

THREE PRECAST CONCRETE HIGH RISE
OFFICE BUILDINGS

ABSTRACT

This thesis is concerned with the utilization of a system of precast and prestressed concrete to formulate the structure of a multi-story office building. Special attention is given to the efficient integration of the structural and mechanical elements concomitant with the simplification and continuity of design and construction.

PREFACE

By presenting the three individual theses with a common analysis of material pertinent to the design of each thesis it is hoped that a more rich and extensive result has been attained.

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INTRODUCTION

The precasting of concrete structural elements has been common practice since the conception of reinforced concrete as a structural material. However it is only in the last few years that precast concrete has been widely applied to structures in the U.S.A.

The first notable all precast concrete structure was the Richards Medical Building in Philadelphia. The building was designed by Louis Kahn and the structural engineer was Dr. August E. Kommandant. This is an eight story rigid frame structure.

Since the now widespread use of prestressed concrete it has been possible to have longer spans in precast concrete. In the Norton Building in Seattle, a 20 story office building designed by Skidmore, Owings, & Merrill, precast pretensioned girders span 70 feet. Using these new structural techniques it is now possible to envisage longer spans and taller buildings in precast concrete. In 1948 Myron Goldsmith designed a project for an 86 story 1 x 3 bay building, by forming a verendell of six platforms. Between each platform there are 15 intermediate stories, seven of which are suspended from the platform above and seven are supported from the platform below. This was a very interesting project as he used prestressed concrete for his main structure, and it offered many good points to be considered.

Reinforced concrete is rapidly taking over from structural

steel as the major structural material for High-Rise Office Buildings, as used in the C.B.S. tower in New York and the Brunswick Building in Chicago. Concrete has many advantages over steel, the main one being that it is a fireproof material.

Precast concrete has many advantages over "in-place" concrete, and the potentials of precast concrete have been expressed in a few recent buildings. The material is essentially a dry construction and offers considerable saving in formwork and scaffolding. It has also, a much faster erection cycle. The material is manufactured under factory conditions, and can take full advantage of industrialized processes. This will ensure quality and dimensional control. Due to technological advance, the handling and transporting of elements is no longer a problem.

Stringent and unprogressive code requirements have been a drawback in the use of precast concrete for High-Rise Office Buildings. But one of the main reasons for it not being used more often is the problem of joints; the system has an inherent lack of stiffness. This is one of the main challenges to the ingenuity of the Architect and Engineer.

For a number of years most of the office buildings built in the U.S.A. have been clad in lightweight curtain walls. These walls have a flat and shiny appearance and lack modelling and texture. The strength and character of precast concrete cladding is one of the reasons for its current popularity. The Pan-Am building in New York is a recent building which is completely clad with precast panels. Precast panels easily meet the fire

regulations. The quality of finish is excellent and can be expressed inside as well as outside. The surface absorbs some moisture, relieving pressure on the joints. Handling and transporting the elements is no longer a problem. The handling process, in fact, often puts more stress on precast wall panels than they will be exposed to after erection. In fact they are far stronger than their ultimate design demands. This prompts the designing of these precast pieces as load bearing elements.

There have been many low-rise buildings constructed using a precast structural facade. The Police Administration Building in Philadelphia by the Architects Geddes, Brecher, Qualls & Cunningham is a fine example of the flexibility of the system in its application to a curvilinear shaped building. Yamasaki's new Research Building at Harvard is an interesting example of the use of long span prestressed wall and floor units.

So far, little has been done to build High-Rise Structures using precast elements. We are making this the basis of our study and we are going to investigate the potentials of the system and its application to High-Rise Office Buildings.

I. Advantages of Precast Concrete

The basic question whether it will be cheaper to erect an office building with a steel or reinforced concrete frame will depend upon the ratio of wages to cost of materials. Wage rates generally govern the cost of concrete construction, the opposite being true in the case of steel construction. Many times the local trade agreements determine the wages and practices required in concrete construction. As an example, New York trade unions forbid the reinforcing steel to be prefabricated off the job site, thus adding to the cost of reinforced concrete construction. Assuming a situation free of distortions caused by unreasonable labor practices, reinforced concrete and particularly precast prestressed concrete has certain definite advantages over steel construction. The most obvious disadvantage of steel construction is that all its components have to be provided with fireproof casings which is not only expensive but which also destroys the distinctive features of steel construction, while precast concrete not only expresses its natural form but in most instances also functions as a finished surface. The advantage of being able to continue construction during cold weather which has been a definite advantage in the past in taller office buildings using steel has been eliminated with precast concrete. The precast members can continue being cast in the plant during freezing weather and assembled on the site in much the same manner as steel members. Precast concrete using prestressing techniques has an added advantage of longer spans with smaller depth than is possible with

steel members.

II. Types of Precast Concrete Systems

A. Floor Framing Systems

There are three primary types of precast prestressed floor systems; the two way system, the one way system and a combination one way and two way system. The simplest method is the one way system. It employs only one typical member if the core is continuous the length of the building or if not requires a girder which in turn frames into the core. Only in the most sophisticated applications of one way systems is both pretensioning and post tensioning performed, the pretensioning carrying the stresses due to handling and dead loads and the post tensioning carrying the live loads and any topping used as a diaphragm or finished floor. The two way floor system may involve only one typical member post tensioned in two directions or one or more typical beams pretensioned with filler panels which are post tensioned forming a two way matrix. In all cases two way systems require post tensioning which involves a more complicated procedure than prestressing. Post tensioning involves placing the jacks on the structure and tensioning the cables after they have been threaded through the members. In a system using pretensioned beams and post tensioned filler panels as in Kahn's Richards Medical Center the beams may carry only the handling stresses and dead load of the beams and filler panels during erection. The filler panels after post

tensioning take a portion of the dead load and live load and begin working with the pretensioned beams as a two way system when all prestressing is completed. Another two way system involves using only one typical unit which after being shored into proper positioning with other similar units is post tensioned in both directions and acts as a two way matrix. Although it eliminates the need for pretensioning this method requires the threading of cables and post tensioning in two directions. A combination one way and two way system involves using a one way system in the interior quadrants and post tensioning the corner quadrants to form a two way system. As with all two way systems a problem of high stress concentration at the corner of the core is created by one half the stresses of the corner quadrant being transferred to one point.

B. Precast Vertical Framing Systems

There are essentially two types of framing systems above the first floor, the load bearing wall or window unit and the column and spandrel. In both cases the transferring of load from the unit above is a problem. All the load in the steel of the column or window unit above must be transferred through steel and not through concrete into the column below. Various methods are possible using shims and welding or bolting. Post tensioning of columns is to be avoided if possible since it reduces the capacity of the columns. On the ground floor the exterior bearing wall or columns if they are closely spaced may bear on a transfer girder which

transfers its load into base columns and into the footings. If columns and spandrels are used in the typical floors the columns may continue directly to the footings instead of bearing on a transfer girder if the soil conditions deem it practical. An example of a precast window unit bearing on a transfer girder is the new Police Administration Building in Philadelphia. Saarinen's C.B.S. Building and S.O.M.'s Chase Manhattan Bank in New York City are examples of a column and spandrel system not framing into a transfer girder.

III. Planning

A. Room Access from Corridors

The subdivision of an office building on plan may be based on either of two principles: the various rooms are accessible from corridors (in which case single double and triple layouts may be distinguished) or alternatively, access to the various parts of the layout is gained directly from the utility core and corridors are dispensed with.

Single, double and triple zone layouts are based on the provision of corridors giving access to the various parts of the layout.

Single-zone layouts are relatively expensive, as the corridor has rooms on one side only. Layouts of this kind are primarily suitable for buildings such as schools, where requirements of hygiene rather than economy are the determining factors.

The double-zone layout, on the other hand, may be regarded as the typical solution for a medium-sized office building. However access to a double-zoned layout may have to be provided in the form of a main and a secondary staircase, a central utility core, two utility cores of equal importance or one centrally located utility core in a connecting unit of the building.

In high multi-story buildings the space requirements for utility cores increase so considerably that the double-zone layout with utility cores located in the office zone becomes a questionable arrangement. The vertical circulation facilities take up valuable office space, and their location within the office zone complicates both the structure and the internal planning of the building. For these reasons the triple ~~zone layout has been evolved.~~

The triple-zone layout consists of a utility core with fire stairs, lavatories and service rooms at each end of the building forming two zones. These two zones are separated by corridors which surround the vertical transportation concentrated in the central area which forms the third zone. This solution tends to restrict the flexibility of the plan to certain office proportions and the greater depth necessary for accommodating larger spaces in plan may not be available.

The determining factor in the layout and arrangement of the utility cores of a plan is the purpose for which the office building is to be used. In administrative buildings internal circulation is the dominant feature, whereas in buildings containing rented offices, traffic within the building will consist mainly of

the movement of people going from the street to any particular office and vice versa. In the latter type of building the service area should be centrally located and should give access to the various offices on each floor without necessitating long corridors. For this reason triple zone layouts are unsuitable for buildings containing rented offices. These layouts are generally employed in high multi-story buildings which are predominantly administrative in character, which have relatively little pedestrian traffic to and from the street, but which do have a considerable volume of internal circulation between floors.

B. The Open Layout

The layout without corridors, which has large artificially lighted and ventilated rooms has been evolved in the United States. It is based on the subdivision of the office floor into large spaces in which smaller separate rooms are provided for senior staff only. This system permits better utilization of the available space, cuts out the considerable cost of rearranging partitions, facilitates supervision of employees and permits much more economical lighting installations. Noise is a disadvantage of the open layout; it can of course, be mitigated by suitable design of the ceilings and walls.

The answer as to whether office staff are able to work with greater or less efficiency in one large room rather than in a number of small separate rooms will primarily depend on the mentality of those concerned, but also what they have been accustomed to in

the past. In Europe the subdivision of the available space into small individual offices is preferred even though this arrangement is operationally less favorable and involves higher construction costs.

One of the most significant advantages of the layout is the saving in space. Whereas a net area of 80-90 sq. ft. must be provided for each employee in a layout based on the two-person room, this figure can be cut down to 43-54 sq. ft. in the case of offices planned on the open layout principle. In the open layout individual rooms can also be varied not only in width but also in depth. In the layout of desks one should try to make this unit dimension identical with the planning module for the layout of the rooms. Depending on the desired distance between desks the unit dimensions will be between 4 ft. 6 in. and 6 ft. A multiple of this dimension will give the length of the smallest individual room. The recent tendency in the United States has been to arrange desks so as to provide the most favorable operational pattern. These groups are then separated by sound absorbing partitions of ceiling height or lower. This layout is based on a unit of area equal to that required for one employee's desk and chair or the unit module of such an area. By this means a more intimate atmosphere is created within the office, while the advantages of the open layout are also retained.

IV. Mechanical Systems

The majority of office buildings constructed today in the U.S.A. have sealed windows and the environment is controlled. The air conditioning takes care of: heating, cooling, ventilating and humidity control. With controlled environment it means that the entire office floor can be arranged to suit any plan, and therefore complete flexibility.

The main mechanical rooms may be located as follows: middle floor, top and basement floors, or in individual mechanical rooms located on each floor. The positioning of the mechanical rooms is a function of the height of the building and subsequently the length of vertical runs. Due to the amount of equipment and ducts the main mechanical rooms will require a considerable volume of space.

There are many mechanical systems and the problem is to select the system for the correct situation. The first system is an "all-air" two duct system, where one duct is for warm air and the other for cool air. These ducts are then linked to a mixing box, which then distributes the air to the rooms at the desired temperature. The second system is the High Velocity Periphery System. This is a combination of air and water. The air is supplied at high velocity into induction units at the window from which it is distributed into the room. Over the induction units are coils linked to hot and cold water pipes. The air temperature can therefore be controlled thermostatically at each induction unit. The periphery system can take care of all unbalanced solar temperature gains. In the interior zone of the building the atmospheric conditions remain

fairly constant throughout, the main thermal gain being from lighting, the employees and from machines. This build-up of heat has to be controlled in the warm weather, but in the winter the heat generated from these elements helps considerably to augment the heating system. The interior zone is usually conditioned with a low velocity system.

It is now fairly common practice to use a combination of the high velocity periphery system, and a low velocity system to service the interior zone. The low velocity system is divided into zones and can be controlled at the mechanical room with the aid of re-heat and cooling coils.

The main vertical supply lines are located in the core of the building and then the services are distributed horizontally at each floor. The high velocity vertical supply lines are frequently located on the periphery of the building as at the Blue Cross Building in Boston.

There are three systems of horizontal distribution for office buildings. The most popular system is when the supply and exhaust ducts are suspended below the structure and then covered by a suspended ceiling. The next system is the air floor, a continuous plenum sandwiched between the main structural floor and a secondary finished floor slab. This gives complete flexibility of distribution, eliminates a suspended ceiling and reduces the depth of the overall floor construction. Finally there is the system whereby deepening the beams the ducts can run through perforations in them. For an office building this is visually and acoustically unacceptable,

besides being rather costly.

Supply and return grills are now being carefully integrated with the lighting and ceiling panels. Quite a considerable advance has been made in recent years. In some cases perforated metal ceiling panels are used for both supply and return. With a luminous ceiling the supply and return grills are located in continuous runners which divide the ceiling panels. There is also open egg crate ceilings with the lights and diffusers positioned above.

Electric and telephone services are important in an office building. The system most commonly used is to distribute these services in concealed floor raceways. The modular distribution of raceways will ensure that all the floor area will be served. This is consistent with the principles of flexibility. Because quite a large proportion of the working area is away from the windows a high level of artificial illumination will be demanded.

Careful consideration must be given to the acoustical treatment as it is an important factor of controlled environment. When the office area is partitioned it is essential in the interests of privacy that the noise isolation properties of the partitions be effective. As the noise level in the office areas tend to be high, noise control by means of acoustical absorption will be necessary.

Vertical circulation will be by means of high speed elevators. The number of elevators will be a function of the number of employees per floor, and the height of the building.

In the core of the building is situated the constant elements required for the efficient functioning of the building: vertical

supply lines, vertical transportation, mechanical rooms, toilets, fire stairs, mail chutes, etc.

It is becoming more important that there should be closer coordination between the Architect, Structural Engineer and Mechanical Engineer. Technology is advancing rapidly and it will take the concerted effort of all members of building teams to keep pace.

V. Analysis of Existing Buildings

A. Police Administration Building

This is one of the most interesting buildings to have been constructed using precast concrete elements. The Architects Geddes, Brecher, Qualls and Cunningham designed a building of serpentine shape, which is generated from six points, three interior and three exterior. This gives three circular elements of 50 feet radius, a basic core and two wing elements. Out-to-out dimension between the two wings is 284 feet. Two gently curving arcs join the two wings and the core element at the rear, and a larger arc connects the front.

Office space on the typical floors is generated by a continuous curved path of a constant 32 feet width. The column free arrangement offers both flexibility in partition layout and highly efficient use of space.

The structure contains about 90% precast concrete elements, comprising: precast structural facade, columns and ribbed floor slab units. Cast in place concrete is limited to core elements.

Key elements in the structural framing are the precast concrete bearing wall panels: 5 feet wide and 35 feet high (3 stories high). The ribbed floor slab units are identical throughout, slab is $2\frac{1}{2}$ " thick. The ribs are $17\frac{1}{2}$ " deep for a span of 32 feet.

The design of the precast wall and slab units was precisely coordinated with the mechanical design. Recesses, depressions and rib spacings are detailed to enclose piping, heating units, air conditioning ducts. All this eliminates the need for a suspended ceiling.

The first floor framing was post-tensioned and the structural facade was supported by units cantilevered out 12 feet from the base columns.

B. Richards Medical Center

Basic Structure: Eight story rigid frame.

The span is 45 feet with prestressed trusses on H columns. Two of the four main trusses are cut into three pieces. Stepped spandrel beams cantilever out from the columns which are at their third points. The bays formed by the spandrel beams and the trusses are spanned by secondary trusses. These trusses are not necessary for the basic structural system, but are used as supports for the pipes and duct work. The secondary trusses do help support the cantilevered spandrel beams.

Joints:

1. Column, truss, spandrel and column:

The inner flange at each column is cut short to form a niche for the truss and spandrel which rest on the column below. The prestressing rods in the columns pass through the spandrel and truss and are prestressed with a force of 90 tons.

2. Truss to truss:

Two of the four main trusses are cut into three pieces. The truss to truss connection is formed by a niche in the ends of the cut trusses fitting into a niche in the sides of the one piece trusses. When in place the three sections are post stressed to form a continuous member duplicating the one piece truss.

3. Secondary truss to main truss:

The secondary trusses join the main trusses in the same manner as the truss to truss connections. But they are not post tensioned.

4. Secondary truss to secondary truss:

One of the two secondary trusses in each bay is cut into two pieces and bolted together after being set in place.

Conclusion:

The speed of erection is attributed to the joining system which provides seats for all members thus assuring faster and more accurate placement than would be possible if welded plates or cast-in-place sections were used at the joints. The rate of erection was three floors a week.

C. Poor Man's Precast Office Building

In Chicago an office building designed by Harry Weese employs a composite method of building construction of precast concrete and poured-in-place.

The building has a pinwheel framing plan with exterior bearing walls. Steel connections in the precast members are welded and then the members are grouted in solid to make the structure monolithic. The bearing walls consist of precast H-frame sections. The frames are two story units which are staggered vertically so each pair of welded joints will always have a pair of continuous columns between them. This facilitates an easier erection process and provides for a stiffer building.

The floor slab consists of precast hollow beams, the lower surface of which serves as an exposed ceiling and the upper surface needs a 2 inch concrete slab to top it off. Each beam has three "fingers" at each end which hook into the core or onto a beam at one end and onto the middle bar of an H-frame or neighboring precast lintel at the other. The beams are arranged in four rafts around the core so that only four load-carrying beams are needed.

The space within the hollow slab is used to move air, run wiring and drainage lines. Because of this the mechanical system reflects the structural system since the hollow tubular beams are used as ducts and the framing plan also becomes the ventilation plan. Alternate cores are used for hot, cold and return air. Every lighting fixture becomes a mixing box with a power thermostat so that each one has its own control. The fan room is two floors

in height and interconnected to the balancing system since the air does not always return to the same fan room it goes out from.

Speed and economy are realized by the composite construction of precast and poured in place. The core could possibly be slip-formed around the clock with the precast elements set in at the lower floors before the core is finished, permitting erection on all four sides of the building simultaneously.

Once the system has been absorbed by the building trades and carefully scheduled it should be possible to erect a multi-story office building in thirty days.

A MULTISTORY PRECAST CONCRETE

OFFICE BUILDING

by

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B.ARCH., Oklahoma State University

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Dear Dean Belluschi,

In partial fulfillment for the degree of Master in
Architecture I hereby submit this thesis entitled, "A Multi-
story Precast Concrete Office Building."

