

I TITLE

INTEGRATED BUILDING SYSTEMS DESIGN

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SUBMITTED IN PARTIAL FULFILLMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF  
MASTER IN ARCHITECTURE AT THE  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,  
CAMBRIDGE, MASSACHUSETTS, 1 AUGUST 1966.

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II SUBMISSION LETTER

CAMBRIDGE 39, MASSACHUSETTS  
1 AUGUST, 1966

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DEAR DEAN ANDERSON:

IN PARTIAL FULFILLMENT OF THE REQUIRE-  
MENTS FOR THE DEGREE OF MASTER OF ARCH-  
ITECTURE, I HEREBY SUBMIT THIS THESIS  
ENTITLED "INTEGRATED BUILDING SYSTEMS  
DESIGN."

RESPECTFULLY,

MICHAEL FRANCIS GEBHART

III ABSTRACT

INTEGRATED BUILDING SYSTEMS DESIGN

MICHAEL FRANCIS GEBHART

SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF MASTER OF  
ARCHITECTURE, 1 AUGUST, 1966

IT IS MY BELIEF THAT THE MODERN ARCHITECT  
MUST BECOME MORE AWARE OF THE TECHNOLOGI-  
CAL ASPECTS OF ARCHITECTURE.

WITH THE RAPID TECHNOLOGICAL CHANGE OCCUR-  
ING ALL OVER THE WORLD, IT SEEMS IMPORTANT  
FOR THE ARCHITECT TO PREPARE HIMSELF IN  
ORDER TO MAKE MORE INFORMED DECISIONS IN HIS  
WORK AND ALSO TO PUT TO USE THE ALMOST UN-  
LIMITED POSSIBILITIES TECHNOLOGY HAS TO OFFER.

THIS UNDERSTANDING, ALONG WITH AN AWARENESS  
OF SOCIAL VALUES, CONTROLLED BY ARTISTIC  
VALUES AND SKILLS, CAN RAISE THE LEVEL OF  
ARCHITECTURE TO A REAL EXPRESSION OF OUR  
MODERN WORLD.

THIS STUDY, CONSIDERED AS ONLY A STAGE IN A  
CONTINUOUS PROCESS, ATTEMPTS TO DEVELOP AN

INTEGRATED SYSTEM OF BUILDING CONSTRUCTION  
WHICH ALLOWS FOR ALL OF THE SYSTEMS IN A  
BUILDING TO WORK HARMONIOUSLY WITHIN THE SYSTEM  
SO THAT CHANGE CAN OCCUR IN ONE SYSTEM WITHOUT  
AFFECTING THE OTHERS.

THE PROPOSAL, UNCONDITIONED BY FORM GIVING  
ASPECTS SUCH AS SITE, CLIENT, OR PROGRAM,  
ATTEMPTS TO EMPHASIZE THE GENERAL ASPECTS OF  
SYSTEMATIZATION BASED ON ENGINEERING PRINCIPLES  
CONDITIONED WITH AN ARCHITECTURAL EYE.



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## VII INTRODUCTION

THE MASTER'S THESIS PERMITS A FOCUSING OF ATTENTION ON THE PRESSING PROBLEMS OF BUILDING CONSTRUCTION FREED FROM THE RESTRICTIONS OF THE UNIQUE REQUIREMENTS OF CLIENT, PROGRAM AND SITE. WHILE THE DISCOVERIES AND PROPOSALS MADE IN A GENERALIZED INVESTIGATION OF THIS NATURE MAY NEVER BE REALIZED AS A WHOLE, THEY MAY HAVE A SIGNIFICANCE FOR THE ENTIRE FIELD OF ARCHITECTURE BY INDICATING SOLUTIONS WHICH ARE CAPABLE OF ADAPTIBILITY ON THE BROADEST SCALE. IN ADDITION THEY MAY POSSESS THE POTENTIALITY FOR FUTURE DEVELOPMENT AND REFINEMENT.

THE INCREASED NEED FOR UNUSUAL FLEXIBILITY DEMANDS THAT BUILDINGS OF MANY TYPES BE CONCEIVED IN TERMS OF LONG RANGE ADAPTABILITY TO NEW FUNCTIONS AND ENVIRONMENTS. THIS IS ESPECIALLY TRUE IN THE CASE OF BUILDINGS CONSTRUCTED OF SUCH PERMANENT MATERIALS AS MASONRY AND REINFORCED CONCRETE, WHICH CAN HAVE A LONG LIFE AND ARE EXPENSIVE TO BUILD AND DEMOLISH.

THE CRITICAL FACTOR IN A BUILDING'S ABILITY TO ADAPT TO NEW FUNCTIONS IS FREQUENTLY THE POSSIBILITY OF FURNISHING THE NECESSARY MECHANICAL SERVICES



INCLUDING HEATING AND AIR CONDITIONING, ELECTRICAL AND SANITARY SYSTEMS. THE PROVISION OF A SYSTEM OF A FLOOR CONSTRUCTION WHICH PERMITS GREAT FLEXIBILITY IN THE ACCOMMODATION AND ALTERATION OF MECHANICAL SERVICES WOULD ESSENTIALLY INCREASE THE LONG RANGE USEFULNESS OF BUILDINGS.

THE DEVELOPMENT OF A PROTOTYPE STRUCTURAL SYSTEM WITH THE POTENTIALITY OF WIDESPREAD APPLICATION DEPENDS ON EMPHASIZING ASPECTS OF SYSTEMIZATION WHILE MINIMIZING SPECIFIC DIMENSIONS, SPANS AND CLEARANCES WHICH COULD BE ADAPTED TO SPECIFIC PROBLEMS. IN ADDITION, SYSTEMATIZATION OF SUCH A STRUCTURE IS ESSENTIAL TO TAKE ADVANTAGE OF THE MOST ADVANCED METHODS OF PRESENT DAY TECHNOLOGY.

THE ASSUMPTION OF CONCRETE AS THE PRINCIPLE BUILDING MATERIAL IS BASED UPON ITS GROWING UTILIZATION FOR BUILDINGS OF ALL KINDS AND THE SPECIAL NEED FOR GREAT FLEXIBILITY IN CONCRETE STRUCTURES.

