BUILDING SYSTEMS DESIGN FOR HIGHER EDUCATION FACILITIES

by

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Lawrence B. Anderson, Dean
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Dear Dean Anderson:

In partial fulfillment of the requirements for the degree of Master of Architecture I hereby submit this thesis entitled "Building Systems Design for Higher Education Facilities."

Respectfully,

William E. Roesner
Abstract

The word thesis is probably not a correct one in describing what follows of what activity took place in arriving at this material. It could be more accurately described as a terminal project, one which was done in conjunction with, and with the aid of, my fellow students, teachers and critics. It is not on the other hand completely terminal either as it is hoped that the repercussions of thought process will be extended to further projects and future work.

This project is concerned with the development of an organic set of systems capable of being reproduced in any juxtaposition according to the variability of site, program or existing structures to accommodate college and university functions normally found in classrooms, lecture halls, and laboratories. There is to be admitted a point at which the application of this or any system can broach on the absurd, and it is with this in mind that this program was written.

Programmatic requirements that will be applied to the system were initially the subject of much discussion and debate. This area is the one where a great many decisions are made which set many of the parameters for later design decisions. It was in this area where, if mistakes were made, the validity of the entire project might be questioned. Thus, as one follows the written portion of this project and the drawings, judgments will be made as to the basic premises of the problem. The premises are subjective in their very nature and reflect a set of values incapable of scientific analysis which are one of the reasons why architecture will never become a pure science and maintains its identity as an art.
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Program

The problem as it was given was to design a building system of construction capable of flexible expansion, growth and change to house the various departments of almost any college or university. This system is to be capable of accommodating almost any type space up to a medium size auditorium or cinema. The restriction upon vertical height of any one space is governed by the height of the building. Since programmatic restrictions are self-imposed, or secondarily by corridor width, parking space under the building, elevators, fire stair regulations, the building which might arise can take any size or form.

Certain restrictions are evident at the outset. By Code the toilets, exit and elevator capacities are calculated on 150 square feet of gross area per person. The maximum distance to fire stairs is 150 feet.

In addition to these requirements the building would have to provide space suitable for at least the following activities.

1. Classrooms
2. Laboratories
   a. Instructional
   b. Research
   c. Testing
3. Workshops
4. Seminar Rooms
5. Small Auditoriums
6. Studios
7. Drafting Rooms
8. Departmental Libraries
9. Administrative and Staff Areas
10. Faculty and Assistants Offices
11. Lounges
12. Restrooms
13. Exhibition Spaces
14. Storage
15. Maintenance
16. Mechanical Equipment
17. Parking

Concept

The resultant design is limited in its height by one factor - the size of column. The system should be capable of achieving a height that is deemed practical within the reinforcing limitation placed on a column 2'8" x 9" in-width. The height possible has not been calculated but it is estimated that 9 floors is maximum.

Internal flexibility and ability to expand are major considerations. The building should consist of two types of non-specialized spaces (large interior and smaller perimeter)
which at any given time can be used for a variety of purposes. Expansion may occur within the building itself. This refers to shifts in the spatial needs of various departments within the building. Consequently, it must be possible to repartition large spaces at any time. Another form of expansion refers to the need to expand the total floor area achieved by lateral expansion of the building at the perimeter. This is done by an ingenious system of girders, columns, and cantilevers. Each cantilever at the exterior of the building is 20 feet. This allows footings to be placed 20 feet from existing footings, double columns and girders placed under the cantilever's edge and additional 'T' sections placed adjacent to existing. The building continues from there.

The demands on mechanical services (i.e., air conditioning pipes, illumination, communications and power) will change as the uses of the spaces change. Internal flexibility requires that any one or all of these services may be brought to any one space at one time. These services should be so designed that it is possible to make alterations in the system without disturbing neighboring spaces.

The design of systems of this sort are rooted greatly in the modular proportioning of spaces and/or the resulting spaces various modules dictate. The module which developed in this project is dependent upon a number of programmatic considerations.

Three feet is a good module in that it is very small for partitioning spaces in a great variety of configurations.
This though, in projects the scale of one which is being approached now, could be ruled uneconomical. 3'0" is also a bit small for some entrances, doorways and frames. 3'4" is a better distance for doors, yet allowing generous flexibility with planning of spaces.

Since it was chosen to use a one way system of structure for ease of construction it was felt that this might easily be expressed in a ceiling module. Given 3'4" for one direction perpendicular to spanning members, it is only logical that (with a reasonable partitioning system) the longer module be twice the 3'4" or 6'8". The rectangular module thus arrived at is further justified in that the standard most economical fluorescent light fixture in terms of initial and operating cost/amount of light necessary is a 4' long bulb easily placed within the 6'8" direction.

The small sub-module is further justified in that the square footage covered by a 6'8" x 3'4" module (21.8 square feet) lies somewhere between a 4' square (16 sq. ft.) and 5' square (25 sq. ft.), neither of which seem at all economical.

