

BUILDING ACTIVITIES CENTER FOR NEW ENGLAND

by

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the Requirement for the Degree of

MASTER IN ARCHITECTURE

from the

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Signature of Author _____

Signature of Head
of Department _____

ABSTRACT

Building Activities Center for New England

by

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A Building Activities Center for New England consists of an organization and building complex where a permanent display of building techniques, materials and equipment will be exhibited and offices, library and supplementary areas where technical information will be gathered and compiled. In addition, a rental office building is included as an assurance of adequate financial income for the continuation of the organization. Particular emphasis has been placed on the development of a new structural form for this office building where the techniques of prestressed and pre-cast concrete have been applied.

Rentals (Arch) Nov 7, 1952

Cambridge, Massachusetts
July 16, 1952

Dr. Pietro Belluschi
Dean of Architecture & Planning
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Sir:

The following report and drawings have been compiled as a partial fulfillment of the requirements for the Degree of Master in Architecture at the Massachusetts Institute of Technology. It is desired to draw your attention to the fact that while the plot plan of the area indicates a possible complete development, the problem of this thesis is the design of the one building complex. The additional area shown follows the use pattern considered feasible by the Boston City Planning Department and is included here to show only the desired relationships to this project.

Sincerely,

/
Robert H. Fowble

ACKNOWLEDGMENTS

I wish to express my thanks to the many persons who have given generously of their time and knowledge, without which this study would have lacked much of its reality. Unfortunately, only selected facts from the fund of information gathered will be presented. Of particular assistance in the preparation of this project has been Mr. Fred Balderson of the Department of Economics, M.I.T.; Mr. Gibson of the John Hancock Life Insurance Company; Professor Holley of the Department of Civil Engineering, M.I.T.; and Mr. Mathews of the Statler Corporation. I wish also to mention the excellent cooperation extended by the City Planning Department of the City of Boston, Producers Council Incorporated (Boston Chapter) and the Massachusetts Building Congress.

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INTRODUCTION

The object of this thesis is the design of a building complex to house a hypothetical organizations for advancement of building design, techniques and information.

The purpose of this organization is to provide objective visual, verbal and written information in the field of building design, materials, equipment and techniques.

In order to carry out these aims the following building elements are necessary:

1. Public Exhibit Area
2. Architectural and Engineering Library
3. Motion Picture and Slide Projection Rooms
4. Meeting Rooms for Study Groups and Congresses
5. Executive Offices
6. Management and Operations Offices and

Auxiliary spaces

Exhibits

The exhibits will be aimed at development of new ideas and stimulation of existing activities.

For the architect and engineer they will be a source of technical information, inspiration and a means of informing his clients of the products under consideration. For the contractor they will be a source of information on building products and their proper use. For the building materials representative they will be a form of public advertising and display for wholesale operations. For the student and interested layman they will afford instruction and relaxation.

Exhibits will require the approval of a committee of control before they may be shown. The approval will be based upon subject matter, documentation and the manner of presentation. An attempt will be made to see that all subjects are presented in a manner of interest to the layman. Proper methods of use and special characteristics are to be stressed in the exhibits.

Three classes of exhibits will be maintained. One of interesting architectural and engineering designs in which special attention will be given to the accredited schools throughout the country and foreign exhibits. A second will deal with the basic construction materials and methods and a third with those items attached to or used within the basic structure.

Architectural and Engineering Library and Film Division*

An Architectural and Engineering Library of 45,000 volumes, 17,000 pamphlets and 800 maps will be maintained for use by the public, architects, engineers, students and other interested persons. In addition a film division stocking 30,000 slides and 500 reels of 8, 16 and 35 mm. motion picture film will be maintained. One, two and six man stalls will be provided for special study groups.

View Rooms

Three viewing rooms equipped for slide projection and 8 and 16 mm. movie projection will be provided. Two will seat fifty persons

*Recommended by Miss Caroline Shillaber, Architectural Librarian, MIT.

each and the third will accommodate one hundred and fifty persons. The large viewing room will be equipped to project 35 mm. movies. These rooms will be made available for public lectures, study groups, seminars or congresses and building materials representatives with offices in the complex.

Meeting Rooms

Three meeting rooms with capacities for fifty, fifty, and one hundred and fifty persons will be provided. These rooms will be made available for like groups as the viewing rooms. A small kitchenette will be provided where coffee and refreshments may be prepared.

Offices, Editing and Work Room

A board meeting room, offices for the president, manager, secretary, treasurer and accountant, an editing room with its clip room and work room will be provided in the office structure. A librarian's office and work room will be provided in connection with the library and a film editing and cutting room with the film division. An exhibition and display work room will be provided adjoining the storage room and having access to the rail and truck dock.

Photo Labs and Studios

Two photo laboratories and studios will be provided, one for use by the film division and one for use by the tenants.

The recommended organizational form for pursuing these aims is a corporation with an executive board to consist of fourteen persons whose responsibility it would be to form all policies, select management personnel and direct operations. The board is to consist of two each of architects, engineers, building products producers, financiers, contractors, educators and lawyers. Each person is to serve for a period of two years and his term of office will be so arranged that one member from each classification will be replaced each year. The architects will be selected by the local chapter of the A.I.A. The engineers will be selected by the local chapters of the national engineering societies with special interests in building construction which are represented in the Boston Metropolitan Area, each having one vote. The building products producer members will be selected by the local chapter of the Producers Council. The contractor members will be selected by the Massachusetts Building Congress. The financiers will be selected by their local chapters of the national organizations by which they are represented in the Boston Metropolitan Area. The educators will be selected by an organization formed for this purpose. All educators employed in fields related to the building industry, by institutions of higher learning in the Metropolitan Area of Boston, will be eligible for membership. The lawyers will be selected by their local chapters of their national organizations. In any case where organizations do not exist, they shall be formed before members of that profession may serve on the governing board.

The original equity for the corporation's properties will be gathered by gifts and the sale of non-voting stock. The major funds for

property development will be by bank or insurance loan for which the developed assets will stand as security. The organizations debt service, operating expense and profits will be derived by rental of corporate properties, services and publications for the building industry, preparation of educational films and slides, displays of model homes and such research as may be carried on by the staff.

Rental properties held by the corporation will consist of display space, office space, auto parking garage, cafeteria and blue printing establishments.

Two attempts at permanent architectural products displays in Boston have been made. Both were located on Beacon Street, the first near the Tremont Street end and the latter opposite the Public Gardens. While it has been impossible to determine their cause of failure it appears to have been due to organizational difficulties in each instance. Both apparently lacked organizational direction and control. The first attempt appears to have had no effort exerted beyond its original instigation, while the second attempt disintegrated thru lack of control of the exhibits. The final results in both instances were the withdrawal of financial support. The lessons which may be learned from these failures are that an active organization, certain basic controls and an operational source of financing are essential.

The errors of the past have been faced in the proposed program by first selecting a number of well qualified persons, each with vested interests, to act as directors of the corporation. The activities of the corporation in carrying out its purpose must be such as to

remind its members and their organizations of its existence and the benefits of participation. This helps maintain an active interest. Through committees a close control may be maintained over the workings of the organization and the provision of rental properties insures a source of continued finance.

SITE SELECTION

Site selection became a major problem as the success of the project was felt to depend to a large extent upon its use by persons of the architectural and engineering professions. Following interviews with a number of these persons the feeling was unanimous that the project must be located as near as possible to their offices for them to receive a maximum of benefit. In interviewing the building products representative in regard to their support of the project and the possibilities of their using it as an operations center for the New England sales organizations, the following attitudes seemed to prevail. The larger organizations appeared to be comparatively satisfied with their present locations and could at first see no advantage to being grouped together. All stated, however, that they would rent display space in such a project and would consider relocating their offices provided any real advantages could be offered them. The following items appealed to them as real advantages:

1. Unattended auto parking on the site.
2. Ease of access to the architectural and engineering offices in the city.
3. Ease of access to the major New England highway network.
4. Rooms provided for meetings and picture projection.
5. A cafeteria in the building.

To make the project more attractive to architects and engineers for office locations provision was thought necessary for a supply store and blue printing service in the building. The building must also be easily accessible to the city hall.

For a project where one thousand or more workers would be located, it is necessary that it be reached easily by public transportation.

For a display building public transportation and auto access are especially important. Auto parking for the public is considered extremely important.

Land cost was at first thought extremely important but after further study seemed of minor importance when viewed in relation with the total cost of the project and the operational factors which are to be met.

A partial study of the architectural and engineering office locations in the Boston Metropolitan District¹. revealed two concentrations of about equal size and constituting approximately 90 per cent of those in the district. Area No. 1 lies east and north of the Boston Common and is roughly bounded by Franklin and Atlantic Streets to the south and east, Market and Mt. Vernon to the north and Spruce Street and the Common to the west. Area No. 2 lies west and south of the Public Garden and is roughly bounded by Stuart and Washington Streets on the south and east, by Commonwealth Avenue, the Public Garden and Boston Common to the north and by Exeter Street to the west.

Due to the difficulty of procuring a tract of land of sufficient size for this project when a number of parties are involved and the cost

1. Study made from information furnished by New England Telephone and Telegraph Company, Producers Council of Boston and the Massachusetts Building Congress.

of demolishing existing structures, search was made for large plots of land having little or no construction on them under single ownership. To be as realistic as possible, areas now advertised for sale were first considered.

Site No. 1 was located on Soldiers Field Road between Cambridge and Western Streets. This location was a distance of 3.5 miles from the center of Boston. The attractive characteristics of this site were its size (about 18 acres), its price (\$1.00 per square foot) and its relation to the Charles River. A railroad siding existed on the property and while not served by subway, it was served by two bus lines and well located in relation to a commuter railway station. This location was considered excellent in regard to the existing and proposed highway systems.² The material producers contacted were unanimous in liking the site because of the parking area and freedom of planning it offered, as well as its excellent relationship to the highway system. The architects and engineers were as unanimously against it on the basis that it was too far from the established firms and public offices to be of maximum use to them. In fact it was stated that the project would be useless to them at that distance out of the city. The final decision was made against the plot after the producers attitude was focused by an Aluminum Company of America representative who stated that the producers would accept whatever the professionals desired as it was upon their acceptance that success or failure depended.

2. "General Plan of Boston - Preliminary Report - 1950" by City Planning Board, December 1950.

The second and final location considered (final because it met these qualifications and was liked by all) was the 28-acre site between Boylston Street and Huntington Avenue bounded on the east by Exeter Street and on the west by Dalton Street.

Many special problems were found to exist upon consideration of this site. First, this property is especially endowed with the public interest and concern as it is the last sizable plot which is available and under a single owner in downtown Boston. Also of special concern is its location in the center of the cultural activities of the city. The City Fathers demand an extensive development of the site in order to increase the city tax base, while the City Planning Board demands a well planned plot with a high percentage of apparent open space. The needs of the city demand a maximum amount of automobile parking space. Second, the subsoil conditions found here are among the worst in the Boston Area. The Boston Blue Clay extends approximately 135 feet below this area. Third, the main line of the Boston and Albany Railroad bisects this plot. The deck level required in order to clear these tracks is thirteen and one half feet above Boylston Street, or level with the deck of the Huntington Street Railroad Crossing. The unusual shape of the plot adds to the difficulties and is discussed later. The cost of the property being approximately eight times that of the former site called for an intensive use of the land. Due to the high land costs and the intensive development demanded by the city, a minimum site area of approximately 5 acres was adopted.