CONCRETE LENDS ITSELF READILY TO MANY FACETS OF SYSTEMATIZATION. AS IT IS A PLASTIC MATERIAL WHICH IS GIVEN SHAPE BY ITS FORMS, REAL ECONOMY CAN BE ACHIEVED THROUGH THE USE OF REPETITIVE MODULAR UNITS MOLDED BY FORMS WHICH ARE RE-USED MANY TIMES.

SUCH AN OPERATION CAN BE EXECUTED MOST EFFICIENTLY UNDER FACTORY CONTROL. THROUGH PRECASTING, A HIGH DEGREE OF PRECISION CAN BE EFFECTED AND COSTLY SITE LABOR AND POOR WORKMANSHIP CAN BE REDUCED. THE ERECTION PROCEDURE CAN BE HIGHLY SYSTEMATIZED WITH LIFTING MACHINERY, CRANES, POST-TENSIONING AND OTHER TECHNOLOGICAL INNOVATIONS.

THE RESULTANT QUALITY OF A STRUCTURE SO CONCEIVED WILL BE ONE OF GEOMETRIC ORDER BASED NOT ON WHIM BUT ON THE LOGICAL PROCESS OF CONSTRUCTION.<sup>1</sup>

<sup>1</sup>MASTER'S THESIS, BURNS, KOLPRITZ, RUDQUIST, 1962, MIT

## VIII OBJECTIVES

## BUILDINGS AS SYSTEMS

### a) PROGRAM

TO DESIGN A FOOTPRINT OF STRUCTURAL, VERTICAL CIRCULATION AND MECHANICAL COMPONENTS FROM WHICH DIFFERENT SIZES OF BUILDINGS, WITH DIFFERENT SPATIAL QUALITIES AND CHARACTER CAN BE DEFINED.

THE SYSTEM TO BE CREATED CAN BE APPROACHED AS AN ORDERLY ORGANIZATION OF COMPONENTS TO ACHIEVE "A FINISHED PRODUCT" FOR EACH CASE, OR AS A SYSTEM OF GROWTH, FOR WHICH IT IS REQUIRED TO ESTABLISH THE GEOMETRICAL, STRUCTURAL AND MECHANICAL SELF-SUFFICIENCY OF EACH UNIT. IT IS ADVISABLE TO DESIGN A STRUCTURAL AND MECHANICAL SYSTEM WHERE THE VITAL COMPONENTS BECOME PERMANENT ELEMENTS OF THE SYSTEMS (COLUMNS, GIRDERS, MAIN MECHANICAL SERVICE BRANCHES) WHILE THE SECONDARY COMPONENTS CAN CHANGE OR BE REMOVED TO ACHIEVE FLEXIBILITY IN USE OR SPATIAL CHANGES, (BEAMS, JOISTS, SECONDARY MECHANICAL SERVICE BRANCHES), THUS BECOMING TEMPORARY ELEMENTS OF THE SYSTEM.

AN INITIAL STEP OF WORK COULD BE THE SIMULTANEOUS STUDY OF A TYPICAL STRUCTURAL AND MECHANICAL BAY, WITH SUCH BEHAVIOR AND GEOMETRY AS TO ALLOW SEVERAL ORGANIZATION PATTERNS TO FORM A SYSTEM OF GROWTH.

STUDY OF DIFFERENT ONE AND TWO WAY STRUCTURAL SYSTEMS IS NECESSARY SEE WHICH ONE OFFERS MORE FREEDOM IN THE RELATION BETWEEN THE STRUCTURAL AND MECHANICAL PERMANENT AND TEMPORARY ELEMENTS OF THE SYSTEM.

b) GROUP RESEARCH

STUDY OF USES OF COLUMNS FOR MECHANICAL SERVICES. DRAW SHOWING IN A SIMPLIFIED WAY THE CONNECTION BETWEEN SLABS, BEAMS, AND COLUMNS AND HOW THE DUCT WORK AND PIPES ARE DISTRIBUTED IN VERTICAL AND HORIZONTAL RUNS. SEE THESIS REPORTS, AVAILABLE IN MY OFFICE, OF FOLLOWING STUDENTS: WITCOMB, HOOK, SOETRISNO, HUBER, HOSKINS, HOOVER, BONAR, BRUNON, VITOLS, HERSHDORFER, TORSUWAN.

DRAW COLUMNS, IN PLAN AND ELEVATION, SLABS, AND PLAN OF COMPLETE DUCT WORK (SUPPLY AND RETURN) WITHIN A BAY.

SAME FOR SHAFTS IN CORES, USED FOR MECHANICAL SERVICES.

SAME FOR CORES USED IN MECHANICAL ROOMS: FRAZER, PREISS.

DRAW IN SHEETS 8-1/2 x 11 BASIC CONSTRUCTION SYSTEMS OF THE FOLLOWING THESIS REPORTS: BURNS, KULPRITZ, RUDQUIST, VITOLS, TORSUWAN, BRUNON, FRAZER, HERSHDORFER, HOOK, HOSKINS, SWANNEY, ZELLMER, DESCRIBING UNITS, PLAN, SECTION, ELEVATION, AND ERECTION PROCEDURE, PLUS CONNECTION OF UNITS TO COLUMNS---- SHAPE OF COLUMNS.

DRAW DIFFERENT POSTRESSING ANCHORAGE SYSTEMS AND HYDRAULIC JACKS, INDICATING MINIMUM DIMENSIONS AVAILABLE RELATED TO STRESSE. CONSULT: PRE-STRESS CONCRETE, BY T. C. LIN, AND PRESTRESS CONCRETE FOR ARCHITECTS AND ENGINEERS. DRAW CRANES, TYPES, REACH AND LOADING CAPACITY: MCGRAW HILL "CONSTRUCTION TECHNIQUES." SEE INFORMATION ON EUROPEAN CRANES.

