A PRECAST PRESTRESSED PUBLIC LIBRARY BUILDING

A thesis submitted in partial fulfillment of the requirements for the degree of Master in Architecture at the Massachusetts Institute of Technology

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ABSTRACT

One of the main objectives of precast prestressed construction method of buildings is repetition of similar structural elements. This demands simplicity of the building in its threedimensional conception. This simplicity may be difficult to apply to any building type which has a program of some complexity. The thesis attempts to clarify to what extent this new building method can be applied efficiently according to construction methods of precast prestressed concrete to a building type with the complexity of a public library.
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Dear Dean Belluschi:

I hereby submit this thesis, entitled "A precast prestressed Public Library Building", in partial fulfillment of the requirement for the degree of Master in Architecture.

Respectfully yours,

Bernhard C. Winkler
DEDICATION

To my wife Esther
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A. THE ORGANIZATION OF A PUBLIC LIBRARY

INTRODUCTION

Books are the main items stocked in a public library and lent to the public. They are documentations of information, knowledge, thoughts and ideas, collected and thought by people from the beginning of historic time to the present. They represent a guide for culture and civilization and it is a great merit and contribution of the present society to make these sources accessible to the public. The emphasis is laid upon individual contact with these sources and the group activities in a public library have only secondary importance.

Since there is a variety and multitude of content in these books, an efficient organization for the placement of the books must be planned. The building itself must add to this simplicity and not be distracting. A main requirement, from the beginning of the existence of the building, is its adaptability to future change depending upon its growth and use.
SERVICES OFFERED BY A PUBLIC LIBRARY

A public library stocks and lends to the public all or some of the following items: books, maps, newspapers, periodicals, records, tapes, slides, films and microfilms. These items are lent out for home reading or reading in the library building itself.

A library is divided into different departments, of which each has a definite location in the library building and with its own staff. The departments accessible to the public are: general reference, periodicals and newspapers, education, government documents, science and technology, history, fine arts, music, social science, literature and language, religion, philosophy and psychology, maps and browsing literature. In addition there are departments for children and youngsters. Departments not directly accessible to the public are: business, print and graphic, rare books, acquisition, cataloguing, classification and central book stack service.

Branch libraries as well as book mobiles are included in the organization, but not housed in the central
public library. Lectures, seminars, theatrical or musical performances and exhibitions are organized either by a department, a group of departments, or an organization not directly belonging to the library. Facilities for these additional activities have to be provided.

THE USE OF THE PUBLIC LIBRARY

Seldom used and outdated books are stocked in a central, closed stack-area, where the public is not permitted. The more often used books are assigned to the different departments, according to their content. These departments place their books in open shelves or closed stacks. They have their own catalogue and office facilities, reading space and probably seminar- or work rooms.

The user of the library can reach the books he is interested in in two ways:

a) Using the main catalogue and order the books at the main take out desk. The books are then brought from the specific departments, where
they were stocked and handed to the user.

b) The user goes to the specific department, uses the catalogue of this department or finds the book himself in the open shelves. The department gives the book to him to take out directly from there.

The entrance to the additional activities, such as lectures, seminars, etc. should not interfere with other library activities.

CIRCULATION IN THE LIBRARY BUILDING

Two separate systems of circulation have to be established:

a) The circulation of the public. Easy orientation to each department is a main requirement of this circulation system. Checking of users to prevent theft of books must be possible at the exit of each department as well as at the main exit of the library.
b) The transfer of books, primarily between departments and the main take out desk plus the communication of book orders.

FLEXIBILITY IN THE BUILDING

Six main groups of use of floor areas are distinctively needed: circulation, public reading area, open stacks, closed stacks, offices, studies and seminar rooms. During the life of the building the floor area used for each of these six groups is changing constantly, in relation to the changes of activities, growth and decrease of departments. Therefore a main objective of the building is not only to fulfill an initial program but to adapt to substantial changes.