The location of the plot within the larger area was based upon the apparently logical division of the site and the published

schemes for its development.³ A second consideration was that of getting direct rail delivery to the exhibition hall which was possible on this site.

3. New England Town and City - December 1951
Christian Science Monitor - July 20, 1951, December 24, 1951,
December 31, 1951.

BEAUTY AND FUNCTION

Two of the basic requirements of architecture are beauty and function. Function is usually easily defined but beauty is a quality which is different for each viewer. Simple well defined forms when well related are beautiful to most observers and this has been accepted as a basis of design for this project. From the many forms which might be so classified the chosen ones meet the functions well.

The exhibition hall must be a clear span structure of large size. A shell constructed structure seems a reasonable choice as this class is well known for these qualities. A triangular dome segment becomes the natural choice when a minimum number of supporting points are desired. Due to the large span required of the floor structure where the railway property is bridged, it is desirable to keep the loading to a minimum. Balconies are required for efficient use of the building volume and their support becomes a problem over this area. The problem is met by the use of a Fuller Geodesic Structure where sufficient strength is easily attained to suspend the balconies from the dome. By use of this structure the daylighting of the crown of the dome is easily handled by use of a glass fiber reinforced polyester styrene skin through which subdued light passes. Due to the large diameter of curvature for this structure a double trussed frame will be used. This trussed structure allows an excellent opportunity for efficient acoustical treatment by suspending absorbent panels in the many planes of the frame. Through the use of this treatment an interesting play of light and color may be created. The major structural problem involved became the support of

the glazing used in the side walls. This was met by forming light metal trusses of the window frames and suspending them from the dome. Sun was then controlled at these windows by use of glass fiber reinforced plastic fins attached to the frames.

Having accepted the irregular site bisected by a railroad as logical and the dome segment as best meeting the needs for the exhibit building, it became the problem to select a suitable shape for an office structure. Economics dictated that the building should be the maximum height allowed. This height had been set by the City Planning Department as twenty stories. The first shape tried was rectangular in plan. This form brought out the fact that a dome segment, instead of being non-directional as previously assumed, has six axes. The rectangle did not relate well and it was soon discovered that its long axis was so near the length of an axis of the dome segment that insufficient contrast was created. To lengthen the building caused a squat appearance and created greater walking distance from centrally located elevators than was felt desirable. To shorten the building made it uneconomical because of the large ratio of outside wall area to floor area. To use the plot efficiently it was felt that the office building must be parallel and adjacent to the railway property. Any other placement seemed to bisect the property and cut down the number of cars which could be parked on the site. It was felt important that a maximum number of cars be provided for. At best there seemed to be odd shaped areas which could not be used for parking. Any building set other than parallel with the property lines was felt to create special difficulties in regards to the development of the remainder of the site.

Once a round building was considered it was seen to look good. It was soon realized that a freedom of placement would be possible provided the area extended through the garage level could be lessened. A building having a central core which would act as the total supporting structure seemed logical when the odd shaped areas not desirable for parking could be utilized in place of the usual basement area. Once office layouts were tried in the structure it could be seen that they would be pleasant spaces in which to work. The plan efficiency of other forms of office buildings could be met. The ratio of exterior wall area to rentable floor space would be very good. If divided into several offices, the ratio of wall area to office area would remain a constant. Desirability of office space would be influenced only by orientation and not by the number of exposures as in most present buildings.

Upon finding axes in the dome segment the visual problems were increased as placement on the site was seen to effect all adjoining structures. Placement was further complicated by having to span the railroad property with the supports. It was desired to span the railroad so that a direct spur could be had to the exhibit building, as this was desirable for the receiving and shipping of display materials.

The effect achieved through presumably logical selection of building types is that of a large sculpture which has been placed among the works of the artists on display in the sculpture garden. The scale, however, is sufficiently large that no conflict should

occur. Detailing is kept small so as not to conflict with the sculpture. The sculpture garden, home display yard and office entries have been designed on the basis of interests created by partial separation of areas, each leading one to explore that beyond.

FIGURES, FACTS AND UNDETERMINABLE QUANTITIES

While cost was never accurately determined for this project a few figures, facts and undeterminable quantities may be of interest.

Of first concern was the ratio of minimum building for varying land cost. W. R. Morton Keast and A. B. Randall had made a study on this subject in which they determined that under \$25 per square foot, land value was a negligible factor in the cost of large projects.⁴ Their figures also showed that a building of less than twenty-five stories could never be a good financial risk. Their system of determining a good financial risk was interesting even though it was felt that experience had shown many lower buildings to be sound business ventures. Mr. Fred Balderston of the Massachusetts Institute of Technology Economics Department approached the subject from the standpoint of a return on an investment. First attempting to determine the income from a project and balancing this against the cost of operation, financing, maintenance and first cost to find the residual which may be invested in property. Mr. Gibson of the Real Estate Department of the John Hancock Life Insurance Company approached the problem of the percentage return on risk capital and showing how much may be spent for a given total capitalization.

While accurate figures could not be found to apply to the project under study, many interesting facts were discovered, a few of

4. "The Minimum Building for Varying Land Values" by W. R. Morton Keast and A. B. Randall, The Architectural Record - Technical News and Research, April 1930.

which an attempt will be made to relate. In projects where elevators are required, tall buildings are better financial risks than those of medium height. This is based on the fact that the cost of building a tall structure does not increase as rapidly as the income increases due to the height. The top floors are normally the first to rent in an office structure. In the City of Boston second floor office space demands only \$3.25 per square foot per year while twentieth floor office space demands \$5.00 per square foot per year. The increase in square foot costs of buildings of first-class construction between the second and twentieth floors is relatively small.⁵ Excellent records of office building income and operating expenses are available from 1920 to the present.⁶ The expense items are recorded by: 1) operation costs, 2) construction costs and 3) fixed charges. Operation costs are broken down into:

1. cleaning
2. electrical system
3. heating
4. air conditioning and ventilating
5. plumbing system
6. elevators
7. general expense - office
8. general expense - building

5. Information from interview with Professor W. C. Voss of the Department of Building Engineering and Construction, M.I.T.

6. National Association of Building Owners and Managers, 134 South LaSalle Street, Chicago 3, Illinois, "Office Building Experience Exchange Report"

Each of these items are recorded in cents per square foot of rentable office space. Construction costs are classified as:

1. tenant alterations
2. repairs - maintenance
3. tenant decorating

Fixed charges are listed as:

1. fire insurance
2. insurance (other)
3. property taxes - land
4. property taxes - building
5. personal property assessment
6. depreciation

Figures from the Boston Area show that for the four office buildings listed which contain 450,000 square feet of floor area, a total rental yield of \$2.82 per square foot per year is realized. Operating cost run \$0.994, construction cost run \$0.181 and total fixed charges of \$0.833 per square foot per year are shown. These figures also disclose that the average square foot per person of floor area in Boston offices is 105.2 compared to the national average of 126.8. The percentage of vacancy in Boston offices listed was 1.2 while the national average was 1.9.⁷

One of the principal factors shown in the Keast-Randall Study was the trends of fixed cost through the years and the size of the fund required for replacement to a higher use due to uneconomical

7. 1949 figures.

land utilization. The cost involved during the construction period and the period from commencing the rental to that of expected normal vacancy was also interestingly discussed.

Of interest is the fact that no rental office building has been built in the Boston Area in the past twenty-five years even though two million, or half the population of the state, live within a fifteen mile radius arc drawn with its center at the State House in Boston.

Costs for buildings of the constructions used in this project were unavailable due to the small amount of experience in these forms. The cost, erected, of a Fuller Dome of similar construction of that under consideration and inclosing a base area approximately 20 per cent greater has been quoted to the M.I.T. Corporation. This information is of little help in estimating this project as a double or trussed dome is considered rather than the single shell quoted. No figures have been found relating to caisson foundations, especially to the depth being here considered. Data is available on the types of footings studied for the John Hancock Tower located near this site.⁸

Subsoil information was compiled from the borings recorded and bed rock charts appearing in the September 1931, October 1949 and October 1950 issues of the Boston Society of Civil Engineers Journal. The parking garage for this project is a modification of one recently built in New Orleans, Louisiana, at a cost of \$400 per car. A parking

8. "The Pile Foundation for the New John Hancock Building in Boston" by Arthur Casagrande, Graduate School of Engineering, Harvard University. Presented to meeting of Boston Society of Civil Engineers, November 20, 1946 and reprinted in the Boston Society of Civil Engineers Journal, October 1947.

garage is considered economically sound by the American Automobile Association, if it costs no more than \$1350 per car.⁹ The modified layout is less economical of space than the prototype due to the requirement of unattended parking. The office tower is of a completely new construction. The pre-cast floor structure of this building somewhat resembles, in construction procedure, the roof structure of the Navy Pre-Cast Concrete Warehouses built about 1946.¹⁰

The number of parties who may wish to use the facilities of such a project who are now in the Boston Area is of interest and a partial tabulation shows that there are thirty-four member firms of the Producers Council and that in the downtown area of Boston there are over one hundred and seventy-five architectural and engineering offices. The Massachusetts Building Congress report a membership in excess of five hundred and, while difficult to classify, all are persons whose firms are related to the construction business in this area and may find the project under consideration of value.

9. "Parking Garage - Series of Unit Buildings," *Architectural Record*, September 1951, page 168.

"Unit Buildings Cut Construction Costs," *Journal of the American Concrete Institute*, Vol. 22, No. 9, May 1951.

"Unit Building System of Reinforced Concrete Construction," *Progressive Architecture*, November 1951, page 102.

10. "Pre Cast Concrete Navy Warehouses," *American Concrete Institute Journal*, June 1947 (two articles).

STRUCTURE

The character of this organization calls for three distinct types of space: 1) a large public display space, 2) office space of from small to moderate size and 3) storage and work space.