STUDY OF MODULE DIMENSIONS CONSIDERING: USES OF ROOMS (ESPECIALLY THE VERY SMALL ONES); WIDTH OF MAIN AND SECONDARY HORIZONTAL CIRCULATION; STAIR OPENINGS (SINGLE AND DOUBLE FLIGHT); DIMENSIONS OF LIGHTING FIXTURES TAKEN IN CONSIDERATION A WIDTH OF RIBS NO LESS THAN 6"; WIDTH OF DOORS; RELATIONSHIP OF AREA -- NUMBER OF LIGHTING FIXTURES TO OBTAIN 60 FC AT WORKING LEVEL; STUDY OF LOCATION OF FIXTURES TO ACHIEVE EVEN ILLUMINATION PER ROOM

(ANY SIZE) IN AN ECONOMIC MANNER; LOCATION OF DIFFUSERS, AND RETURN GRILLS TO ACHIEVE FLEXIBILITY TO MOVE PARTITIONS WITHOUT REMOVING DIFFUSERS. COMBINATION OF LIGHTING FIXTURES AND DIFFUSERS. IN ALL CASES, FLUORESCENT LIGHTING SHOULD BE CONSIDERED ALTHOUGH THERE ARE 2, 3, 4 and 8 FEET TUBES, THE LARGER THE TUBE IS THE MORE ECONOMICAL AND FEASIBLE THE SYSTEM BECOMES. MODULES COULD BE SQUARE, RECTANGULAR OR COMBINED, FOR TWO OR ONE WAY CONSTRUCTION.

DRAW PLAN AND SECTION OF 4 PASSENGER ELEVATORS 5X7, INDICATING CAR DIMENSIONS, CLEARANCES, WIDTH OF DOORS, WALLS, PIT, OVERHEAD RUN AND MACHINE ROOM FOR 350 F/M, 500 F/M, 700 F/M. SAME FOR SERVICE ELEVATOR WITH FRONT AND FRONT AND BACK DOOR. CAR DIMENSIONS 6X8 - SPEED 250 F/M.

DRAW DIFFERENT WAYS TO BUILD SINGLE AND DOUBLE SET OF FIRE STAIRS, BASED ON MINIMUM WIDTH OF 66", FOR A MINIMUM HEIGHT (FLOOR TO FLOOR) OF 14 FEET, PAYING ATTENTION TO CONSTRUCTION AND COMFORT.

DRAW SHEET METAL WORK, INDICATING TRANSITION OF DUCT WORK FOR VARIABLE SECTIONS; CONNECTION OF VERTICAL AND HORIZONTAL DUCTS; CONNECTION OF

DUCTS AND DIFFUSERS - SYSTEMS OF DIFFUSERS  
AVAILABLE IN THE MARKET.

DRAW IN ACCEPTED STANDARD DIMENSIONS TOILETS  
WITH METAL PARTITIONS, LAVATORIES, URINALS,  
AND VERTICAL PLENUM NECESSARY FOR PLUMBING FOR  
EACH TYPE OF FIXTURE. DESIGN NOT LESS THAN 5  
SOLUTIONS OF WELL ARRANGED TOILET ROOMS FOR EACH  
SEX, WITH FIXTURES DISTRIBUTED IN SUCH A WAY AS  
TO ALLOW INCREASE OF NUMBER OF FIXTURES WITHOUT  
CHANGE IN DESIGN CONCEPT, AND PROVIDING PRIVACY  
FROM OUTSIDE VIEW. STUDY LOCATION OF ENTRANCE  
DOOR TO PROVIDE FLEXIBILITY IN THE USE OF ANY  
SOLUTION FOR A GIVEN CORE CONDITION. USE 5 FOOT  
MODULE INCREMENTS FOR EACH SOLUTION.

ALL DRAWINGS WILL BE DRAWN ON A TRANSLUCENT  
SHEET 8-1/2 X 11, IN PENCIL, WITH VERY STRONG  
LINES OR INK, AND WITH CLEAR LETTERING ABOUT  
1/8" HIGH. INDICATE SOURCE WHERE INFORMATION  
WAS OBTAINED. ALL DRAWINGS WILL BE DONE IN  
SCALE, AND EACH GROUP WILL KEEP SAME SCALE FOR  
COMPARISON AND CONTRAST OF DIMENSIONS.

- c) INDIVIDUAL RESEARCH
1. TO FORMULATE GENERAL OBJECTIVES
  2. MAKE MATERIAL ASSUMPTIONS

3. DO RESEARCH ON MECHANICAL SYSTEMS
4. DO RESEARCH ON STRUCTURAL SYSTEMS
5. DO RESEARCH ON CONSTRUCTION TECHNIQUES
6. TO STUDY GEOMETRICAL CHARACTERISTICS OF SYSTEM
7. ESTABLISH ERECTION PROCEDURES
8. REFINE AND MAKE A PROPOSAL



## IX DESIGN CRITERIA

A. VARIATIONS IN ADAPTABILITY      THERE IS A WIDE RANGE OF BUILDING TYPES INCLUDING OFFICE BUILDINGS, EDUCATIONAL STRUCTURES, RESEARCH LABORATORIES, STORAGE STRUCTURES AND COMMERCIAL STRUCTURES WHOSE FUNCTIONAL AND MECHANICAL DEMANDS ON THE SYSTEM ARE SUFFICIENTLY SIMILAR THAT IS IS RESPONSIBLE TO SEEK A SOLUTION FOR THEIR GENERAL REQUIREMENTS.

SUCH BUILDING TYPES GENERALLY REQUIRE STRUCTURES OF GENEROUS OVERALL DIMENSIONS AND LARGE BAY SIZES WHICH ARE DESIRABLE FOR GREATER FLEXIBILITY.

A SYSTEM OF ORDERLY GROWTH SHOULD BE POSSIBLE WITH AN INTEGRATED STRUCTURAL, MECHANICAL, AND CIRCULATION SYSTEM TO MEET THE FUTURE DEMANDS OF A BUILDING PROGRAM.

B. QUALITY OF SPACE      THE SPACE CREATED BY THE SYSTEM COMPONENTS SHOULD BE SUFFICIENTLY NEUTRAL TO PERMIT ACTIVITIES OF MANY TYPES WHICH ALLOW FOR SMALL AND LARGE SCALE HORIZONTAL AND VERTICAL SPACE POSSIBILITIES AS WELL AS INTERNAL AND EXTERNAL EXPANSION.