GROWTH OF THE BUILDING

The expansion of the whole building has to be planned from the very beginning. The existing floor area may
be enlarged for various uses and additional cores for circulation and mechanical supplies must be provided. Also the structural conception must allow expansion in the same system.
B. A PUBLIC LIBRARY AS A BUILDING SYSTEM

THE BUILDING AS A SYSTEM

A definition of a building as a system can be formulated as follows: The whole and the parts and their relationship are regulated by a construction order. This construction order is related first to the purposes and the activities, for which the building is designed, second to the circulation channels for people, goods and supplies, and third to an efficient use of the proper building material and construction method.

The building has to express a hierarchy of importance and meaning of these above mentioned activities. The pattern of circulation has to emphasize this hierarchy. Activities and circulation establish the principal organization of the building and have to be related closely to the construction order. This relationship is expressed in the selection of the following elements: size of floor- and roof spans, sizes of typical bays, size of construction module
floorheights, location and dimensions of cores, the floorsystem and its ability to integrate the supply lines, the outside enclosure and the inner subdivision of the building and the structural material used for the building.

THE CONCEPT OF THE BUILDING

The basic idea of this public library building consists in the design of a typical floor in respect to spans, bay sizes, floor heights, location of cores, etc. Each typical floor is planned to fulfill all the specific demands of the five main groups of activities: individual reading, storage of books, distribution of books, group activities and circulation. The floor area needed for each of these five groups of activities changes with certainty and therefore adaptation to these changes is of primary importance. As a consequence, lighting, air supply and interior subdivision has to be adaptable to these changes as well. This floor system must also be adaptable to the unavoidable differences in organization on the entrance floor and the administration floor, containing also the main group activity facilities.
APPLICATION

The public library chosen for this project is supposed to be the main library for a metropolitan area of approximately 2 million inhabitants. The library will stock in the beginning 1.5 million books, but could contain about 2 million books without exterior expansion. The total floor area of the building is 300,000 sq.ft. and on each floor 42,000 sq.ft. It has to be underlined that the proposed building represents a large public library building.

THE ORGANIZATION OF THE BUILDING

The public access to each floor is from the center of the rectangular building, using two cores on both sides of a central court. The peripheral areas of each floor are designated as reading areas, open stacks, closed stacks of single or double height, offices, seminars or small lecture rooms. The circulation of books and other library items or of the staff uses the two circulation cores from the outer sides, but is collected on the ground floor, where the admini-
stration, the main take out desk and the main catalogue are located. The first floor is the entrance floor and most frequently used departments are located there. The top floor is designated for special departments and a cafeteria, the basement for closed stacks, containing less frequently used books.

ARCHITECTURAL EXPRESSION

The flexibility wanted on the typical floor does not allow the expression of the specific activities on the outside of the building. Though the types of floors, the heavily used first floor and the specifically used top floor, are expressing activities on the outside. Emphasis is laid upon the expression of the structure of the building.

SPANS AND BAY SIZES

The size of the typical bay is 27 x 54 ft. and on
each floor there are two areas of 54 x 243 ft. without any columns. A large floor area without columns is one of the main objectives for the provision of flexibility in the organization of the floor.

MODULE

The module of the building is based upon the size of the stacks. They are 3 ft. long and 4\(\frac{1}{2}\) ft. center to center, which allows for a minimum aisle of 2\(\frac{1}{2}\) ft. A module of 9 ft. matches the stack sizes in both directions and is used in this building.

FLOOR HEIGHT

The height of stack areas is usually 7 ft. 3 in. Double stacks demand a height of 15 ft. The height of 15 ft. for the typical library floor has been determined for the following reasons:

a) to add a second level of stacks in the future,
according to the growth of the book stock of the library gives a possibility of interior expansion.

b) as most of the rooms have a fairly large floor size, the height of 15 ft. gives generally better room proportions.

To provide maximum flexibility on each floor, the whole floor has to have the same floor height, even if 15 ft. is excessive for office space. However the office space is less than 10% of the floor area on the typical floor.

FLOOR SYSTEM

The live load of the floor with double stacks is 200 lbs. sq.ft. Again the flexibility of the plan demands, that the whole floor area is dimensioned to carry such a live load. To carry these heavy live loads, a substantial floor depth of 3 ft. is necessary. Within this depth is integrated an air distribution system using the floor as a plenum in which the air of the air-conditioning system is
moved. The lighting is integrated in the floor in such flexible way that its brightness can be regulated according to the demands at any specific location. Sound absorbing material is also provided within the floor depth.