Since perimeter space is at a premium, it is also logical that the smaller dimension of the module be the one which dictates the size of spaces at the perimeter. This will allow spaces with windows at the surface of the building, 6'8", 10'0", 13'4", 16'8" on up in increments of 3'4". Thus both the very smallest office up to large classrooms or secretarial pools could conceivably exist at the
perimeter. This module back into the building would be 6'8". Structure then will follow this direction and the cantilever described in the drawings can occur. The cantilever is 20 feet which is three modules into the building. This is fine for larger offices, seminar rooms and classrooms. It is also possible to arrange smaller spaces, seminar rooms, and offices at the exterior which are 13'4" deep with a 6'8" corridor which is the minimal corridor possible, as well as being quite economical.

Since this cantilever-office partitioning-corridor arrangement works so well it was deemed necessary for reasons of esthetics as well as constructional economics (the placing of spanning members, mechanical equipment) to drop the girder carrying the spanning members so that there occurs in the ceiling a discontinuity expressing the two types of spaces possible (perimeter and large interior).

Structure

As was explained previously the structure system is a very simple arrangement of double girders and columns, precast on the site and posttensioned into place. When the column-girders are in place a simple spanning member (a part of the girder) is lowered onto the ends of the column-girder and the spans are completed.

The columns are 2'8" x 9" and the girders are 2'0"x 9". The spanning members (over a distance of 53'4") are a specially formed 'T' section built to incorporate electrical ducting
as well as mechanical and lighting equipment. They are 2'8" deep and rest simply supported on the girders. These 'T's are perforated with a series of holes 6" high by 12" wide to allow the passage of at most two flexible ducts 5" in diameter. These holes occur opposite the junction of the secondary supply and return ducts and the flexible ducting may extend beyond the channel in which that secondary ducting lies.

The wind loading is taken through a reinforced topping slab which acts as a diaphragm against cores. For this reason the building is again limited in height to at best ten stories.

Since the 'T's occur every 3'4" the structural economic advantage is sacrificed to a modular partitioning pattern and mechanical equipment versatility and economy.

Construction

Since the mechanical system is fed from cores and as such is independent of the structural system, except for wind loads, the least building possible is a building of one bay and a core 33'4" x 53'4". That is, a building of minimal structural and mechanical integrity. The system is designed to be built totally in precast concrete, except for unique situations such as footings, cores, and some joints and topping. Speed of construction was kept in mind at all times and the process is such that it would go up very quickly. The only post-tensioning operations that
are involved are in columns using the Ryerson bonded tendon system which allows the tensioning of one floor at a time. The spanning members are just lowered onto girders with no fastening operations. They would be braced until made stable by reinforced topping.

The cores would be poured in place concrete with most of the floors (in front of elevators, corridors and rest-rooms) utilizing portions of the same 'T' sections. They would be poured just after the above structure was placed and would keep pace with the construction floor by floor.

**Mechanical Systems**

The primary aim in the design was to develop an integrated framework of structurea and ducts, integral and yet independent, that would permit the use of several different types of mechanical systems depending upon the demands and technology of the future. The design premise was based on a minimum planning module of 6'8" x 3'4", the smallest room that could require either supply or return of air, lighting, plumbing, power, communications (telephone, signal, intercom or closed circuit T.V.) and acoustical control. The source of all these services (except the last) would be a mechanical room adjacent to a core, either in a penthouse or in a garage. These services and distribution would be planned as follows; however, the total system does offer the space and flexibility to introduce other, more specialized, services when the situation might warrant it.
A. Air Conditioning

The overall system is geared to high velocity dual duct supply system (5000 feet per minute); these two supplies hot and cold, are tapped with 15" ducting, by a variable volume mixing box designed to serve up to 3500 square feet of floor area including a portion of the perimeter. The perimeter air is adjusted in temperature to meet the demands of high variability, by means of a four pipe induction unit system incorporated into the precast window units or below the floor. The horizontal secondary distribution is at 1200 feet per minute velocity. Lighting fixtures are to be designed such that any one of them could serve as either diffuser or return depending on unique conditions in a room at any one time. The 5" diameter flexible ducting is such that it can reach any of these diffusers, and can change from diffuser to diffuser as room partitioning and planning requirements might change. Return air in large spaces would be ducted directly to return air chases and to cores.

The primary air supply and return ducts, plumbing and mixing boxes are located within the suspended ceiling in major corridor spaces. This allows air to pass up and over girders into 'T' beam chases freely, ductwork problems are kept to a minimum. All air supply and return ducts were calculated as to necessary size under given velocities by means of slide rule calculators (ductulators).
B. Lighting

Each module was allotted its own diffuser light fixture and light fixtures contain two 4 foot 30 watt fluorescent lamps generating a 65 footcandle light level in an average classroom. The system permits the use of almost any type of lighting - incandescent, luminous lowered ceilings, indirect lighting from above ducts (when acoustical control is no problem) when desired. Additional lighting can be obtained individually from the floor mounted power supply. Major corridor lighting as well as other major circulation spaces and lounges are lit with incandescent lighting from between structural members. Natural lighting is also possible in areas where deemed necessary by large skylight areas taken from absent flanges of T beams.