C. GEOMETRY      THE GEOMETRY OF THE SYSTEM SHOULD BE VERY SIMPLE TO ALLOW FOR PLANNING FLEXIBILITY AND EASE OF CONSTRUCTION AS WELL AS FREE VERTICAL AND HORIZONTAL

MOVEMENT OF MECHANICAL SERVICES.

D. STRUCTURE

THE STRUCTURAL SYSTEM SHOULD BE CONCERNED PRIMARILY WITH MODERN CONSTRUCTION TECHNIQUES, EFFICIENCY OF ITS COMPONENTS, EAST OF MECHANICAL SERVICES PASSING HORIZONTALLY AND VERTICALLY THROUGH IT, AS WELL AS ACOUSTIC CLOSURE. IT SHOULD ALLOW FOR AN ORDERLY AND SMALL SCALED PARTITIONING MODULE TO MEET THE VARIOUS PROGRAMMING DEMANDS.

E. CONSTRUCTION

ATTENTION SHOULD BE GIVEN TO ESTABLISHING AN EFFICIENT, ORDERLY SEQUENCE OF CONSTRUCTION, ECONOMY IN TERMS OF THE SCALE AND HANDLING OF ELEMENTS AND QUALITY CONTROL, AS WELL AS TRANSPORTATION OF ELEMENTS.

F. MECHANICAL EQUIPMENT

THE FLOOR SYSTEM SHOULD ALLOW FOR FREE MECHANICAL MOVEMENT FOR HEATING AND AIR CONDITIONG DUCTS, WATER AND SANITARY SYSTEMS, AND ELECTRICAL SERVICES.

G. ACOUSTICS

A VARIETY OF ACOUSTICAL PROBLEMS MUST BE SOLVED WITHIN THE CEILING SYSTEM IN TERMS OF CONTROL FOR SOUND ISOLATION, LOWERING SOUND INTENSITY LEVELS, REVERBERATION, AND OTHER CONDITIONS.

H. LIGHTING

THE SYSTEM SHOULD ALLOW FOR STANDARD LIGHTING UNITS TO BE SIMPLY INSTALLED ACCORDING TO LIGHTING REQUIREMENTS, AND NOT TO INTERFERE WITH MECHANICAL EQUIPMENT.

I. PLANNING AND CIRCULATION

THE SYSTEM MUST ALLOW FOR AN ORDERLY AND FLEXIBLE SYSTEM OF PARTITIONING BY INTEGRATING THE PLANNING GRID WITH THE STRUCTURAL GRID IN A MANNER WHICH WILL DEVELOP A DETAIL OF CONNECTION FOR A WIDE RANGE OF MATERIALS. IT MUST ALLOW FOR FLEXIBLE CIRCULATION PATTERNS FOR PEDESTRIANS AND MUST ALLOW FOR AUTO MOVEMENT AND STORAGE WITHIN THE STRUCTURAL "FOOTPRINT".

## X. PROPOSAL

A. VARIATIONS IN ADAPTABILITY    A ONE WAY STRUCTURAL SYSTEM WAS ADOPTED BECAUSE OF ITS EASE OF PRECAST CONCRETE CONSTRUCTION AND ITS INHERENT SPATIAL FLEXIBILITY.

THE ONE WAY SYSTEM ALLOWS FOR MORE PLANNING POSSIBILITIES IN TERMS OF REMOVING ELEMENTS OF MANY DIFFERENT DIMENSIONS TO CREATE A MULTITUDE OF DIFFERENT SPATIAL CONDITIONS AND EDGE CONDITION VARIATIONS WITHOUT TOO MUCH OF AN EFFECT ON THE STRUCTURAL ACTIONS OF THE SYSTEM.

B. QUALITY OF SPACE

THE SPACE CREATED BY THE PROPOSED SYSTEM IS SUFFICIENTLY NEUTRAL TO ALLOW FOR SMALL AND LARGE SIZED ACTIVITIES AS WELL AS TO PERMIT INTERNAL AND EXTERNAL CHANGE AND GROWTH.

C. GEOMETRY

THE GEOMETRY IS A RECTANGULAR GRID SYSTEM BASED ON A UNIT WHICH IS SELF SUFFICIENT IN TERMS OF STRUCTURE AND MECHANICAL SERVICING. INHERENT IN THE UNIT ARE THE FOLLOWING SELF-IMPOSED REQUIREMENTS FOR FLEXIBILITY:

- a) SMALL SCALED SELF SUFFICIENT UNIT-ADAPTABLE TO GROWTH IN TWO DIRECTIONS.
- b) LARGE AND SMALL SCALE OPENING POSSIBILITIES

- c) TWO WAY CANTILEVER POSSIBILITIES
- d) SMALL SCALED AIR DISTRIBUTION
- e) SUB-MODULE FOR PLANNING
- f) CONTAINED MAJOR CIRCULATION PATTERN

#### D. STRUCTURE

THE STRUCTURE WAS APPROACHED AS AN ENTIRELY PRECAST PRESTRESSED, FLUSH, SIMPLY SUPPORTED SYSTEM OF LARGE SCALE COMPONENTS WHICH WOULD HAVE MINIMUM CONSTRUCTION DEPTH DIMENSIONS, AND SMALLER SCALED ELEMENTS WHICH COULD BE COORDINATED WITH PLANNING AND MECHANICAL SERVICING REQUIREMENTS.

WITHIN THE ONE WAY SYSTEM, REASON TO ESTABLISH A "FIXED" AND A REMOVABLE SECTION EMERGED. THIS ALLOWS FOR INTERNAL FLEXIBILITY AND EXTERNAL GROWTH.

THE FIXED UNIT ALLOWS FOR A NUMBER OF STRUCTURALLY STABLE CONDITIONS WHICH DO NOT RELY ON SYMMETRY TO ACHIEVE RIGIDITY.

THE UNIT IS COMPOSED OF FOUR DOUBLE COLUMNS, FOUR PRINCIPLE DOUBLE GIRDERS OVER THE COLUMNS, TWO GIRDER INFILLERS, FOUR SECONDARY DOUBLE BEAMS SPANNING TRANSVERSELY AT THE 1/4 POINT OF THE GIRDERS' SPAN WHERE THE MOMENT IS ZERO AND ALLOWS

FOR AN OPENING IN THE GIRDER WHERE JUST A MINIMUM AMOUNT OF COMPRESSIVE CONCRETE IS REQUIRED.

