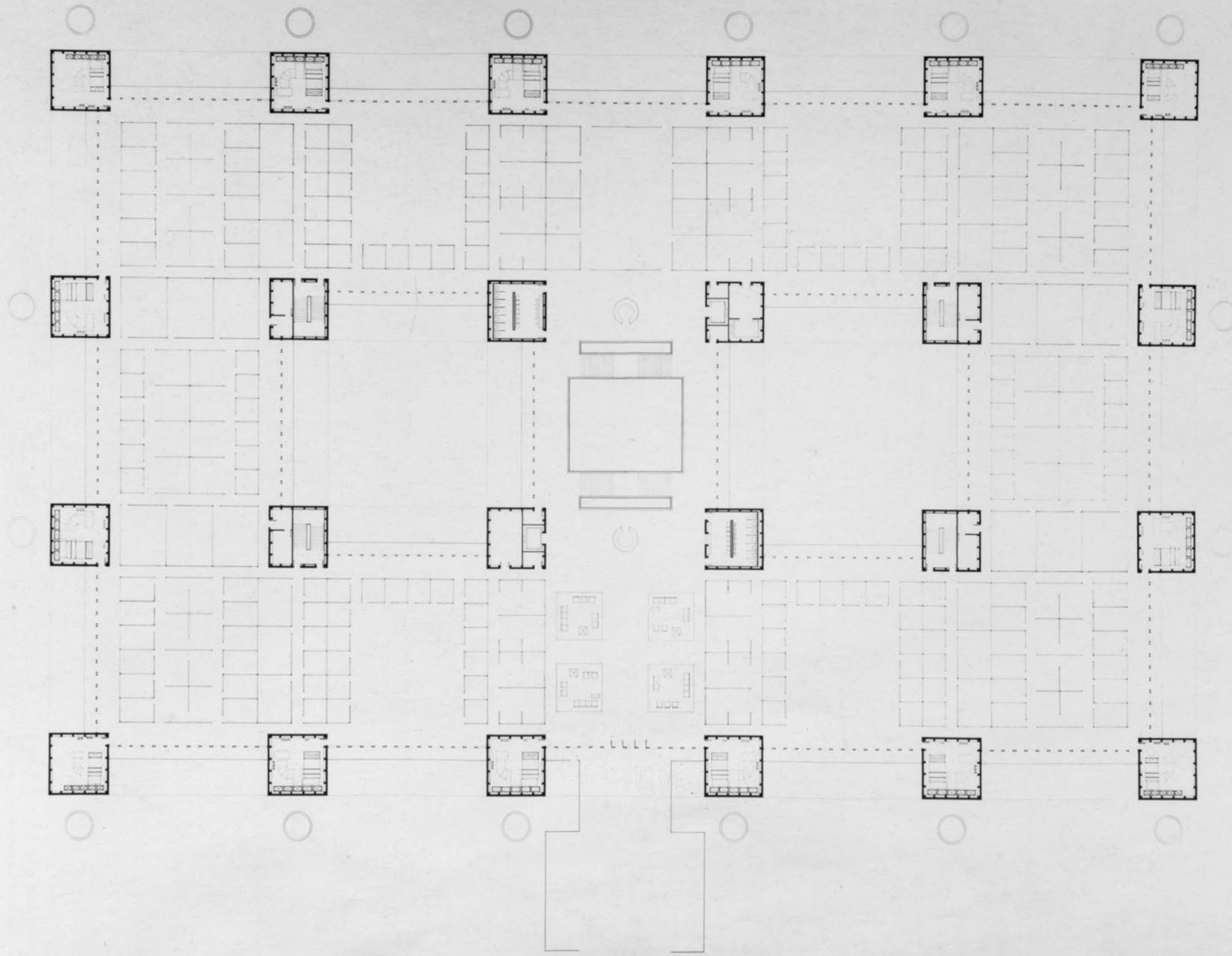
At this point the procedure reverts to step four and is repeated for three more floors. Mechanical service system and space division system are then installed separately respecting the structural sequence.



