AN INTEGRATED BUILDING SYSTEM

BY

R. Michael Schneider

Bachelor of Arts
University of Minnesota
(1964)

Bachelor of Architecture
Harvard Graduate School of Design
(1965)

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Signature of Author

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DEAR DEAN LAWRENCE B. ANDERSON:

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARCHITECTURE, WE HEREBY SUBMIT THESE PROJECTS ENTITLED "AN INTEGRATED BUILDING SYSTEM".

R. MICHAEL SCHNEIDER
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AN INTEGRATED BUILDING SYSTEM
PREFACE

THE OBJECTIVE IS TO CREATE A SYNTHESIS OF IDEAS INTEGRATING THE
CONSTRUCTION, MECHANICAL AND STRUCTURAL SYSTEMS INTO A HARMONIOUS
RELATIONSHIP BETWEEN THE SYSTEMS, THE BUILDING ENVIRONMENT FORMED
BY THESE SYSTEMS, AND MAN.
STRUCTURE

1 WAY 30x60 BAY

ADVANTAGE: FAIR ECONOMICALLY
CAN CHANGE DIRECTION

Units

4 TON ASSEMBLED COLUMN 5x5 CAST IN PLANT
14 TON CAPITOL 20x25 CAST ON SITE
14 TON CHANNEL 10x55 CAST IN PLANT

CAN BE HANDLED BY ROLLING CRANE; LESS UNITS TO HANDLE DUE TO SIZE;
THEREFORE FASTER.

MECHANICAL

Single duct 5000 CFM MAIN BRANCH 18"x20"
WITH ATTENUATOR 10"x10"
IN EACH COLUMN 1200 CFM FEEDER 7½ ROUND

DIFFUSED THROUGH DIAPHRAMS IN CHANNELS;
DIFFUSER BOOT CAST IN DIAPHRAM.
REHEAT MODULE AND DIFFUSER UNIT, PLUG IN BASE OF BOOT WHEN ACTIVATED.
CONTROL EVERY MODULE (5x10) MAXIMUM IF NEEDED.

ELECTRICAL

LIGHTING - FLUORESCENT TUBES WITH BALLAST LOCATED IN DIAPHRAMS.
DISTRIBUTION IN FLOOR RUNNER CHANNELS, ALSO HAVING FLOOR OUTLETS. PARTITIONS
HANDLE WALL OUTLETS WHICH ARE LOCATED UNDER DIAPHRAMS AND CHANNEL EDGES, FOR
EASE OF DIRECT SWITCH CONNECTION.
PARTITIONS HAVE REMOVABLE PANEL ON ONE SIDE FOR MAINTENANCE ACCESS.

CORES

MAY BE LOCATED ON 10 FOOT INTERVALS ANYWHERE BETWEEN COLUMN CAPITOLS.
MAY BE INDEPENDENT OF STRUCTURE.
BUILDING EDGE

Building edge may vary on 10 foot intervals across 30 foot bay face, and up to and including a 20 foot cantilever without post tensioning out from column. In 60 foot bay direction 10 foot cantilever may vary every 25 feet. (Both building edges are removeable.)

FLOOR TO FLOOR DEPTH

2'-8" with topping.

FLEXIBILITY

Exterior - For expansion, since every column and capital are completely independent except for fire code egress, the building may be expanded column capital unit by column capital unit since the channel units are wide enough (10) for an office space, theoretically if the need should arise.

Interior - Partitioning can be located under diaphragms and channels every 5x10 module, and voids may be opened to spaces a minimum of 15 feet and maximum of 55 feet in one direction and a minimum of 10 feet and unlimited maximum dimension in the other direction.

WHY PRECAST CONCRETE

Precast concrete was selected over cast in place concrete for the following reasons:

1) Easy and speedy construction on the site.

2) Parts can be fabricated on a 24-hour basis.

3) Factory control of raw materials assures uniformity and high quality.