DIAPHRAGM "LADDERS" SPAN TRANSVERSELY FROM THE SECONDARY BEAMS TO ASSIST IN GIVING LATERAL STABILITY TO THE STRUCTURE AS WELL AS TO ESTABLISH A CEILING MODULE FOR PLANNING.

PRECAST "TABLES" FORM THE SUBFLOOR, PROVIDE FORMING FOR THE POURED SLAB AND SEAL AND DEFINE THE FREE SPACE ABOUT THE DIAPHRAGM. " DAYS."

THE UNIT CAN GIVE A DOUBLE CANTILEVER SPAN OF 77<sup>8</sup> FEET, ALTHOUGH THE COLUMNS ARE SPACED 47<sup>8</sup> APART.

THE REMOVABLE INFILL UNITS ARE SIMPLY SUPPORTED BETWEEN THE FIXED UNITS.

COLUMNS  
A

THE COLUMN IS COMPOSED OF TWO PRECAST CONCRETE ELEMENTS WHICH SPAN FROM THE TOP OF THE GIRDER TO THE BOTTOM OF THE GIRDER ABOVE. IT HAS PRINCIPLE STEEL REINFORCING BARS WHICH ARE PLACED AFTER GIRDER IS IN PLACE AND WELDED TO PLATES ANCHORED IN THE COLUMN AND IN THE GIRDER TO TAKE THE TENSION IN THE COLUMNS. SEE JOINT 1 .

GIRDER  
B

THE GIRDERS ARE COMPOSED OF TWO PRECAST CONCRETE SECTIONS WITH DIAPHRAGM LUGS CAST INTERGRALLY. VERTICAL GROOVES WITH STEEL PLACES TO RECEIVE VERTICAL COLUMN STEEL ARE PREFORMED. THE NOTCH TO RECEIVE THE TRANSVERSE BEAMS AND THR GIRDER INFILL OCCURS AT THE 1/4 POINT OF THE SPAN.

SEE JOINT 2 .

GIRDER INFILL  
B<sup>1</sup>

THE GIRDER INFILL IS COMPOSED OF TWO PRECAST CONCRETE SECTIONS WITH DIAPHRAGM LUGS CAST INTEGRALLY. THE INFILL IS NOT REQUIRED STRUCTURALLY AS THE DIAPHRAGMS CAN OFFER LATERAL STABILITY, BUT IT IS USED FOR VISUAL CONTINUITY. SEE JOINT 2.

BEAM  
C

THE BEAM IS COMPOSED OF TWO PRECAST SECTIONS WITH DIAPHRAGM SUPPORTING LUGS INTEGRALLY CAST. THE NOTCHES IN THE BEAM ARE OVER THE 1/4 POINT OF THE GIRDER SPAN AND ALLOW FOR A FLUSH CEILING BECAUSE THE UPPER SURFACE REQUIRES ONLY FIREPROOFING OF STEEL WHICH IS RESISTING THE NEGATIVE BENDING OVER THE GIRDERS. MEMBERS IN THE PLANE OF THE BEAMS, ACROSS THE LOWER PORTION OF THE GIRDER RESIST COMPRESSIVE FORCES AT THIS POINT. SEE JOINT 2.

SLOTS ARE PREPARED ALONG THE BEAM TO ALLOW MECHANICAL EQUIPMENT TO PASS INTO THE FREE SPACE ABOVE THE DIAPHRAGM UNITS.

THE BEAMS ARE SIMPLY LOWERED INTO THE PREPARED NOTCH IN THE GIRDER AND GROUTED.

BEAM INFILL  
C<sup>1</sup>

THE BEAM INFILL IS COMPOSED OF TWO MEMBERS AND IS SIMILAR TO THE BEAM EXCEPT FOR THE REVERSE NOTCH AT THE END WHICH SIMPLY RESTS ON THE NOTCH IN THE BEAM. SEE JOINT 4 .

DIAPHRAGM  
D

THE DIAPHRAGM "LADDERS" ARE COMPOSED OF TWO MAJOR BEAMS WHICH SPAN BETWEEN THE SECONDARY BEAMS.

A STEEL PLATE IS ANCHORED TO THE LOWER SOFFIT OF THE NOTCHED PORTION OF THE DIAPHRAGM EDGE WHICH RESTS ON THE DIAPHRAGM LUGS ON THE BEAM. WELDING OCCURS WHEN PLACED. SEE JOINT 3 .