The physical site has the following characteristics which bear upon the structures which may best be used: The subsoil condition is one of the worst which may be encountered. This consists of a crust of approximately 15 feet of gravel which is underlaid with some 5 feet of mud. Under this is a layer of from 12 to 30 feet of sand. From this depth the famous Boston Blue Clay extends to a depth of some 120 feet where it becomes mixed with pebbles to a depth of 135 feet or bed rock. Bed rock consists of slate.¹¹ This is in the deepest portion of the Boston Blue Clay Strata. The site is now being used as yards for the Boston and Albany Railroad and is bisected by the main line of that organization. While the main line may be built over, it may not be changed in elevation and any construction must not interfere with the operation of the line. For this reason heaving or settlement of the earth becomes a major consideration. Boylston Street, to which the project must relate, is on a level of +18.0 feet while the rail bed lies at +10.5 feet and Huntington Avenue rises to an elevation of +31.5 feet at the point where it crosses the railroad.¹² This is the high point with the roadways dropping off in every direction. Minimum

11. Boston Society of Civil Engineers - Journals September 1931 and October 1949.

12. Boston City Base Elevation (Reference 0) is 5.65 feet below mean sea level. Boston Society of Civil Engineers, October 1947.

bridge clearance is 15 feet and 4 inches above the rails. Desiring to provide services from a private rail siding for the project and desiring to make use of the existing storm drainage system throughout the site imposes the limitation of minimum excavation. The need of the organization for truck as well as rail delivery to serve both offices and display area indicates the use of a common loading dock. As the rail elevation is predetermined it seems logical that the truck service should also be at this elevation. Since this is the ground level, the building structure, other than the access ramps, would not have to be designed to carry loaded trucks. Location of the access ramps at the lowest adjacent ground level removes the entrance as far as possible from the intersections at Huntington Avenue and Boylston Street while shortening the length of ramp. Providing truck service at basement level sets the requirement of a 15 foot clearance over the roadway, a minimum radius of curvature (outside edge) of 40 feet and a clear width of 12 feet and 6 inches along the truck route. Ramps may have maximum pitch of 15 per cent.¹³ As the maximum height of autos is 6 feet 4 inches, a clear height of 7 feet in the auto storage area should be permissible.

Desiring to obtain the maximum auto parking and a minimum amount of earth disturbance seems to indicate the use of a minimum number of concentrated supports for the building structures. In line with this thinking, a triangular segment of a dome, in which there are but three points of support and a large uninterrupted space is

13. Architectural Graphic Standards, Third Edition, pages 245-246

needed for display purposes, appears to be the answer. An egg shell type of construction, where the need of horizontal restraint at the supports is eliminated, would be ideal. An approximation to this is found in the Fuller Geodesic Dome segment. As this is a patented product I will not attempt to give the design data.¹⁴ If horizontal restraint was found to be needed, tension cables could be placed in the plane of the floor very easily. The skin for the dome segment would be of glass fiber reinforced polyester styrene and the balconies and enclosed spaces within the dome would be suspended from the structure, thus requiring only the ground floor to be supported by separate foundations.

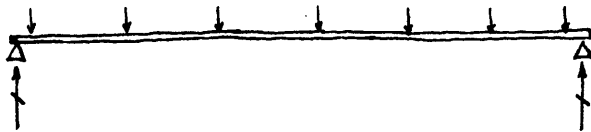
The structure of the office building is new in concept and began to take form when a round building was considered. The standard construction of the first considered rectangular building did not lend itself easily to the auto parking requirements of the basement area. In addition, the foundation requirements were such that it would be very difficult to place footings without disturbing the surrounding ground. These dissatisfactions, when combined with the esthetic considerations of a standard office structure, caused the search for a special form. The concept of the building under consideration is that of a utility core mast from which office area is cantilevered. The foundation is a caisson extension of the core which is taken home on bed rock. This caisson is poured at ground level in floor height sections and sunk by removing the earth within it. The weight being

14. Patent held by Richard Buckminster Fuller.

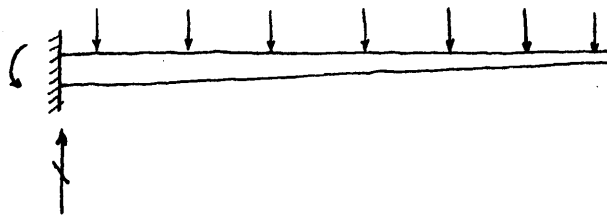
sufficient to overcome the effect of skin friction, no driving operation is needed. In this way the surrounding earth is disturbed a minimum amount. This is an operation common to bridge construction but rarely used for building footings. Thus, when lateral loads are applied, the core of the building acts in the same manner as a flagpole. Above ground the core is placed one story at a time. It is prestressed at the points where the cantilever floors tend to cause tension by being wrapped in the same manner as a prestressed pressure tank. The restraining couple for the cantilever beams outside of a large compression stress at the bottom of the section and a small compression stress in the concrete at the top of the beam. The tension forces in the couple are taken by wires near the top of the beam. These wires are carried through the walls of the core and are anchored on the inside. The post stressing operations on the beam are done by tensioning from within the core structure. The floor is designed to be made of pre-cast segments. In this manner each floor structure may be completed as the building is raised and will form a platform from which the work may be continued without the delays normal to reinforced construction. The form of floor support and structure came about through the following process of considerations: Once the core mast was considered the design of a reasonable cost and lightweight cantilever floor system became necessary for success. Upon reviewing the structure of Frank Lloyd Wright's Johnson Wax Tower and finding that even with the prohibitive cost of using twelve thousand pound concrete in its floor construction, the inverted cone support became ten inches thick at the core with a

cantilever varying from thirteen to eighteen feet.¹⁵ It was seen that something different was required if the necessary thirty-three foot cantilever was to be realized. Immediately a prestressed structure came under consideration although no evidence of the use of prestressed cantilever beams has been discovered. Advice was sought from Professor Holley of the M.I.T. Department of Civil Engineering. The first idea presented for his consideration and from which the final plan grew was that of an inverted cone structure formed of pre-cast segments which would be prestressed by wrapping at the outside diameter as in a prestressed tank. This was arrived at by a study of the manner in which a beam could be held in equilibrium. The study progressed in the following stages:

Stage 1. Simple Beam Freely Supported

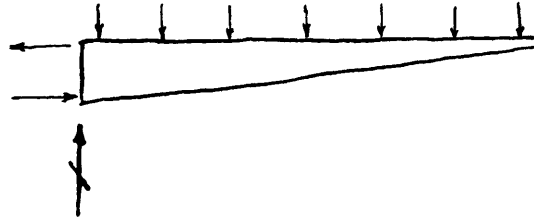


Stage 2. Cantilever Beam

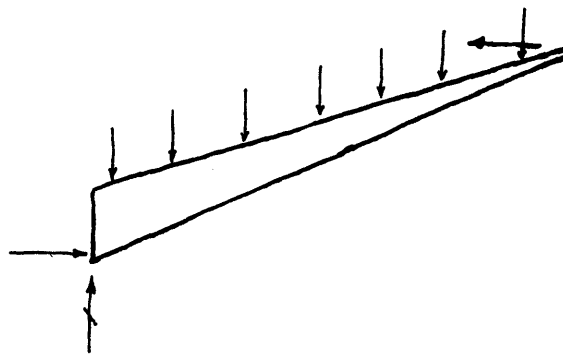


15. The Magazine of Building, January 1951, pages 77 and 80.

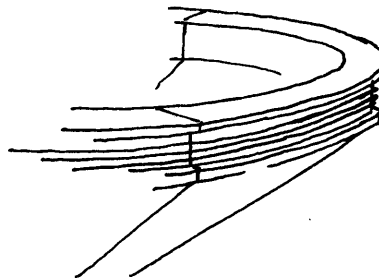
Stage 3. Moment Replaced by Couple



Stage 4. Efficiency of Couple Increased by Inclining Beam



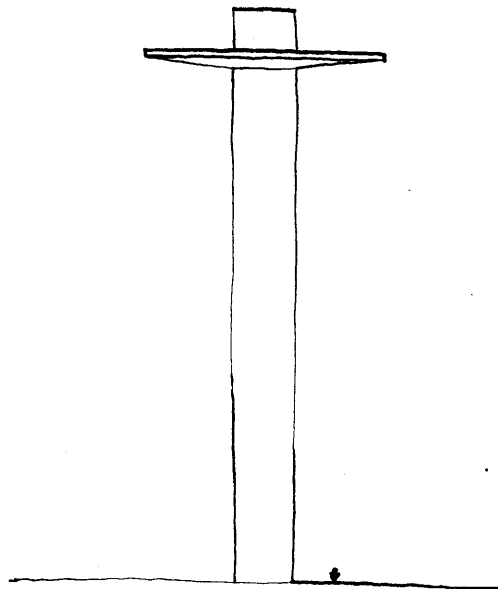
The restraining force could easily be attained through the wrapping process. The system was not considered feasible because of the following:



Due to the long lengths of wire required to circle the structure and the extremely flat angle to which the inward force would be resolved a very high tension would be required and a very slight yielding within

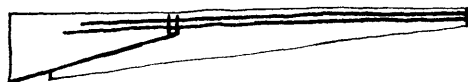
the wire, which may result due to live loading, would allow a relatively large deflection at the outer edge of the structure. Such a deflection would require a special joint and supports at the outside wall and would also require a floating floor. The floor would be difficult to design and probably quite heavy. This deflection would also cause difficulties with any utilities placed in this area.

Next was considered a system similar to the first but with a prestressed ring formed on the ground level and hoisted into position. The ring would be constructed in pre-cast segments and would act as a continuous arch, the system becoming stable in space only after the floor segments were placed. The advantage of this system would be the lack of secondary structure required to carry the wrapping equipment. One interesting feature of this system is that the core must be built to full height prior to placing the floors and the uppermost floor



must be placed first. Undoubtedly this spectacle would cause much comment and interest, the core being thirty-four feet diameter and the roof or top floor being two hundred and twenty feet above the terrace grade and one hundred feet in diameter.

A radial beam was next considered. Some of the faults remained and new ones were created, and the following advantages relative to the former systems were noted:



Because the tops of the beams were horizontal the floor support was simplified and a much lighter construction was allowable. As the system was still considered as wrapped at the exterior edge, the problem of deflection remained. To this was added the problem of the relatively short curve which the prestressing wires must assume at the ends of the beams as the members for horizontal restraint should logically run the cord of the circle rather than the diameter.

The final design¹⁶ eliminates the former problems. First, the core may be erected as the building progresses and no secondary structure is required, the wrapping machinery being carried by the core

16. See Appendix A for calculations and sketches.

structure. The floors being erected as the core is raised act as scaffolding for those above. By wrapping the core instead of the outside circumference of each floor, the length of wire per coil is reduced to one-third its former length and thus the yielding within the wire becomes much less critical. The inward thrust of the former wrapping is replaced by radial wires running through the beam and core, the beams being poststressed by jacking from the inside of the core. Level floor supports are provided with a minimum deflection due to yielding of the wire under action of the live load. These wires are now only thirty-five feet long and are placed in direct opposition to the loading rather than acting along force resultants.

The core design is of interest in that it acts as a prestressed cantilever beam with the weight of the building materials acting as the prestressing force. While this core acts in the manner of a flagpole a simple check, the resultant of vertical and horizontal forces taken through the center of gravity of the building, shows that no part of the core material will ever be in tension. The core will be of poured concrete cast in place using 3750 psi mix; 5000 psi concrete will be used for all pre-cast members.

