PAN SLAB CONSTRUCTION FOR

INTEGRATED MECHANICAL SYSTEMS

Submitted in partial fulfillment of the requirements

for the degree of Master in Architecture

at the

Massachusetts Institute of Technology

Rainer F. Schildknecht

Diplomingenieur
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Professor Eduardo F. Catalano
Department of Architecture
Massachusetts Institute of Technology

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M. I. T. Graduate House
Cambridge, Massachusetts
August 1966

Lawrence B. Anderson, Dean
School of Architecture and Planning
Massachusetts Institute of Technology

Dear Dean Anderson:

In partial fulfillment of the requirements for the
degree of Master in Architecture, I hereby submit this
thesis entitled "Pan Slab Construction for Integrated
Mechanical Systems."

Respectfully,

Rainer F. Schildknecht

A C K N O W L E D G M E N T S

THESIS SUPERVISOR

Eduardo F. Catalano

STRUCTURES

Waclaw Zalewsky

MECHANICAL

Sidney Greenleaf

T A B L E   O F   C O N T E N T S

I. INTRODUCTION

The following thesis relates to multistory buildings two
to eight stories high and to building types such as
buildings for educational facilities and large admini-
stration buildings.

The large institutions of our mass society need buildings
which are able to serve an increasingly large number of
people. There is a need for spaces with different pro-
perties used for different activities. There is a need
to change room sizes and to change the acoustical, mechani-
cal and visual properties of spaces within the building.

The question arises, what are the unchanging elements of
a building which have to be integrated in any part of the
building. Unchanging are the structural elements of a
building and the presence of spaces for services such as
air-conditioning, piping and electrical supply, the spaces
for circulation, such as stairs and elevators, and spaces
for unchanging needs, such as toilets.

I I.   A I M   O F   T H E   T H E S I S

The aim of the thesis was the design of the architec-
turally most important unchanging elements for buildings
as described in the introduction, the design of the
structural system and the system of supply and return
ducts for air-conditioning, and the design of a pipe
system for sinks.

At the early stage of the investigation a decision was
made to use a two-way structural system, which means that
the supports of the floor structure are equidistant from
each other in two directions and girders spanning from
each support to the next four supports.

A two-way structural system offers a greater flexibility
in the location of large spaces, which can extend free
of supports in two directions.

It was thought of using precast concrete elements for the
two-way floor construction. However, as it is possible
to transport structural pieces of large sizes only when
they are small in one dimension, the precast members for
two-way construction would either be small and long
elements -- which is against the principle of two-way
construction -- or the precast members would be small
square-shaped elements, which would mean that a very
large number of elements would have to be jointed to-
gether. Since all the joints would have to transmit struc-
tural forces, such a method of construction seems to need
extreme exactness, which is hardly feasible for a widely

usable standard construction.

These considerations led to the choice of a cast-in-place structure.

III. THE STRUCTURAL SYSTEM

A. Principles of concrete floor construction.

The common concrete floor constructions follow the principle of the reduction of dead load by avoiding unnecessary masses of concrete. A flat slab is a common concrete floor construction for spans up to a 24 foot square bay. The structural depth is not more than 10 inches.

A greater span would make a greater structural depth necessary. A flat slab would become unnecessarily heavy. A reduction of the amount of concrete in the tension zone makes the structure more efficient. The result is a pan slab.

The main advantage of concrete, when it is cast in place, is the lack of joints and their tolerances. No welding of joints, grouting or topping is necessary. The structure has continuity in all directions. Neither the continuity of the floor nor the continuity of the columns is interrupted.

An efficient floor construction has continuity between the beams and the floor slab, so that the floor slab at the top of the structure takes the compression. The tension zone has to have a certain distance from the compression zone to give the structure rigidity. Tension and compression zone have to be connected by diagonal steel reinforcement to take the shear forces.

B. Pan slab with perforated joists

The considerations about the principles of concrete floor
construction led me to the structure of this thesis, a
pan slab with perforated joists.

It is logical to reduce the dead load by perforating the
joists when the structure exceeds the depth of about 20
inches.