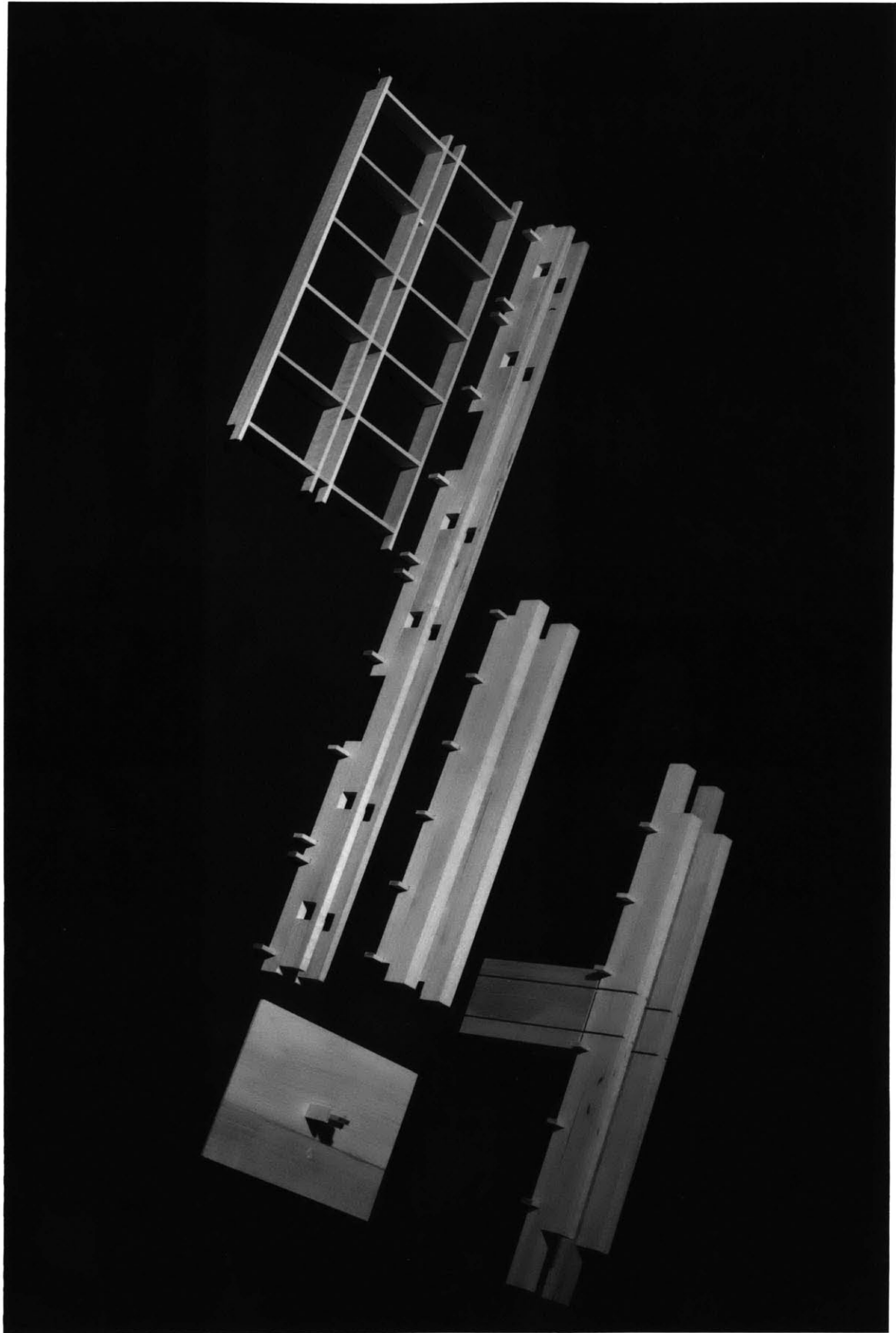
TRANSVERSE DIAPHRAGM CLOSURES ARE INTEGRALLY CAST TO MAKE UP THE UNIT.

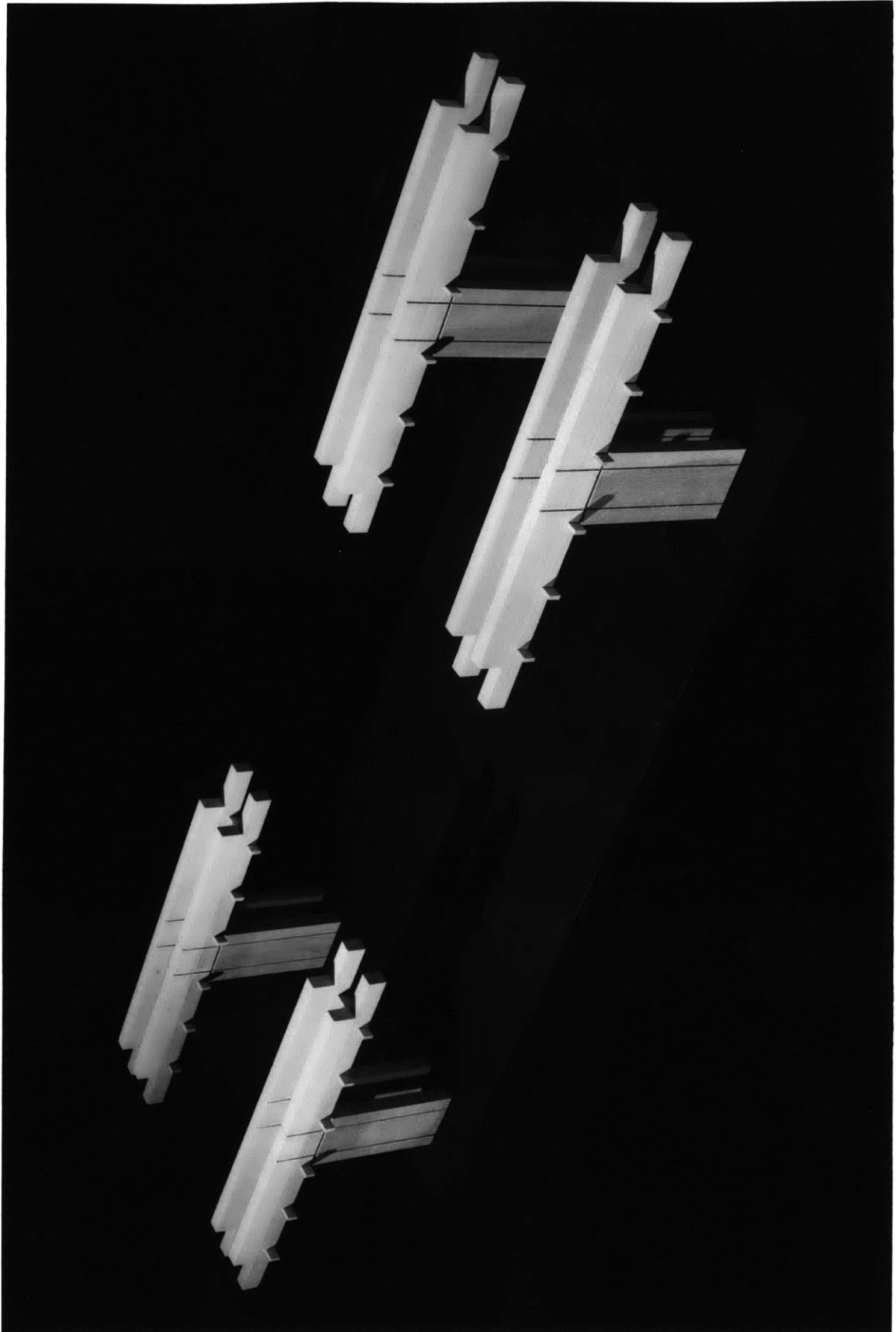
FLOOR  
E

THE FLOOR "TABLES" ARE COMPOSED OF A SINGLE PEDESTAL INTEGRALLY CAST WITH THE SLAB.