Respectfully,

Alan W. Brunken

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I. Introduction to the Problem

As in all architectural problems it was necessary in the design of the proposed office building to determine a hierarchy of requirements as to design. By this is meant which problem must be solved first, second and so on, in the context of trying to solve them all. In approaching the problem of the office building many aspects of its design were considered; the structural frame, aesthetic considerations, functional requirements and mechanical services. After approaching the problem from many directions using the different aspects of its design, a principle approach was determined. It was decided while always trying to achieve an environment architecturally pleasing and also conducive to an efficient working space to first solve the mechanical services of a typical office floor and their relation to the structural framing, the goal being to integrate the two systems in an efficient and logical manner letting the building function as a whole and retain a certain integrity of design throughout. One of the results of trying to achieve this integration of mechanical and structural systems was the reduction of the floor thickness which in turn achieves the maximum number of floors and hence the greatest amount of floor area in the total height of the building. Consideration was also given to the techniques used in precast concrete, the shape of the beam unit being somewhat determined by these techniques. The aesthetics of the building, especially the transition from exterior space through the facade into the typical

floor space, was one of the basic considerations. It was hoped to create a transition space between these two large volumes which the curtain wall on most of today's highrise office buildings ignores.

II. Plan

Design Criteria

Through research it has been found that office floors become efficient for office layout planning as well as economics near 14,000 gross area. A total building cubage starting at 150,000 to 190,000 has been found to be the minimum for desirable investment. Office planners desire a core to exterior wall depth of thirty to forty feet. This allows for an office, corridor and secretary pool of efficient proportion without creating excessive interior offices, which are not desirable psychologically. The net office area should be equal to or greater than 75 per cent of the total gross floor area. This is an accepted standard of efficiency.

Because the exterior wall is a main contributor to the cost of the building and a main source of load on the mechanical system, it is desirable to keep its surface area to a minimum. For this reason a square plan is advantageous since it is the rectangle which most nearly approximates a circle. The possibility of renting a floor to one, two, three or more clients is desirable to allow flexibility in rental areas.

The ancillary facilities required on each floor include elevators, fire stairs, mechanical shafts, men and women toilet facilities, electrical and telephone switching gear, plumbing chases, janitor closet, water fountains and mail shutes.

Description

The envelope of the building is nearly square being 130 by 120 feet, giving a floor area of 15,600 sq. ft. The net office area is eighty per cent. This does not include any circulation in the core area. I restricted the number of mechanical floors to two which limited the number of floors to fifteen, the practical run for mechanical shafts being six to eight floors.

The net office area is kept completely free of columns for maximum flexibility in office arrangement. A module of five feet was chosen to integrate the lighting, mechanical services and office furniture into a grid giving efficient office sizes.

The circulation space in the core was designed to provide the maximum number of possibilities for tenants per floor. This plan gives the possibilities for one to four tenants to occupy a floor without a perimeter corridor.

ELEVATOR SELECTION

Controls -- Type A

Number of floors served 14

Floor to floor height 11'-0"

Capacity of building

Useable floor area 120x130x.80 12500 sq.ft.

Sq. ft. / employee 125

Number of employees 12500/125 100/flr.

Capacity of building 14x100 1400 employees.

Desired interval equals 30 to 40 seconds

Total travel 14x11 154 ft.

Assume average traffic of 13 % of population

traffic/5 min. $.13(1400)$
182 employees

Minimum travel speed 500 FPM use 700 FPM

Assume 4000 lb. elevator

Round trip time 140 secs.

Elevator capacity 21 passengers/trip

Capacity per five minutes $\frac{60 \times 5 \times 21}{140}$

45 passengers/car/5min.

Number of cars required $\frac{182}{45}$

4 cars

Check: interval $\frac{\text{Round trip time}}{\text{Number of cars}}$

$\frac{140}{4}$

35 seconds.

PLUMBING SELECTION

Total 100 persons/floor 5 w.c.'s.
5 lav.

Assume 60% women 3 w.c.'s
3 lav.

40% men 2 w.c.'s or 2 w.c. & 1 ur.
2 lav.

Also -- 1 drinking fountain/75 persons
Use 2 drinking fountains.

III. Structural System

Design Criteria

Assuming precast concrete as a parameter to design a structural system taking advantage of precasting techniques and at the same time integrating the mechanical services and structural system to achieve minimum ceiling to floor height, to provide adequate noise control within the space and attenuation between spaces when partitions are used. The module inherent in the structure should allow the placement of partitions in a manner giving flexibility in sizes of private office areas and location of partitions, integration of lighting, electrical, telephone and signal systems into the module to allow flexibility in the location of office furniture.

Description

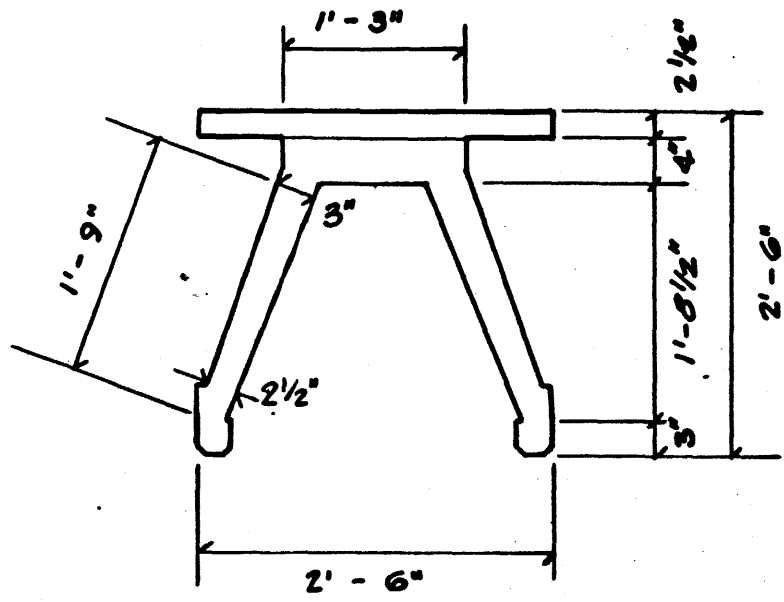
The structure consists of a one way system of beams framing into the core which acts as a sheer wall. A one way system was chosen in light of precasting techniques. It allows one typical member to be used and also the use of prestressing. The one way system eliminates the need for post-tensioning which a two way system requires and simplifies the erection process. The shape of the beam and the module inherent in it were determined by the needs of the mechanical services as to the desired module for lighting and ventilating and also the functional requirements of the system. The requirements for good acoustics were also considered as basic in the design of the beam unit. The building is

framed in the following manner. The beams on either side of the core frame into a prestressed girder spanning between the core and an exterior column. The section modulus of the girder, since it is one of the critical members on the system has been calculated. See page 11. The beams framing into the core frame into beams which carry the load into the core. This allows free movement of mechanical duct work. The column at the core which receives the load of the girder has been calculated to determine its area. See page 15. The capacity of the typical beam has been calculated and found to be adequate. See page 110 for the calculations. The beams are welded at the diaphragm points to insure uniform deflection of the beams under live load and to resist racking by the wind thereby transferring the wind load to the core. One diaphragm at midspan of the beam section is required by the ACI code for handling purposes. The additional diaphragms distribute throughout the beam the shear caused by the welds restraining unequal deflection and racking by wind. The wind load is transferred to the core since the columns are designed to take no moment. The core takes all wind loading and transfers it to the footings and into the soil. The two and one-half inch topping of concrete placed over the floor beams is not required structurally since the beams are welded. It is needed only as a finished floor. A precast topping therefore was contemplated to eliminate the need for pouring wet concrete but was abandoned because of the difficulty encountered of concealing the joints between panels and of the panels warping. All joints in the structure are made by precasting

milled steel plates into the members. The plates are then welded together. Adjustment in the column joint and other joints where necessary is achieved with metal shims. After the shims are in place the joint is welded. Steel plugs are used to align the column in the horizontal direction. To eliminate shrinkage cracks in the columns when they are precast only one bearing plate will be welded to the column steel during the casting process. After the column is cast and the concrete is allowed to shrink the second bearing plate is welded to the column steel at the proper elevation. Grout is injected under pressure between the bearing plate and column if it is needed.

A comparison of the quantity of concrete required of my inverted 'V' beam system as compared to a 'T' beam system was made.

QUANTITY COMPARISON



AREA OF SECTION

$$2 \times 2.75 \times 21 = 116$$

$$2 \times 3 \times 3 = 18$$

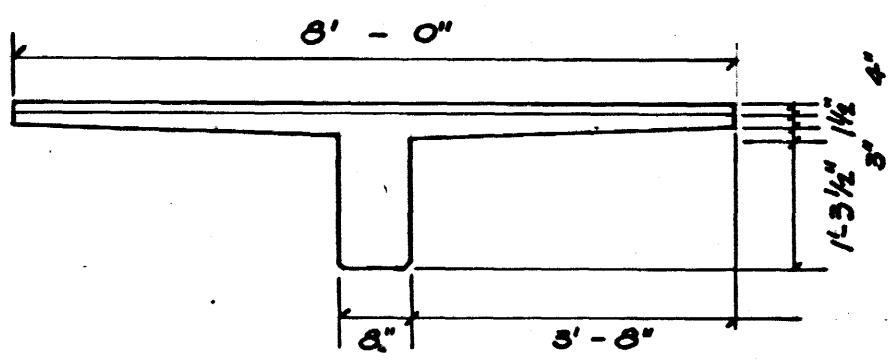
$$1 \times 15 \times 4 = 60$$

TOPPING $1 \times 30 \times 2.5 = 75$

DIAPHRAM $\frac{1}{60} \times 15 \times 22 \times 3 = 16$

285 SQ. IN.

SQ. IN./IN. WIDTH = $285/30 = 9.5$ SQ. IN.



AREA OF SECTION

$$96 \times 1.5 = 144$$

$$3 \times 44 = 132$$

$$8 \times 18.5 = 148$$

TOPPING $4 \times 96 = 384$

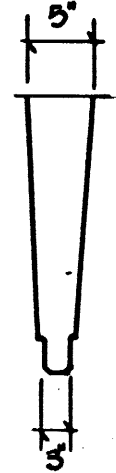
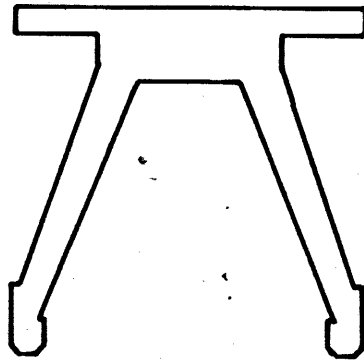
808 SQ. IN.

SQ. IN./IN. WIDTH = $808/96 = 8.4$ SQ. IN.

STRUCTURAL CALCULATIONS

LOADS

(BEAM UNIT)

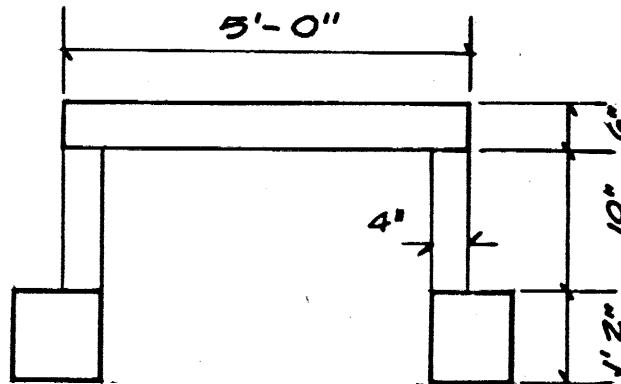


STIFFNER

AREA OF SECTION = 285 SQ. IN.
(SEE QUANTITY COMPARISON)

$$\begin{aligned} \text{WT. / SQ. FT.} &= \frac{285 \times 125}{2.5 \times 144} \\ &= 100 \text{ LBS/SQ. FT.} \end{aligned}$$

(GIRDER)



AREA OF SECTION

$$\begin{aligned} 6 \times 60 &= 360 \\ 2 \times 8 \times 4 &= 224 \\ 2 \times 4 \times 10 &= \underline{80} \\ &664 \text{ SQ. IN.} \end{aligned}$$

$$\text{WT. / SQ. FT.} = \frac{664 \times 125}{144 \times 5} = 115 \text{ LBS/SQ. FT.}$$

GIRDER DESIGN

TOTAL LOAD ON GIRDER

$$\begin{aligned} \text{DEAD LOAD} &= 100 \times 40 + 115 \times 5 \\ &= 4575 \text{ LBS/FT.} \end{aligned}$$

$$\begin{aligned} \text{LIVE LOAD} &= 80 \times 45 \\ &= 3600 \text{ LBS/FT.} \end{aligned}$$

$$\text{TOTAL LOAD} = 8175 \text{ LBS/FT.}$$

$$\begin{aligned} M_T &= \frac{WL^2}{8} \times 12 \\ &= \frac{8175 (30)^2 \times 12}{8} \\ &= 11,000 \text{ IN. K.} \end{aligned}$$

SECTION MODULUS

$Z_b = \text{MIN. ALLOW. SECTION MODULUS}$

$$\begin{aligned} &= \frac{M_T}{n f_{bi} - f_b} \\ &= \frac{11,000}{.85(3600) - (-468)} \\ &= \frac{11,000}{3060 + 468} \end{aligned}$$

$$Z_b = 3125 \text{ IN}^3$$

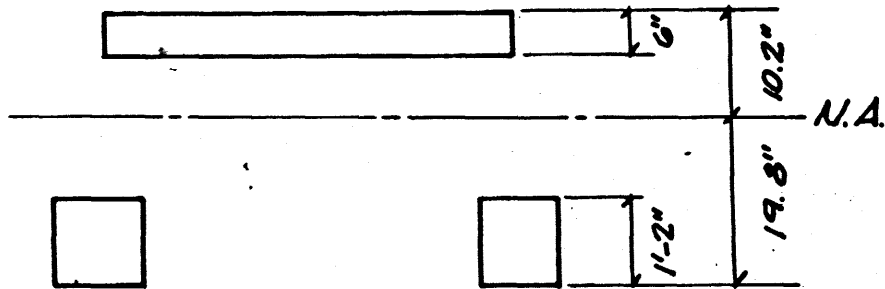
$f_{bi} = \text{ALLOW. COMP.}$
 BOTTOM FIBER
 AT TRANSFER
 $.6 f_c = 3600 \text{ PSI}$

$f_b = \text{ALLOW. TEN. STRESS}$
 $= 6 f_c$
 $= -468$

$$M_T = M_{D.L.} + M_{L.L.}$$

$$n = .85$$

ACTUAL SECTION MODULUS



| | | |
|------------------------------|----|-------------|
| A | y | A y |
| $2 \times 14 \times 8 = 224$ | 23 | 5150 |
| $6 \times 60 = 360$ | 3 | 1080 |
| <u>584 sq. in</u> | | <u>6230</u> |

$$\bar{y} = \frac{6230}{584}$$

$$= 10.2''$$

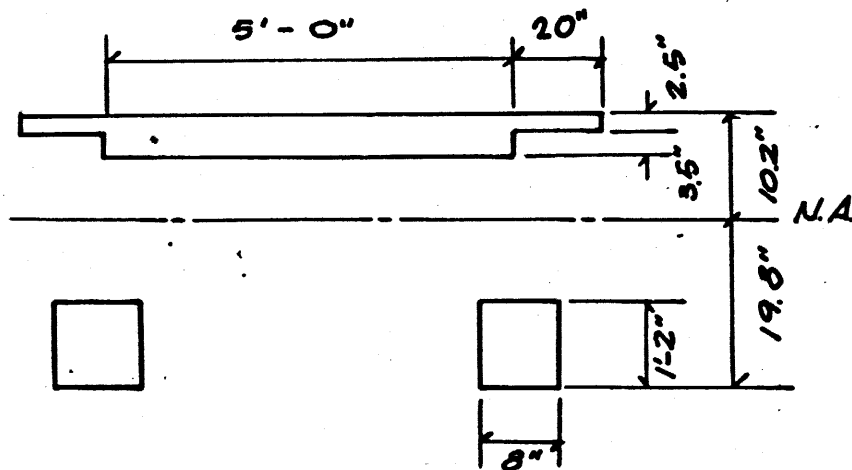
$$I = \frac{1}{3} [60(10.3)^3 - 60(4.2)^3 + 16(19.8)^3 - 16(5.8)^3]$$

$$= \frac{1}{3} [63700 - 4450 + 124,000 - 3120]$$

$$= 60,040 \text{ in.}^4$$

$$Z_b = \frac{60,040}{19.8}$$

$$= 3100 \text{ in.}^3 < 3125 \text{ in.}^3$$



| | | |
|--------------------------------|------|-------------|
| A | ∇ | A ∇ |
| $2 \times 14 \times 8 = 224$ | 23 | 5150 |
| $6 \times 60 = 360$ | 3 | 1080 |
| $2 \times 2.5 \times 20 = 100$ | 1.25 | 125 |
| <u>684</u> | | <u>6355</u> |

$$\bar{y} = \frac{6355}{684}$$

$$= 9.3''$$

$$I = \frac{1}{3} [100(9.3)^3 - 40(6.8)^3 - 60(3.3)^3 + 16(20.7)^3 - 16(6.7)^3]$$

$$= \frac{1}{3} [80,500 - 12,550 - 2160 + 142,000 - 4800]$$

$$= \frac{1}{3} [203,000]$$

$$I = 67,666 \text{ IN}^4$$

$$Z_b = \frac{67,666}{20.7}$$

$$= 3230 \text{ IN}^3 > 3125 \text{ IN}^3$$

SHEAR AT SUPPORT

$$V = \frac{WL}{2}$$

$$= \frac{8175 \times 30}{2}$$

$$= 123,000 \text{ LBS}$$

$$A = 2 \times 12 \times 14 + 2 \times 8 \times 16$$

$$= 336 + 256$$

$$= 592 \text{ SQ. IN.}$$

$$v = \frac{V}{A}$$

$$= \frac{123,000}{592}$$

$$= 208 \text{ PSI}$$

$$\text{ALLOW. } v = 240 \text{ PSI}$$

NOTE: WHERE HOLE OCCURS INSERT A STEEL PIPE SLEEVE WITH EQUAL SHEAR STRENGTH AS THE AREA OF CONCRETE REMOVED.

$$\text{AREA OF CONCRETE} = 10.5 \times 12$$

$$= 126 \text{ SQ. IN.}$$

$$\text{SHEAR CAPACITY} = 126 \times 240$$

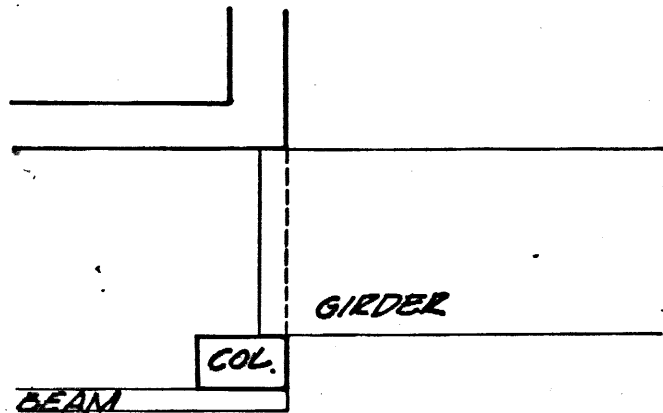
$$= 30,300 \text{ LBS.}$$

$$\text{REQUIRED PIPE THICKNESS} = \frac{1}{2} \left(\frac{30,300}{13,000} \right)^{\frac{1}{2}}$$

$$= .1 \text{ IN.}$$

COLUMN DESIGN

(FOR PRELIMINARY DESIGN ASSUME NO ECCENTRICITY)



