THE DESIGN OF AN INTEGRATED BUILDING SYSTEM
AND ITS APPLICATION TO AN URBAN UNIVERSITY

by

EDWARD PRESSMAN
B. Arch., Western Reserve University, 1964

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Signature of Author.................................................. Edward Pressman

Certified By......................

Eduardo F. Catalano
Thesis Supervisor

Accepted By...

Lawrence B. Anderson, Dean
School of Architecture and Planning
Dear Dean Anderson:

In partial fulfillment of the requirements for the degree of Master of Architecture, I hereby submit this thesis entitled, "The Design of an Integrated Building System and Its Application to an Urban University".

Respectfully,

Edward Pressman

June 1967
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INTENT OF THE INITIAL PHASE OF THE PROJECT

The major intent of the initial phase of this thesis project was to design a footprint of structural, vertical circulation and mechanical components which when combined forms a self-sufficient, integrated building unit. This unit when combined with other such units could grow horizontally and vertically to form various building sizes with different spacial qualities.

It was also important to design the structural components in such a manner as to achieve: flexibility within the system; simplicity of construction; openings for cores independent of the structure; a variety of edge condition possibilities; and possible circulation patterns.

The system developed for this project will be applied to the design of an urban university as the final phase of the thesis. Thus the size of module and dimensions of a typical bay should generally fulfill the needs of academic buildings, laboratories, classrooms, office facilities, etc.
GENERAL DESCRIPTION OF THE SYSTEM

The system that I developed was a linear system. Definite advantages exist in choosing this system over a two-way system. First, there is greater flexibility in creating openings in the structure for stairs, courts, multi-story spaces and cores because structural continuity is not required. Also, there is no need for on site scaffolding and complex post-tensioning since the structural members are all simply supported. Finally, the mechanical system is inherently a linear one and since mechanical and structural should be integrated, it seemed most logical to develop the one way system.

An important idea behind the development of this system was to naturally cantilever out from a double dual column in both directions. By separating the columns by ten feet into two U-shaped elements, I was able to reduce the span of a typical bay, reduce the initial cantilever of the independent building unit, create a circulation pattern between the split columns, and create a good mechanical distribution pattern.

This basic building unit is thus composed of: a split double column; a primary double tee girder which is placed upon
the columns; two secondary girders that are placed perpendicular to and cantilever out from the primary double girders; and two double tee infill beams which are simply supported between the secondary girders. When constructed, the floor area of the basic building unit covers 30 feet by 40 feet. By repeating these basic units on 60 feet by 80 feet centers and using infill girders and more double tee infill beams, a typical structural bay can be formed. Also, by simply excluding these infill girders or double tee beams, a variety of spacial openings can be created without disturbing the structural efficiency of the system. The clear span between columns is 55 feet by 60 feet. The longest structural members are reduced to 40 feet. The reduction in clear span and size of structural members is made possible by the configuration of the cantilevered building unit.

Cantilever Flexibility

The ability to vary the peripheral dimensions of the structural system plays an important part in giving flexibility to interior spacial planning and in varying the visual exterior characteristics. These considerations play important roles in creating a flexible system.
The structural system was designed in such a way to avoid unnatural, "glued on" cantilevers requiring scaffolding and post-tensioning methods. Here cantilevering is created naturally in both directions and is an inherent part of the system. The distance the structure can extend from the edge of the column in both directions can vary from 0 to 20 feet and depends mainly on a balancing of the structural loads.

Planning Module

The basic modular dimension is 5'-0" by 10'-0". The 5'-0" dimension between the double tee section will stay constant, but in the other direction can vary depending on the size of the space enclosed. This, in turn, influences the placement of the diaphragm members. In larger spaces the diaphragms might not be needed, but in smaller spaces, say a 10'-0" by 10'-0" office, there could be four 5'-0" by 5'-0" modules or two 5'-0" by 10'-0" modules. These considerations would depend on the function and character of the spaces being created.

The cantilever from the face of the column provides the possibility of locating rooms along the building periphery which could vary in depth from 10'-0" to 40'-0".
Design and Location of Cores

The sizes and characteristics of the cores are defined by their location within the building. The core elements include: passenger elevators; freight elevators; fire stairs; toilets; storage areas; and janitor, electric, and telephone closets. This system allows for the cores to be placed anywhere between the girders which means the dimension in that direction will be a constant 40'-0". In the other direction, it can grow in 2'-6" intervals according to functional needs. The cores are structurally independent of the structural system; thus, they can be constructed separately.