THE UNITS ARE LOWERED AND GROUTED INTO THE PREPARED POSITIONS BETWEEN THE DIAPHRAGM UNITS.



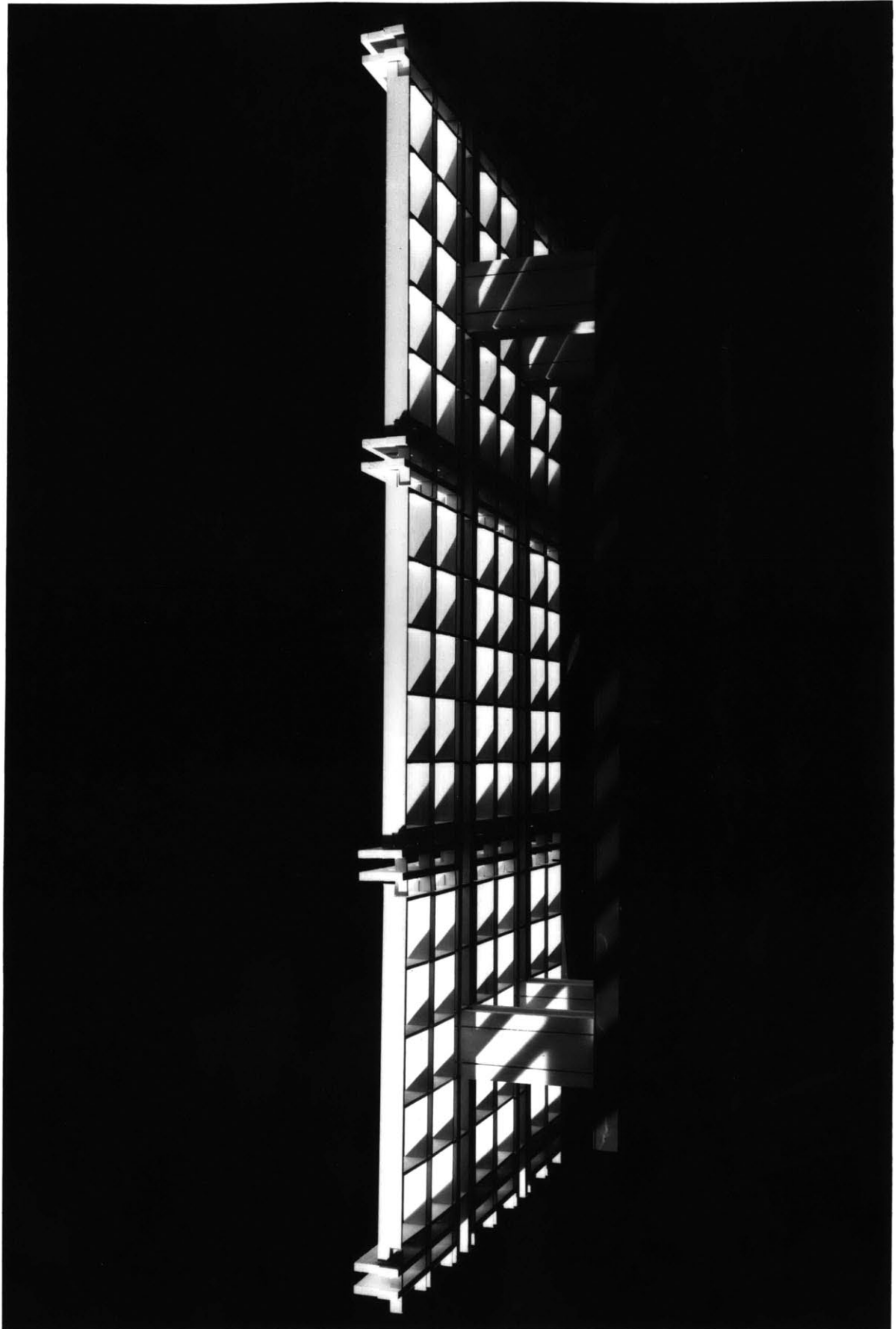












IN ALL MEMBERS REINFORCING STEEL EXTENDS THROUGH PRECAST MEMBERS TO PROVIDE A CONNECTION TO THE POURED IN PLACE SLAB TO COMPLETE THE STRUCTURE.

**E. CONSTRUCTION**

**a) GENERAL**

THE CONSTRUCTION USES PRESTRESSED PRECAST CONCRETE MEMBERS WHICH ARE PREPARED IN A PRECASTING PLANT UNDER IDEAL QUALITY CONTROL SITUATIONS AND TRANSPORTED TO A SITE FOR ASSEMBLY.

IN AN EFFORT TO HELP REDUCE LABOR AND MATERIAL COSTS THE SYSTEM WAS DESIGNED TO ELIMINATE SCAFFOLDING AND ON THE SITE FORMWORK. ONLY TEMPORARY COLUMN AND GIRDER SHORING IS REQUIRED.

GENERALLY, THE SYSTEM USES LARGE SCALE MEMBERS AS IT WAS APPARENT THAT IN PRECASTING THIS WAS MORE EFFICIENT THAN THE USE OF SMALLER ELEMENTS.

**b) ERECTION PROCEDURE**

**FOOTINGS - STEP #1**

THE SITE IS PREPARED - PRECAST ELEMENTS ARE DELIVERED AND PROPERLY STORED ON THE SITE RELATIVE TO THEIR LOCATION IN THE BUILDING STRUCTURE.

THE FOOTINGS ARE POURED IN PLACE. COLUMN FOOT-

INGS POURED WITH LEVELING BLOCKS TO ALLOW FOR GROUTING AFTER PRECAST CONCRETE COLUMNS ARE LOWERED INTO PLACE. HEAVY REINFORCING BARS ARE LEFT EXPOSED TO BE PLACED INTO PREPARED RECESSES IN THE COLUMN FACE.