The third class of structure is that required for storage, auto storage being the principal function. One major problem is the provision of parking for the maximum number of cars in the available space without attendant parking which would be undesirable for area

sales personnel. The "Unit Buildings System"¹⁷ employed in a recent New Orleans parking garage with excellent space efficiency and economy was adopted to fill the requirements of this problem. The New Orleans parking garage was designed by the following team: Diboll-Kessels, Associate Architects-Engineers; Laurence G. Farrant, Consulting Engineer and W. C. Harry, Project Engineer.

The selection of pre-cast, poststressed floor elements for the office structure deserves additional discussion.

A system which consists of many identical parts of sizes easily handled is a natural for a pre-cast system. Forms or molds being rather expensive elements require that their cost be distributed among a large number of castings. The larger number of identical parts to be produced, the better the forms that may be justified. In the structure being considered every pre-cast part will be repeated a minimum of two hundred eighty times. With this number of repetitions cast stone (concrete) forms are considered practical. These have good dimensional stability and remain sharp and true through the life of the job. An oil film may be used between the mold and casting to keep them from sticking and compressed air may be used to assist in removing the casting from the form. All cast parts will be handled by cranes

17. "Unit Buildings Cut Construction Costs," Journal of American Concrete Institute, Vol. 22, No. 9, May 1951.

"Parking Garage: Series of Unit Buildings," Architectural Record, September 1951, pages 168 through 171.

"Unit Building System of Reinforced Concrete Construction," Progressive Architecture, November 1951, pages 102 and 103.

through use of special designed lifting devices. Vacuum lifting pads will be used with all large thin sections. All castings must be sufficiently reinforced to counteract handling strains. The concrete will be placed by use of mechanical vibrators and the mix will be so proportioned with early setting cement that the molds may be reused every twenty-four hours.¹⁸

The economy resulting from prestressed concrete is basically due to the better quality (5000 lb.) concrete that is used and the utilization of the larger percentage of the concrete in the section. Both of these factors contribute to the reduction of the amount of concrete used and the resulting reduced weight of the structure.

Further advantages found in the design of the particular beams for this office building project resulted through the erection process. The first preliminary calculations indicated that a large amount of concrete would be necessary in the top flange of the segments to resist the compressive stresses resulting from the prestressing operations. By use of the poststressing process the dead weight moments may be used to counteract a portion of this compression and when the poststressing is applied in two stages, it is found that the amount of concrete in the upper flange may be very small. The first stage of poststressing is the application of just sufficient tension to overcome the dead load when the floor structure is in place. This is applied to the structure as it is placed. The second stage of post-tensioning is the applying of tension sufficient to carry the live plus

18. "Pre-Cast Concrete Navy Warehouses," American Concrete Institute Journal, June 1947 (two articles).

the dead load moments and is done once the floor structure is complete. The saving of both material and weight is considerable when this system of two stage stressing is used. Another device used in the special considerations of these being cantilever beams was the multiple beam. By this system the outer portion of beam has only the amount of steel and the section required for the comparatively small moment at its base, while the inner portion of beam has the increased section and area of steel required to hold its larger moment. The number of sections in which these beams are designed is governed by the pre-casting operation, steel areas required and the size member handled without difficulty.

This floor system as preliminarily designed appears logical. However, a system of floor beams and separate floor sections should be considered as having an easier access to mechanical equipment located within the floor structure.

APPENDIX

Design Method and Data for Office Structure:

Beam:

1. Determine characteristics of concrete and steel to be used.

$$f_s = 200,000 \text{ psi}$$

$$f_c = 2,250 \text{ psi} \quad (\text{Boston Building Code})$$

$$N = 6$$

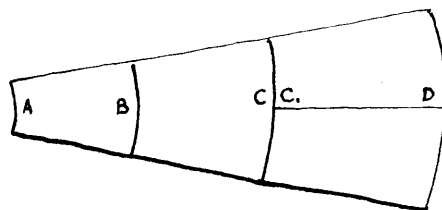
$$f_c(\text{bearing-less than } 1/3 \text{ of area}) = 2250 \text{ psi}$$

$$f_c(\text{bearing-full area}) = 1250 \text{ psi}$$

2. Determine Maximum Moment (dead and dead + live) which beam must be designed to carry. (Live load moment is defined as the moment due to all dead and live loads applied after member has been prestressed).

Determine Floor Frame Pattern and segment

dimensions: (see Final Drawings)



Loading:

Live Load = 50 lbs. per sq.ft.

Movable Partition Allowance = 22 lbs. per sq.ft. }

Boston
Building Code

Mechanical Equipment Allowance = 5 lbs. per sq.ft.

Floor Structure = 77 lbs. per sq.ft.

Total Distributed Load = 154 lbs. per sq.ft.

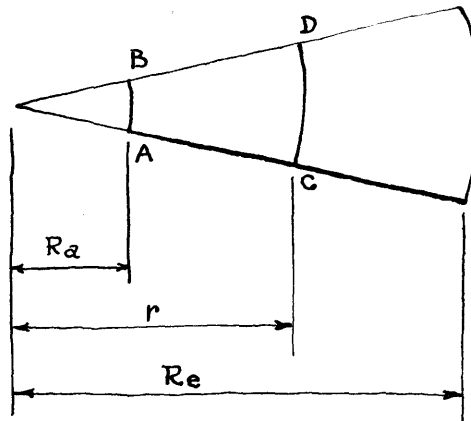
Exterior Wall = 110 lbs. per ft. of circumference.

Total Dead Load = 77 lbs. per sq.ft.

Total Live Load = 77 lbs. per sq.ft. plus concentrated exterior wall load of 110 lbs. per foot of exterior circumference.

Moment due to distributed loadings:

Divide area into pie-shaped segments



Assume AB = 1 ft.

Find shear equation from statics and by integration find bending moment equation.

Total shear at any radius r , $V_r = w \times$ area of annular ring between r and R_e .

$$V_r = w (\pi R_e^2 - \pi r^2) = \pi w (R_e^2 - r^2)$$

Total circumference = $2\pi r$

$$AB = 1 \text{ ft.} = \frac{1}{2\pi R_a} \text{ of total}$$

shear at any radius r

$$= \frac{V_r}{2\pi R_a} = \frac{\pi w (R_e^2 - r^2)}{2\pi R_a} = \frac{w}{2R_a} (R_e^2 - r^2) \text{ per foot at AB.}$$

Bending moment at any radius $r = M_r$ equals the integral of the shear equation from $r = r$ to $r = R_e$

$$\begin{aligned}
 M_r &= \int_r^{Re} V r dr = \int_r^{Re} \frac{W}{2Ra} (Re^2 - r^2) dr \\
 &= \frac{W}{2Ra} \left(Re^2 r - \frac{r^3}{3} \right) \Big|_r^{Re} \\
 &= \frac{W}{2Ra} \left(\frac{2Re^3}{3} - Re^2 r + \frac{r^3}{3} \right)
 \end{aligned}$$

Moment due to weight of exterior wall = Px.

Moments at A Due to wall = 428,000 in lbs.
 Dist. Live = 3,772,000 in lbs.
 Dead = 3,772,000 in lbs.

Moments at B Due to wall = 323,000 in lbs.
 Dist. Live = 2,280,000 in lbs.
 Dead = 2,280,000 in lbs.

Moments at C' Due to wall = 97,200 in lbs.
 Dist. Live = 442,000 in lbs.
 Dead = 442,000 in lbs.

Moment at D = none

3. Compute the required section modulus by dividing the live load moment by the allowable working stress.

At A 4,200,000 + 2,250 = 1,870

Note: Due to use of thin shell structure the stresses in the exterior concrete governs.

4. Find the necessary prestressing force (P) required and the eccentricity (e) of application. (1) Concrete must not go into tension; therefore, under dead load the top fibers must have a compressive stress equal or greater than the tension stress which will result from the live load. (2) Similarly the stress in the bottom fibers under dead load must not be less than 0.

Dead load stresses in top and bottom fibers at point of maximum live load moment:

$$f_c \text{ top} = \frac{P}{A} + \frac{Pe}{S} - \frac{M \text{ Slab}}{S} \leq 2250 \quad (\text{Compression is } +)$$

$$f_c \text{ bottom} = \frac{P}{A} - \frac{Pe}{S} + \frac{M \text{ Slab}}{S} \geq 0$$

$\frac{P}{A}$ is compressive stress due to prestressing load P applied at the ends of the beam; $\frac{Pe}{S}$ is the stress due to the eccentricity of the prestressing force; $\frac{M \text{ Slab}}{S}$ is the stress due to the dead load moment.

The sign of $\frac{Pe}{S}$ is plus when the strand is on the same side of the neutral axis as the point being considered and minus when on the opposite side.

P and e are unknowns and any number of values might satisfy these equations so the sections used for this design were determined by trial and error until a section was found which satisfied the above prestressing load requirements and the following live load requirements.

$$f_c \text{ top} = \frac{0.85P}{A} + \frac{0.85Pe}{S} - \frac{M \text{ (total)}}{S} \geq 0$$

$$f_c \text{ bottom} = \frac{0.85P}{A} - \frac{0.85Pe}{S} + \frac{M(\text{total})}{S} \leq 2250$$

The sections were checked at each end and it was assumed that a straight line relationship existed between these points.

The width of the sections were pre-determined and the eccentricity was assumed as the distance from the neutral axis to a point 2.5 inches below the top surface. A 2 inch sheel was assumed as a basis of preliminary design. The factor of 0.85 used in the latter equations is to compensate for shrinkage and flow in the concrete and is sufficient that the final loading will never cause the original prestressing tension in the strands to be exceeded. (See photostat at end of Appendix for calculations.)

5. Horizontal Shear and Diagonal Tension were not checked for this preliminary design as it is assumed that by the method of construction use these stresses will be taken completely by steel used in joining the sections. (Required steel area not computed.) The method of calculation would be, however, as shown in Catalog T-916 of the John A. Roebling's Sons Company, Trenton 2, New Jersey, entitled "Roebling Strand and Fittings for Prestressed Concrete."

6. Patented fitting would be used on the prestressing cables (a number are on the market) and the actual cable and anchor design would be calculated by the supplier. However, a loop system of reinforcing is suggested to minimize the number of prestressing operations. (This has been successfully used in bridge construction.) The anchorage at the loop would be due to bearing on the contained concrete and

assuming a 0.600 diameter strand (D_s) the loop diameter (D_1) would be determined by:

$$D_1 = \frac{2fc}{D_s \cdot fc(\text{bearing})} \text{ or for the case stated}$$

equals 33.3 inches which is sufficient diameter that it may be assumed that the wire will be equally tensioned throughout its length.

The anchor wires will pass through the building core at equally spaced intervals so that the stresses applied will be equivalent to those existing within a pressure vessel.

Conduits will be run through each casting in order to receive the strands from those further from the core.

The deflection (δ) at the outer end of the beam due to live load (maximum) equals:

$$\delta = \frac{fxL^2}{3ECx} \text{ or } \frac{fL^2}{3EC} = 0.6 \text{ inch}$$

where E = Modulus of elasticity of concrete

$$= 1000 f'_c = 6,000,000 \text{ (A.C.I. Building Code)}$$

C = Distance from neutral axis to outermost fiber.

$$l = 33 \text{ feet} = 396 \text{ in.}$$

$$\delta = \frac{1325 \times 396^2}{6,000,000 \times 18 \times 3} = 0.60 \text{ in.}$$

The segments will be made to work together by use of a mortar key along their edge.