LOADS

$$\begin{aligned} \text{GIRDER } V &= \frac{WL}{2} \\ &= \frac{8175 \times 30 \left(\frac{1}{2}\right)}{2} \\ &= 61,500 \text{ LBS} \end{aligned}$$

$$\begin{aligned} \text{BEAM } V &= \frac{WL}{2} \\ &= \frac{(100 \times 22.5 + 80 \times 22.5) 20}{2} \\ &= 4050 \text{ LBS} \end{aligned}$$

$$\begin{aligned} \text{TOTAL } V &= 61,500 + 4,050 \\ &= 65,600 \text{ LBS.} \end{aligned}$$

REQUIRED AREA

$$\begin{aligned} A &= \frac{N}{.213f'_c + f_s P_g} \\ &= \frac{985.6}{.213(6) + 24(.04)} \\ &= \frac{985.6}{2.24} \\ &= 440 \text{ SQ. IN.} \end{aligned}$$

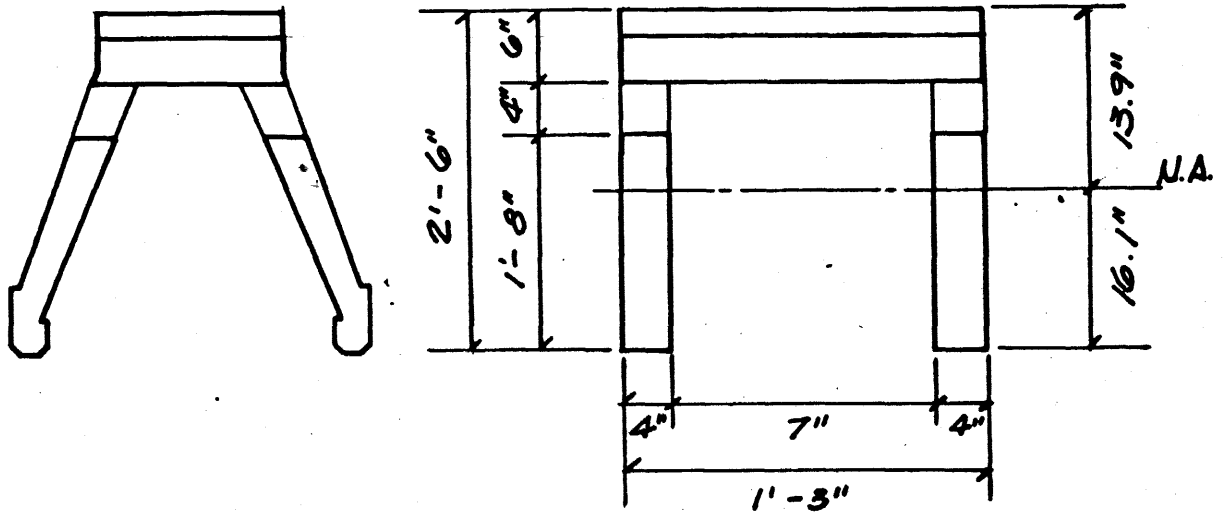
$$\begin{aligned} N &= \text{AXIAL LOAD} \\ &= 15(65.6) \\ &= 985.6 \text{ K.} \end{aligned}$$

$$f'_c = 6000 \text{ LBS/SQ. IN.}$$

$$\begin{aligned} f_s &= .40 f_y \\ &= 24,000 \text{ LBS/SQ. IN.} \end{aligned}$$

$$P_g = .04$$

BEAM DESIGN



TOTAL LOAD ON BEAM

$$\begin{aligned} \text{DEAD LOAD} &= 100 \times 2.5 \\ &= 250 \text{ LBS/FT.} \end{aligned}$$

$$\begin{aligned} \text{LIVE LOAD} &= 80 \times 2.5 \\ &= 200 \text{ LBS/FT.} \end{aligned}$$

$$\text{TOTAL LOAD} = 450 \text{ LBS/FT.}$$

$$\begin{aligned} M_T &= \frac{WL^2}{8} \times 12 \\ &= \frac{450 (20)^2 \times 12}{8} \\ &= 270,000 \text{ IN. LBS.} \end{aligned}$$

SECTION MODULUS

$Z_b = \text{MIN. SECTION MODULUS ALLOWABLE}$

$$\begin{aligned}
 &= \frac{M_T}{n f_{bl} - f_b} \\
 &= \frac{270}{.85(3600) - (-468)} \\
 &= \frac{270,000}{3528} \\
 &= 76.5 \text{ IN}^3
 \end{aligned}$$

ACTUAL SECTION MODULUS

| A | \bar{y} | A \bar{y}^2 |
|----------------------|-----------|---------------|
| $6 \times 15 = 90$ | 3 | 270 |
| $8 \times 20 = 160$ | 20 | 3200 |
| <u>250.0 SQ. IN.</u> | | <u>3470</u> |

$$\begin{aligned}
 \bar{y} &= \frac{3470}{250} \\
 &= 13.9 \text{ IN.}
 \end{aligned}$$

$$I = \frac{1}{3} b h^3$$

$$\begin{aligned}
 &= \frac{1}{3} [15(13.9)^3 - 15(7.9)^3 + 8(4)^3 + 8(16)^3] \\
 &= \frac{1}{3} [40,000 - 7,400 + 512 + 32,800] \\
 &= \frac{1}{3} [65,912] \\
 &= 21,970 \text{ IN}^4
 \end{aligned}$$

$$Z_b = \frac{21,970}{16.1}$$

$$= 1,360 \text{ IN}^3$$

IV. Mechanical System

Design Criteria

To provide a system giving maximum flexibility and control of the climate in the work space to allow the placement of equipment with high heat producing characteristics where ever desired. This equipment may include accounting machines, duplicating equipment or tabulating machines.

Description

A high velocity dual duct mechanical system with mixing boxes placed in the work area was chosen. An outline of the system is as follows. (See sheet three for plan of system.) Mechanical floors are located on the basement level feeding the entrance level and seven typical floors above, also on the fifteenth floor feeding down seven floors. From the mechanical equipment floor the conditioned air moves vertically at a high velocity through the shaft in the core to the floor served. On each floor the air moves from the vertical shaft at a high velocity through ducts down each of the girders as shown on sheet seven. From this duct branch the ducts running between floor beams which supply the hot and cold air to the mixing boxes. The structural system provides possible mixing box locations on a module five feet by seven and one-half feet. Each location will be stubbed to receive mixing boxes. The mixing boxes control the static pressure in the system and reduce

the speed of the air to lower velocities before injecting it into the work space. The mixing boxes are controlled by thermostats located in the work space they serve. If desirable it is possible to have more than one mixing box controlled by a thermostat. All ducts have been sized with the aid of Mr. Crowley and have been drawn to scale on the drawings. One inch of insulation is required on both hot and cold ducts. The return air is located between the two lighting coffers in the floor system and draws the heat from the lighting directly into the return air plenum before it enters the work space. The return air plenum is also a pipe chase to allow the installation of wash basins in executive offices if they are desired. The return air travels through the plenum in the floor system and into the plenum in the girder and into the core area, or simply into the core area if it doesn't frame into a girder. A damper is located at the end of the plenum in the floor system feeding into the girder plenum or core area to control the static pressure. The return air in the vertical shaft of the core takes the air to the mechanical floor. It is mixed with fresh air, filtered, conditioned to the proper temperature and enters the system again as supply air.

Using this system a degree of flexibility of control ranging from a large space using three to five mixing boxes controlled by one thermostat to the control of one mixing box by one thermostat where desired is possible.

By using double glazing composed of heat absorbing glass on the outside and plate glass on the inside, the solar heat transmission was reduced from ninety to fifty per cent of that incident

on the glass area, while the light transmission has been reduced from eighty-eight to sixty-eight per cent. The double glazing also has the advantage of eliminating condensation from forming on the inside surface of the glass during winter months.

V. Electrical System

Design Criteria

To provide an electrical system giving freedom in the location of electrically operated office machines, telephones, and signal apparatus. The system shall also be capable of changing as the need arises allowing new or additional wiring to be placed where needed.

Description

On two sides of the core are located electrical galleries housing the electrical power, telephone and signal switching gear. Each gallery serves one-half the office floor. The wiring is fed through a main raceway duct which in turn feeds down secondary raceways between beams. The main raceway is located in the two and one-half inch finish floor slab while the secondary raceways lie within the depth of the beam. By being able to locate my secondary raceways within the depth of the beam I save an inch and one-half in floor depth. The secondary raceways serving all the area are on a five foot module with each access strip being five feet wide.

VI. Lighting System

Design Criteria

To integrate the lighting into the structural system in a manner sympathetic to the structural and office furniture module. A minimum amount of glare is desirable to reduce eye strain. Fifty to sixty foot candles of light intensity is desired on the work surface as set forth in the Illuminating Engineers Society recommendations.

Description

The module selected of five feet allows fluorescent light bulbs and fixtures to be easily integrated into the module, the standard length of light bulb being four feet. The white tectum or insulrock cast into the coffer of the floor unit has a reflection factor of between eighty and ninety per cent. This is within the recommendations given by the Illuminating Engineers Society. By using the coffer of the beam unit as the light fixture the structural system is revealed giving harmony to the supporting framework and the work space below. The coffers, by offering the possibility of recessing the light fixtures also eliminates the need of a hung ceiling which would increase to ceiling to floor height. By recessing the fixtures the amount of glare is reduced keeping the direct light to a minimum. This reduces the contrast of

surrounding surfaces while providing adequate foot candles on the work surface. By varying the number of fluorescent tubes in each fixture the intensity of illumination can be adjusted. The heat absorbing glass used in the exterior glazing reduces the amount of natural light transmitted. This also reduces the contrast with surrounding surfaces and lessens the amount of glare.

VII. Acoustics

Design Criteria

To provide acoustical comfort in the work space by eliminating distracting noises and by maintaining a level of background noise conducive to an efficient working environment. This level of background noise lies between forty and fifty decibels.

Description

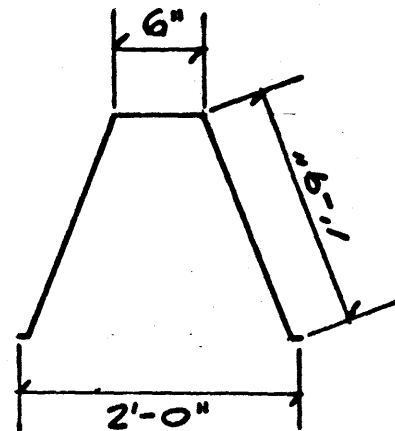
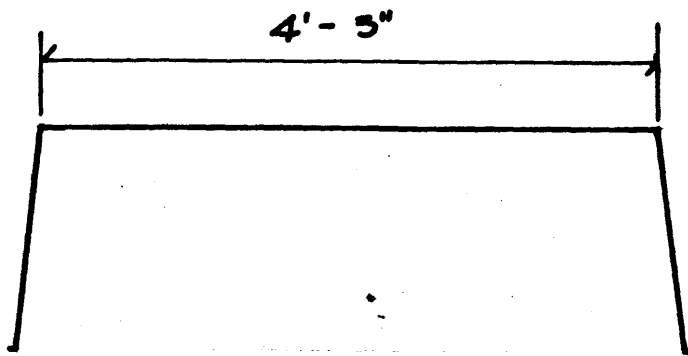
The double glazing on the exterior wall reduces the transmission of outside noise into the building. Ordinary $\frac{1}{4}$ inch plate glass has a noise reduction coefficient of thirty decibels while the double glazing has a noise reduction coefficient between forty and fifty decibels.

The additional surface area created by the coffers increases the area of absorptive material by two hundred thirty per cent. The equivalent noise reduction is given by the equation:

$$\begin{aligned} \text{N.R.} &= 10 \log \frac{a}{a} \\ &= 10 \log \frac{2.3}{1} \\ &= 10(.36) \\ &= 3.6 \text{ db} \end{aligned}$$

This gives an apparent noise reduction to approximately three quarters the original sound using a flat ceiling. The insulrock or tectum has the advantage of being able to be painted while still maintaining its acoustic properties.

All flooring will be laid over resilient material to eliminate impact noise.



SURFACE AREA OF COFFER

$$\begin{aligned}
 2 \times 1.75 \times 4.5 &= 15.75 \text{ SQ. FT.} \\
 2 \times 1.25 \times 1.75 &= 4.40 \text{ SQ. FT.} \\
 .5 \times 4.25 &= \underline{2.13} \\
 A &= 22.28 \text{ SQ. FT.}
 \end{aligned}$$

SURFACE AREA OF FLAT CEILING

$$\begin{aligned}
 2 \times 4.75 &= 9.5 \text{ SQ. FT.} \\
 A &= 9.5 \text{ SQ. FT.}
 \end{aligned}$$

$$\begin{aligned}
 \text{PERCENT INCREASE} &= \frac{22.3 \times 100}{9.5} \\
 &= 230\%
 \end{aligned}$$

A PRECAST CONCRETE HIGH-RISE

OFFICE BUILDING

by

THOMAS HENNEY

D.A.(Edin.) Edinburgh College of Art

(1959)

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF

ARCHITECTURE

at the

MASSACHUSETTS INSTITUTE OF

TECHNOLOGY

June, 1963

Signature of Author
Thomas Henney

Certified by
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Lawrence B. Anderson
Chairman, Department of Architecture

June 17, 1963

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

Dear Dean Belluschi:

In partial fulfillment of the requirements for the degree of Master in Architecture, I hereby submit this thesis entitled: "A Precast Concrete High-Rise Office Building."

Respectfully,

Thomas Henney

ABSTRACT

This thesis is concerned with an investigation of precast concrete structural elements, and its application for a high-rise office building. Special attention is given to the integration of the structural and mechanical systems.

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The members of the M.I.T. Faculty who participated in the preliminary jury, May, 1963.

I. Design Criteria

In order to formulate a program for the design of a prototype office building, it is essential to outline a set of goals. In any building there must be a group of constants that will ensure the liveability and efficient function of the building. To give a total architectural expression all these constants must interact. The organization of the building must be clearly defined and can be expressed by an hierarchy of elements. In order to stimulate life within the building, the building must have good dimensions. This will give a good space for flexibility and richness of area distribution.

The complexity of the servicing in a contemporary office building will demand a rational and systematic solution to the design. The mechanical systems should be integrated with the structural system to express a clear organization of elements.

The building will have a center of gravity, which will have the concentration of vertical communication and supply lines; also constant, ancillary areas.

Design Requirements

In an office building, it is important to have a good ratio of office space to ancillary space. The ratio is approximately 80% of the total gross floor area to be allotted to office space. The dimensions of the service core will have a direct relationship between the total floor area and the total number of floors. To

ensure flexibility the floor area should be of generous dimensions and be free of columns and other vertical elements. The core is the center of gravity of the building and should be carefully organized to act as a servant space for the general office space. The service core should be efficiently distributed so that all vertical circulation elements are clearly defined and the circulation is contained within the core.

The office space should be designed on a modular basis. The size of the module will depend on the optimal size of rooms required. There should be an integration between the building module and the structural and mechanical systems so that these elements interact to give complete flexibility of partitioning and space distribution.

Structural Requirements

The building is to be constructed of precast concrete elements using prestressing techniques. In the interests of flexibility it would be advisable to have a clear span of the floor from the window wall to the core wall. The main load-bearing elements will be on the periphery of the building and around the core. To give stiffness to the building and give it the capacity to resist wind loading and shear, the core of the building will require to be constructed of cast-in-place concrete. Careful study will be required to be given to the joints and also how all the elements relate. Also to be considered is the relationship of the building to the ground level.

Mechanical Services Requirements

An investigation must be made to find the correct location for the mechanical equipment rooms. Also the location of the vertical and horizontal supply lines so that they will all comply with the general design criteria. The right air conditioning system should be selected. The electrical and telephone raceways should be systematically distributed to give service to each module. Lighting should be positioned on a modular basis to give a good general level of illumination.

II. Building Concept

The 36 story office building has a total gross square footage of 1,200,000 square feet. Each floor has a gross square footage of 34,000 square feet, with a total rental space of 27,000 square feet which is approximately 80% of the total area. The flexible office space has a 50'-0" or ten module span in all directions from the core to the facade. The building is set out on a 5'-0" x 5'-0" module, and the module line is on the inside face of the column so as to conform to a standard module for movable partitions. The underside of the floor structure is left exposed and the ribs form a 5'-0" x 5'-0" grid, which will allow partitioning to be located on the underside of the ribs. On the soffit of each matrix is located a fluorescent light fixture with either supply or return grills combined into the fixture. Acoustical material is placed on the ceiling above the fixture, which is designed to make full use of this acoustic absorption.

Above the structural slab is positioned an air floor which integrates the air conditioning, power and telephone services.

The floor plan was designed so that all primary circulation is contained within the core, all secondary circulation will be contained within the general office space. The office space was considered for one major rental. It can be sectioned off to accommodate up to four tenants per floor.

There are 20 automatic elevators serving the building; they will be staged so that ten elevators will serve up to the first

eighteen floors and the other ten will serve the remaining floors. Both groups of elevators serve on to the transitional eighteenth floor. The core will also contain: fire stairs, vertical service risers, mechanical rooms, toilets and janitors' rooms.

III. Structural Concept

Structural Facade

The structural facade is constructed of precast concrete window units. The mullions are 12" x 12" on the top floors and they increase in width and depth to 14" x 42" at the base. 6,000 p.s.i. concrete is used throughout and the strength of the steel 75,000 p.s.i. The mullions were tapered out so as to express the accumulation of stresses as they gather loading. The glass line remains constant so that the modeling of the facade will get progressively stronger as it drops to the base of the building. As shown on drawing #7, the mullions are fixed to each other vertically by means of dowel joints. The reinforcing in the mullion section is welded to bearing plates. This is all done in the precasting process. When the window units are placed, the dowels slip into sleeves and the bearing plates are shimmed with steel shims to get the correct elevational alignment. The dowels and the joint between the bearing plates are then pressure grouted. The window units are fixed laterally by welding the reinforcing together in preformed pockets left in the column; the pockets are then pressure grouted. The joints are designed to have hinge action, so that all dynamic and bending stresses will be deflected via the floor slab into the structural core walls. The window units are finished with an exposed white quartz aggregate. The units will be vibrated after being cast, using the Schokbeton system. This will give a dense section and the edges and form

will be sharp and clean. The formwork will have curved corners and beveled surfaces to give ease of pouring and removal of forms. This plastic modeling of the units will truly express the homogeneous nature of the material. Special attention will be given to the joints between units, so that they are carefully gasketed and caulked. The glass will be fixed by neoprene gaskets which are fixed to steel angle frames cast into the concrete.

The precast floor units will be fixed by welding the bottom of the ribs to the continuous boot lintel on the window unit.

Floor system

Different types of precast floor systems were investigated, and it was decided to use a one-way system. Basically the precast floor unit is a channel section with diaphragms at 5'-0" centers. The webs of the channel are pretensioned and the unit is five feet wide and spans 50 feet from the facade to the core. The bottom of the ribs and diaphragms are checked to take the partitioning. At the corners the units are framed into precast concrete girders which span from heavy columns to the buttressed corners of the structural core. The heavy column will have a precast shell and the core will be cast in place. This column will help to give rigidity to the building. The precast girder will be lifted up into position in three sections and then post-tensioned.