C. Plumbing

All plumbing except roof drains is supplied from the cores and runs in much the same pattern as air distribution. Vent pipes and roof drains occupy where necessary the space between the double columns. The four pipes of the induction units run at the perimeter through a void designed for that purpose. They travel from the core to the major circulation ceiling to a channel where either supply or return air do not exist to the perimeter.

D. Power

Normal 110 AC power will be distributed from the garage mechanical room vertically in core chases adjacent to
elevators with a breaker panel at each floor serving each typical bay. Horizontal distribution to major transverse ducting into secondary conduit in floor which runs at the center of every module so as to remain free of partitioning. Electrical services which must run in partitioning (thermostats and lighting controls) will run through a small duct provided at the bottom of each 'T' section, where it can run to any transverse filler piece, up, and to lighting fixture.

E. Communications

Telephone distribution will be similar to the electrical, using a panel board in the core for an individual bay with distribution in floor conduit. Telephone equipment rooms would be located in the mechanical floors. Special signal, intercom, and television wiring might have to be distributed from the cores in conduit as piping.

F. Acoustics

Since the ceiling is sealed in a horizontal plane by lighting and absorptive material, the transfer of sound from room to room (providing partitioning is air tight) will be minimal if at all existent. Reverberation is controlled by fuzz in the ceiling in a perforated metal casement containing lighting diffusers. Also the fact that the ceiling is not a flat plane but an irregular surface with a variety of different sized components at about the same wavelength as normal spoken and machine made noises, indicates that there will be a great deal of sound diffusion. Where necessary added absorption can be added by means of
carpeting, drapery and other fabric type materials.

Partitioning of Spaces

Partitioning can be accomplished by almost any method desired. With the ideal of total flexibility in mind, the normal systems, depending on the type of space, would be exposed block walls, dry-wall partitions of gypsum board on metal studs, or single panels (glass or hardboard) in metal frames. All of these are relatively easy to install and remove and are usually much less expensive and durable than the commercial, movable partition systems. Where sound isolation is desired, the use of fiberglass blankets and resilient mounting clips can bring drywall partitioning up to acceptable levels of good privacy. Higher requirements will necessitate the use of heavier, less flexible walls as a solution. In all instances, the exposed webs of the structural system provide the anchorage point for the top of the partition, as well as the transfer point of wall borne electrical conduit to the small ducts, and impose a predetermined modular order on all space planning.

Conclusions

A unified system can be developed that satisfies almost all of the criteria set forth. However, there are inherent contradictions that require some compromises to be made in achieving a flexibility and construction simplicity. Ideally, the mechanical services should be able to distribute
in any direction on the shortest line from point to point, but in order to achieve a needed sense of architectural organization and control of planning, the use of the exposed structural system regularizes the paths of the services and forces them to move laterally in right angle turns - to the point of having to double back on themselves in some instances.

The attempt to have a generally distributed system by integrating the services with the structural supports also has a built-in contradiction as it demands that both the structure (mass) and the service space (void) maximize at the same point. To meet both requirements these points quickly outgrow the sense of being a column and become instead distributed mechanical chases and as such are impeding elements, contrary to the desire for unobstructed floor space. The other alternative, of supplying all the services from the cores, generally requires some very large horizontal chases that cannot, it was learned, be handled with normal structural module and are then run above predetermined corridor spaces. In this solution the attempt was made to use the normal area created by the column groups for minor vent stacks and drains, and the larger spaces available in the cores thus accepting the major corridors with their dropped ceilings as opposed to the huge, inefficient, column-mechanical shafts.

Finally, the attempt to design a system of parts and pieces of a building without the application or testing
of these parts to determine what proportions might arise in building form was deemed not a valid approach. It is placing too much faith in technology and not enough in the individual as a designer and it points up in some a real fear of the results of a system that may or may not have gotten out of hand.

The advantages of various plan configurations, one over the other, on the other hand, was not explored, nor was the integration of ground plane elements, theatres, auditoriums, etc. into the building framework to possibly serve as linking elements to the total academic complex. It would seem that there are quite a number of problems to be explored and worked out before one could call this study complete.
NOTE:
CORES ARE MODULAR AND INDEPENDENT
WHEREVER NECESSARY
BAY SIZE: 32'4" x 36'8"
MODULE 8'6" x 14'
POWER AND COMMUNICATIONS DUCTS
SPANNING MEMBERS OVER GIRDER
MECHANICAL DISTRIBUTION AND RETURN DIAGRAM

REFLECTED CEILING PLAN
MECHANICAL BRIDGE FROM CORE TO CORE

RETURN AIR SYSTEM

SUPPLY AIR SYSTEM

COLD AIR

HOT AIR

MAJOR AND MINOR REINFORCING DIAGRAM

ELEVATION OF SPANNING MEMBERS

STRUCTURAL - MECHANICAL SECTION

BUILDING SYSTEMS DESIGN
FOR EDUCATION FACILITIES

M.Arch. Thesis MIT 66
WM. E. ROESNER

A PIPES TO INDUCTION SYSTEM AT PERIMETER ZONE