Core:

1. Determine characteristics of concrete and steel to be used:

$$f'_c = 3750$$

$$f_c = 1688$$

$$f_s = 120,000 \text{ psi}$$

Use prestressing wire 0.30 in. diameter as this is handled by standard wrapping machine and is less expensive than strand. The tensioning loading for this wire is 9000 pounds.

The idea behind the prestressing of tank structures is to keep the concrete from ever going into tension. To do this the concrete is prestressed by application of a wire coil around its outer circumference which implants sufficient compression into the concrete that the release due to the loading will never exceed this amount. The concrete stress under full design load would equal zero and the full load would be carried by the wrapping. Once the wrapping is applied, it is covered with a coat of concrete as a protection. Any number of layers may be applied, each separated by a concrete layer. The added stress in the tension wires caused by application of full design load is sufficiently small that it may be ignored.

The number of coils of wrapping required (n) may be calculated by:

$$n = \frac{PN}{4xAsxfs}$$

where P = the total stress applied due to one segment
of floor.

N = the total number of floor segments.

A_s = the area of the wrapping wire.

f_s = the allowable stress (psi) of the wrapping steel.

$$n = \frac{435,000 \times 32}{4 \times 0.07 \times 120,000} = 415 \text{ coils}$$

Applied as six layers the wrapping would require a recess in the beam six inches deep and twenty-two inches wide. This allows for one half-inch of concrete between layers of wrapping and a two-inch protective covering over the exterior.

The thickness of concrete in the core wall is governed by the vertical load requirements.

The total dead load per floor exclusive of elevator equipment and core walls equals 678,000 lbs. The total live load (design) per floor equals 565,000 lbs.

$$20 \text{ floors} \times \text{dead (678,000)} = 13,560,000 \text{ lbs.}$$

$$10 \text{ floors} \times \text{live (565,000)} = 5,650,000 \text{ lbs.}$$

(50% reduction of Boston City Code)

$$\text{Elevators} = 24,000 \text{ lbs.}$$

$$\text{Water tank} = \underline{20,000 \text{ lbs.}}$$

$$\text{Sum (exclusive of core walls)} = 19,254,000 \text{ lbs.}$$

$$\text{Core Walls (15" thick)} = \underline{4,583,000 \text{ lbs.}}$$

$$\text{Total} = 23,837,000 \text{ lbs.}$$

$$\text{Effective circumference (c less openings)} = 969 \text{ in.}$$

$$\text{Total area required} = \text{total load} \div f_c = 14,116 \text{ in}^2$$

$$\text{Thickness of wall} = 14,116 \div 969 = 14.6 \text{ in.}$$

Make walls 18" thick to allow for eccentric loadings.

$$\text{Wall wt.} = 5,499,000 \text{ lbs.}$$

Tension in Core Material and Stability of Building:

A test to see if tension can come into core wall is to see if the force resultant of vertical and horizontal loadings on the building, acting through its center of gravity, can be driven outside the core area. Provided the resultant always stays within the inner two thirds of the core at the point of no stresses due to bending (approximately 1.5 x core diameter under ground surface) the building will be stable. In computing this it will be assumed that one side of the building is in full use while the other is vacant (not apt to occur) and that a wind pressure of 20 lbs. per sq. ft. acts on two-thirds of the projected area of the building. (Boston City Building Code allows that two-thirds of the projected area of round structures be assumed as loaded and that from 0 to 40 ft. a pressure of 10 lbs. apply, from 40 to 80 ft. 15 lbs. and above 80 ft. 20 lbs. Thus a worse condition has been assumed than the code calls for.) The dead load weight of 19,083,000 lbs. is assumed applied at the center of the structure and one half the live load after code reduction, 2,825,000 lbs. is assumed applied at the centroid of the semi-circle segment (29 ft. off center). This eccentrically applied load effectively moves the center of gravity of the building to a new position 7.7 feet off the center of the structure. The wind loading as applied creates a horizontal force of 295,000 pounds horizontally acting at one half the building height. The resultant of this force and the total vertical load, 22,000,000 pounds, acts at an angle with the vertical which tangent equals 0.00134 or less than 0.1 degree. When acting through the center of gravity (eccentric loading considered) the resultant would still pass through the middle two-thirds of the base

at bed rock, some 135 ft. below ground surface. Therefore, no tension will act in the core walls and the building will be stable.

Footings:

The office building foundation consists of a thirty-four foot diameter caisson taken to bed rock. In sinking this caisson 122,500 cu. ft. or 12,250,000 lbs. of earth would be removed. Bed rock consists of slate with an average ultimate strength of 10,000 lbs. per sq. in. At a 20% working load this will support 57,600 lbs. per sq. ft. Adding an additional five million pounds, to account for the weight of the caisson, the total load to be supported equals 27,000,000 lbs. and a footing of 470 sq. ft. is required. The caisson walls should be thickened to five and one half feet at the base. Some support would be gained by the side wall friction of the caisson as in a friction pile so that after more complete calculations by competent engineers, this base area may be reduced.

Note: All calculations shown in this appendix are for preliminary design only and final design calculations would be made by licensed structural engineers.

Utilities

Water: Water for both domestic use and fire control will be stored in prestressed concrete tanks which will form the top of the office building core. The necessary booster pumps at the fifteenth floor will be installed in the space left by the split system of elevators.

Above the fifteenth floor the space left due to the split system of elevators will be used for mechanical equipment, storage and darkrooms.

Smoke & Fumes: Smoke and fumes from the cafeteria kitchen will be carried off over the roof by a metal chimney located in one of the duct spaces. The air required for the ventilating of restrooms, darkrooms, etc., will be taken in through the hollow floor systems of the buildings. There is ample spaces above the false ceilings of the restrooms for the necessary fans and other forms of equipment.

Heating: The building will be heated by warm air. Heat will be conducted to each level by steam pipes from the basement area and through the use of a heat exchange system warmed air will be directed into the hollow shells of the floor structure where two outlet locations will be provided. The major outlet will be along the outer window wall and will act to stop cold drafts as well as provide circulation of air in the room. The second or inner ring of outlets will be located fourteen feet out from the core wall and will provide heat and air circulation in any interior offices or work space. The controls for the system would operate by a pressure system. The segments all having air passages

between them would allow the system to remain in operation as long as there was a heat demand at any segment of the floor. When the last segment opening was closed the fans would cease to operate. Through this method each office space could be controlled separately with a minimum of mechanical equipment. During the warm months this same system could be used to circulate natural air. A cooled air system was considered not to be necessary or desirable in Boston. The John Hancock Life Insurance Building is the only one in the city having such a building wide system at present and the several employees questioned on the subject all showed they did not care for it. The steam for this system would be purchased from the municipality as this system appears to vie very well with the operation of one's own steam plant for a project of this size.

Snow Removal: Snow removal coils (warm water) would be imbedded in the structure of all exposed auto ramps.

Electricity: Electricity would be distributed throughout the building by a system of concealed bus bars ten inches above each floor level within the outside wall. Plug locations would be provided at each window mullion location and all movable partitions will be provided with plug-in conductors for any of these locations. Lighting of the general area will be handled by use of small flood lights attached to the outside window mullions and selected partition sections which may be directed toward the ceiling or floor as desired.

Acoustics: Acoustic treatment in the office spaces and corridors will be through patches of acoustical materials cast into the

ceiling structure and by the furnishings within the office. Floor to floor sound isolation should be rather good even though the structure is used as heating ducts. The heating openings will be on one side only and will be rather small. The spaces opposite these openings will be patched with sound absorbing materials so that sound will not tend to travel from one outlet to another on the same floor. The wear surface for all floors will be cork which will help reduce impact noises. All plumbing runs will be suspended by resilient hangers so that a minimum of such noise will be directed into the structure. Doors to all restrooms will have a 40 lb. rating and will be efficiently gasketed.

Natural Ventilation: Natural ventilation will be provided all office spaces by opening windows.

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1. Assume 2" Concrete Shell Box Beam
2. Assume Strands 2 1/2" below top surface.

At base $P = 17'$

$$A = 288 \quad b = 39.84 \quad b' = 35.84$$

$$c = 14 \quad d = 36 \quad d' = 32$$

$$S = \frac{bd^3 - b'd'^3}{6d}$$

$$S = \frac{39.84 \times 46,700 - 35.84 \times 32,800}{6 \times 36} = 3171$$

$$f_{top} = \frac{P}{288} + \frac{14P}{3170} - \frac{3,772,400}{3170} = 2250$$

$$\therefore P = 435,000$$

$$f_{bottom} = \frac{435,000}{288} - \frac{435,000 \times 14}{3170} + \frac{3,772,400}{3170} = 780 > 0$$

$$f_{top} = .85 \times 1510 + .85 \times 1920 - \frac{7,970,000}{3170} = 402 > 0$$

$$f_{bottom} = 1284 - 1632 + 2514 = 2166 < 2250$$

At $P = 25'$

$$A = 320 \quad b = 58.81 \quad b' = 54.81$$

$$c = 12 \quad d = 29.44 \quad d' = 25.44$$

$$S = 3370$$

$$f_{top} = \frac{P}{320} + \frac{12P}{3370} - \frac{2,280,000}{3370} = 2250$$

$$\therefore P = 437,000$$

Reduce to 250,000

$$f_{bottom} = \frac{250,000}{320} - \frac{250,000 \times 12}{3370} + \frac{2,280,000}{3370} = > 0$$

$$f_{top} = \frac{.85 \times 250,000}{320} + \frac{.85 \times 12 \times 250,000}{3370} - 1420 = 134 > 0$$

$$f_{bottom} = 664 - 890 + 1420 = 1194 < 2250$$

at $r = 35'$

$$A = 398 \quad b = 82.56 \quad b' = 78.56$$

$$e = 8'' \quad d = 21.24 \quad d' = 17.24$$

$$S = 3210$$

$$P = 250,000$$

$$f_{top} = \frac{250,000}{398} + \frac{250,000 \times 8}{3210} - \frac{884,000}{3210} = 978 < 2250$$

$$f_{bottom} = 630 - 623 + 275 = 282 > 0$$

$$f_{top} = .85 \times 630 + .85 \times 623 - \frac{1,962,000}{3210} = 425 > 0$$

$$f_{bottom} = 506 - 530 + 611 = 587 < 2250$$

Outer Panel at $r = 35'$

$$A = 232 \quad b = 41.28 \quad b' = 37.28$$

$$e = 8 \quad d = 21.24 \quad d' = 17.24$$

$$S = 1610$$

$$f_{top} = \frac{P}{232} + \frac{8P}{1610} - \frac{742,000}{1610} = 2250$$

$$P = 271,000$$

Reduce to 80,000

$$f_{bottom} = \frac{80,000}{232} - \frac{8 \times 80,000}{1610} + 270 = 215 > 0$$

$$f_{top} = .85 \times 345 + .85 \times 400 - \frac{981,000}{1610} = 12 > 0$$

$$f_{bottom} = 281 - 340 + 609 = 550 < 2250$$

$V = \frac{W}{2R_e} (R_e^2 - r^2)$ at total design load.