The bay size is 45 by 45 feet. The structural depth is
30 inches.

Theoretically this structural depth would be enough to
span 60 by 60 feet. In any air-conditioned building, the
overall depth ceiling-floor results from the structural
depth plus the space for the mechanical installations.

The minimum structural depth would be 24 inches. The
minimum space needed for ducts and pipes is 18 inches
in this mechanical system. The minimum space needed for
lighting and diffusers is 6 inches.

24 plus 18 plus 6 inches equals 48 inches or 4 feet over-
all floor depth. The pan slab system with perforated
joists and integrated mechanical system has a depth of
30 inches or $2\frac{1}{2}$ feet, which is $1\frac{1}{2}$ feet less. 8 times $1\frac{1}{2}$
feet is the height of one story. That means that a 9 story
high building using the system of this thesis has the same
volume as a conventional 8 story high building.

C.   The structure and the module

The joists which connect the columns need 5 times more
steel than the joists in between. When the ceiling is
flush, the main joists, of which there are only four on
each bay, have to be broader in dimension or the joists
in between, of which there are 14, are oversized.

A structural module of 5 feet was chosen according to
small room sizes. It was decided to use the same pan
size all over. This allows the use of only one size of
ceiling element, which contains acoustical material,
lighting fixture and diffuser.

Wherever the partitions cross the main joists there have
to be "between elements" in the partitions or different
panel sizes.

The decision to use the same pan size all over was made
since it was not possible to have a smaller space between
the joists in the area where the attenuators are located
and the horizontal pipes come together.

IV. THE AIR CONDITIONING SYSTEM

A. Velocity

The air-conditioning system is a single duct system. The velocity is 4000 feet per minute in the vertical supply and return ducts. After going through an attenuator, the air runs with a velocity of 1200 feet per minute in horizontal ducts. The high velocity in the vertical ducts reduces their size considerably.

B. Control

Every half bay, an area of 1013 square feet, can be controlled individually. An attenuator with constant volume control regulates the volume before it goes to the diffusers. The attenuators are located in the first ceiling modules around the support.

C. Horizontal ductwork

Generally, supply or return is on alternate modules. Since the joists are perforated in two directions, the system allows the installation of diffusers for supply and return registers on every module. Although not often needed, this is an advantage when small rooms have to be equipped with a proper number of diffusers and return registers. Any crossing of ducts is avoided, which means that the floor depth is dimensioned to the general case and not to accidental crossings of ducts.

D. The perimeter zone

The perimeter zone of a building is next to the glass
walls induction units, which are served by the same air
supply system plus hot and cold water supply.

E. Calculation of the duct sizes

Vertical ducts: velocity 4000 feet per minute. One duct
serves one half bay on each story.
bay size 45' square
room height 10'
6 air changes per hour
$$\frac{1}{2} \times \frac{45 \times 45 \times 10 \times 6}{60} = 1008 \text{ cf/m}$$
5 stories
5 x 1008 cf/m = 5040 cf/m
The resulting duct size taken from the 'Trane' ductulator
is 11" x 18" or 15" x 15".

Horizontal ducts: velocity 1200 feet per minute.
Maximum area served: ½ bay
Needed: 1008 cf/m
The resulting duct size taken from the 'Trane' ductulator
is 12" diameter for a round duct.

V. P I P E   S Y S T E M S

Between ducts and floor slab remains a space of 7",
which allows the horizontal passage of pipes for sinks -
drain, vent, warm water, cold water.

The installation of sinks and lavatories is possible in
any location of the bay. The pipes run horizontally in
the structure and are fitted to the vertical pipes in
the supports.

VI. CASTING OF MODEL

The photographs at the end of the report show a model which was casted in the scale: 1 inch equals 1 foot.

The first step was to build the formwork. PVC - Pans were vacuum-formed over a steel dime. Some of the photographs show this process. The steel dime is standing on a "table." Above the "table" a flat PVC sheet is clamped between two metal frames. The PVC is heated by a heating plate above. When the PVC has a certain softness, the table is moved up against the PVC and the air is sucked out between the table and the PVC. The atmospheric pressure forms the PVC around the dime.