Circulation

Horizontal circulation could exist within the system in a variety of ways. One possibility would be to place perimeter corridors between the split columns. Therefore a linear pattern of circulation could be established, while at the same time perimeter room depths could vary depending on their function and cantilever flexibility. Another condition would be the interior circulation pattern. This major circulation, interconnecting the cores, could occur alongside the columns. In this case, the corridor width between column and core would be 10'-0".
Vertical circulation can occur in two ways - through the cores or by means of open stair wells. The cores contain a continuous means of vertical travel by elevators or stairs, single and scissors. Open stairs can exist to link major two story spaces or to reduce the number of stops for the elevators, since people could use the stairs for traveling between areas with the same functions.
STRUCTURAL COMPONENTS

The components of the structural system are all made of pre-cast concrete. The shapes were developed with these important factors in mind: high structural efficiency; prefabrication; ease of transport; and construction and erection process. The final results yielded a minimum of components, simply shaped and easily erected. The basic components are two U-shaped columns at each support, primary double tee girders, secondary girders, infill girders, double tee infill beams, and diaphragms.

Columns

The columns are cast in floor to ceiling lengths of 10'-0" thus reducing the weight and size of each member for ease of transport to the site. The columns are U-shaped to attain lateral stability, achieve continuity between the backs of the columns, and have one side open for access to the mechanical equipment. The top and bottom column sides are open. Here reinforcing rods are extended to achieve continuity between columns and girders. Each side of the column measures 1'-4" by 6'-4" and encloses a mechanical space 3'-8" by 4'-6".
Primary Girder

This prestressed girder was developed for a combination of functions. It takes the shape of a double tee in section. This provides an immediate horizontal floor slab to walk on. Construction is simplified by placing the girders, as one, upon the columns. The slab also helps to strengthen the section in tension and provides lateral stability. The slab of the double tee girder is 10 feet by 39 feet and has two openings which correspond to the openings for the mechanical in the columns. These double tee girders have a total depth of 3'-8" and a width of 1'-4" directly over the columns. The other width dimension is 1'-0" but it has a 2 inch ledge on each side to add to the compressive strength of this member and to provide a seat for the ceiling fixtures. Two openings are located at the center of the girders, where shear is at a minimum, to provide for horizontal passage of the mechanical components.

Secondary Girder

This member is used to support the double tee infill beams and also to transfer their weight back to the primary girders. It has a length of 25 feet and a depth of 3'-8".
The width of this girder is 1'-0" with 2 inch ledges which increases its compressive efficiency and also provides a seat for the ceiling fixtures. This member is also pre-stressed. Tension takes place at the top while compression acts at the bottom of the section. Small openings occur on 5 feet centers to allow the end of the mechanical runs to pass through. Two other openings also exist acting as slots for the primary girder connections. (See drawing "Sections through Structural Components") Lugs are placed 5 feet on centers and simply support the double tee infill beams.

Infill Girder

This girder is simply supported on the ends of the secondary girder and is 35 feet in length. Its other dimensions and characteristics are the same as the secondary girder except that compression takes place at the top while tension acts at the bottom of the section.

Double Tee Infill Beam

This prestressed member can be placed anywhere between the secondary or infill girders and is simply supported on
their lugs. The tee sections are 5 feet on centers with a slab overhang of 2'-6" on both sides. Thus the slab of the double tee beam is 10 feet by 39 feet but could vary by casting tee sections to meet the need of interior openings or exterior fascia conditions. Examples could be single tees or double tees with one 2'-6" slab overhang removed. The depth of the double tee beam is 3'-8" and its width is 5 inches with 2 inch ledges which increase the strength of the member in tension and act as supports for the ceiling fixtures. Casting the slab as part of the double tee simplifies construction and strengthens the section in compression. Two openings occur in the center of the beams to allow for mechanical circulation. This is the most efficient place for openings in a simply supported beam because of minimum shear.

Diaphrams

These members are placed between the beams either on 5 feet or 10 feet centers or not used at all, depending on the size and function of a room. Their dimensions are 6 inches wide by 10 inches deep by 4'-7" long. Diaphrams are needed to take partitions in the transverse direction and to support the coffered ceiling fixtures.
MECHANICAL COMPONENTS

The mechanical system distributes itself integrally within the structural system between the floor of the double tee beams and the recessed ceiling fixtures. The mechanical module is the same as the structural and follows a similar pattern of growth. Thus wherever extensions or voids exist within the structural system, they can be mechanically serviced without special conditions or awkward patterns of distribution.