4) The shapes which best facilitate mechanical equipment passage are not easily formed on the site and poor results, even with experienced labor, are likely to result in poured in place concrete.

Additionally, the building can be "weathered-in" quickly allowing mechanical trades to proceed even during inclement weather without physical hardship or damage to the installation.
STRUCTURAL SYSTEM

The basic structural bay, which is the backbone of the system, dictates the planning configuration. This bay is rectangular, sixty feet by thirty feet; it is formed by column clusters (four per cluster) at each of its corners. At the sides of this bay, parallel to the sixty foot dimension, is a column capital having twin girders with three main arms on top of the column clusters. From these column clusters span a series of 10 foot wide canted channel beams. The channels may be omitted at any point within the bay to produce vertical penetration. Within each of the column clusters all mechanical, electrical and plumbing services are transported vertically through the structure. At each level, these services leave the column group penetrate horizontally into the bay. The void remaining between the two girders acts as a raceway for all the air supply ducts and major mechanical services. Sub-supply lines may then leave the girders and penetrate transversely into the bay by means of the space made available by the canted channel beams. (The sub-supply lines stand in a relationship to the major supply as the vessels to the arteries in the human body.) A more detailed analysis of the structural-mechanical relationship will occur in a later section.

The resulting structure is simply formed by a repetition of bays. Expansion of the building can be achieved at any time by repeating this column, capital, channel combination. The maximum uninterrupted horizontal space is limited only in the sixty foot dimension. This dimension also corresponds to the efficient use of prestressed concrete. Spatial flexibility and economy of structure and the minimum number of simple elements were of prime consideration in evolving this structural system. The 30 by 60 bay also follows this criteria (see plans).
The span of the secondary members, 30 feet, allows the designer to include vertical spaces of adequate dimension without imposing unique conditions upon the structure. Flexibility to provide these spaces must be considered at the initial planning stages. It is highly impractical to consider that they be formed after the structure has been completed, although it is possible.

The column cluster is made up of four main structure supporting elements bonded together to form two main structural bearing elements. Included also between these elements is a 6" wide reveal for receiving partitioning. In addition, there are two filler panels, one of which serves as an access panel to the mechanical equipment located inside. There is a strong possibility that casting the whole unit as a tube rather than the before mentioned pieces might be more practical even though the column cluster tube would be difficult to form and the access panel would have to be provided. In addition, these elements and services could be prefabricated prior to erection. Each column cluster weighs approximately 6 tons.

The column and capital are secured together by four steel bars welded continuously to angles imbedded in the capital cross member, abutting also the bars from the above column. The space formed by this cluster, a vertical shaft or tube, is used for mechanical services. Of the total cross sectional area of 25 sq.ft., 16 sq.ft. is available for mechanical use. The remaining 9 sq.ft. is structural. All vertical piping, ductwork, attenuators, main electrical conduit, branch duct connections, fire extinguisher boxes, electric box, etc. can be located in this vertical void.

The cantilever is made possible by the use of the column capital. A 20 foot cantilever in two directions and 10 feet in the other two directions is attained; this is accomplished without any post tensioning. The column
Capital is in one piece, 20x25 unit, consisting of two main cross girders with three tapered arms running perpendicular to the girders. This unit is secured by continuously welding four steel bars to the angles imbedded inside the column cluster. Using these column capitals also cuts down the required span length from 55' to 35' by utilizing the capital arms negative moment. Also, no filler girders are needed between capitals thus reducing the number of structural elements to an absolute minimum of columns, capitals and channels.

Forming

Column - Forming of the column is a relatively simple task if it is done in the factory and in four basic pieces as described before. It would probably be more efficient if cast as a tube, consequently slip forming would be necessary in the factory. The corners of the column tube would therefore have to have considerable bevel so that the form could be pulled. The finish on the exterior, either smooth, retarded, or bush-hammer, could be handled quite easily.