TYPICAL FLOOR PLAN

PROTOTYPE RESEARCH BUILDING

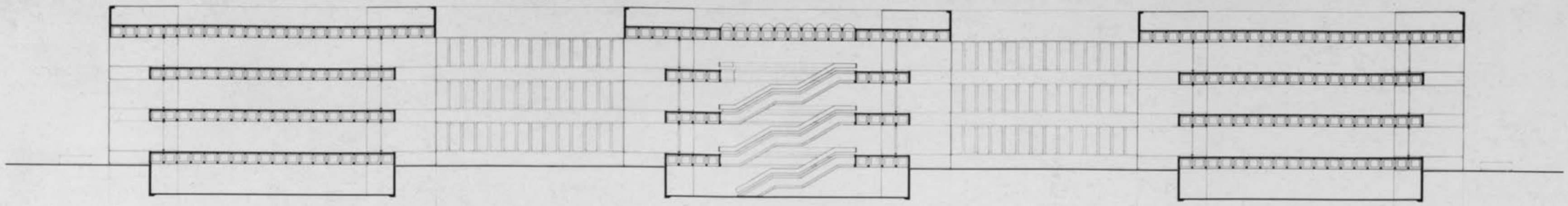
MASTER IN ARCHITECTURE THESIS
FREDERICK A. PREISS M.I.T. 1963