Consideration was given to making the corners of the building operate as a two-way system, by post tensioning the units laterally through the diaphragms. This system had the advantage of making

the row of side columns participate in the support of floor loads. After weighting up the pros and cons of the two systems it was decided to use the one-way system. To post-tension each diaphragm at 5'-0" centers on all four corners of the building would have meant using rather complicated structural techniques. It would have been a time-consuming process which would have negated the reasons for using precast units.

The side columns which stretch from the corner of the building to the big structural support column, are not actively participating as structural load-bearing elements. However, they are necessary for the continuity of the modular planning. They give a consistent window mullion treatment all the way around. They will be expressed differently from the load bearing mullions, by keeping the units a consistent depth all the way down the height of the building.

The floor units are welded together at quarter points and the joints are grouted. They are also welded at the facade and core seatings.

The core wall is cast in place and is constructed by using slip-form methods. The walls shall increase in thickness as it picks up the loads of the structure. The corners of the structural core wall will thicken out to form buttresses to support the precast floor girders.

The erection procedure will be quick and efficient. The core walls will be constructed first in stages using slip form. Two climbing tower cranes will be used to lift the elements

straight from the truck into position. The window unit is placed first and then the floor unit. The building will rise consistently in story height stages.

Thermal Expansion

Thermal expansion is one of the primary structural design considerations. By a special study of the connections on the top ten floors, the floor units can be designed so that the end that rests on the core has a hinge connection and can rotate freely. The beam is then able to fluctuate and adjust to the thermal movement of the facade. Another problem is for the floor to rack at the corners. This can be solved by careful designing. Movable partitions on the top ten floors are designed so that any deflection of the floors can be accommodated without damaging or distorting the partitions.

Wind Loading

It is assumed that the structural core will take the greatest proportion of the stresses due to wind loading. Residual stresses will be taken up by the double row of columns that are parallel to the direction of the wind.

Transfer Girder

To provide a satisfactory connection at the ground the structural facade will be supported by a cast-in-place concrete transfer girder. The ground floor columns are then spaced at wider spans.

The advantages of the structural concept are as follows:

1. The facade expresses the structure and the module used in the building.
2. Using precast elements will speed up the erection time and ultimately a saving in cost.
3. The different types of precast elements are reduced to a minimum as the building is systematic, and universal sections have been used.
4. The office space is free of columns which provides efficient and flexible use of office space.
5. The soffit of the floor units are left exposed, and express the structure. They give additional height and interest to the ceiling.
6. The core walls are structural and allow freedom of planning inside the core.

IV. Mechanical and Electrical Services

The mechanical rooms are located on the second floor, eighteenth floor and on the roof. On the second floor the full depth of the transfer girder is utilized for the mechanical room. The vertical distribution is divided into four zones of eight floors. The second floor mechanical room serves the bottom eight floors. The roof mechanical room serves the top eight floors and the intermediate mechanical room serves the remaining sixteen floors. Vertical service risers are located in the core of the building.

Horizontal distribution for each floor is divided into zones, governed by the exposure of the building.

The periphery of the building is served by a high velocity system. The interior space by a low velocity system.

The distribution of the systems is by means of an air floor which allows the passage of ducts and services above the structural floor. The ducts and services supply the floor above and the floor below. The plenum of the air floor is used as an exhaust system. The supply and return grills for the ceiling are combined with the fluorescent lighting fixture. These units are controlled by damper. The window induction units are supplied by a high velocity single duct system, which has integral re-heat and cooling coils. These coils will be served by water. Each unit is thermostatically controlled.

Heat loads have been reduced by using tinted heat resistant

glass. Provision is made for the installation of venetian blinds or drapes.

The columns and spandrils are insulated on the internal face and are furred out and plastered.

Lighting

Each 5'-0" x 5'-0" module has a fluorescent light fixture to ensure a good general level of illumination. Underfloor ducts serve telephone and electrical services to each module.

A MULTI-STORY PRECAST CONCRETE

OFFICE BUILDING

by

RODNEY AMES WESTBURY

B.ARCH., CLEMSON COLLEGE

(1961)

SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF

ARCHITECTURE

at the

MASSACHUSETTS INSTITUTE OF

TECHNOLOGY

June, 1963

Signature of Author

Rodney A. Westbury

Certified by

Eduardo Catalano
Thesis Supervisor

Accepted by

Lawrence B. Anderson
Chairman, Department of Architecture

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June, 1963

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

Dear Dean Belluschi,

In partial fulfillment for the degree of Master in
Architecture, I hereby submit this thesis entitled, "A Multi-
Story Precast Concrete Office Building."

~~Respectively,~~

/Rodney A. Westbury

ACKNOWLEDGEMENTS

I am grateful to the following people for their invaluable advice and assistance during the thesis:

Dr. Howard Simpson

Mr. Charles A. Crowley

Mr. William Connolly

Eduardo Catalano, Thesis Supervisor

and the members of the M.I.T. faculty who participated in the preliminary jury, May, 1963.

I. Design Criteria

In the examination of a building an inductive sequence must take place with established architectural requirements. The building concept must reflect the design requirements, the structural and mechanical considerations and the methods of construction and economy.

A. Envelope

The envelope of the building consists of precast curtain wall window units of lightweight concrete. These units are a direct expression of the module and contain the induction units of the periphery mechanical system. The quality of finish in these units is excellent and can be expressed inside and out. The precast elements easily meet fire regulations. They also present a rigid surface in a continuous line around the perimeter of the building to receive interior partitions. Expression of the floor and ceiling line is achieved along with considerable solar protection to the glazed surface areas.

B. Design Requirements

Investigation has shown that recent buildings under construction or completed have a minimum of 14,000 square feet rentable office space per floor. Each floor in the proposed office building will have a total gross square footage of 17,590 square feet with a net rentable area, excluding the core, of 14,800 square feet or approximately 85% of the gross square footage. The 20 story

office building has a total square footage of 351,800 square feet. The opportunity for flexible arrangement of office partitions will be provided on each floor. Each floor will contain a column free interior with a central service core of elevators, stairs, toilets and service shafts. Each floor will be designed around a 4' - 6" working module with all structural and mechanical elements related to it. This module gives more flexibility in planning of office layout, and standard wall and ceiling materials may be used.

C. Structural

The office building structure will be precast prestressed concrete. The structural bay will have a clear span of 49'-6" x 31'-6". This creates a column free interior space with maximum flexibility. The floor system shall be prestressed concrete and the ceiling to floor depth shall be kept to a minimum to reduce the overall height and cost of the building. Attention will be given to forming and methods of construction.

D. Mechanical and Electrical

A study will be made to determine the location of the main mechanical equipment floors and also the vertical and horizontal distribution and the individual supply and return grilles. The electrical lighting will be integrated with the modular system and give the proper illumination at desk level. The power and telephone supply will also be established on the modular system to insure flexibility.

II. Building Concept

Rapid advancements in the mass production of precast prestressed concrete components have enhanced the utilization of these elements in high-rise buildings. Where the framing system must have a clear span of 30 feet or more, the utilization of these components tied together compositely with cast-in-place concrete can bring about very significant cost savings.

Experience has shown that simplicity of erection and handling of utilities can be achieved by utilizing a combination of precast units and cast-in-place concrete in a composite system. Framing for a typical floor in this system requires precast prestressed channels and girders with stirrups in the top flange to develop composite structural action with the cast-in-place floor slabs. On the job the units are individually hoisted into position. To achieve the highest efficiency, all connections between precast units should develop full bearing and continuity. The connecting ends will rest on the intersecting units. Mild reinforcing will be added in the poured topping to serve as continuity ties along with steel bearing plates and weld points. The precast prestressed channels have grooves formed in the top flange in which the mild reinforcing will be laid and grooves in the bottom of the webs to receive partitions. To express the floor structure the ribs of the one-way channels will be exposed along with the soffits of box girder webs. This will allow partitioning to be attached to the bottom of the ribs. Where partitions run perpendicular to the

one-way channels precast concrete diaphragms will be inserted which will be flush with the bottom and sides of the channels. This will tie the partitions into the structure and will contain acoustical reverberation within the rooms.

The space between the webs of the channels and the box girders will be used to run mechanical ducts. The ducts will feed out from the core within the box girder which will be perforated to allow the ducts to branch off and run down the channels. The channels are one module in width. Every alternate channel will house a supply duct and the adjacent one will contain a return air duct. This will give a 9'-0" mechanical module containing both a supply and return air duct. The electrical raceways will be contained within the poured topping.

The structural core will be poured one floor at a time. The precast columns will be secured into position. The box girders and spandrel girders will be positioned and the channels will be let into position onto their bearing ledges. Reinforcing and electrical raceways will be laid out. The topping will then be poured. The precast window units will be let into place and secured. Mechanical equipment ductwork and acoustical panels will be installed, completing the main structural and mechanical work for the floor.

Eight automatic elevators will be housed in the structural core to provide high speed service from the lobby to all floors. Toilets, janitor closets, stairs and service shafts will also be housed in the structural core.

III. Structural Concept

The structural framing consists of box girders spanning from the poured-in-place structural core to the precast load bearing columns on the exterior walls. Spandrel girders will span the distance between the column supports within the exterior wall on the short side of the building. All girders will be precast and prestressed using 6000 PSI concrete. They will be 2'-6" in depth with a clear span of 32'-0". The box girder will be precast with a three inch top flange with steel reinforcing extending above the surface. The girder will then be hoisted into position and mild reinforcing will be placed over the girder and will extend into the grooves in the top of the channels. Wire mesh reinforcing will be laid on top of this and extend out on both sides of the girder. This will activate additional strips on both sides which may be considered as eight times the thickness of the topping or in this particular case 2'-0" in effective width. The 3" topping will then be poured in place. This will give a 6" upper flange to the box girder and also create a continuous joint connection in the channels which will negate the dead load moment at the middle of each span.

All girders will be cast with collapsable steel forms. The spandrel girder will have a void in the center to reduce the dead weight as this section in area is structurally inert. The box girder will be cast with perforations in the webs to permit mechanical ducts to branch out on both sides.

Ledges will be formed at the bottom of the webs on the box girders and on the interior lower side of the spandrel girders. Neoprene pads will be placed on the ledges. The channels will be 27" in depth with a clear span of 49'-6". The webs of the channels will be notched at the bottom with a steel bearing plate cast into the web which will rest upon the ledges of the girders. The soffit of the channel webs will be grooved to receive partitions. The top of the channel webs will be grooved to receive mild reinforcing which will be laid across the top of the girder and extend a sufficient distance on both sides of the girder to achieve a continuous bond. The extension of the mild steel reinforcing will also be an insurance against any cracking in the floor topping along the joint lines.

The entire structural network will be united harmoniously by the 3" poured topping which will, in effect, create a monolithic structure.

The precast columns will be tapered in cross section from the first through the thirteenth floor. This reduction in area will be directly proportional to the diminution of stress as the number of floors acting on the column decreases. The columns will be precast in collapseable steel forms. Cylindrical steel rings will be cast into the sides of the columns to permit mechanical pipes and ducts to pass through to the induction units in the window elements. The columns will be notched to receive the girders which will bear upon neoprene pads. A steel channel will be cast in the top of each column section identical to the channel cast in

top of the girder. Each column section will be precasted one floor height which will establish the top of the column section at the same elevation with the girder. A steel rod will be welded to the column channel and girder channel producing a fixed end connection.

Steel dowels will extend from the top and bottom of each column section with a recess in the interior face of the column which permit the insertion of a steel jacket coupler. The columns can then be dry-packed and bolted together. The recessed slabs will be grouted in to make the joints continuous.

The columns containing mechanical equipment will have a cover panel on the interior to permit access for maintenance and alterations.

The advantages of this structural concept are as follows:

1. The floor structure is exposed and expressed the structure, giving additional height order and visual strength to the ceiling.
2. The forms used for the girders, channels, columns, and window units may be reused.
3. The facade is an expression of the module and structure of the building.
4. When the core walls are structural it allows for maximum freedom in planning of the core.

IV. Calculations

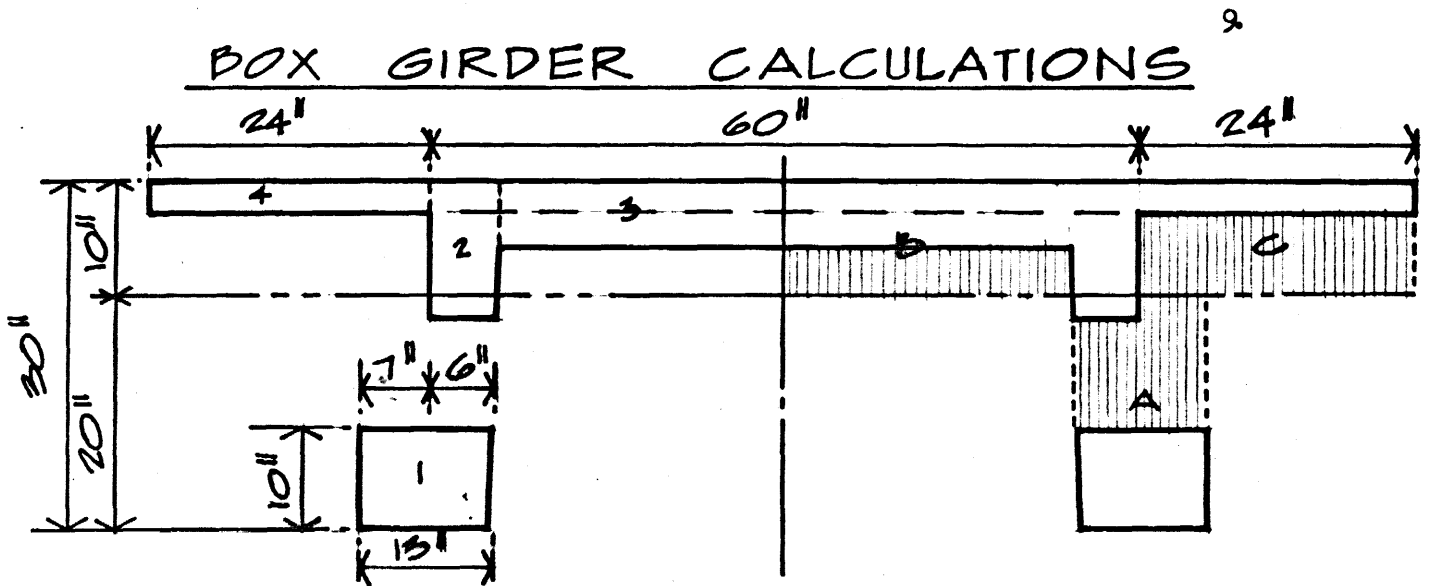
Subjects covered in calculations:

Box Girder Calculations

Spandrel Girder Calculations

Column Calculations

BOX GIRDER CALCULATIONS



| | A | X | d | = | M |
|----|-----|---|------|---|------|
| 1. | 130 | | 5 | | 650 |
| 2. | 72 | | 24 | | 1728 |
| 3. | 144 | | 27 | | 3888 |
| 4. | 72 | | 28.5 | | 2050 |
| | 408 | | | | 8316 |

$$\bar{y} = \frac{8316}{408} = 20 \text{ IN}$$

MOMENT OF INERTIA

$$I_T = I_A + I_B + I_C$$

$$I_T = \frac{1}{3} \left[13(20)^3 - 6(8)^3 - 6(10)^3 + 30(10)^3 - 24(4)^3 + 24(10)^3 - 24(7)^3 \right]$$

$$I_T = \frac{139600}{3} = 46,533 \text{ IN}^4$$

SECTION MODULUS

$$Z_b = \frac{I_T}{c}$$

$$Z_b = \frac{46533}{20} = 2326.65 \text{ IN}^3 > 4572 \text{ IN}^3 = Z_{b \text{ MIN}}$$

BOX GIRDER CALCULATIONS 10.

MINIMUM SECTION MODULUS : $Z_{b \text{ MIN}}$

$$A_g = 5.43 \text{ SQ FT}$$

$$5.43 \text{ FT}^2 \times 150 \text{ \#/FT}^3 = 800 \text{ \#/FT}; \text{ D.L. GIRDER}$$

$$w_D = .8 \text{ K}$$

$$\text{CHANNEL} : 90 \text{ \#/FT} \times 45' = 4050 \text{ \#/FT}$$

$$3'' \text{ TOPPING} : 37.5 \text{ \#/FT} \times 45' = 1688 \text{ \#/FT}$$

$$\text{LIVE LOAD} : 80 \text{ \#/FT} \times 49.5' = 3960 \text{ \#/FT}$$

$$w_a = 9.7 \text{ K}$$

$$W_a = 9.7 \text{ K} \times 32' = 310 \text{ KI}$$

$$M_a = \frac{W_a l}{8} = \frac{310 \times 32}{8} = 1240 \text{ KI}$$

$$W_D = .8 \times 32 = 26 \text{ KI}$$

$$M_D = \frac{W_D l}{8} = \frac{26 \times 32}{8} = 104 \text{ KI}$$

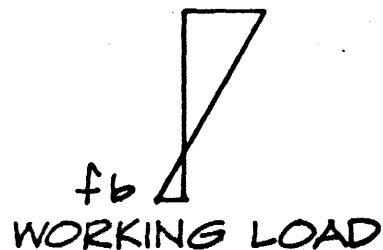
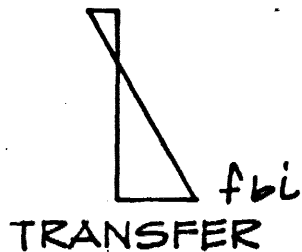
$$M_T = 1344 \text{ KI}$$

$$Z_{b \text{ MIN}} = \frac{M_a + M_D}{\eta f_{bi} - f_b};$$

f_{bi} = ALLOW. COMP. IN BOTTOM FIBER @ TRANSFER.

f_b = ALLOW. STRESS IN BOTTOM @ WORKING LOAD.