Column Capitals - Column capitals would be cast on the site. This was decided due to the many connections that would have to be made casting it in pieces. The one great advantage of this casting over other usually problematical on site castings is that virtually none of the capital is exposed to view. It is an almost strictly internal structural element. Therefore, other than basic dimensional and tolerance considerations little attention has to be paid to the finish of the piece. Great attention should be paid to the formwork however and considerable care must be taken to have enough small, removable steel or wood-plastic-faced pieces so as not to chip or crack the capital in removing the formwork. Also consideration should be given to stabilization of the capital during erection and casting proximity to crane boom location.
Channel - The channel, being 55' long and 10' wide with cast cross diaphragms a maximum of 12 per channel, is not an easy operation even in an up to date casting factory; but the advantage gained, as outlined, is worth the extra care necessary in making formwork for this element. A series of steel pans would be set into an earth or sand form in the raised floor table level, leaving the diaphragm voids exposed. A small vibrator would be placed under each pan in the earth form and controlled from the outside. Then the mechanical diffuser boots that are cast in the diaphragms would be added. Only after all pieces are stabilized are the unitized, reinforced canted side pieces added. The element is then poured and vibrated and the top added for leveling and finishing purposes. After removing the the earth form from under the pans used for forming, the pans can be removed. This is done to a dimension of two pans or 10 feet at each end. Then two truck cabs with adjustable bed heights can be located under each end of the channel. The element is secured to the truck beds and the remainder of the earth form is removed. One channel element is now loaded for delivery. By varying the floor table height that the forms are set on, approximately 2'-4" in height for each table and by loading the trucks perpendicular to the long axis of the channel, three to four units can be easily stacked, one under the other, on a stratified swivel truck bed. Approximately four to five trips per day could be made to the site, delivering 15 to 20 channel elements, provided the site was within reasonable distance, and the plant forming set ups during the delivery time were on schedule. Upon delivery the crane would lift the elements into place without having to re-position its base due to the mobility of truck delivery within ideal boom distance.
between the girder pairs of the column capital. These supply ducts then feed sub-supply ducts which enter the bay at 10 foot intervals. The 10 foot interval corresponds to the width of every channel of the structural system and the ducts (supply and return) are located in the space of the sloping or canted sides of the channel. The electrical is in the floor runner channels and channel diaphragms. The plumbing and water supply is located at 10 foot intervals, 10 feet from the edge of the column cluster, forming a 25 foot wide continuous plumbing sector or raceway every 60 feet with access at every channel. Due to the frequent occurrence of vertical shafts, the length of the horizontal supply runs are reduced. The efficiency of organization promotes maximum flexibility by minimal means.

While all air supply is carried within the ceiling of a space, the other services must be reached from the floor. This is facilitated by regular openings in the channel filler spaces and floor raceway access panels.

The diaphragm located in the channels performs many functions:
1) It serves as an acoustic baffle between rooms.
2) It contains the fluorescent light ballast and also wiring for convenience outlets since a partition can be located under every diaphragm.
3) It contains the reheat coil module for maximum space temperature control and also may contain a thermostat control outlet for individual space or grouped sector control.
4) It contains a boot plug in receiver for activation of a supply and a return diffuser.
5) It also serves to stabilize the 10 wide, 55 long, 2½ thick, typical channel during erection.
MECHANICAL SYSTEM

The mechanical system consists of a single duct system with an attenuator in each column cluster, that reduces the velocity of the 5000 CFM air in the main branch ducts to 1200 CFM in branch feeder ducts and sub-feeder ducts. The air is then diffused to the various sized spaces by means of a boot shaped tube coming from the sub branch. This tube is cast into the diaphragm which are located at a minimum distance of 5' apart for maximum temperature control and any can be left out on any interval of 5' depending on the planning circumstance. At the end of the diaphragm boot a room control diffuser is located. Also within the diaphragm are located electrical services, but that will be covered in more detail later. The return air system is reverse of the air supply system and interlocks between it (see page 3) so that there is supply air return control every 10' in one direction and every 5' in the other direction, which is also the building module and the smallest programmed space.