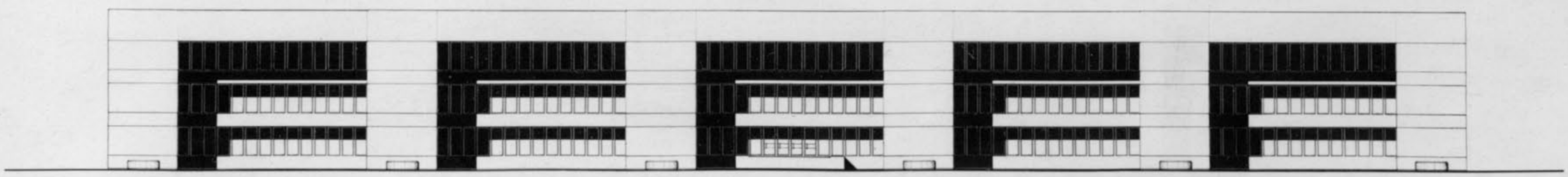
GROUND FLOOR PLAN

PROTOTYPE RESEARCH BUILDING

MASTER IN ARCHITECTURE THESIS
FREDERICK A. PREISS M.I.T. 1963



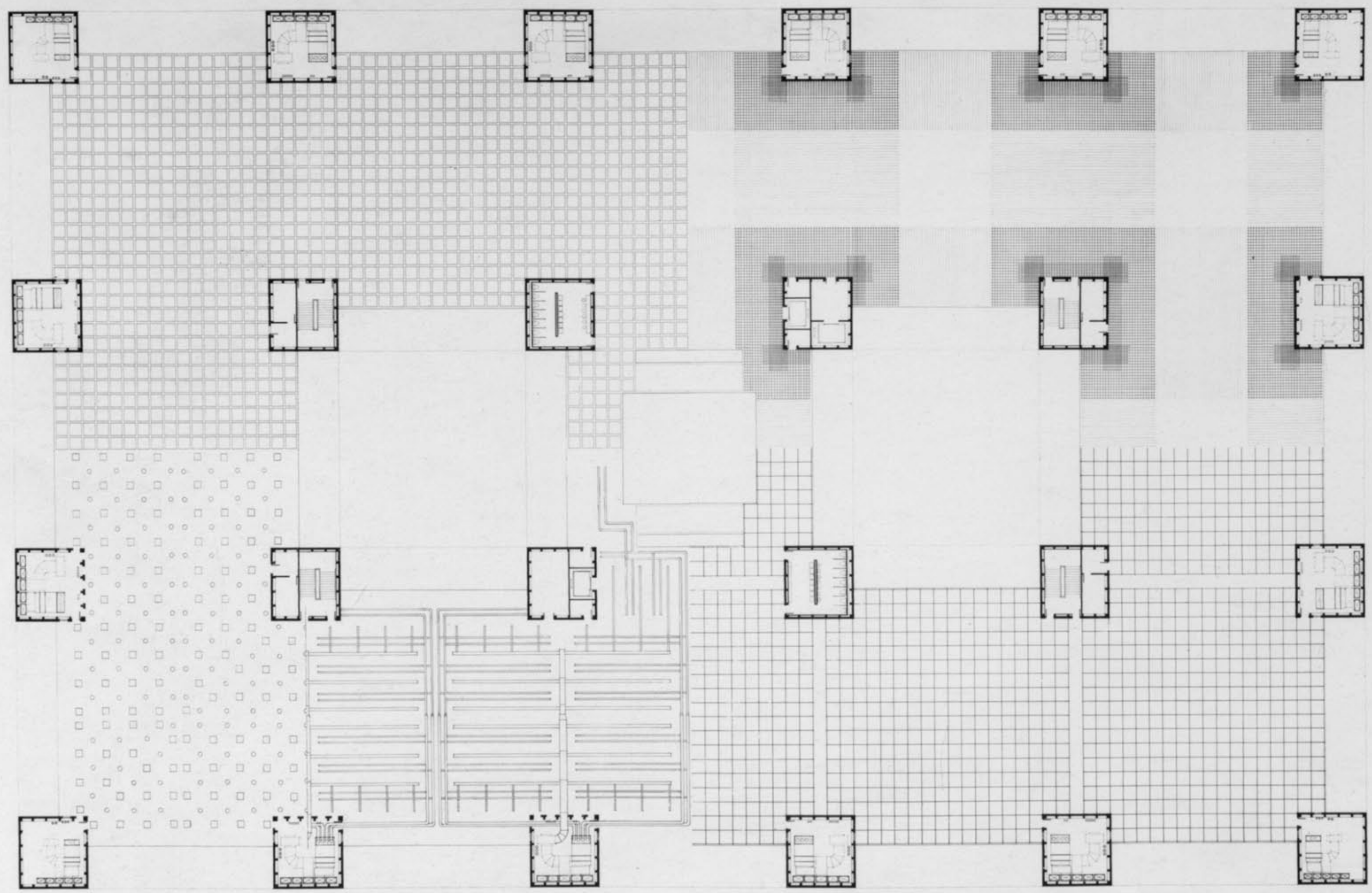
SECTION



ELEVATION

PROTOTYPE RESEARCH BUILDING

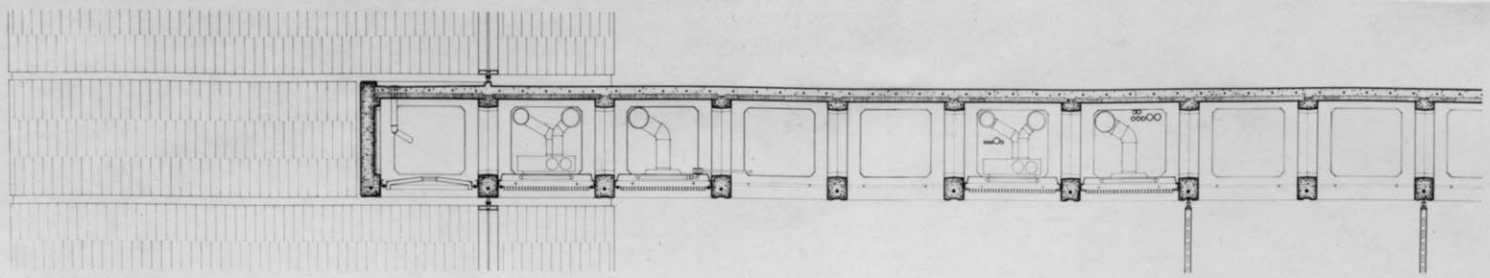
MASTER IN ARCHITECTURE THESIS
FREDERICK A. PREISS M.I.T. 1963