Air Supply and Return

Duct space is provided within each double split column. A single high velocity air duct at 4,000 f.p.m. supplies cooled air vertically through one of these columns. The other column returns the used air through a duct at a low velocity of 1,500 f.p.m. This system was designed to handle five floors with the mechanical equipment being at one location. (If this equipment were located at the top and bottom of a structure, it could handle twice as many floors.) At each floor the air system is distributed horizontally around each double split column to cover an area of 4,800
square feet or one bay. Located between the two split columns is a velocity reducing, sound reducing attenuator box. Here supply air is reduced in velocity to 1,500 f.p.m. The main branches of the supply and return ducts split in two and run parallel between the split columns for 30 feet. Secondary branches are taken off perpendicular to the main branch and run parallel between the double tee beams for 40 feet. Reheat coils are inserted into the main and secondary supply branches according to where different zone control is needed. Supply diffusers and return grilles are attached to the underside of the secondary branches. These in turn are connected to the recessed ceiling fixtures.

Plumbing

The pipes, including hot and cold water supply, waste, and ventilation are distributed vertically at two locations depending on their function. Pipes located in core shafts serve toilets and janitor closets. Secondary piped services are located in columns with the air supply ducts. These pipes follow the same horizontal distribution pattern as the supply and return air system. All of the vertical and horizontal pipes are accessible and may be readily serviced or replaced.
Recessed Ceiling Fixture

This unit which sits on ledges provided by the structural components serves many purposes. First, it acts as an acoustical isolation barrier between rooms and as a sound absorber within rooms. Secondly, this fixture contains built-in fluorescent panels which illuminate evenly each recessed ceiling module and the floor below. Each light panel could contain from two to four bulbs depending on the foot candle intensity needed for each particular room. Also, this fixture contains two air grilles at each end of the light panel: one for air supply, the other for air return.

(In some larger spaces, like laboratories or work rooms, diaphrags and recessed ceiling fixtures would not be needed. Here the mechanical system could be exposed with lighting units hung down from the ceiling.)
CONSTRUCTION SEQUENCE

1. The U-shaped columns are placed upon the primary girders and column below, and welded at their bearing plates.

2. Reinforcing rods that extend from the columns and girders are tied together and the rectangular open joints are poured thus attaining continuity with the structure below.

3. Primary double tee girders are positioned on each set of split columns and welded at four bearing points. Four rectangular open joints between columns and girders are poured to gain continuity.

4. Secondary girders are supported perpendicularly to and on the end extensions of the primary girders. They are positioned into place from the sides and secured by welding.

5. Infill girders are placed, simply supported, on the end extensions of the secondary girders. They are dropped into place from above and their bearing connections welded.

6. Double tee infill beams are placed from above anywhere between secondary or infill girders. The beams are positioned onto lugs of the girders, grouted and welded secure.
7. Electrical and telephone chases for wiring are placed on top of the structural pre-cast floor.

8. A four inch topping is then poured over the top of the structural pre-cast floor thus insuring continuity within the structure.

9. Mechanical duct work and pipes are placed vertically in the columns.

10. Ducts and pipes are then hung horizontally from the underside of the pre-cast structure. Attenuators and re-heat coils are placed. Then all the necessary connections are made.

11. Diaphragms are inserted, where needed, between the webs of the double tee beams.

12. Recessed ceiling fixtures are then placed on ledges in the ceiling modules created by the tee beams and diaphragms.

13. All the necessary electrical connections for the lighting and mechanical connections for supply outlet diffusers and return inlets are then made.
STRUCTURAL COMPONENTS AND CONSTRUCTION SEQUENCE
INTENT OF THE FINAL PHASE OF THE PROJECT

The major intent of the final phase of this thesis project was to develop a new campus in an urban environment using the flexible building system developed previously. The program and system affords us an opportunity to develop prototype campuses that have the ability to expand horizontally and vertically within the limitations of the system and to serve functional changes that are expected to occur.

It was also important to investigate the potential use of a continuous grid developed over the site as a means of designing the university. The structural module, the removal of non-supporting construction elements to create voids and define spaces, the location of cores were all important factors in the development of a concept for this urban university.

Finally, this project was used as an exercise in large scale planning and in the organization of many functions within the limits of a previously developed flexible, integrated structural and mechanical system.
A site was to be chosen or created near the center of a very densely populated area of the city. The basic area allotted for campus development was 65 acres. This includes two stages of construction. The first stage for approximately 6000 students would satisfy the college needs until 1980. The enrollment was planned to double at the turn of the century for the second stage.

The elements of the program are divided into four major parts: academic; group activities for public and student use; housing; and parking and mechanical areas. The academic disciplines include science, engineering and computer center, architecture and planning, and humanities. Group activity functions include a university library, museum, auditorium, theater, arena, athletic facilities, and a student center which includes a medical department. Housing for students includes an undergraduate center, graduate center, and married student housing. The parking areas are to provide space for at least 2500 cars, most of these to be placed below the university along with the mechanical areas and the power plant.
THE MAJOR DESIGN CONCEPT OF THE PROJECT

In developing a hypothetical site I was given the opportunity to set my own limitations for the project. A rectangular site inclosed by four streets was chosen. One major divided roadway is on one short side, a secondary road is on the other side. On the long sides are two public transportation streets with a mixture of older residential and commercial buildings facing the campus. Around the whole general area surrounding the site are older low and high-rise apartment buildings. The density of these areas is extremely high. Eventually it is expected that the construction of the new university will influence the renewal of such areas which hopefully will become an integrated part of a larger development.