All the air handling equipment is housed in the two story mechanical "bridge", located in the upper floors of the building. This equipment carries fresh air from the intake heads at the perimeter of the structure. Used air is exhausted at high velocity directly above the machines. Each unit services one structural bay through the entire height of the structure. Decentralization of these units allows great flexibility and economy. Peak loads may be accommodated at specific points within the building without requiring total output of the system by the use of small reheat coils located in problem areas. Major air supply arteries feed directly from these machines down into the structure within the column clusters. This artery or main branch is "tapped" at each floor by horizontal supply ducts traveling
SPACE FOR THE PERIMETER MECHANICAL SYSTEM TO PASS THROUGH. THE LAST UNIT COMBINES WITH THE SILL TO FORM THE WINDOW UNIT. THIS ELEMENT IS COMPLETE WITH WINDOW GASKET REVEAL AND IMBEDDED ANCHORING ANGLE FOR WELDING THE UNIT TO THE FLOOR. ALL THESE ELEMENTS ARE NON-STRUCTURAL AND THE HEAVY TACTILE QUALITY OF THEIR EXTERIOR SURFACE WOULD INDICATE DIFFERENTIATION BETWEEN THE TWO, THE STRUCTURAL ELEMENTS HAVING A COMPARATIVELY SMOOTH SURFACE.

INTERIOR PARTITIONING

ALL INTERIOR PARTITION IS EIGHT FEET IN HEIGHT, WITH GLASS ABOVE TO THE 10 FOOT CEILING HEIGHT. THIS ENABLES CEILINGS IN SMALL SPACES (10x10 OR SO) TO HAVE LOUVERS OR THE LIKE AT THE 8 FOOT CEILING LEVEL GIVING THE ROOM A BETTER PROPORTION. ALL DOORS WOULD BE 7 FEET IN HEIGHT. BOTH DOORS AND WALL FILLER PARTITION PANELS TIE INTO A ONE FOOT DEEP BAND THAT WOULD BE A STEEL, WOOD-CLAD, MEMBER THAT WOULD ALSO RECEIVE THE GLASS ABOVE. BOTH THE AREA BETWEEN THE CHANNEL AND THE NON-ACTIVATED DIAPHRAM IS ADAPTED TO RECEIVE THE GLASS. THE CRITERION FOR THE 8 FOOT PARTITION HEIGHT RESTS ON THE DESIRE TO ATTAIN VISUAL CONTINUITY OF THE STRUCTURAL SYSTEM BY THE USE OF THE 2 FOOT GLAZED PANEL OR UNIT ABOVE THE PARTITION. THIS SYSTEM ALSO OFFERS MAXIMUM FLEXIBILITY FOR SELECTION OF MATERIAL TYPES OF THE WALL FILLER PANELS.

ACOUSTIC

TECTUM TREATMENT IS USED ON THE TOP OF THE PAN FORMS IN THE ELEMENTS. THE DIAPHRAMS BLOCK SOUND FROM ROOM TO ROOM. CARPETING THROUGHOUT ALL AREAS POSSIBLE AND PRACTICAL. TECTUM PANELS ARE ALSO THE FLOOR AND CEILING ON THE GIRDER AREAS. THIS NOT ONLY SOFTENS AMBIENT NOISE BUT MECHANICAL AS WELL. SPECIAL ACOUSTIC TREATMENT SHOULD BE LOCATED AROUND
ERECTION AND CONSTRUCTION SEQUENCE

One of the prime considerations in erection is the positioning and efficient use of the crane. In this case a rolling crane is used of 32 ton maximum load lifting capacity which could efficiently lift to a five story height about 15 tons, the maximum height of the building.