The finished pans were glued on a large PVC sheet and Poliyurethane pieces were laid between the pans for getting the perforations in the joists. Then the model was cast with Hydrocol. After 6 hours of drying the formwork was removed.
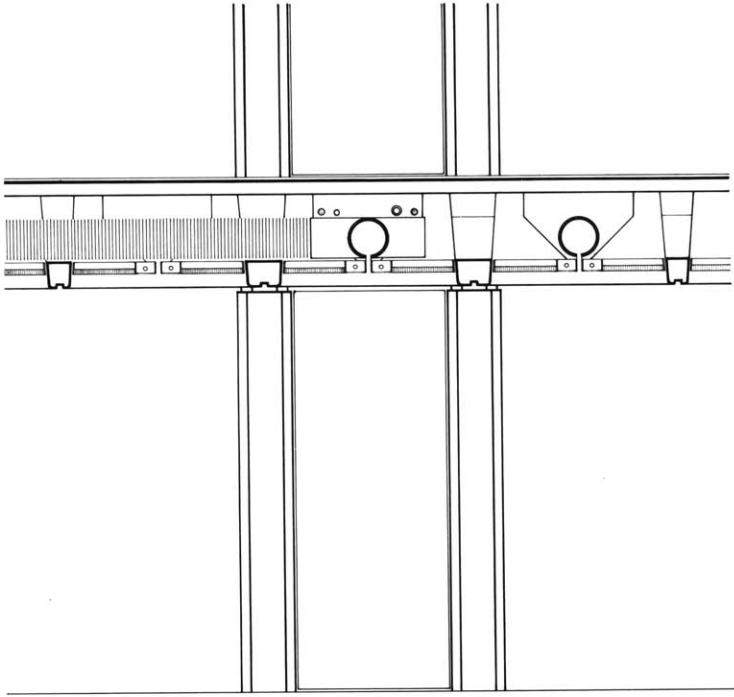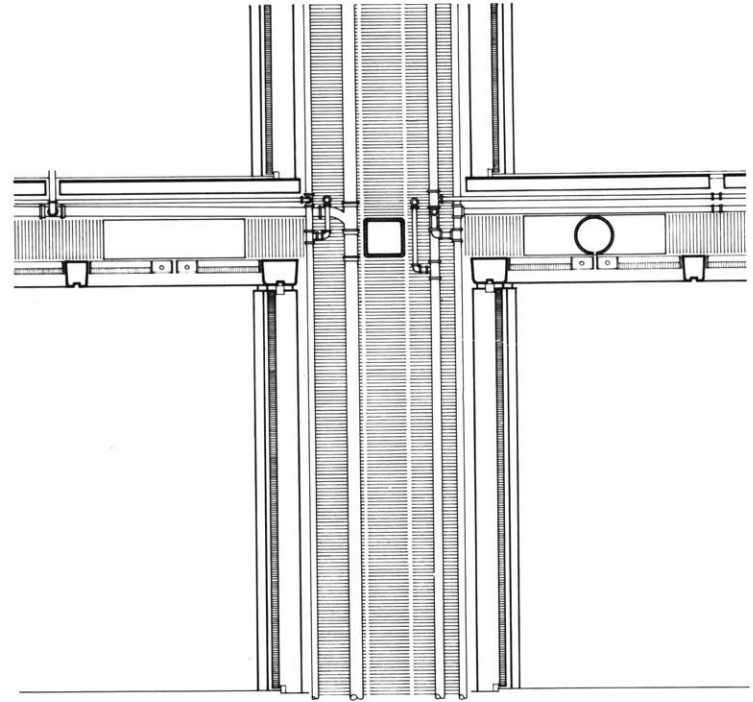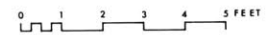
COLUMNS
GIRDER
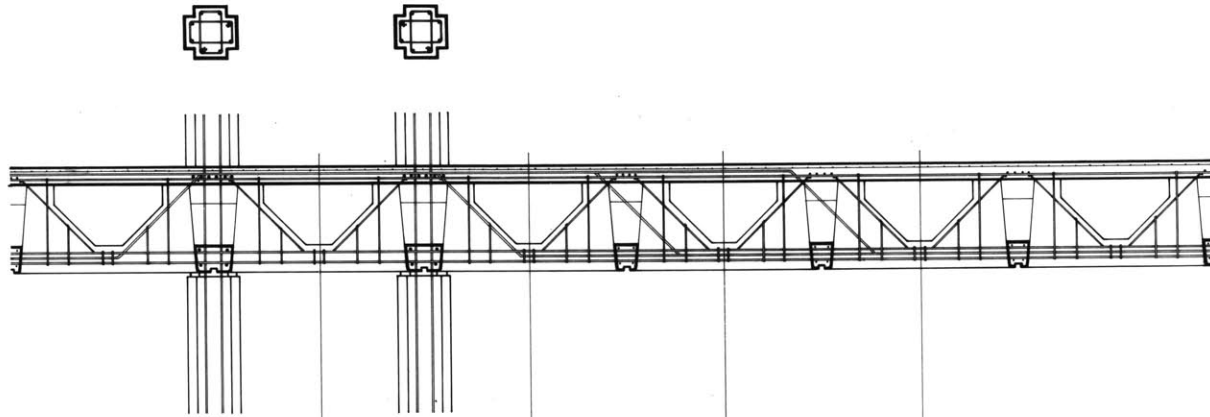
BEAM
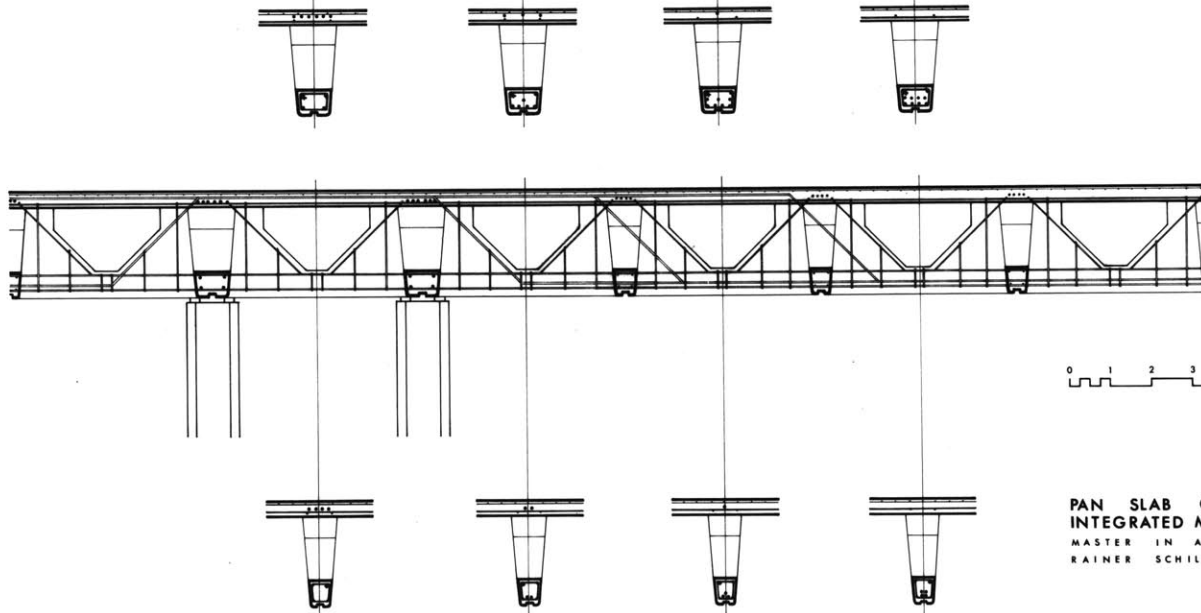
0 1 2 3 4 5 FEET