The major pedestrian entrances and automobile entrances are on the long sides of the campus. Minor entrances for pedestrian, automobiles, and services are on the short sides of the campus.

The major design concept behind this proposed campus was the development of two major axes of circulation within the university. The first axis is perpendicular to the long street
with the main entrance to the campus at its center. Grouped along this axis are public activity buildings. The student center and athletic facility with an arena above are on opposite sides of the main entrance. Inside the heart of the campus and facing each other are the theater and auditorium. The end of the axis is culminated by the university library and museum. The functions in these highly active areas will obviously attract a great number of people. Thus the way in which the buildings are grouped forms the major space. Working as a void in the system, the space is created by removing twelve structural bays. The dimensions of the space are 200 feet by 240 feet. The second axis is perpendicular to the first and is created by two parallel spines that are each three floors high. Here interior circulation is dispersed. At the center of the campus all activity buildings grow out from the spines. At the ends of the spines are the academic buildings: humanities, science, engineering, and architecture and planning. Secondary academic spaces are formed by the removal of nine structural bays at the two ends formed by the two circulation spines, the academic buildings and the theater and auditorium. The dimensions of the secondary spaces are 165 feet by 200 feet.

By separating the buildings that grow out from the two spines, secondary pedestrian entrances to the interior spaces and the
spines are formed. Thus at ground level each entrance to
the courts is open with separate entrances into the buildings
through the spines. The second and third levels of the spine
are inclosed for through circulation and link all the func-
tions of the university. Also the spine carries the needed
vertical circulation through the cores that are spaced along
these circulation paths. Also placed along the spine at
these two levels are multipurpose lecture halls that could
serve all academic functions plus lectures open to the pub-
lic from the surrounding community. The upper level of the
spines and the roofs of the theater and auditorium are used
for exterior circulation with entrances to most university
functions from this level. It is hopeful that enough funds
could be raised to landscape this important circulation level.

The building design of the academic units were handled in
such a way as to decrease the floor area on the upper floors.
This was done in order to create laboratory spaces that would
be used for long periods of the day, thus the necessity for
natural light. Upper terrace areas are developed by stepping
back the structural bays in certain areas on each upper floor
above the spine. Hopefully these areas could also be land-
scaped. The lower floors, which have much greater floor
areas, contain offices at the perimeter and interior class-
rooms which are only used for short periods of time.
Below the ground level of the university complex are two lower level floors. The basic shape is a simple rectangle which covers almost the entire building area that grows above. This level contains truck dock facilities, parking for 1500 automobiles, and the vertical cores that serve shipping and vertical circulation. Therefore, the pedestrian by taking elevators in a specific core could go directly to his destination. In the center of this level is a pedestrian island. It contains the lower levels of the theater and auditorium with some of their related functions plus escalators that connect their lobbies. Space is also provided for shops, like a small drugstore or bookstore. Most important though are the landscaped courts that are open to the major and secondary spaces above with stairs directly connecting these spaces with this lower parking level. The lowest level contains parking for 1000 cars, a vertical circulation pattern, space for mechanical equipment, and the university power plant.

Housing for the university is developed across the streets at the ends of the public activity axis. Each of the two developments contain three towers growing from a main terrace which connects the university with pedestrian overpasses. One group of towers contains undergraduate housing, the other group contains graduate and married student housing. At grade level under the raised platform are commons facilities.
and open courts with stairs that lead to the overpasses and the campus. Below each commons area is one level of parking facilities for the students.
POTENTIAL GROWTH OF THE URBAN UNIVERSITY

The first stage of construction for 6000 students covers approximately 45 acres of the 65 acres of the purchased land. Ten acres on each end of the site still remains to be developed. Thus when the university expands, it will expand linearly in two directions and will continue to grow out from the two spines.

The public activity areas will not expand except for the library which will expand downward and take over the two floors of parking just directly below the library. Thus the center of gravity of the university and the character of the central space will not be altered by expansion.

Major expansion for the university will take place in the academic facilities where floor areas will double in size. This expanded growth is designed in such a way as not to change the architectural character of the first design stage and its surrounding spaces, but to create a continuous sequence of spaces by proper placement of the new buildings. Two levels of parking and services will expand below and in conjunction with the new buildings.
URBAN UNIVERSITY

UPPER BASEMENT LEVEL PARKING PLAN

SECOND STAGE PARKING EXPANSION

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