ENCLOSURE OF THE BUILDING

On the typical library floor windows would technically not be needed. The air conditioning system could be substantially simplified without windows. Artificial lighting is better than the natural light, because of its regularity and adjustment to needs. Acoustic insulation from the outside would be provided easier without windows. There is however, a psychological need for visual contact with the outside environment. The windows suggested are 1\text{\frac{3}{4}} ft. wide and 10 ft. high with a distance between them of 9 ft. on center. The glass is darked in order to avoid a glaring effect in contrast with walls and to diminish entrance of sun light.

The prefabricated wall elements, representing the outside enclosure are not structural and can be removed
and replaced easily in case of expansion of the building. This fact allows for the expansion of a continuous floor area without narrow connections.
C. THE CONSTRUCTION METHOD USING PRECAST, PRESTRESSED CONCRETE

MAIN CHARACTERISTICS

The precast, prestressed concrete construction method has as its main merit more efficient use than ordinary reinforced concrete, because of the physical characteristics of the two involved materials: concrete for compression, steel for tension. The resulting greater strength and smaller weight of the structural members allows easier transportation and handling. Therefore, these elements can be produced in a centralized, mechanized and automatized plant. This allows for more control of the production of these elements and a greater precision in the sizes of the dimensions. The quality of the concrete can be improved by supervision in a well equipped laboratory in the plant.

A basic demand is repetition of same precast elements but other demands have to be considered carefully, as follows.
FORMING

The material of the formwork can be wood, steel, concrete or plastic. Wood is the most economic for small series. After a wooden form has been used about 50 times, it has to be repaired or replaced. The steelform requires a large amount of simple elements. Concrete forms guarantee a high precision of reproduction of the same element because of its stability. Plastic forms allow more elaborate forms of elements, but are the most expensive.

It is generally an advantage, especially concerning the precise similarity of elements, if the formwork does not have to be taken apart in order to remove the concrete element. A pitch of 1 : 5 on all the sides of the elements which allows easier lifting out of the form is needed. Treating the formwork with special chemicals before pouring the concrete can not replace the need for this pitch.

The wood and steelforms are adaptable to slight changes or specific adjustments of elements, such as shorting of flanges, placing of recesses or holes. This fact allows a certain variability of the design of elements, where it could be considered as inconsistent with the production method.
REINFORCING

The ordinary steel reinforcement can either be put together in the built up forms or be prepared ahead and laid in the form as a whole. A specific problem arises, when an element has a finished concrete surface exposed to the view of people. No spacing-blocks or other similar devices to separate the reinforcing steel from the form can be used. The reinforcing steel has to be either suspended from above or from the sides. This limits the suitable dimensions of such an element considerably, except where these spacing blocks could be considered in the design and integrated in it.

Structurally the ordinary reinforcing must take care mainly of sheerforces or tension caused by prestressing forces.

TENSIONING

Two principles of prestressing of a concrete element can be used:

a) Pretensioning: The steel is tensioned before the
concrete is poured in the form. After release of the tensioning forces into the concrete, they are picked up by the first few feet of enclosing concrete. This method allows the tensioning of many similar elements in one operation in a form of a length up to 400 ft. The difficulty is the guidance of the cables to follow the main lines of negative moments through the elements. Several devices to achieve this goal can be used. The element once poured can never be turned upside down because the deadload is a working force to keep the element straight against the pretensioning forces.

b) Posttensioning: Tension is applied to the concrete element after it has been poured. A cable is introduced in the element through a pipe or a similar device, if the cable had not been put in the form, insulated against the contact with concrete by an oil paper or a plastic tube. The first method demands filling of the tube with grout after the tension has been applied. Posttensioning can be used to establish a rigid connection between different single concrete pieces. It permits also for the tensioning forces
to be applied to the structure in accordance to the increase of superimposed deadload. At the present time only posttensioning makes possible two way slabs in pretensioned concrete structure. The disadvantage is the performance of complicated and highly precision demanding operations on the site, sometimes in places, where access is difficult. Introducing the steelcables through several elements can be a complicated procedure.