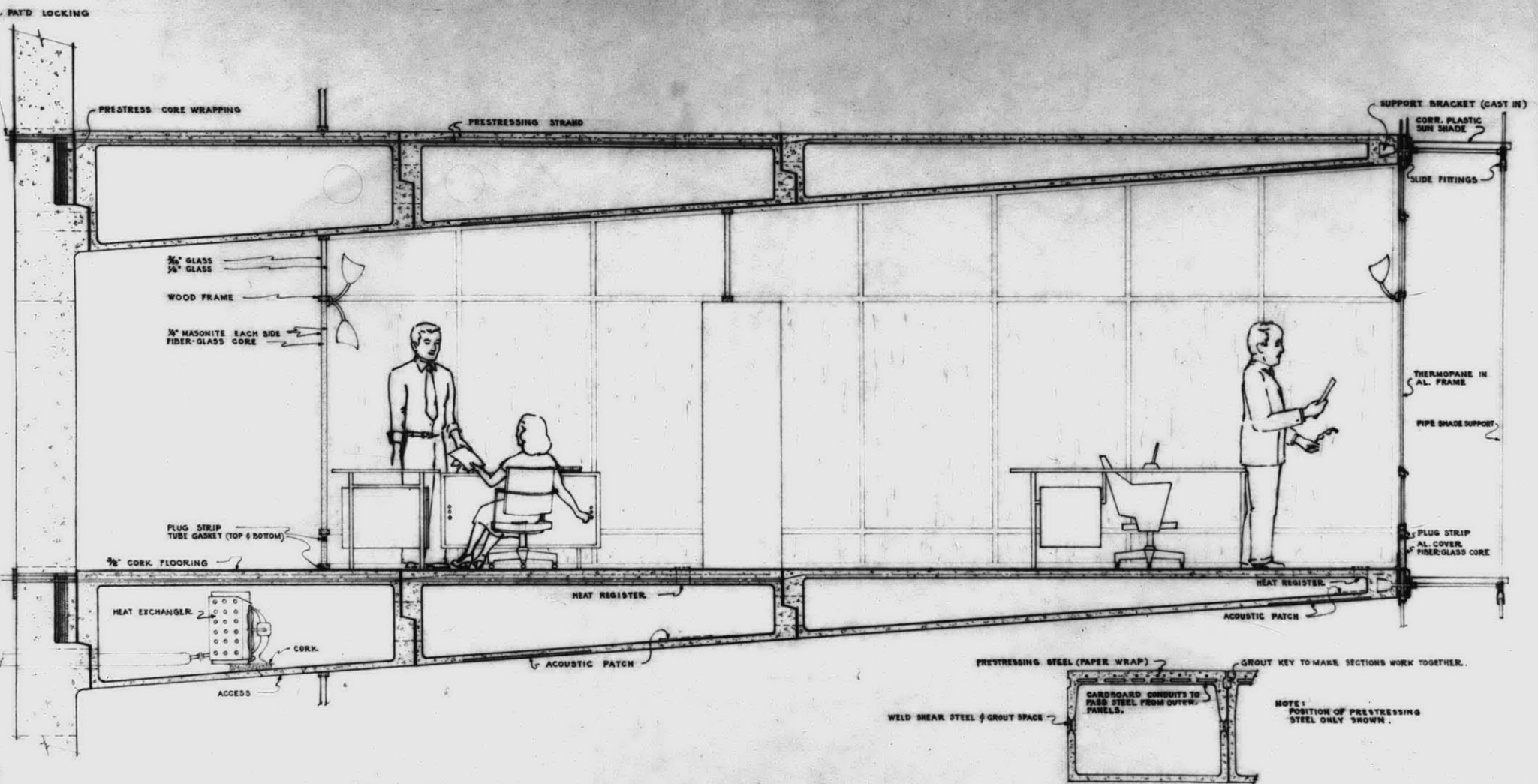
$$\frac{77}{17} (2510 - 289) = 10,000 \text{ lb/ft of core Segment} = 33,200 \text{ lb.}$$

Outer Wall

$$\text{Segment} = 1,100 \text{ lb}$$

$$\text{Total} = 34,300 \text{ lb.}$$

$$34,300 \div 1250 = 27.5 \text{ in}^2 \text{ req'd in bearing}$$



B. A. C.

OFFICE SECTIONS
SCALE 3/8" = 1'-0"

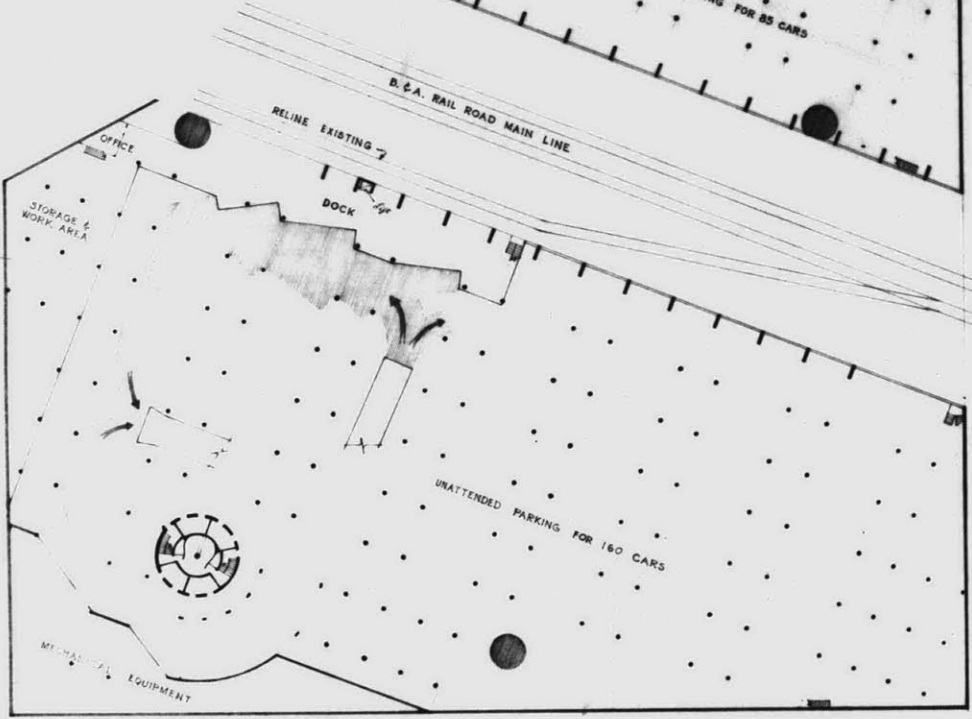
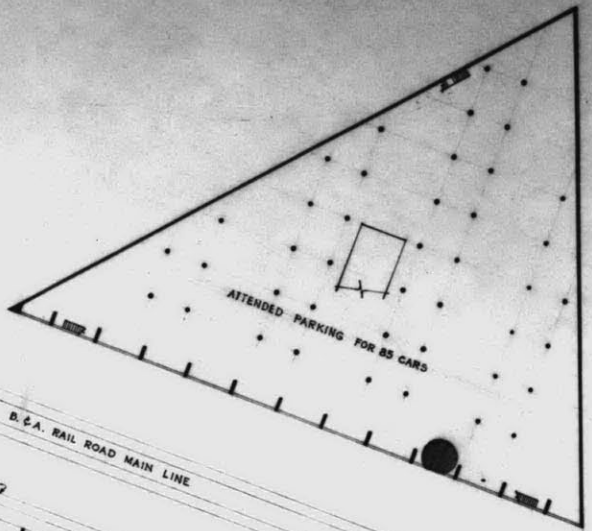
M. ARCH. THESIS M. I. T.
ROBERT H. FOWLER



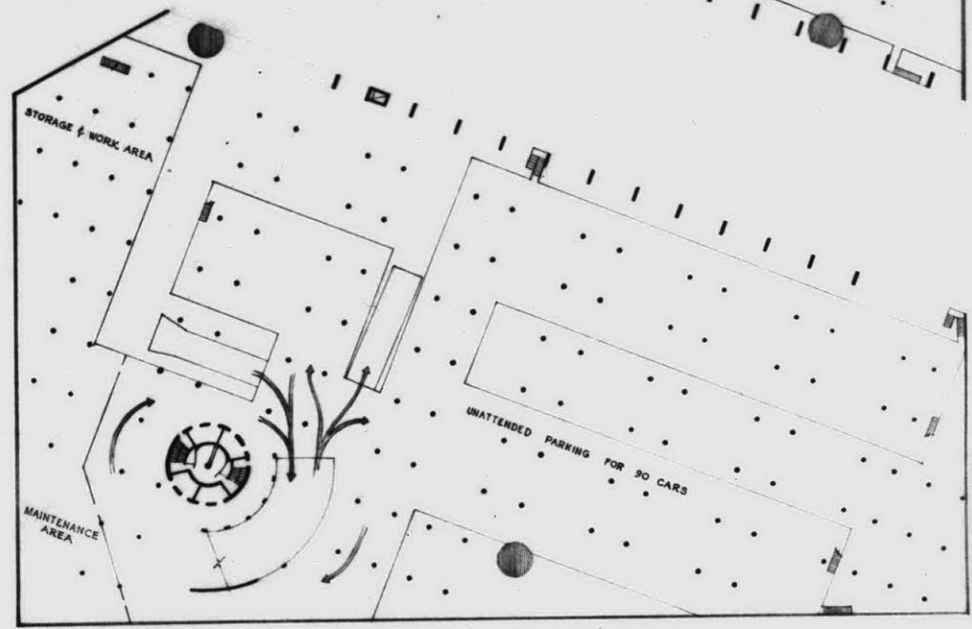
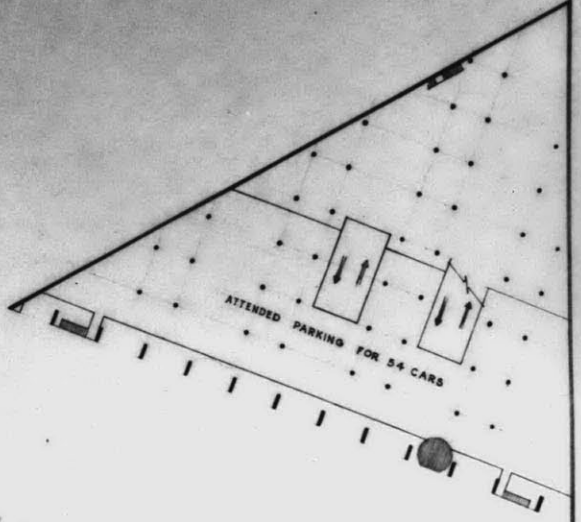
BUILDING ACTIVITIES CENTER for NEW ENGLAND

PLOT PLAN
Scale 1 in. = 60 ft.