Structural elements are designed so that they coincide with the efficient use of the crane. The cranes are located on opposite sides of a 60 bay, approximately 100 feet apart due to the cantilever conditions. The crane procedure is as follows:

1) Column cluster - weight 6 ton approx.; lift in place by a single crane.
2) Column Capital - weight 10 ton approx.; lift in place by a single crane.
3) Large channel units - weight 15 ton approx.; lift by 2 cranes simultaneously at either end of the 55 unit. 5 to 15, 20 cantilever channel units can be lifted by a single crane.
4) All other elements with the exception of machinery and assembly column cluster services are man size units to be handled by construction personnel.

For construction sequence see page 10.

EXTERIOR WALL ELEMENTS

The exterior wall elements are made of precast concrete poured around a core of rigid insulation. This acts to lighten the weight of the individual members, while still retaining the desired dimensions for visual considerations. There are four basic exterior wall elements. One combines to form the solid wall elements, another forms the parapet edge which is 3'-0" in height. Another similar unit forms the window sill unit base allowing
ATTENUATOR AND MECHANICAL MACHINERY. Special attention also should be paid to sound leaks as at door under cuts, borrowed light, glass to glass detailing, gasketing, etc. Acoustical control is far easier within the one way structure. Sound transmission, therefore, is possible only in one direction.

LIGHTING

The lighting elements would be exposed fluorescent tubes with the ballast and electric lighting wiring located in the diaphragm. Varying foot candle intensity can be incorporated depending on the task performed in that module sector. An example of one luminaire sector system would be 4-40 watt lamps producing 66 foot candles which is reasonably efficient and gives even light distribution in most spaces. These would occur approximately every 7 feet on center. Also various reflector and louvering devices may be incorporated easily where needed to efficiently light special tasks. (See page 9.) This system has ease of maintenance and maximum flexibility.

IN CONCLUSION, THIS SYSTEM SEEMS TO ANSWER THESE FOUR BASIC BUILDING PROBLEMS:

1) A STRUCTURAL SYSTEM OF ELEMENTAL SIMPLICITY, DICTATED BY THE DEMANDS OF PRECAST AND PRESTRESSED CONCRETE.

2) THE SYSTEMATIZATION AND INTEGRATION OF STRUCTURE AND MECHANICAL SERVICES.

3) A STRUCTURE CAPABLE OF UNLIMITED EXPANSION.

4) A SYSTEM OF SPACES PROVIDING HORIZONTAL AND VERTICAL FLEXIBILITY.
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R. MICHAEL SCHNEIDER
M.I.T.
PLAN OF SERVICES

MASTER OF ARCHITECTURE
JUNE 1965-1966
AN INTEGRATED BUILDING SYSTEM
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CONSTRUCTION SEQUENCE

1) PREPARE SITE; POUR FOOTINGS AND SET COLUMNS.*
2) PLACE COLUMN CAPITALS (COMPLETE THIS SEQUENCE FOR EACH FLOOR).
3) SET NEXT COLUMN, GROUT AND WELD CONNECTIONS.*
4) SET MAIN FLOOR UNITS AND ANCHORS. (REPEAT SEQUENCE UNTIL ALL STRUCTURE IS COMPLETED.)
5) INSTALL ALL DUCT WORK, ELECTRIC BOXES AND RUNNER CHANNELS.
6) INSTALL TECTUM GIRDER FLOOR PANELS AND CEILING PANELS.
7) ADD EDGE CONDITION UNITS.
8) COMPLETE EXTERIOR SKIN. (REPEAT SEQUENCE.)

* REMEMBER TO SET COLUMN STABILIZERS WHILE ERECTING COLUMN COMPONENTS.
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M. I. T.
AN INTEGRATED BUILDING SYSTEM

BUILDING SECTION THRU 60 FT BAY DIRECTION

MASTER OF ARCHITECTURE
JUNE 1965-1966

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