η = RESIDUAL PRESTRESS FRACTION



$$f_{bi} = .6 f'_c$$

$$f'_c = 6000 \text{ PSI}$$

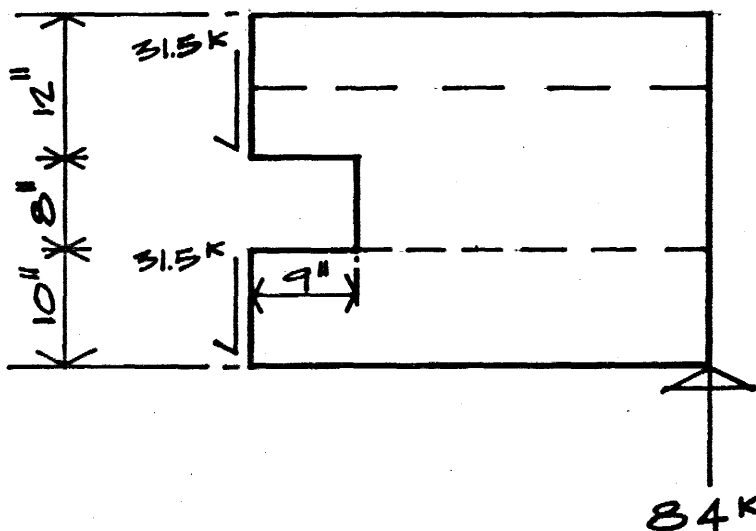
$$\therefore f_{bi} = 3600 \text{ PSI}$$

$$\eta = .85$$

$$f_b = -468 \text{ PSI FOR } f'_c = 6000 \text{ PSI}$$

$$Z_{bMIN} = \frac{1344}{3528} \times 12000 = 4572 \text{ IN}^4$$

ANALYSIS OF SECTION @ PERFORATION FOR SHEAR



$$b = 12''$$

$$d = 10''$$

$$V = 42 \text{ k}$$

$$M = 42 \times 7.5 = 31.5 \text{ k-ft}$$

$$v = \frac{32000}{12 \times 10} = 267 \#$$

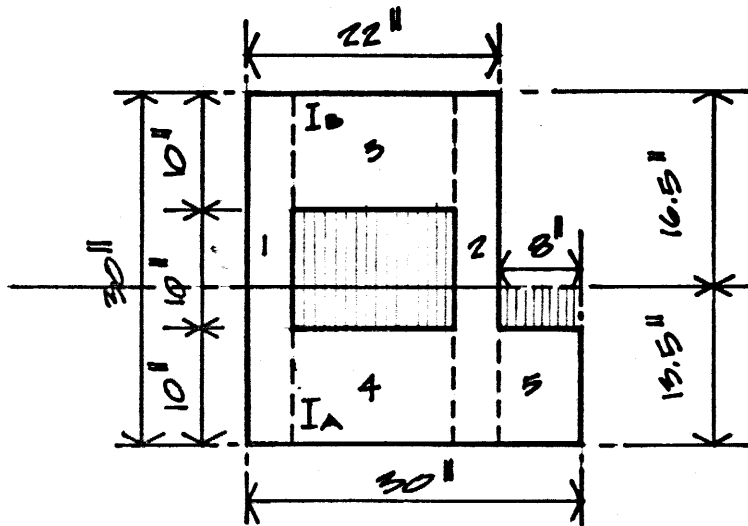
$v_{ALLOW. FOR } f'_c = 5000 \text{ PSI} = 240 \text{ PSI}$
SECTION REQUIRES ADDITIONAL STEEL IN STIRRUP
REINFORCING @ POINT.

ANALYSIS OF SECTION @ PERFORATION
FOR LOCAL BENDING.

$$d = \sqrt{\frac{M}{k b}} \quad k = 393 \text{ FOR } f'_c = 5000 \text{ PSI}$$

$$d = \sqrt{\frac{32 \times 1000 \times 12}{393 \times 12}} = 9''$$

SPANDREL GIRDER CALCULATIONS¹³



| | A | X | d | = | M |
|----|------------|---|----|---|-------------|
| 1. | 120 | | 15 | | 1800 |
| 2. | 120 | | 15 | | 1800 |
| 3. | 140 | | 25 | | 3500 |
| 4. | 140 | | 5 | | 700 |
| 5. | 80 | | 5 | | 400 |
| | <u>620</u> | | | | <u>8300</u> |

$$\bar{y} = \frac{8300}{620} = 13.5''$$

MOMENT OF INERTIA

$$I_T = I_A + I_B$$

$$I_T = \frac{1}{3} [30(13.5)^3 - 14(3.5)^3 - 8(3.5)^3 + 22(16.5)^3 - 14(6.6)^3]$$

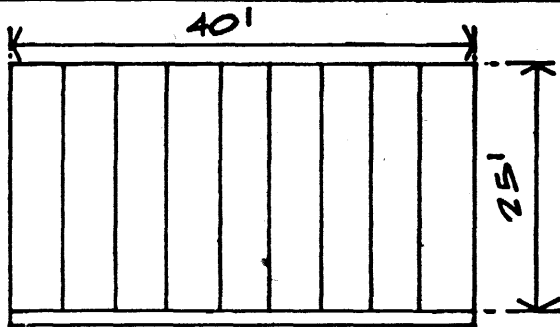
$$I_T = \frac{168,224}{3} = 56,100 \text{ IN}^4$$

SECTION MODULUS

$$Z_b = \frac{I_T}{c}$$

$$Z_b = \frac{56,100}{16.5} = 3390 \text{ IN}^3 > 3490 \text{ IN}^3$$

SPANDREL GIRDER CALCULATIONS ^{14.}



CHANNEL: $90 \#/\text{FT} \times 25 = 2250$
 TOPPING: $37.5 \#/\text{FT} \times 25 = 938$
 WINDOW UNIT: $500 \#/\text{FT} \times 1 = 500$
 LIVE LOAD: $80 \#/\text{FT} \times 25 = \underline{2000}$

$$w_a = 5688 = 5.6 \text{ k}$$

GIRDER: $A_g = 4.3 \text{ SQ FT} \times 150 = 645 \#/\text{FT} \times 1 = 645$

$$w_d = .6 \text{ k}$$

$$W_a = 5.6 \times 40 = 224;$$

$$M_a = \frac{224 \times 40}{8} = 1100 \text{ KI}$$

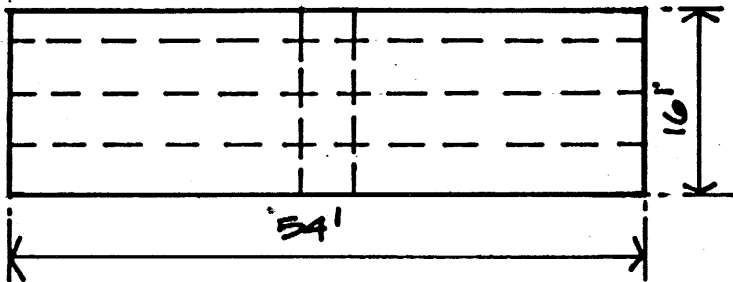
$$W_d = .6 \times 40 = 24;$$

$$M_d = \frac{2.4 \times 40}{8} = 11 \text{ KI}$$

$$M_T = 1111 \text{ KI}$$

$$Z_{b \text{ MIN}} = \frac{1111}{3528} \times 12000 = 3490 \text{ IN}^4$$

COLUMN CALCULATIONS



GIRDER: 178 PSF

CHANNEL: 90 PSF

TOPPING: 38 PSF

DEAD LOAD: 306 PSF

LIVE LOAD: 80 PSF

TOTAL 386 PSF

16X54 = 850(386) = 320,100 #

LIVE LOAD REDUCTION - 7,100 #

313,000 #

WEIGHT OF COLUMN

43,125 #

356,125 #

21 FLOORS

7,478,625 #

$$N = A (.215 f'_c + f_s P_g)$$

$$f'_c = 6000 \text{ PSI} \therefore .215 f'_c = 1290 \text{ PSI}$$

$$f_y = 60,000 \text{ PSI}$$

$$f_s = .85(.40 f_y) = .85(24,000) = 20,400 \text{ PSI}$$

$$P_g = .04$$

$$20,400 \times .04 = 816 \text{ PSI}$$

$$A = \frac{N}{1290 + 816} = \frac{7,478,625}{2106} = 3551 \text{ SQ IN}$$

$$\frac{3551}{21} = 170 \text{ SQ IN/FLR REDUCTION OF A.}$$

V. Mechanical and Electrical Systems

The main mechanical areas are located on the eighth floor and the penthouse. The eighth floor mechanical area feeds down seven floors and up seven floors. The penthouse mechanical area feeds down six floors. The mechanical areas have been located in the most advantageous positions, as it is easier to move air with gravity and the intermediate mechanical floor feeds in both directions. Fresh air will be taken in as well as exhausted at each mechanical floor.

Several visual expressions exist for mechanical floors at the midpoint of the building; it can be ignored or expressed, played up or down. I have elected to recess the mechanical floor. Set-backs differentiate special areas of the building; offer contrapuntal punctuation in its surface, and enhance the post and beam character of its structure. In an urban environment such recesses give vitality to a building.

Two mechanical systems have been employed in my building. One is a high velocity periphery air-conditioning system which is supplemented by the second system. The second system is a low velocity central system supplied from the service core. The high velocity periphery system will be supplied by vertical risers within the two interior columns on each facade. These columns will then be the major structural and mechanical columns on every side of the building. There will be run-outs on each floor feeding in both directions from the columns into the precast window units. A flexible

connection will be made to each induction unit beneath the window sills. Hot, cold, return and condensate pipes will also feed out along with the air duct. This periphery system will have individual controls at each unit which will obviate any zoning of the building. These induction units can handle a maximum depth into the building of 23 feet. My layout will be for a depth of three modules or approximately 14 feet. The majority of the air in this peripheral zone will not be returned but will pressurize this area and dissipate back into the core.

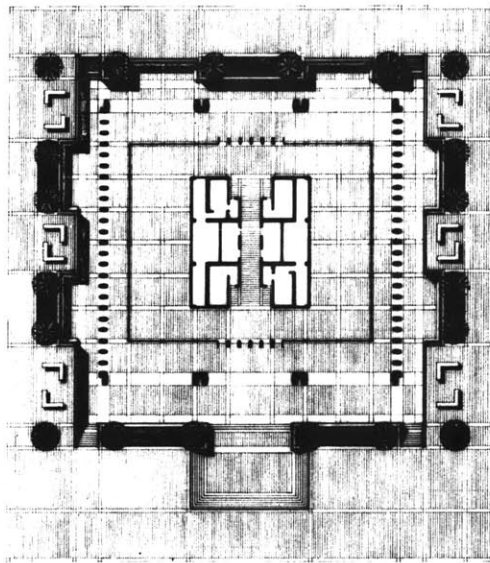
The periphery system will function in conjunction with the low velocity central system. The ducts of this system will emanate from the central core with the main trunks running within the box girders from whence the ducts will branch off into the channels. Every other channel will have a supply duct with the adjacent channel housing the return. This gives a mechanical module of 9'-0" which will then contain both a supply and return air duct. The low velocity system will have a temperature and air-volume control on each floor with a re-heat coil situated in the core. The return air grille will be combined with the lighting fixture which will be perforated to allow heat to be removed from its main source. The supply grille will be the same size as the lighting fixture.

By integrating these two systems flexibility and efficiency will be realized. Running vertical riser ducts up the columns will save on square footage otherwise necessitated in the core which in turn would usurp rentable office space. The need for

ceiling ducts will be reduced, thereby reducing the floor construction from that required by an all duct system from the core. Another advantage of the system is the creation of continuous surfaces on the interior wall space. No columns or ducts project into the interior space. It is also possible with the application of heat removal techniques to evidence considerable saving in the operating cost of cooling and heating systems.

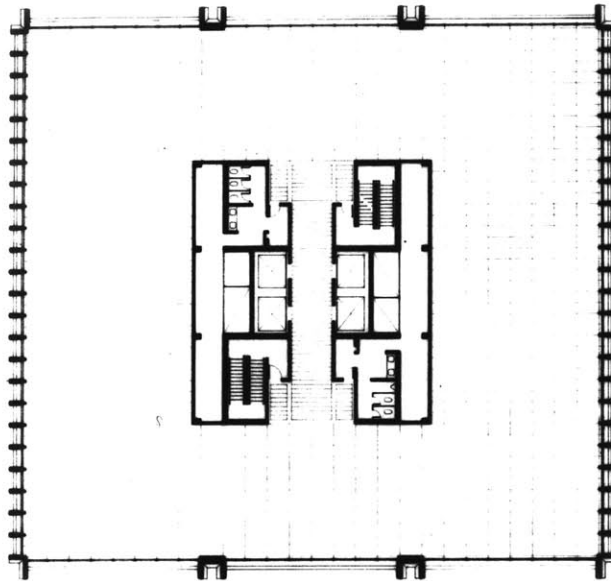
Lighting

A continuous strip of lighting will be contained in every other channel which will also be a heat removable troffer. This will provide the required foot candle capacity at desk levels in the office spaces. Telephone and electrical service will be situated in under floor ducts with access at the center of each module. Electrical bus conduits will be contained in the structural and mechanical columns and the telephone service will originate from electrical closets located in the service core on each floor.



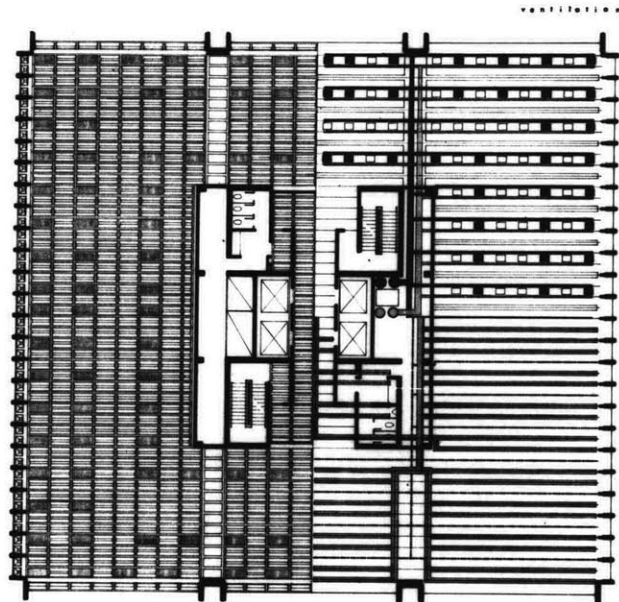
PLAN OF ENTRANCE LEVEL
.....

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
ALAN W. BRUNSON
Master of Architecture Thesis
M. I. T. JUNE 1963



PLAN OF TYPICAL FLOOR
1:10

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OFFICE BUILDING
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Master of Architecture Thesis
M.I.T. JUNE 1963

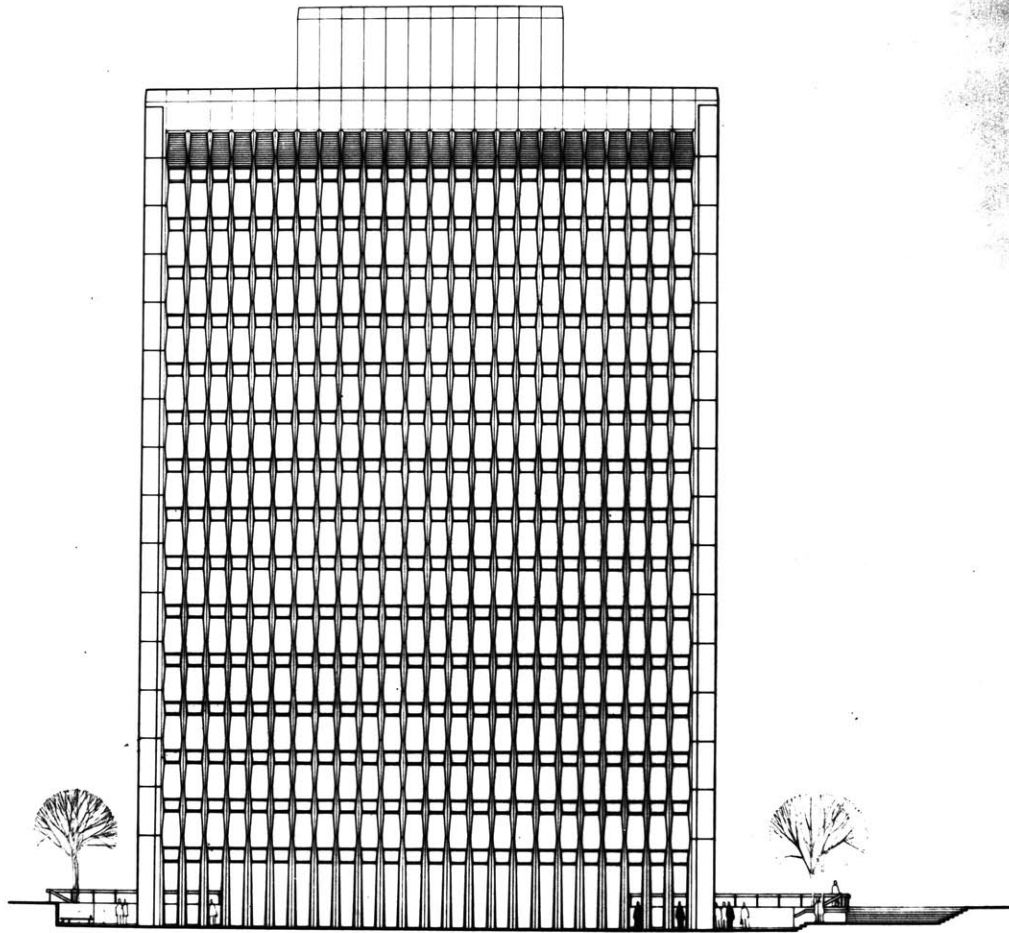


reflected ceiling plan

electric
plumbing

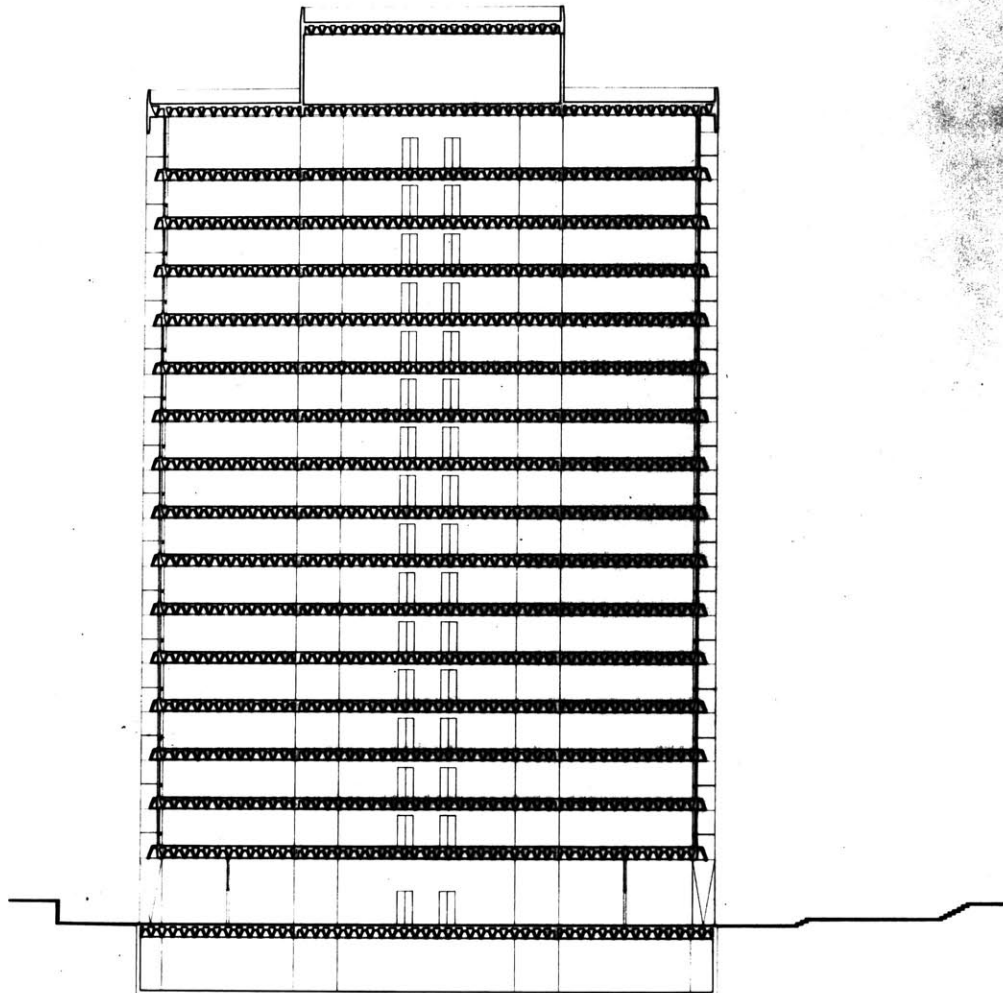
PLAN OF MECHANICAL SYSTEMS
SCALE

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
A L W W B Y N S S W
Master of Architecture Thesis
M.I.T. June 1963