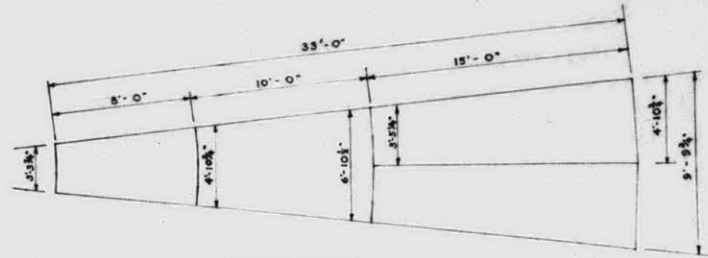




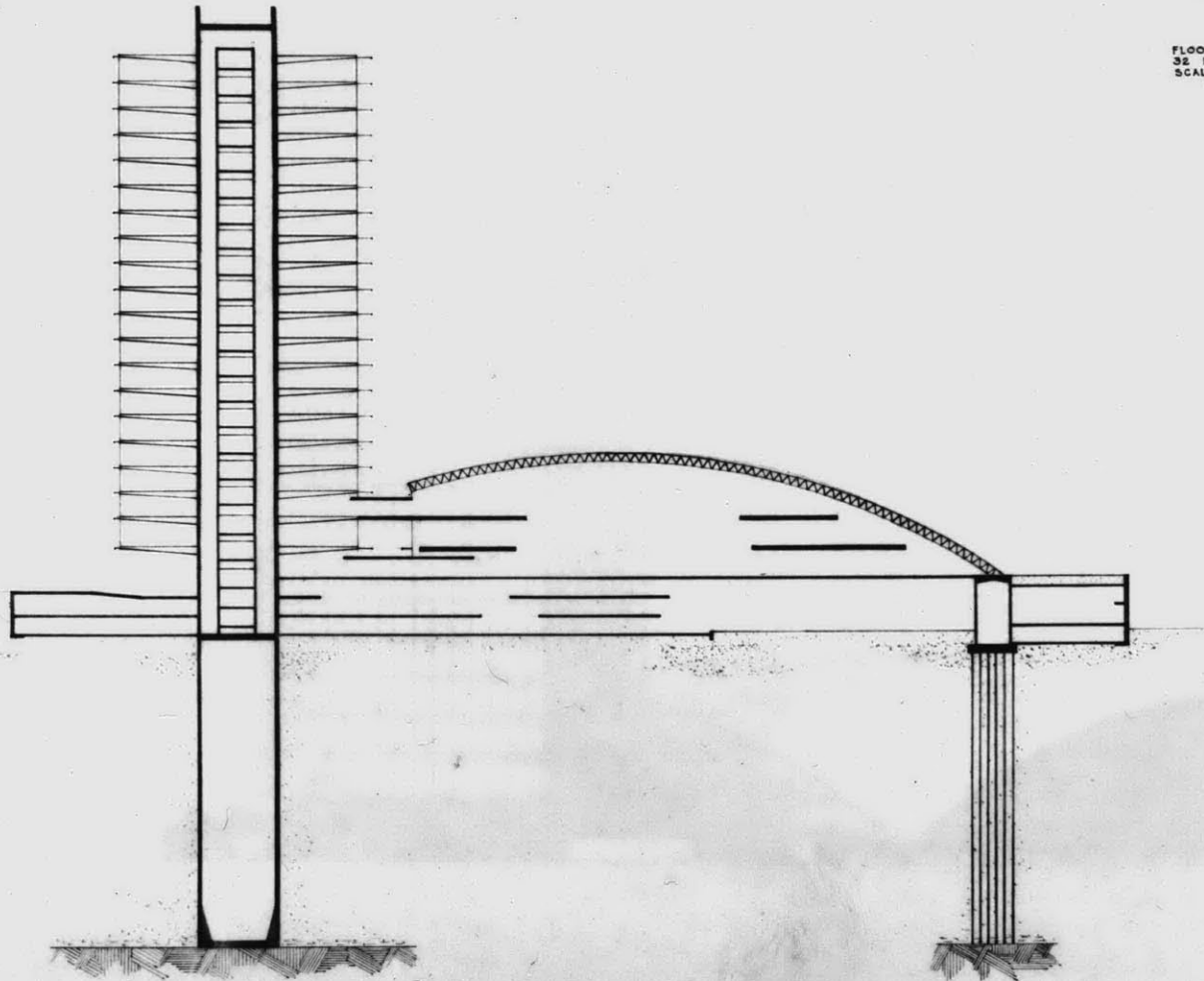
BASEMENT PLAN - LOWER LEVEL



BASEMENT PLAN - LOWER BALCONY



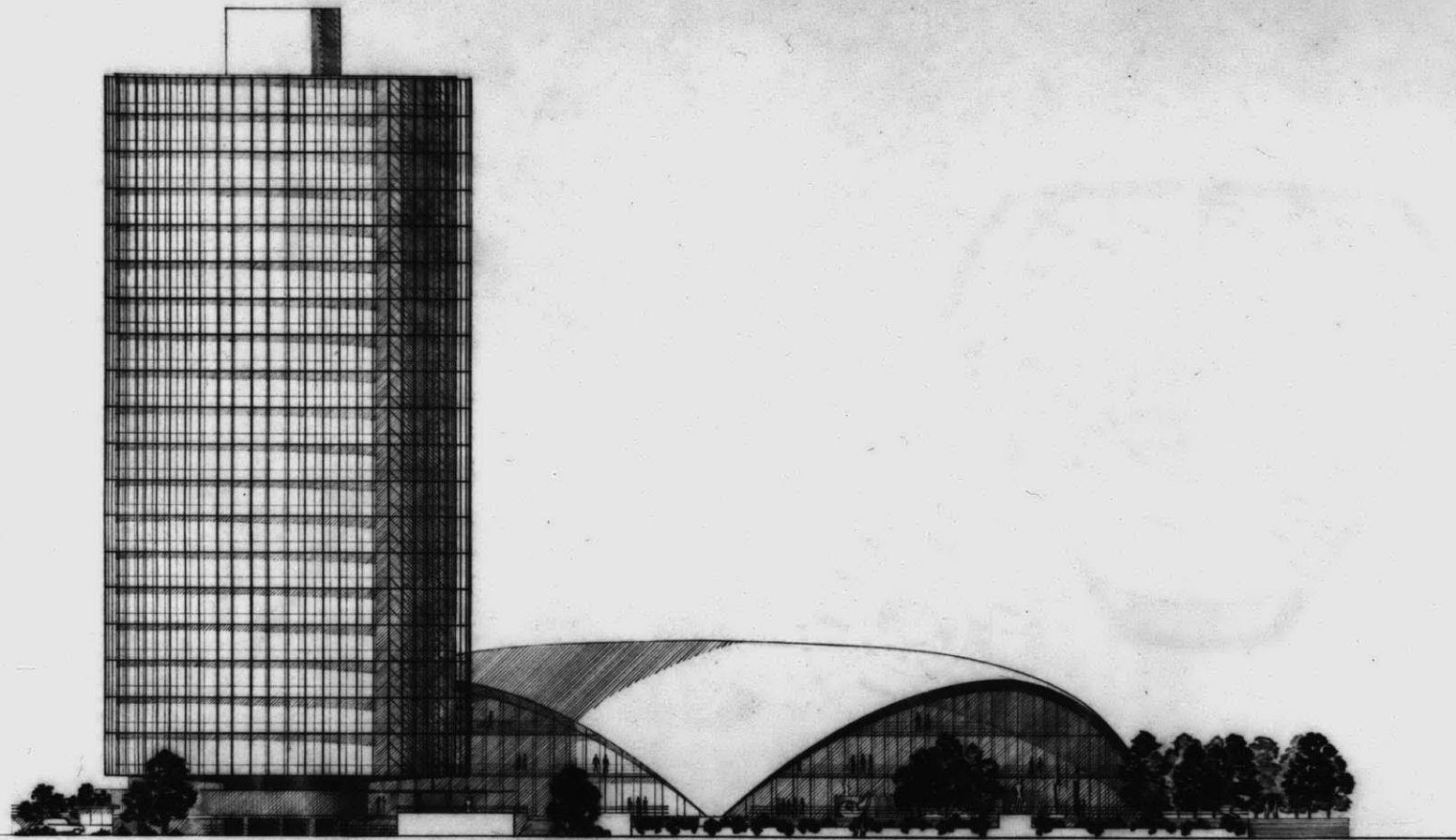
FLOOR SEGMENT
 32 REQ'D PER FLOOR
 SCALE 1/4" = 1'-0"



B. A. C.

SECTION A-A
 SCALE 1/4" = 30'ft

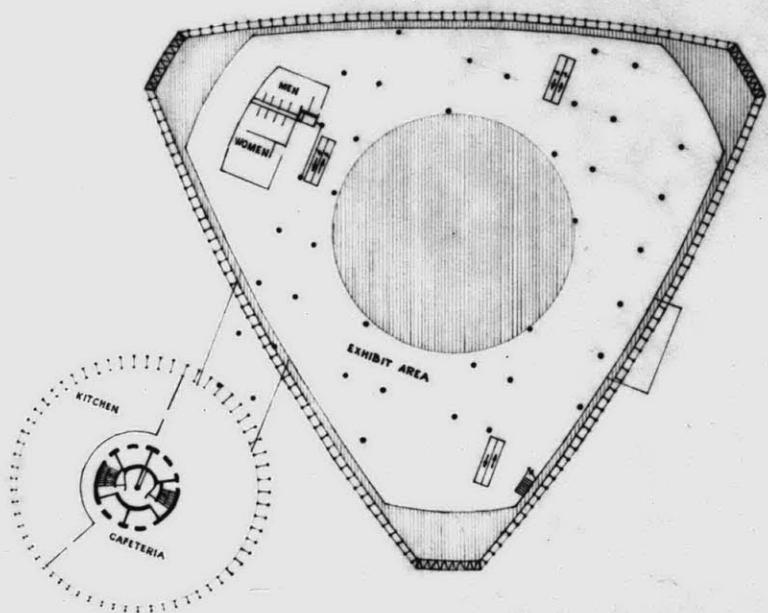
M. ARCH. THESIS M.I.T.
 ROBERT H. FOWELL



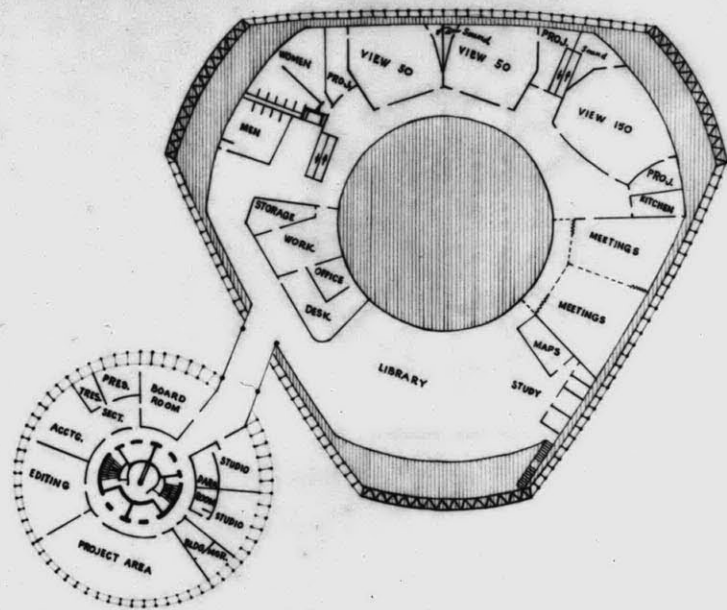
B. A. C.