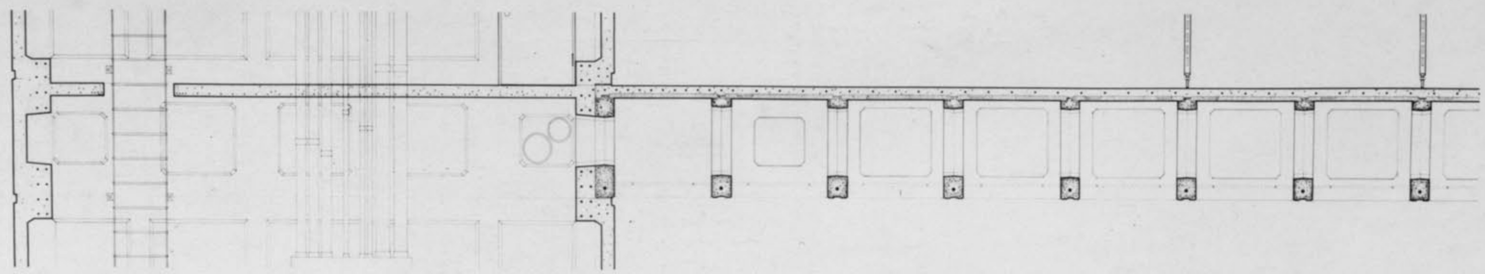
STRUCTURAL AND MECHANICAL PLANS

PROTOTYPE RESEARCH BUILDING

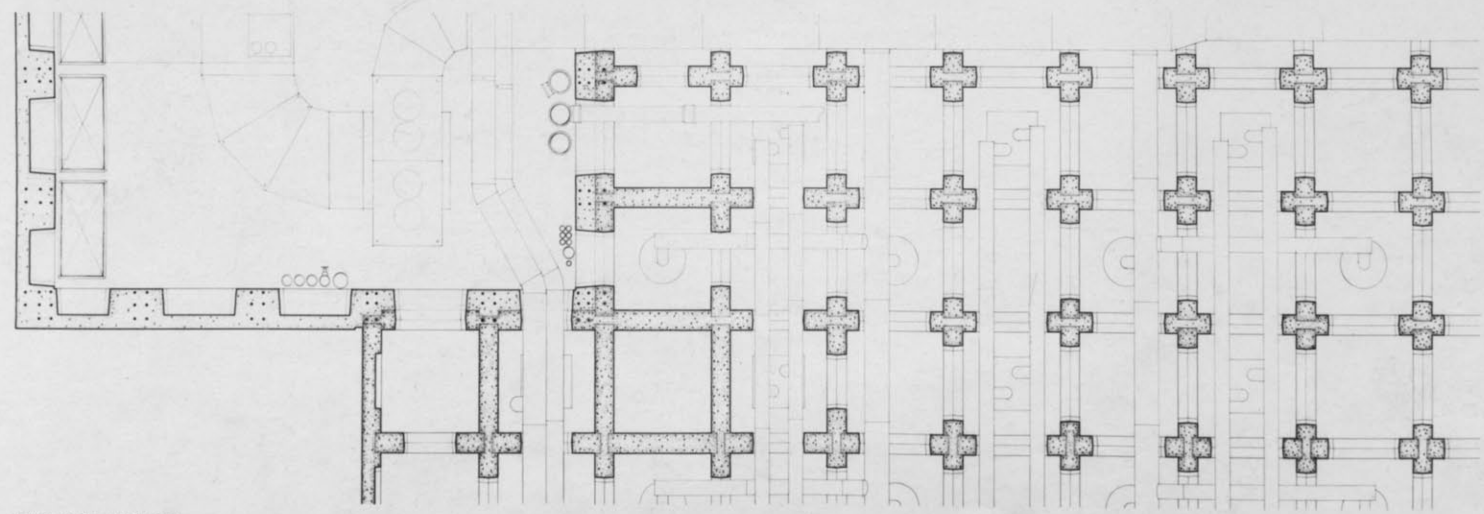
MASTER IN ARCHITECTURE THESIS
FREDERICK A. PREISS M.I.T. 1963