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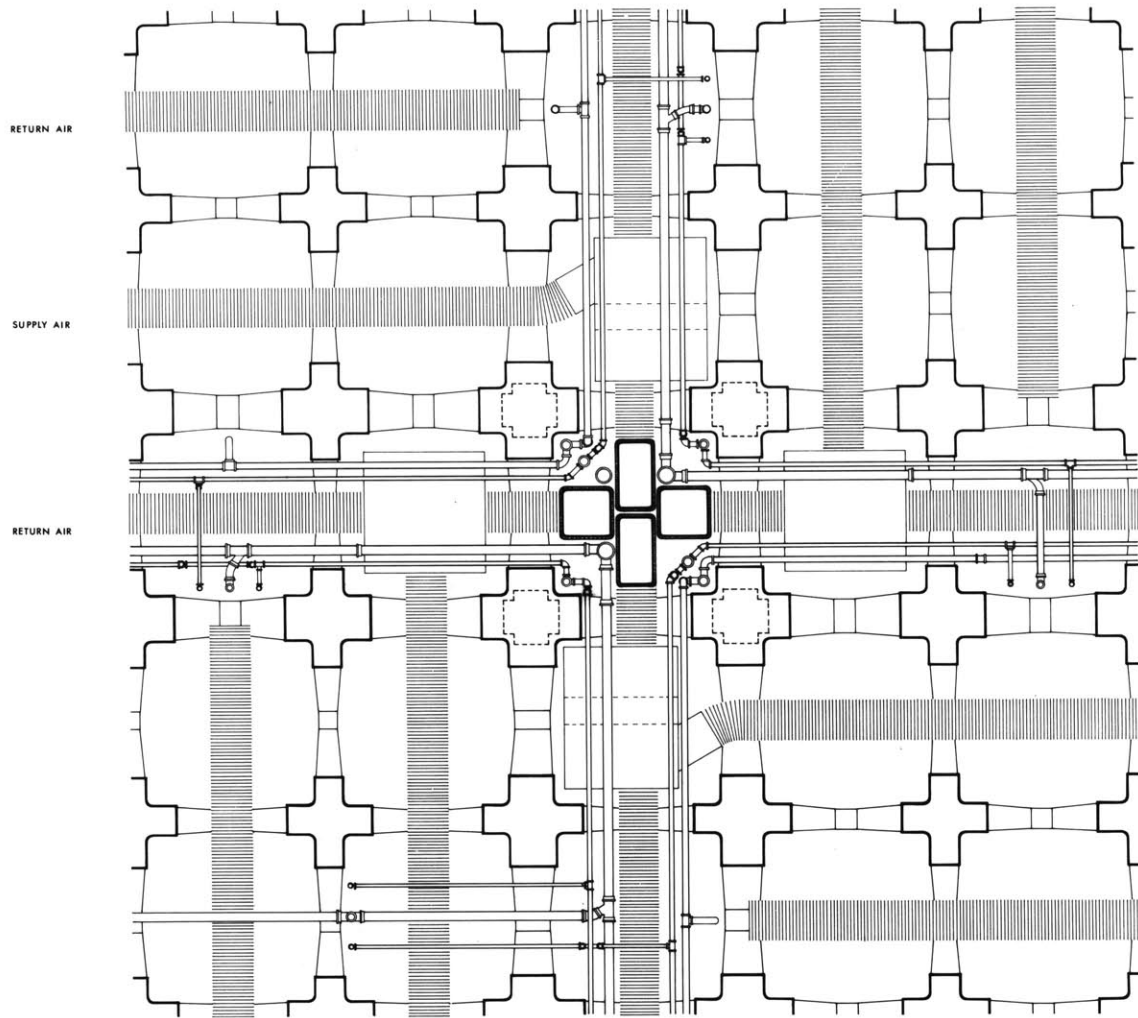RAINER SCHILDKNECHT M.I.T. 1966

ELEVATION OF COLUMN, SECTION OF SLAB
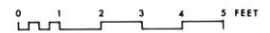
SECTION OF COLUMN

0   1   2   3   4   5 FEET

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RETURN AIR

SUPPLY AIR

RETURN AIR

HORIZONTAL SECTION OF SLAB AND INTEGRATED
MECHANICAL SYSTEMS

0 1 2 3 4 5 FEET

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