Pretensioning in a plant is a further mechanized or even automatized production process than posttensioning on the site. Though there are situations, where one or the other method offers more advantages.

POURING OF THE CONCRETE

As mentioned above, the concrete quality can be improved substantially by production in a plant. If the plant is an enclosed one, the dependence on weather and outside temperature conditions is eliminated. A number of chemicals can be added to the concrete to effect special
reactions. A light-weight concrete of 105 psi can be developed, which has big advantages in diminishing the weight of the elements and facilitates transportation and erection. The surface of the concrete can be developed to a high standard of smoothness, so that the element can be exposed as a finish wall or ceiling in buildings with a high standard of finishes throughout. With certain provisions, additional elements such as acoustical tiles can be laid in the form and still match the standard of high quality of finishes.

VIBRATION

The quality of the concrete is depending to a very high degree on the method of vibration and the care with which vibration is done. There is no effect on the quality of the concrete whether the concrete itself is vibrated inside the form, or the form is vibrated from the outside. Depending on the water containment of the concrete, the compactness of the steel reinforcing and stability of the form work; either the inside or the outside vibrating method
is used. The shocktable produces the best quality of concrete. There the whole form with concrete infilled is shocked. This method allows the use of almost dry concrete, but is limited to small elements which can be mounted on the shock table.

TRANSPORTATION AND ERECTION

The pretensioned parts have always to be transported as a whole from the plant to the site. The posttensioned parts can be transported in parts and connected on the site. Special reinforcing of these parts must be provided for the transportation and erection. Because of the great weight of the elements it is also necessary to limit the parts' movements during transportation and erection. Therefore the erection has to be organized in such a way, that the elements can be lifted directly from the truck into their final position in the building. This demands a very elaborated organization of the erection procedure, especially when other services as electrical or air conditioning are already involved in the erection stage of the building.
The high strength concrete has a tendency to become brittle and as the concrete often is used as a finish for wall or ceiling surfaces, it must be handled with great care. In situ placed concrete has none of these problems.

CONNECTIONS

As the elements are exposed to many different forces, the connections between them is of crucial importance. The welding of steel parts, sticking out of the concrete elements is a simple procedure. The great danger of welding is, that the tension in the steel can be reduced or even destroyed because of the excessive heat of the welding operation, especially if performed at the end of a beam. Another disadvantage of the welded connection is the concentration of force transmission through almost one single point. There are a multitude of methods that avoid welding, but some may demand temporary bracing of elements during erection. Poured connections can disturb the smooth finish and give a different texture.
D. THE INTEGRATION OF MECHANICAL SERVICES

A building such as a public library needs a mechanical service for an airconditioning system, providing heating, cooling and humidity control.

MAIN CHARACTERISTICS

The amount of air supplied to an area depends on the production of heat and cold in that area. Heat in a building like a public library can be produced by people, lighting, office machines, sun radiation and outside air temperature. The cold is usually produced by the outside temperature. The inner part of the building is rather constant in temperature, while the outside temperature changes usually only effect the periphery of the building. As a consequence of the depth of the building, the interior part is depending on artificial lighting as an important heat source. This heat source and the people demand an almost constant cooling of the inner part of the
building. The periphery zones are exposed to heat and cold and the air conditioning system has to match this different condition at the periphery.

TECHNICAL ASPECTS

The size of ducts depends on the amount of air needed and the speed of the air movement. As air cannot enter a room occupied by people faster than with a certain limited speed, the high velocity air has to be slowed down before entering the room.

The complexity of the air conditioning installation depends upon the differentiated demands of warm and cold air supplied to different zones of the building and the number of zones the building is divided into. The air ducts should be accessible for alterations and repairs. Completely structurally enclosed ducts may cause great disturbance in case of failure. The main air handling equipment can be located at several positions in the building. Main objectives for its location are the efficient supply to the floor areas,
the avoidance of disturbing noises of the machines and the possibility of easy provision of air intakes and outlets.
E. THE STRUCTURE AND THE MECHANICAL SYSTEM OF
THE PROPOSED PUBLIC LIBRARY BUILDING

CORES

The two cores and the outside enclosure of the basement are in situ poured concrete construction. The cores perform the function of the main wind bracing of the building. The air supplies to the different floors are led through these cores.