VERTICAL SECTION — MIDSPAN

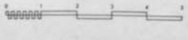


VERTICAL SECTION — SUPPORT



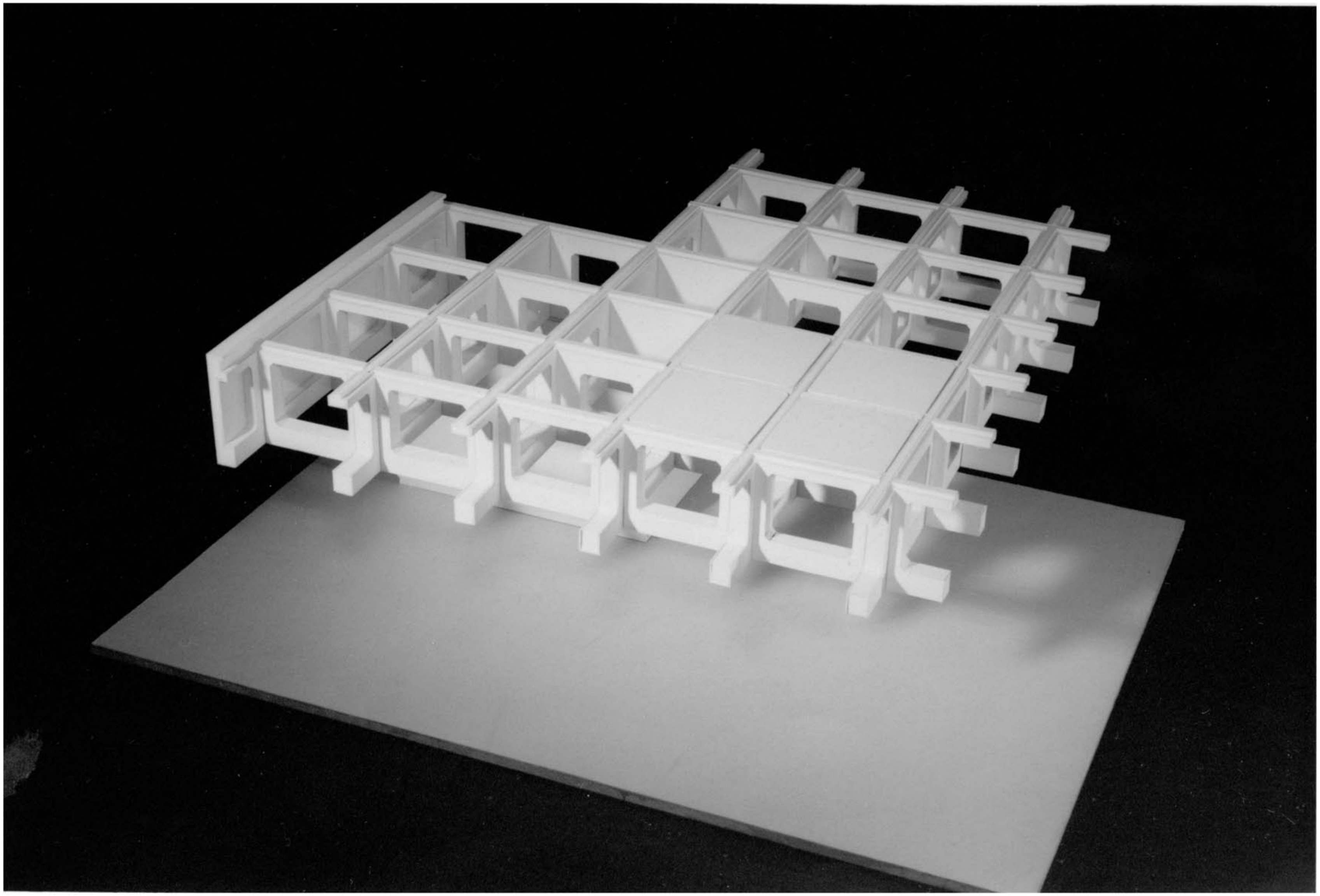
HORIZONTAL SECTION — SUPPORT AND SLAB