NORTH ELEVATION
SCALE 1 in = 20 ft

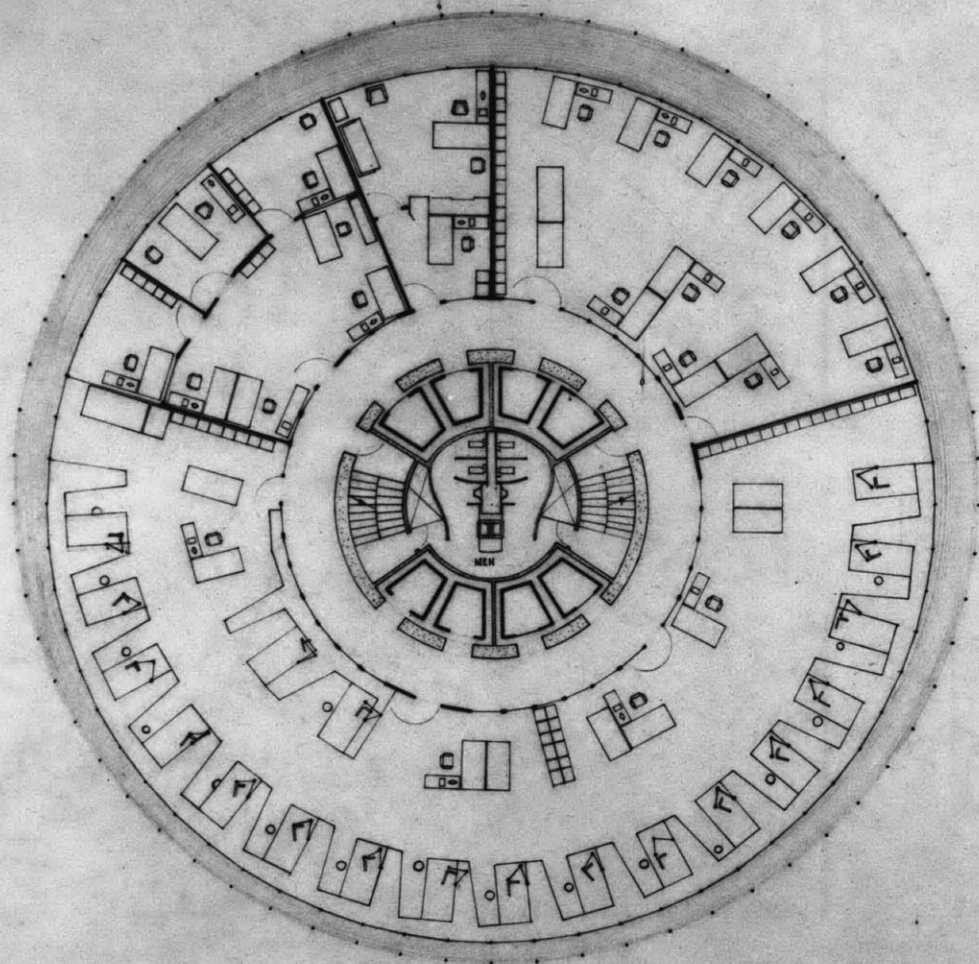
M. ARCH. THESIS M.I.T.
ROBERT H. FOWLE



SECOND FLOOR.

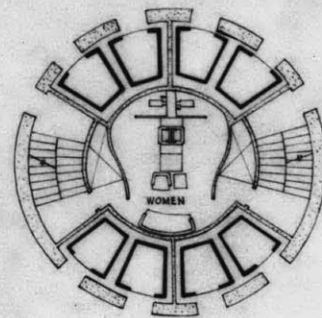


THIRD FLOOR.

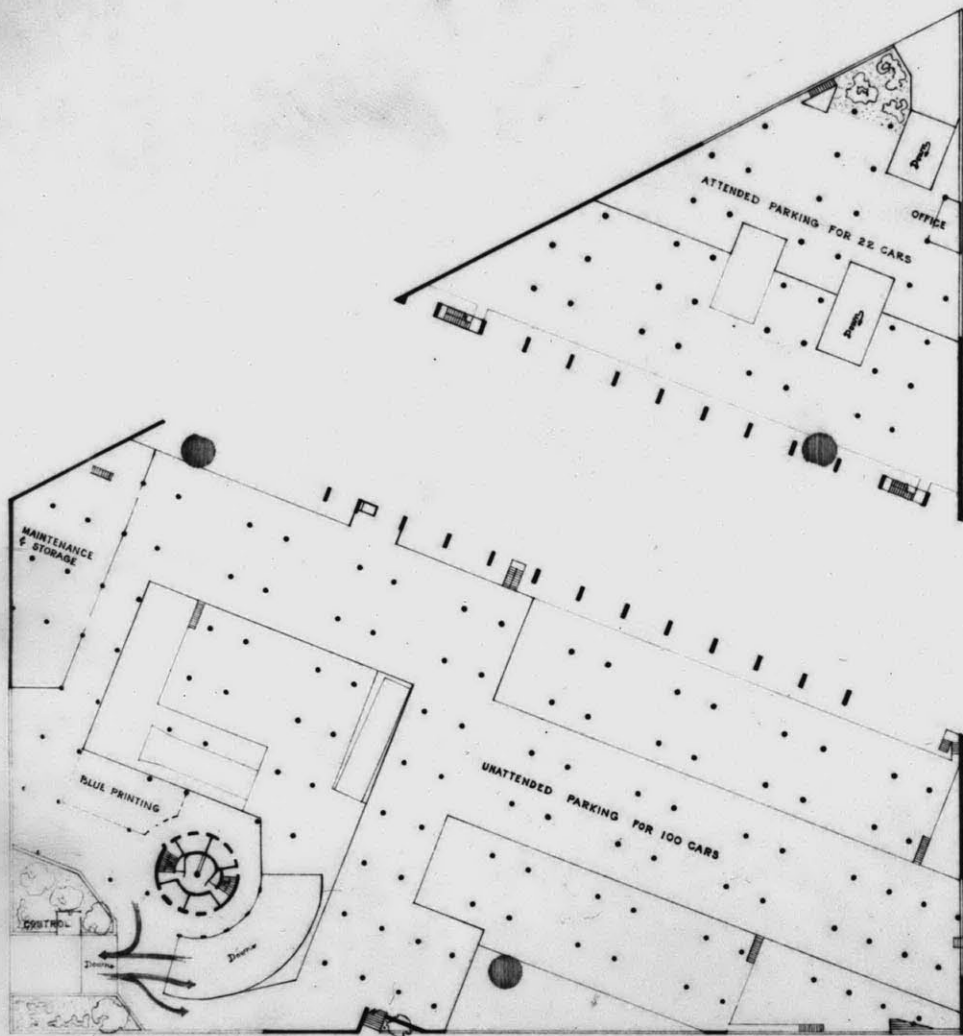


TYPICAL RENTAL FLOOR

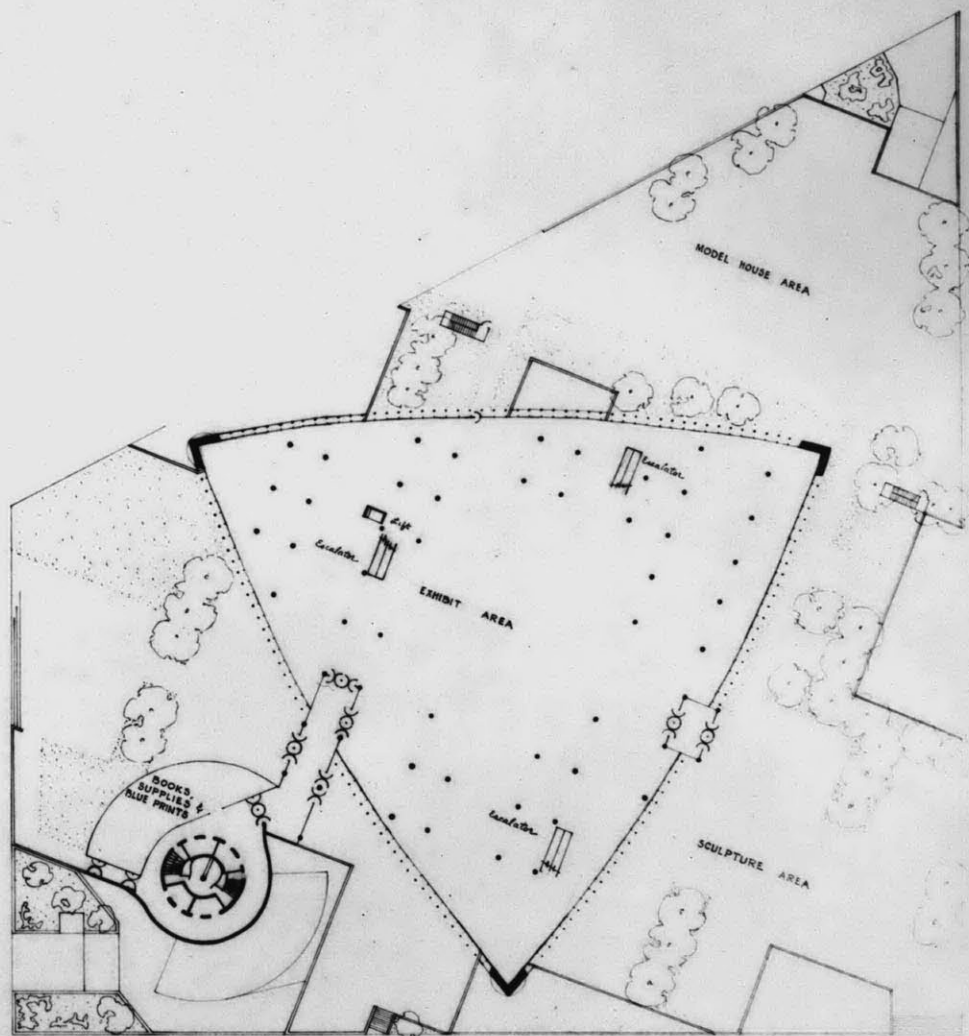
PLAN EFFICIENCY
 RENTABLE AREA 79 %
 CIRCULATION 2.4 %
 CORE AREA 11.6 %



ALTERNATE CORE PLAN



BASEMENT PLAN UPPER BALCONY



FIRST FLOOR