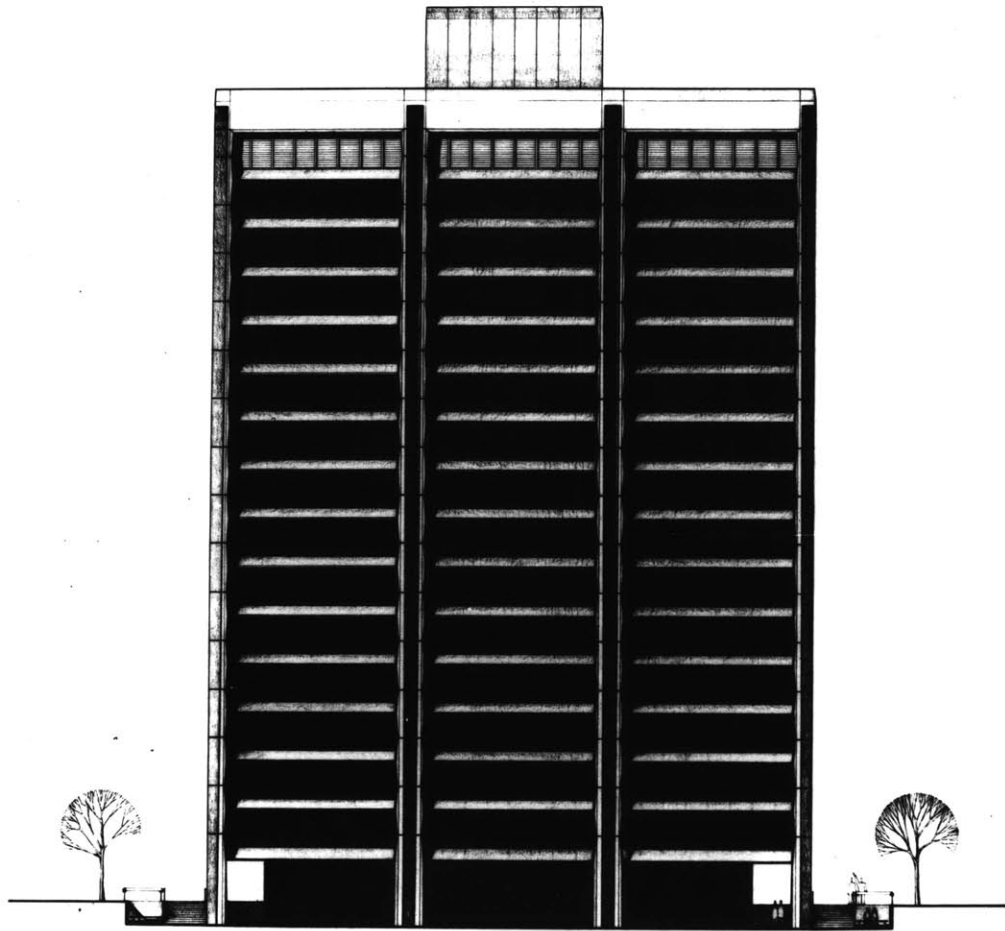
SOUTH ELEVATION
1963

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
A I G A W. B R U N S O N
Master of Architecture Thesis
M. I. T. J U N E 1 9 6 3



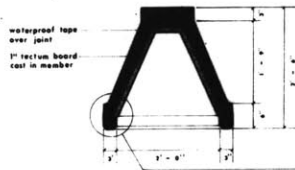
SECTION OF BUILDING
10012

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
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WEST ELEVATION
SCALE 1/8" = 1'-0"

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
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Master of Architecture Thesis
M.I.T. JUN 1963



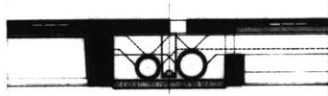
TYPICAL FLOOR UNIT
1:20



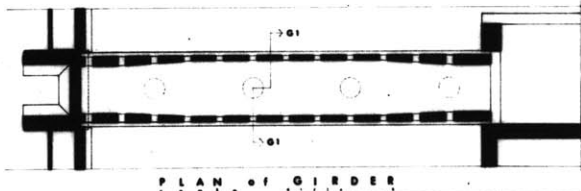
TYPICAL SECTION
1:20



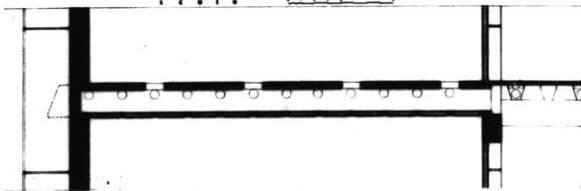
FORMING DETAIL
1:20



SECTION 01
SCALE

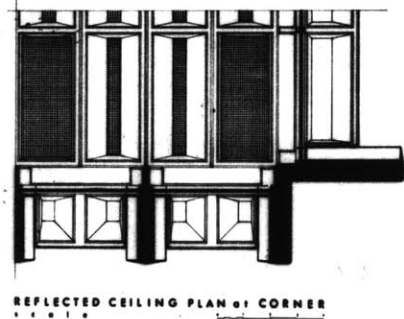
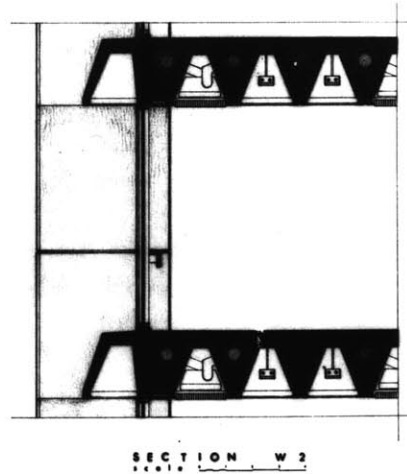
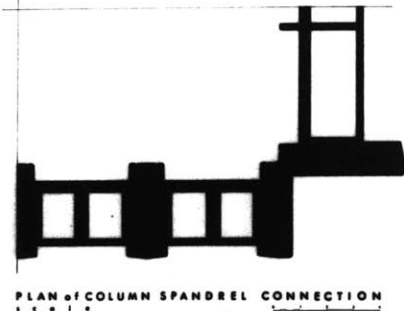
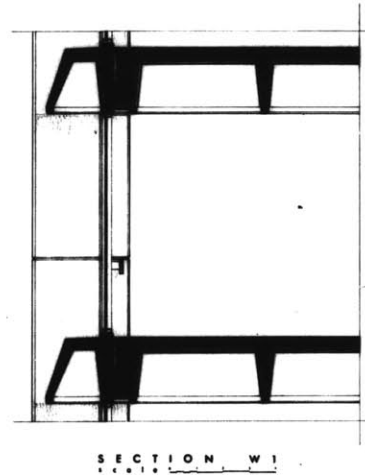
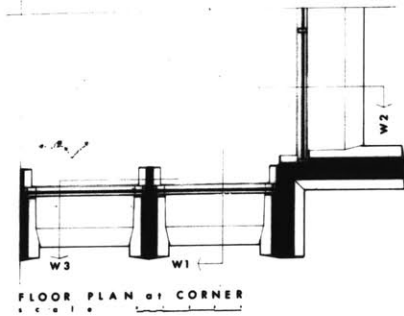


PLAN OF GIRDER
SCALE

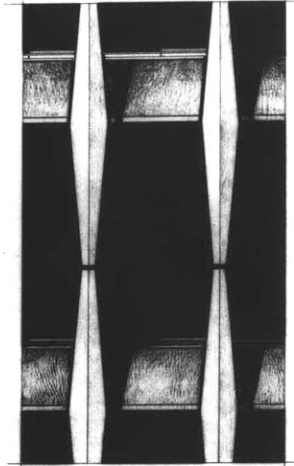


SECTION OF GIRDER
SCALE

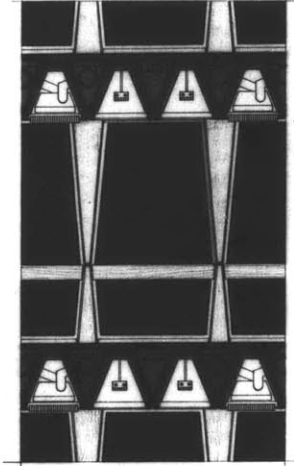
A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
ALAN W. BRUBAKER
Master of Architecture Thesis
M.I.T. June 1963



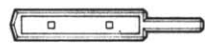
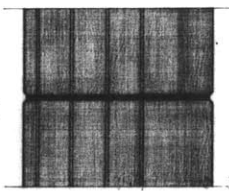
A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
A THOMAS W. STUBBS
Master of Architecture Thesis
M.I.T. JUN 1963



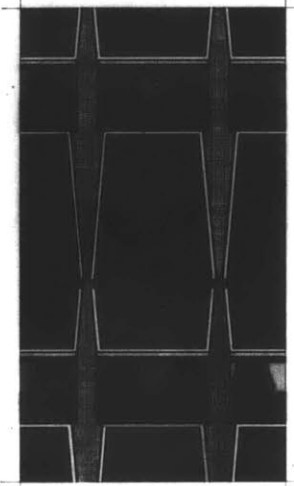
EXTERIOR ELEVATION
1961



INTERIOR ELEVATION
1961

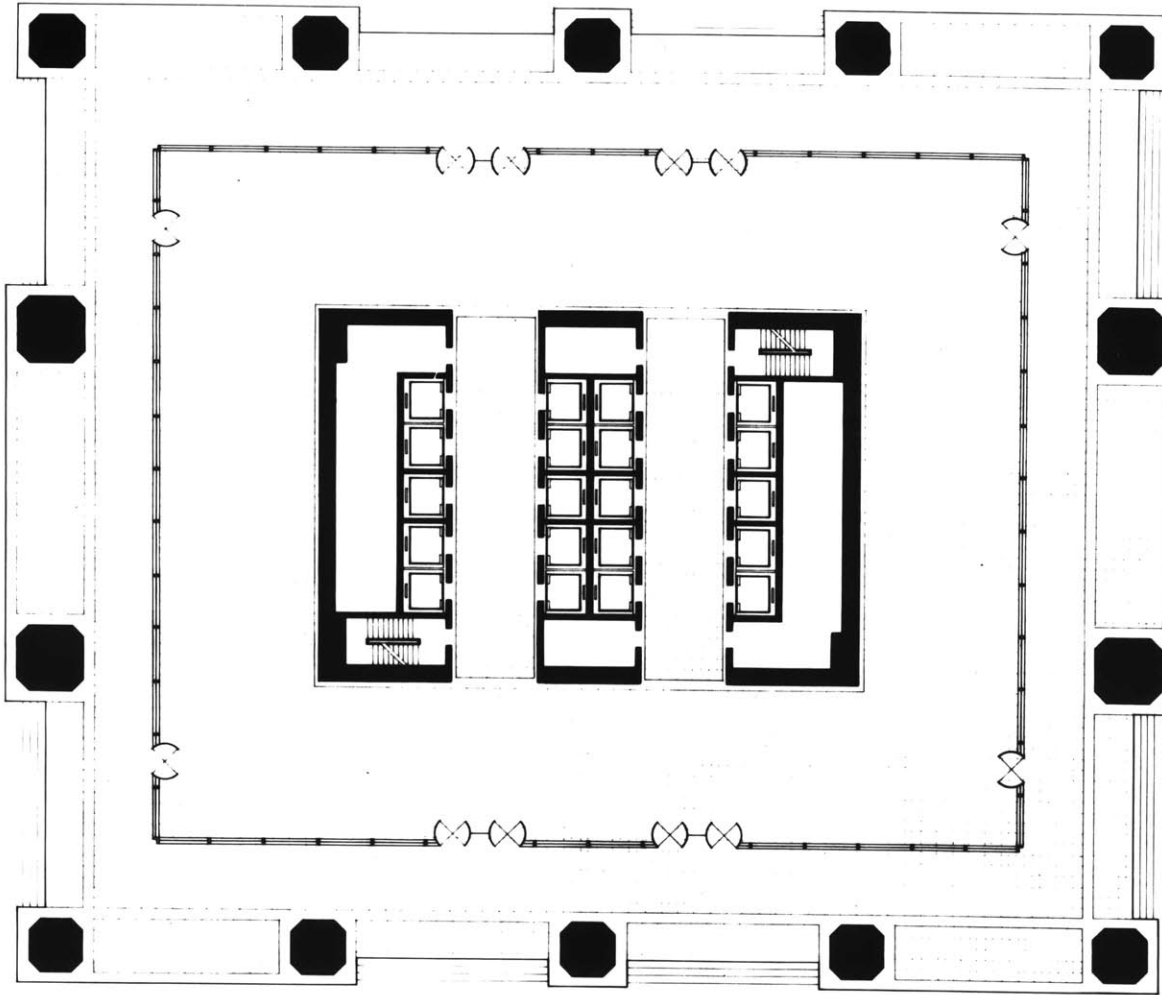


DETAIL of COLUMN CONNECTION
1961



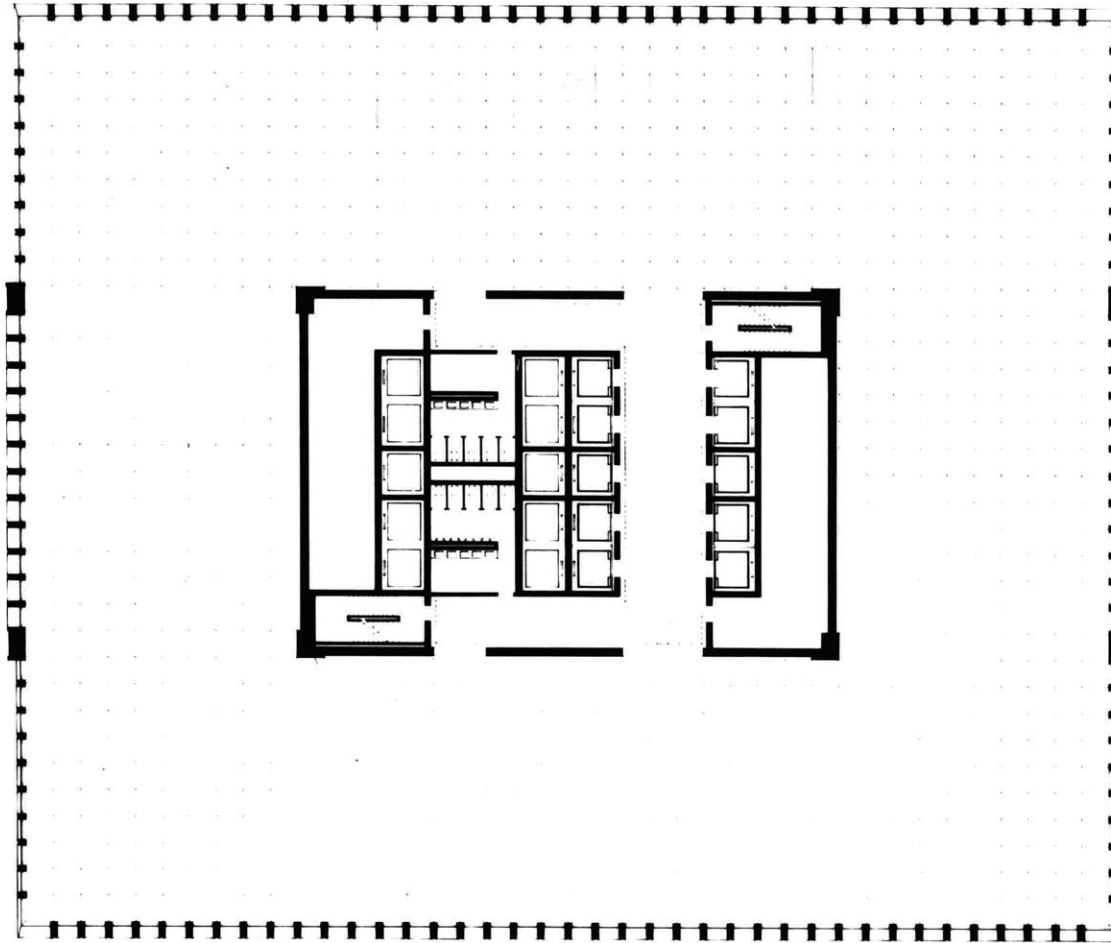
SECTION W3
1961

A MULTISTORY PRECAST CONCRETE
OFFICE BUILDING
ALAN W. BRUBAKER
Master of Architecture Thesis
M.I.T. June 1963



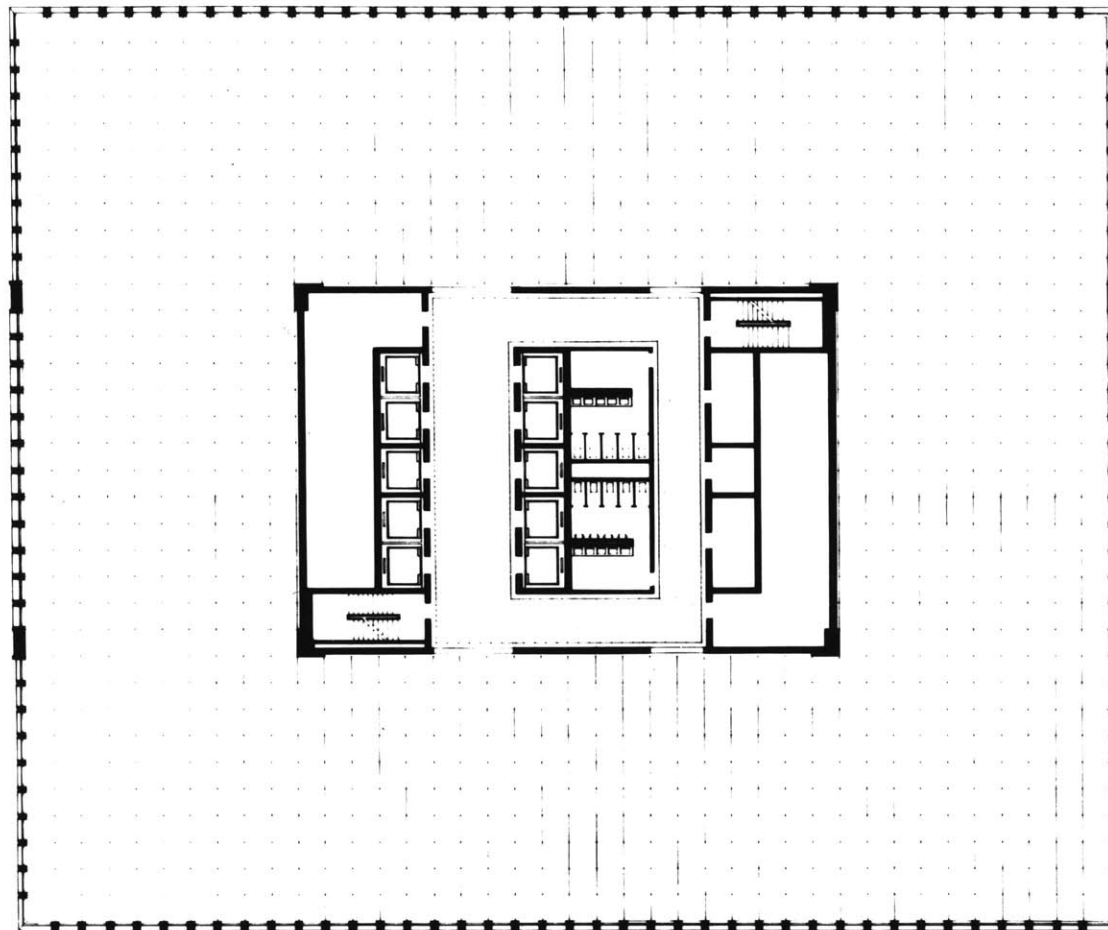
ENTRANCE LEVEL
 0 5 10 20 30 40 50 FEET

A HIGH RISE PRECAST CONCRETE
 OFFICE BUILDING
 MASTER IN ARCHITECTURE THESIS
 THOMAS RENNEY M.I.T. JUNE 1963.