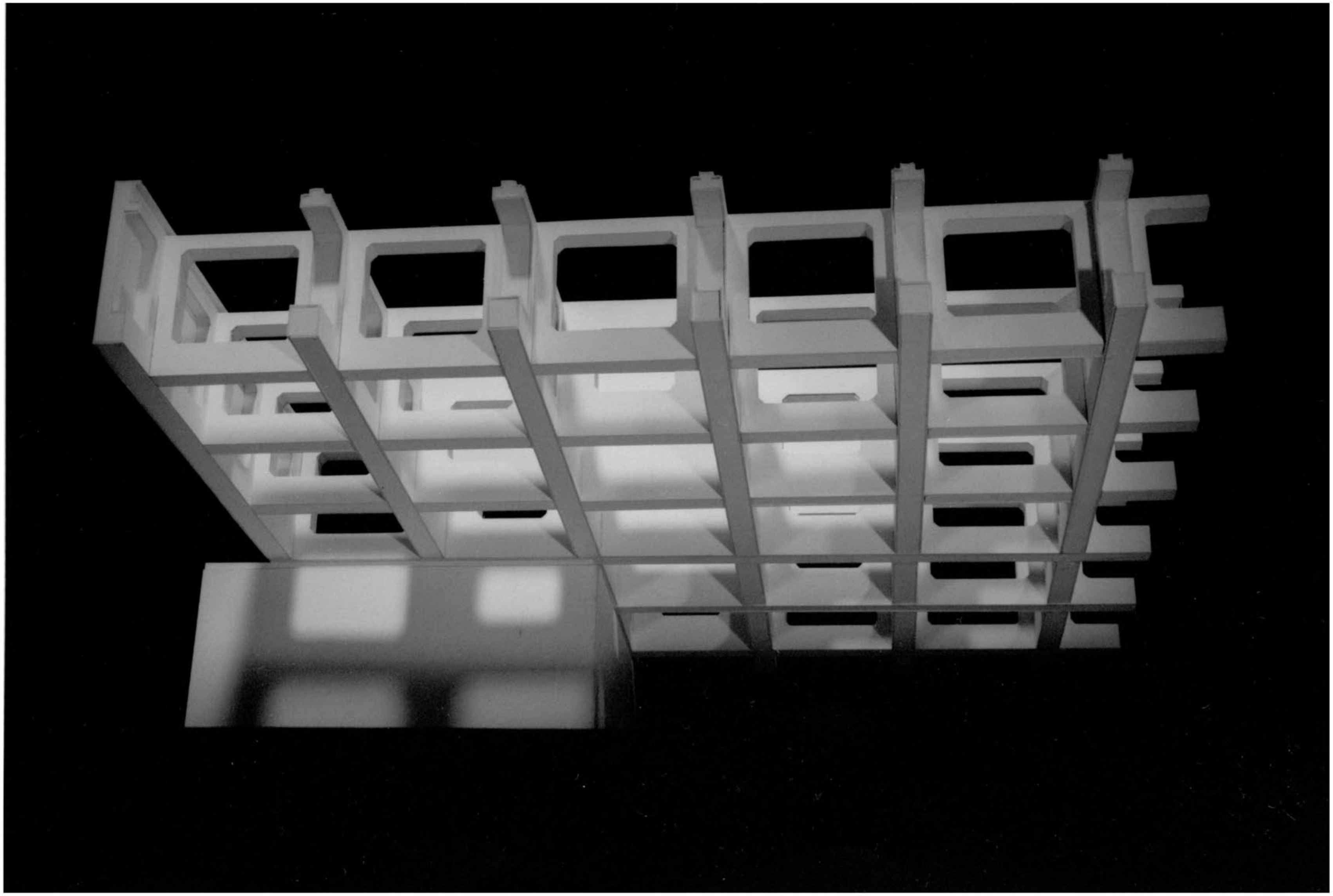
STRUCTURAL AND MECHANICAL SECTIONS

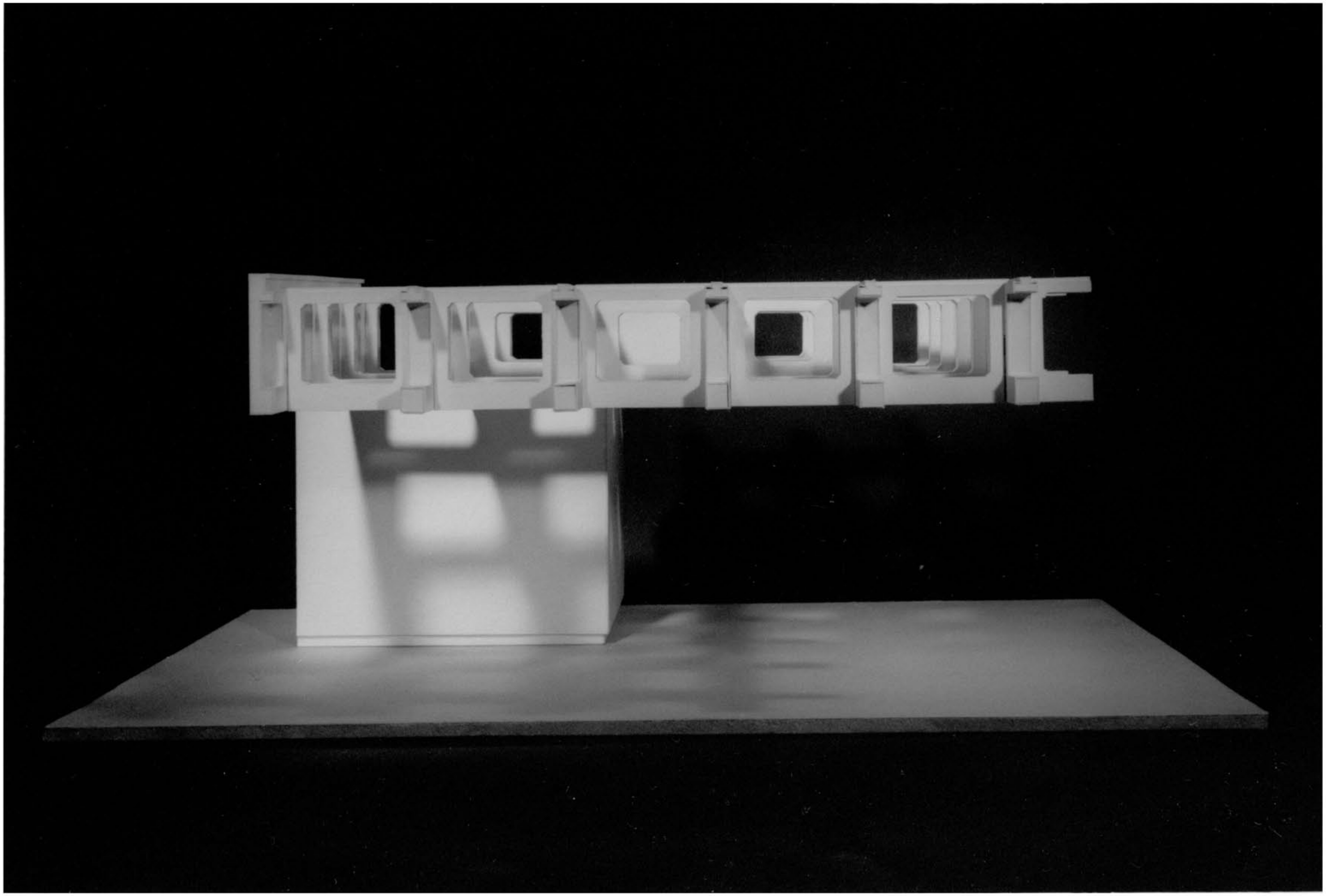


PROTOTYPE RESEARCH BUILDING

MASTER IN ARCHITECTURE THESIS
FREDERICK A PREISS M.I.T. 1963







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APPENDIX

copy of report submitted to School Industrial Management for NASA research project (minus photographs)