COLUMNS AND BEAMS

These structural elements are prestressed and precast. Most of the columns have a size of approximately 3 floors, the beams are generally 25 ft. long. These elements may be fabricated in wooden forms, because some adjustment at the corners and at the cores are necessary. They are all exposed.
FLOOR SYSTEM

The floor system is a composite design. A T-beam and an I-beam are forming together the structure that carries the live load of 200 lbs/sq.ft. and in addition provides voids for the air handling. This floor is a one-way system. The T-beam is the factory produced Lyn-Tee, 36 in. deep, 8 in. wide. The I-beam is composed of an inverted 24 in. deep 8 in. wide T-beam and the 3 in. thick topping. The flange of the T-beam is the lower, the topping the upper flange of the I-beam. The connection between the topping and the stem of the inverted T-beam is very important. For its production in plant, the forming is only needed for the stem and very small part of the flange. The rest of the flange is poured directly from above, as the beam is poured in the position which it is going to have in the building. Calculations show, that the two elements carry approximately the same weight of the floor, the T-beam 54 %, the I-beam 46 %. Temporary bracing of the inverted T during the erection is necessary but is removed, when the topping is applied.

The advantage of the T as well as the inverted T-beam is, that the flanges are both structural parts of
the floor and ceiling as well as surfaces. In three pieces the floor area of 1000 sq.ft. can be erected. This includes also the plenum of the air handling system.

WALL PANELS

The wall panels are prefabricated, with insulation provided as much as possible. As they are pretensioned, welding to the beams is possible. This allows, in case of expansion of the building, easy removal of these panels by melting the welded connections of these elements. The joints between these elements are secured against water infiltration with a steel spring and against temperature loss by caulking.

ERECCTION

The two cores are built first. Then the building starts from the cores outwards in direction of the narrower building side, always in its full height.
The stability of the cores diminishes the necessity of bracing during this process. If the center field of the building is erected, the two side fields are added.

CONNECTIONS

The prefabricated, prestressed columns, beams and T-beams are all connected together with the same type of connection. A steel bar is inserted into the holes in both elements. Crouting has been provided in these holes before the insertion of the bar. To allow slight adjustments of height of elements, neoprime pads are laid between elements. As mentioned above, the exterior wall panels are welded to the beams.

MECHANICAL SYSTEM

After the erection of the building the mechanical air system can be installed. The main horizontal supply lines on each floor run in the 8 ft. wide space between the column rows. This work of
installation can be done from above. The space between the T-beam and the inverted T-beam is used as a plenum for the air distribution. The air outlets and returns are next to the lighting fixture and can be regulated according to the need of the specific area. The building is divided into four zones on each floor and has four periphery systems on each floor. The periphery system leads air to outlets placed under the windows. The air supply is conducted in insulated ducts through the plenum to the outside wall. Some of these installations have to be performed after the erection of the floor from below. The mechanical machine rooms are located on the top-floor, feeding the mechanical spaces in the core.

ELECTRICAL

The light fixtures allow a flexibility of lighting of the floor area, providing exchange of whole lighting fixture with different strength. They are mounted from below and contain air outlets and return devices. A system of electrical and telephone race ways are laid in the 3 inch toping of each floor.
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CONNECTION OF EXTERIOR COLUMN AND BEAM

CONNECTION OF CORNER COLUMN AND BEAMS

CONNECTION OF INTERIOR COLUMN AND BEAMS

HVATIONAL SECTION THROUGH OUTSIDE SEAM

HORIZONTAL SECTION THROUGH EXTERIOR WALL

VERTICAL SECTION THROUGH TYPICAL FLOOR

A PRECAST Prestressed
PUBLIC LIBRARY BUILDING

S T R U C T U R A L D E T A I L S