TYPICAL LOW RISE FLOOR PLAN
0 5 10 20 30 40 50 FEET

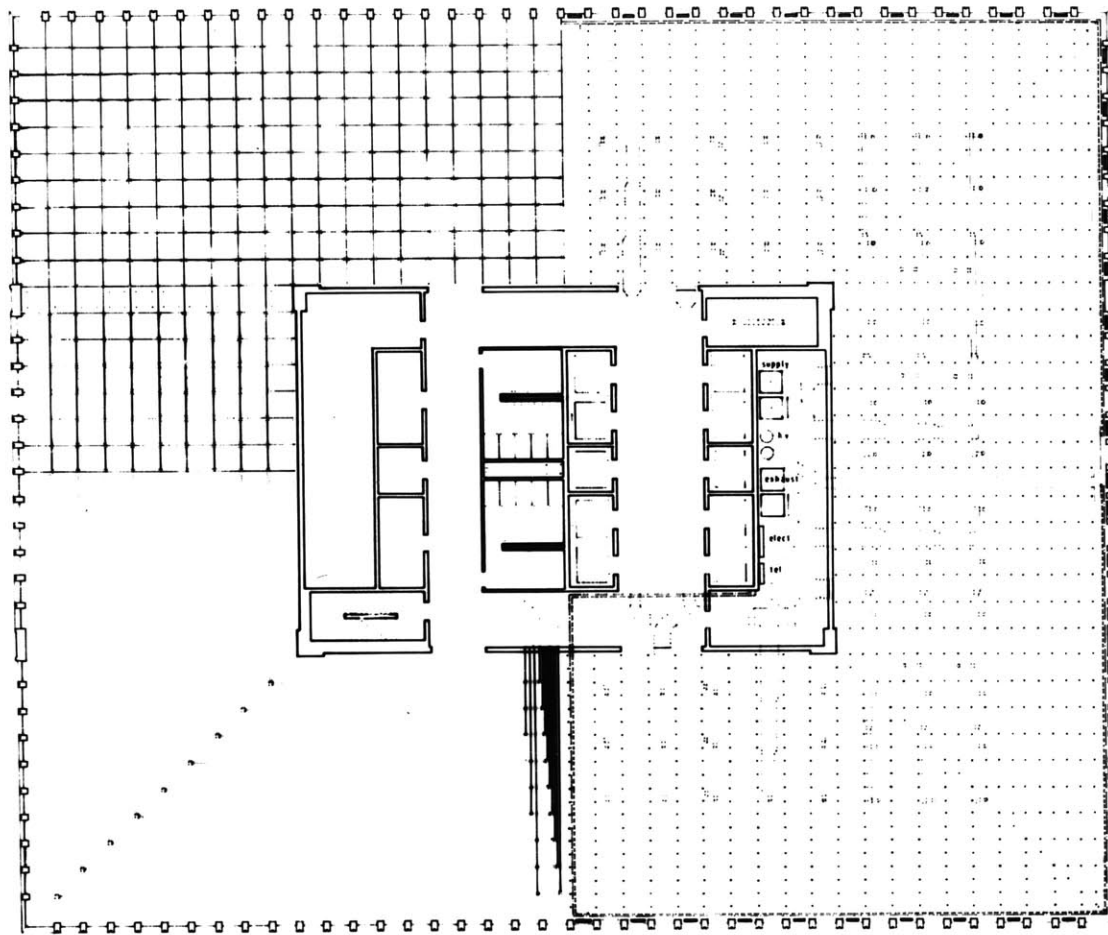
A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER IN ARCHITECTURE THESIS
THOMAS HENNEY M.A.T. JUNE 1963



TYPICAL HIGH RISE FLOOR PLAN
0 5 10 20 30 40 50 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING **3**
MASTER IN ARCHITECTURE THESIS
THOMAS HENNEY M.L.T. JUNE 1963

LIGHTING & STRUCTURAL GRID



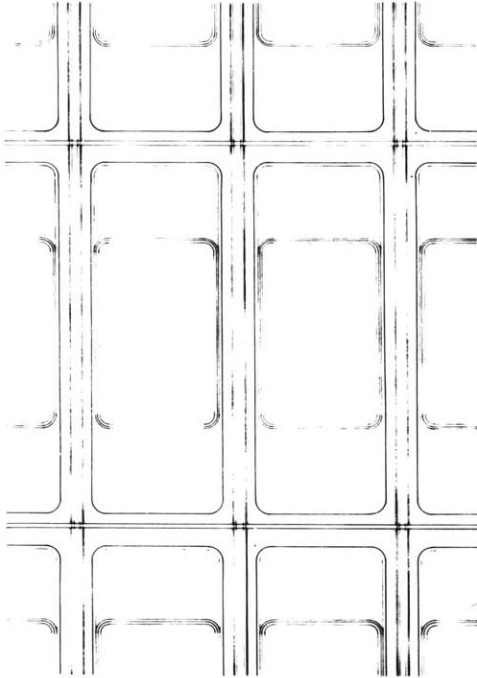
POWER & TELEPHONE

AIR CONDITIONING

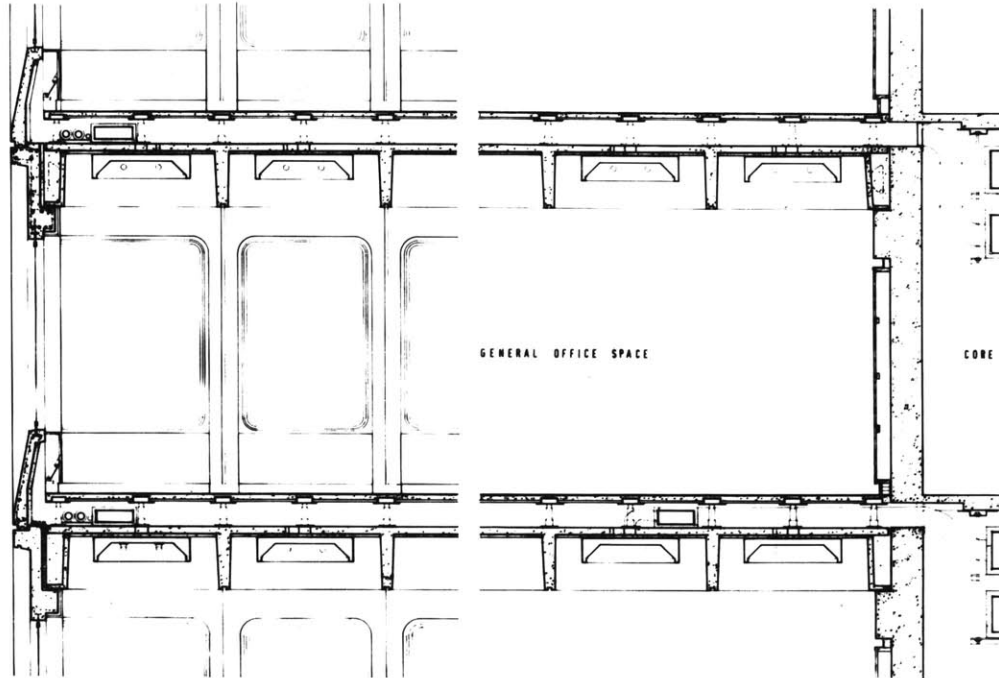
ELECTRICAL MECHANICAL & STRUCTURAL SYSTEMS

0 4 8 12 16 20 24 28 32 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER IN ARCHITECTURE THESIS
THOMAS HENNEY MIT JUNE 1963



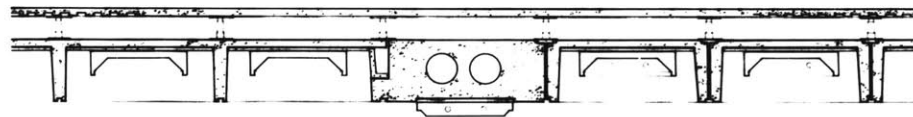
ELEVATION



CROSS SECTION



PLAN

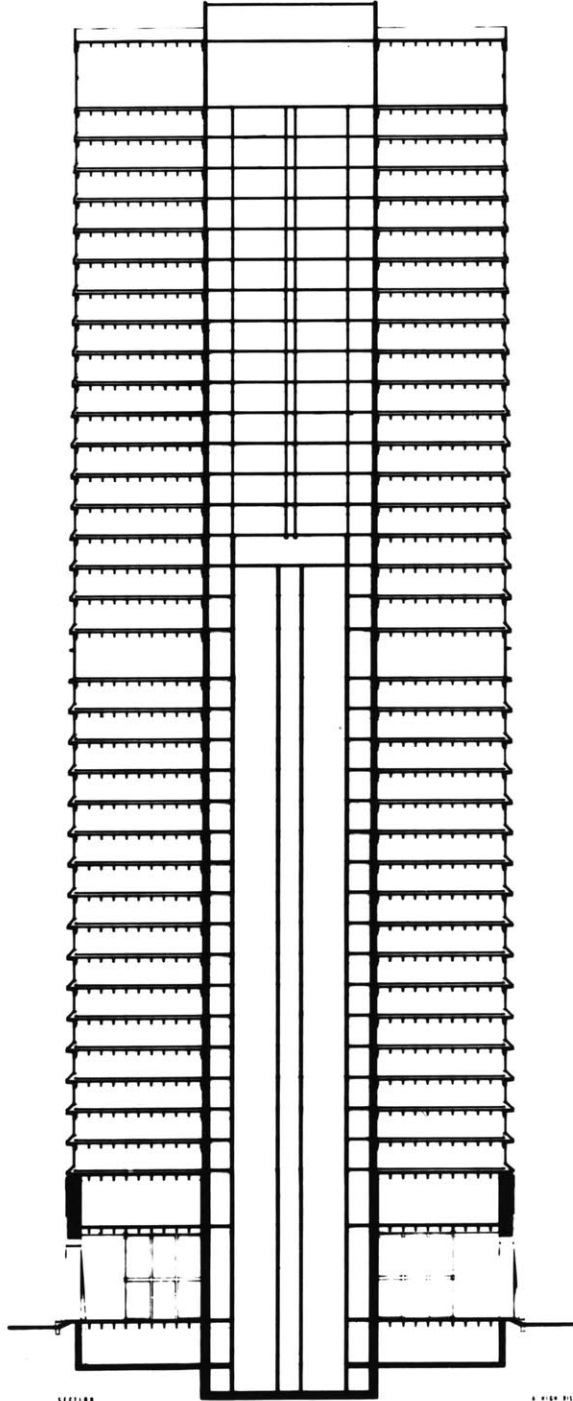


SECTION THRO' GIRDER

STRUCTURAL AND MECHANICAL DETAILS

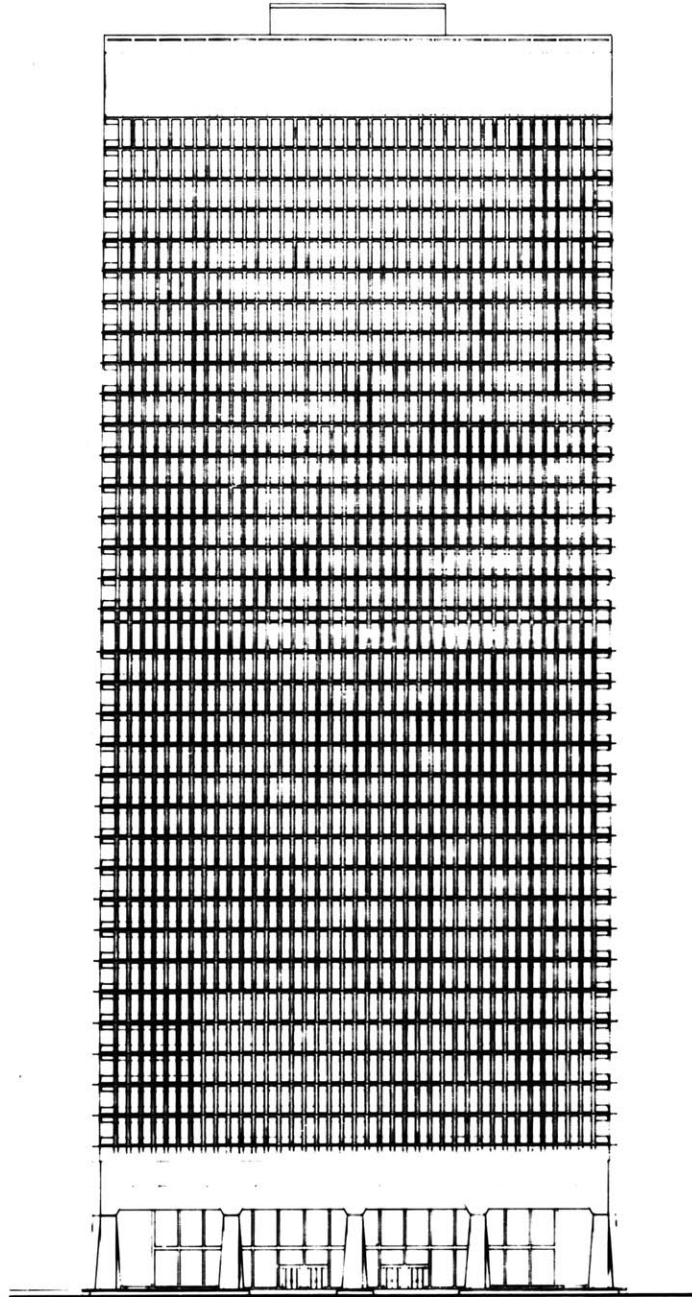
0 1 2 3 4 5 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER IN ARCHITECTURE THESIS
THOMAS HENNEY MIT 1967



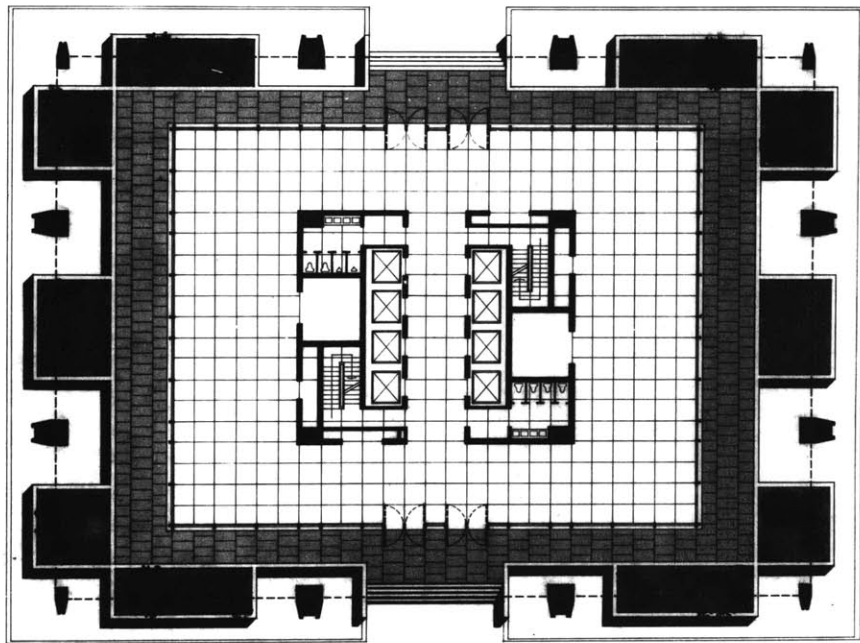
SECTION
1 1/2" = 1' - 0"

A HIGH STRENGTH PRECAST CONCRETE
CORE BUILDING
DESIGNED BY ARCHITECTURAL MODEL
THOMAS HERRICK, INC. 1961-1962



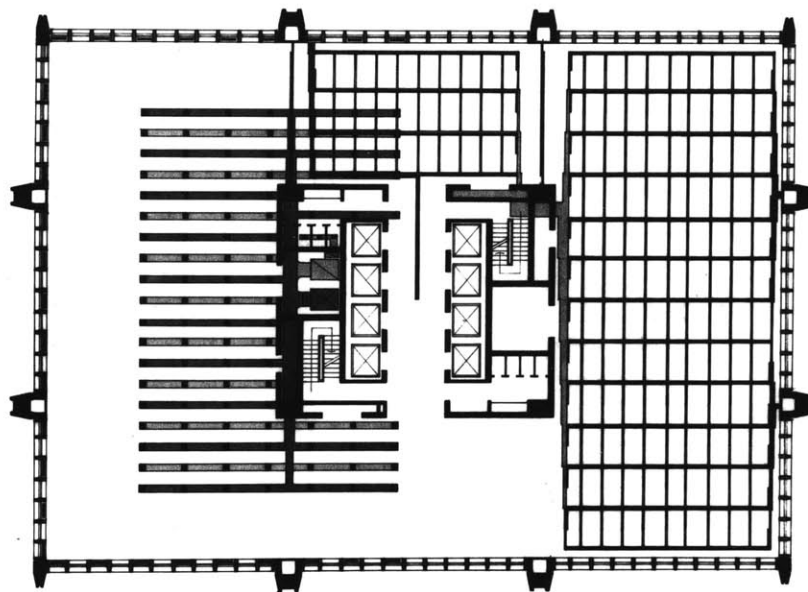
FACADE ELEVATION
1/4" = 1' - 0"

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
DESIGNED BY ARCHITECTURAL PARTNERS
PHILADELPHIA, PENNSYLVANIA 19103



ENTRANCE LEVEL
0 5 10 20 30 FEET

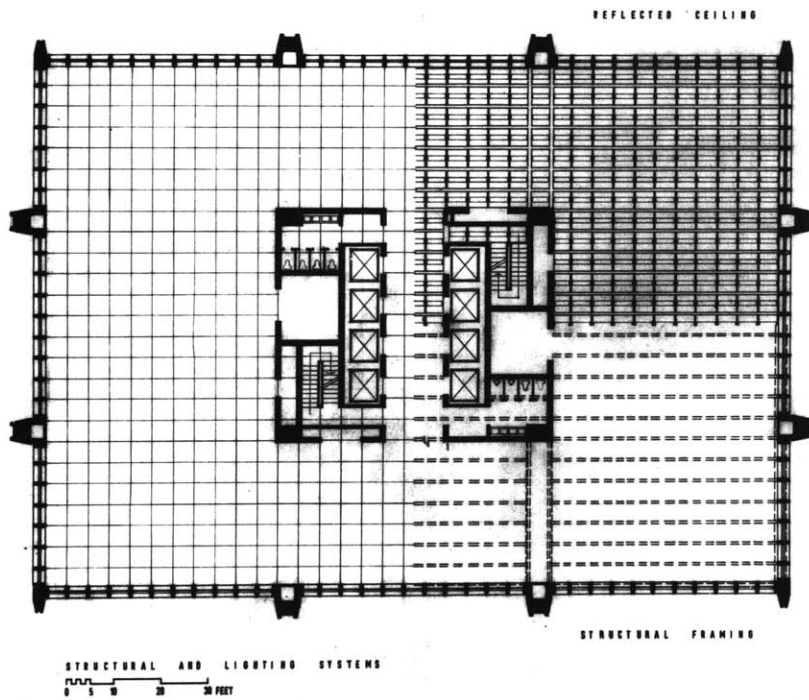
A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



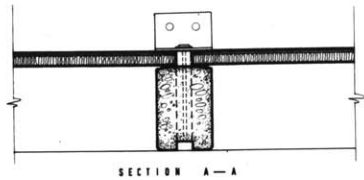
DUCT LAYOUT
 MECHANICAL AND ELECTRICAL SYSTEMS
 0 5 10 20 30 FEET

ELECTRICAL LAYOUT

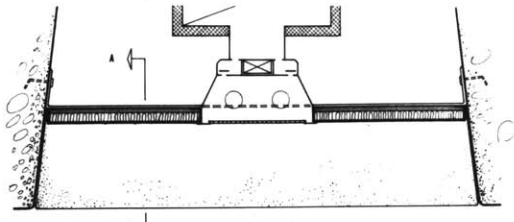
A HIGH RISE PRECAST CONCRETE
 OFFICE BUILDING
 MASTER OF ARCHITECTURE THESIS
 RODNEY AMES WESTBURY M. I. T. JUNE 1963



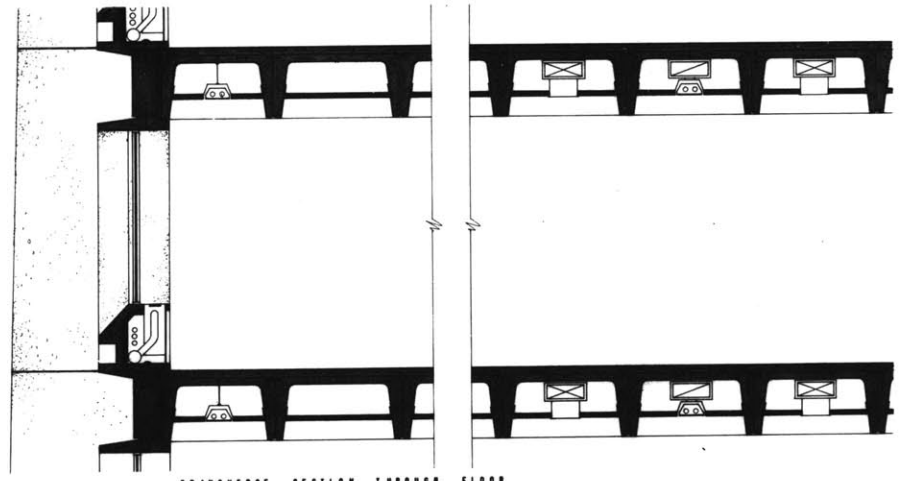
A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



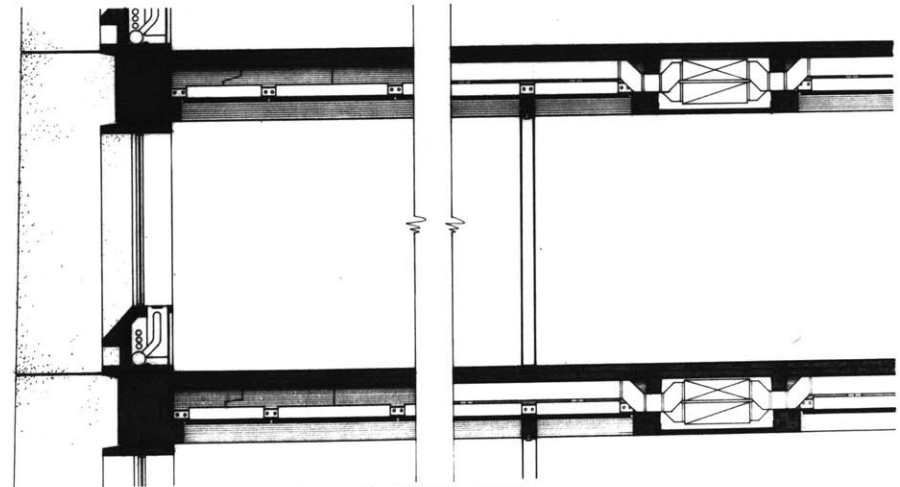
SECTION A-A



CEILING PANEL DETAIL



TRANSVERSE SECTION THROUGH FLOOR
0 1 2 3 4 5 FEET

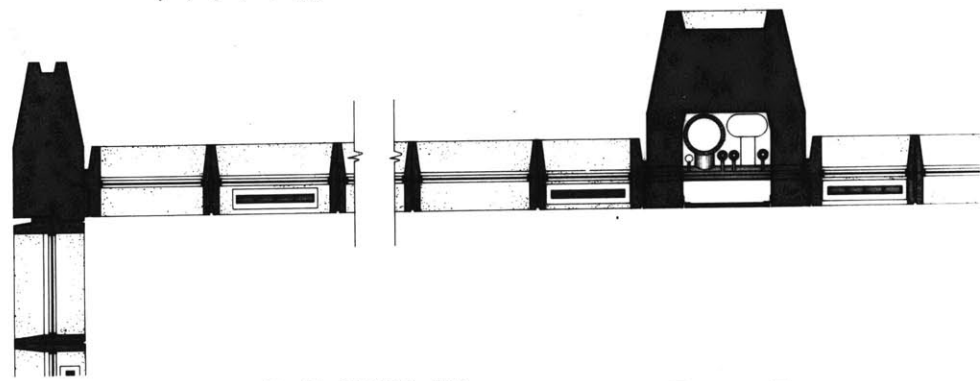


LONGITUDINAL SECTION THROUGH FLOOR
0 1 2 3 4 5 FEET

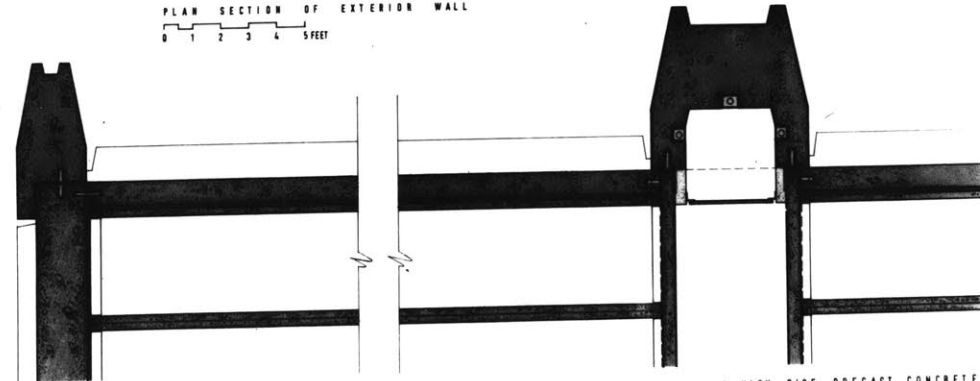
A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



ELEVATION DETAIL
0 1 2 3 4 5 FEET

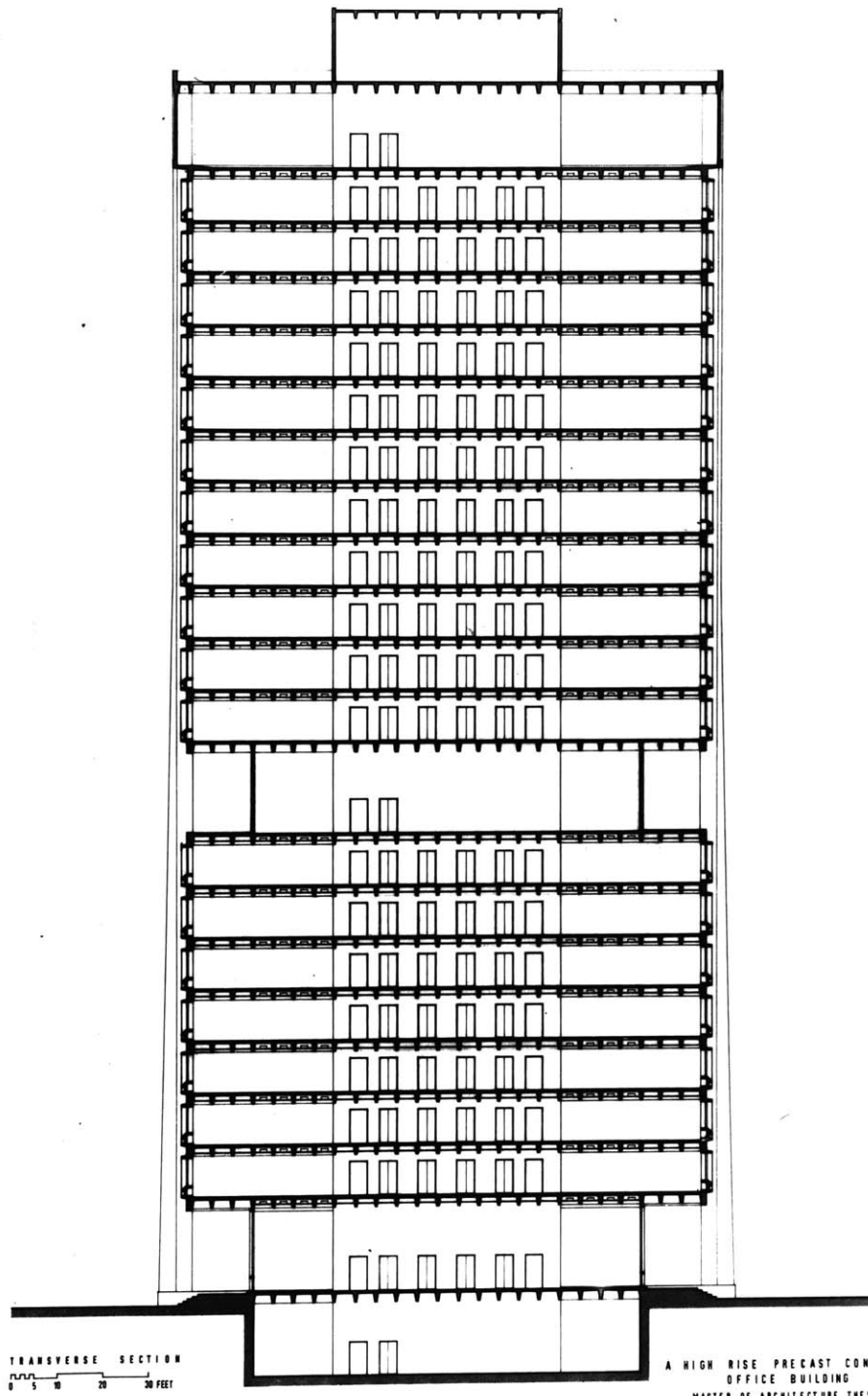


PLAN SECTION OF EXTERIOR WALL
0 1 2 3 4 5 FEET



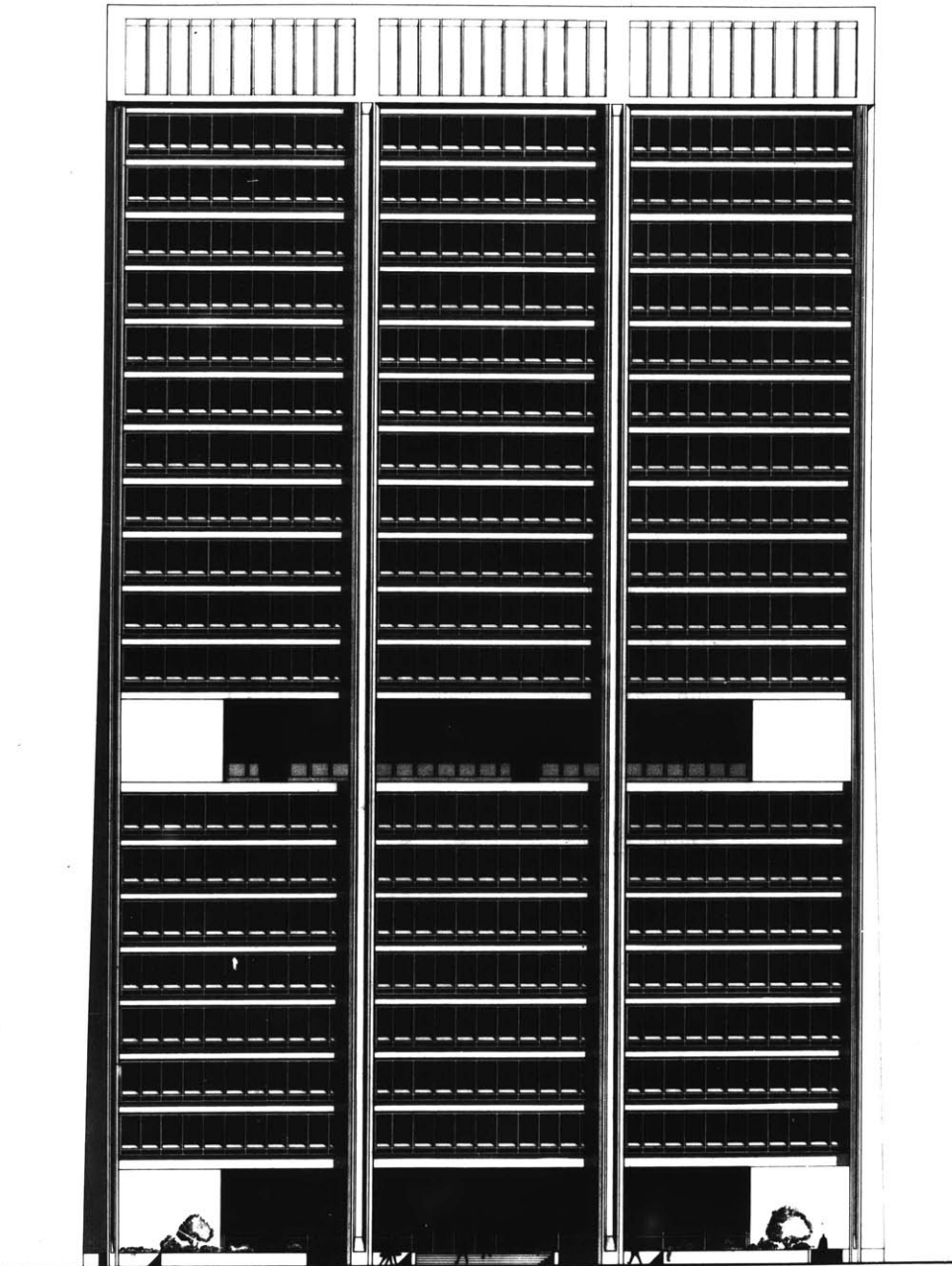
FRAMING DETAILS
0 1 2 3 4 5 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



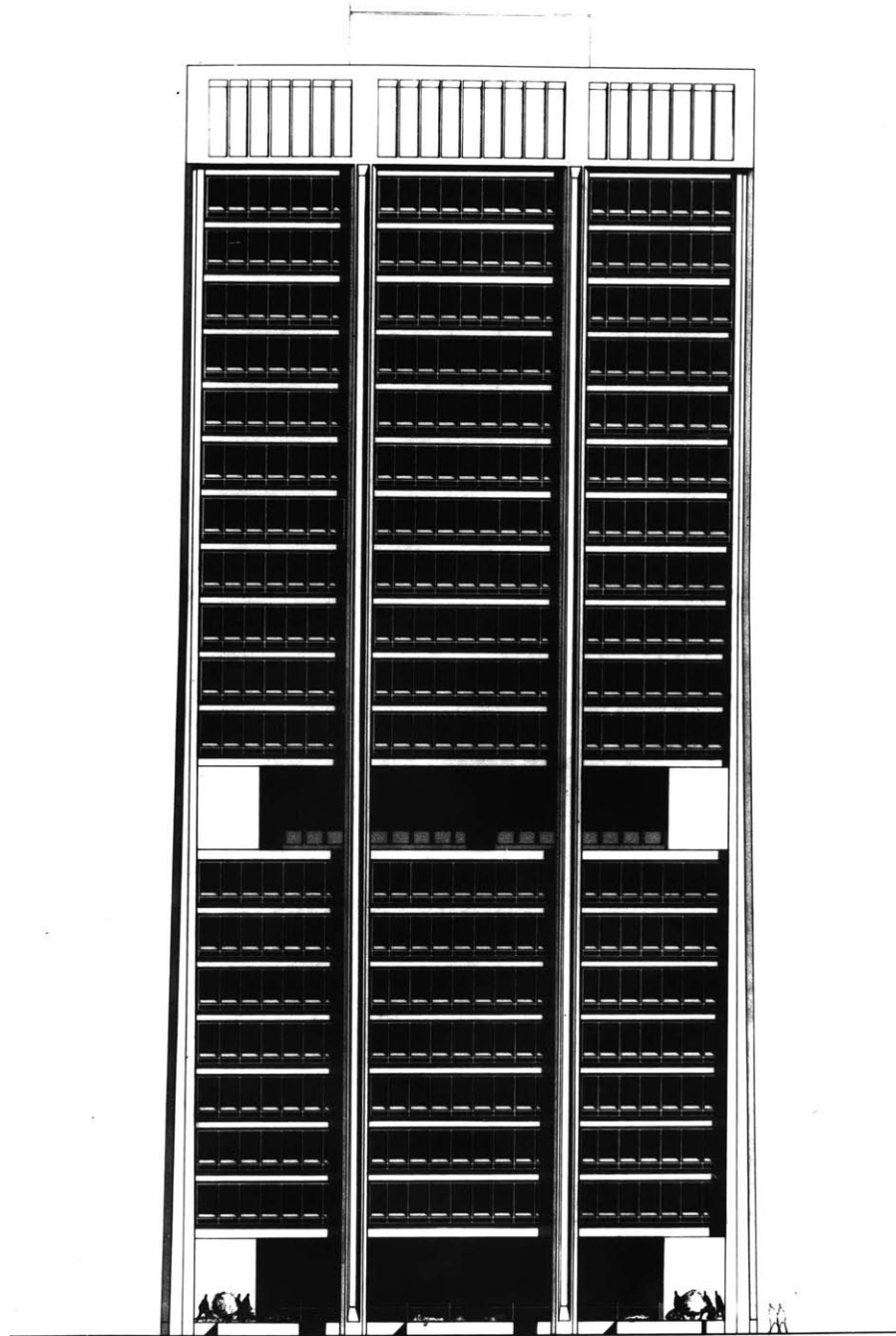
TRANSVERSE SECTION
0 5 10 20 30 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



FRONT ELEVATION
0 5 10 20 30 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1963



END ELEVATION
0 5 10 20 30 FEET

A HIGH RISE PRECAST CONCRETE
OFFICE BUILDING
MASTER OF ARCHITECTURE THESIS
RODNEY AMES WESTBURY M. I. T. JUNE 1967