#### COLUMNS - STEP #2

THE LEVELING BLOCKS ALSO ARE INTEGRAL. THE PRECAST COLUMNS ARE POSITIONED. EXTENDED REINFORCING BARS FROM THE FOOTINGS ARE POSITIONED RELATIVE TO THE REVEALS IN THE COLUMN. MESH WHICH EXTENDS FROM THE COLUMN IS WRAPPED AROUND THE BARS, AND GROUTING TAKES PLACE.

A COLUMN FILLER PANEL IS PLACED AFTER MECHANICAL EQUIPMENT IS IN PLACE LATER.

#### GIRDERS - STEP #3

THE GIRDERS ARE SET ON TOP OF THE COLUMNS. EXTENDED REINFORCEMENT FROM THE COLUMNS ARE PLACED INTO THE REINFORCEMENT REVEALS AND ARE GROUTED AND WELDED. GROUTING ALSO OCCURS UNDER GIRDER AFTER GIRDER IS LEVELED BY MEANS OF SHIMS ON THE COLUMN SURFACE.

THE REINFORCEMENT EXTENDS UP THROUGH PRECAST FLOOR TABLES TO RECEIVE THE POURED IN PLACE SLAB TO ESTABLISH A BOND WHEN SLAB IS POURED LATER.



GIRDER FILLERS - STEP #4

THE GIRDER FILLERS ARE PLACED OVER THE EXTENDED LUGS ON THE GIRDERS. THEY ARE LEVELED AND GROUTED. REINFORCEMENT EXTENDS TO RECEIVE SLAB.

THE SLABS ARE PLACED LATER.

BEAM - STEP #5

THE BEAMS ARE PLACED AT THE 1/4 POINTS OF THE GIRDERS. OPENINGS IN THE GIRDERS ARE PREPARED FOR GROUTING.

THE BEAM INFILLERS ARE PLACED LATER WHEN THE ENTIRE BAY IS PREPARED.

DIAPHRAGMS - STEP #6

BEARING PLATES OCCUR ON THE BOTTOM SURFACE OF DIAPHRAGMS TO BE WELDED TO THE BEAM LUGS BEARING PLATES.

GROUTING THEN OCCURS.

FLOOR - STEP #7

THE PRECAST FLOOR "TABLES" ARE PLACED AFTER THE DIAPHRAGMS ARE IN PLACE. REINFORCEMENT SLOTS ARE PLACED IN SLAB TO RECEIVE EXTENDED BARS FROM THE PEDESTAL.

THE PEDESTAL SITS IN BETWEEN THE TWO PRINCIPLE SPANNING DIAPHRAGMS AND IS SIMPLY GROUTED.

COLUMNS - STEP #8

THE PRECAST COLUMNS ARE PLACED AS IN STEP #2.

TOPPING - STEP #9

THE FLOOR TOPPING IS POURED TO COMPLETE THE SEQUENCE.

F. MECHANICAL SYSTEM

THE BASIC STRUCTURAL UNIT IS ALSO THE BASIC MECHANICAL UNIT. THE INTENT TO MINIMIZE THE VERTICAL FLOOR PENETRATIONS AND THE LENGTH OF THE HORIZONTAL RUNS TO GIVE MORE GROWTH AND CHANGE POSSIBILITIES GIVES REASON TO PASS DUCT WORK AND PIPES VERTICALLY THROUGH COLUMNS AND HORIZONTALLY THROUGH THE GIRDERS.

1) AIR SYSTEM

A HIGH VELOCITY DUAL DUCT SYSTEM INCLUDING HOT, COLD AND RETURN AIR DUCTS WAS SELECTED AS THE SYSTEM WHICH WOULD GIVE OPTIMUM ROOM TEMPERATURE CONTROL.

WITH THE MECHANICAL ROOMS LOCATED ON THE ROOF, THE AIR IS SUPPLIED AND RETURNED VERTICALLY THROUGH THE DOUBLE COLUMNS AT VELOCITIES BETWEEN 3000 TO 5000 FPM. AT EACH FLOOR LEVEL THE MAIN HORIZONTAL DUCTS WHICH HOLD 1200 FPM AIR PASS THROUGH THE PRIMARY AND SECONDARY GIRDERS INTO THE DIFFUSION UNITS. CONNECTIONS, USING FLEXIBLE DUCT WORK LINK THE FEEDER DUCTS WITH THE STRIP

DIFFUSERS LOCATED IN EACH MODULE.

A MIXING BOX UNIT WITH TERMINAL MIXING AND ATTENUATION (PRESSURE AND SOUND REDUCTION) BLENDS AND DELIVERS AIR AT SELECTED TEMPERATURES AS THERMOSTATIC CONTROL ADJUSTS THE PRESSURE SENSITIVE MEMBRANE IN THE BOX.

THE POSITION OF THE BOX WOULD BE DETERMINED BY A SPECIFIC PROGRAM WHICH WOULD ESTABLISH IN A BUILDING AN EXTERIOR AND INTERIOR ZONE(S) WHICH WOULD REQUIRE SPECIAL CONDITIONING AND SUGGEST AIR ZONES AS THEY RELATE TO THE ENVIRONMENTAL FORCES WHICH AFFECT THE MECHANICAL SYSTEMS.

THE AIR SUPPLY DIFFUSERS ARE LOCATED ON A 12<sup>8</sup> MODULE BETWEEN DIAPHRAGM UNITS IN THE FORM OF 0<sup>2</sup> BY 4<sup>4</sup> GRILLES. RETURN AIR GRILLES ARE IN THE ALTERNATING MODULES.

THE DUCT WORK IS EASILY ACCESSIBLE IN THE CEILING BY REMOVING THE HORIZONTAL ACOUSTIC CEILING PANEL.

## 2) PLUMBING SYSTEM

THE VERTICAL WET LINES (HOT, COLD WATER, WASTE, ROOF DRAINS) ARE LOCATED IN THE COLUMNS. HORIZONTALLY THEY MOVE WITHIN THE DOUBLE GIRDERS WITH

THE POSSIBILITY OF TAPPING INTO THEM ALONG THIS ZONE.

VENTS AND WET PIPING TO TOILETS WOULD BE CONTAINED IN THE SERVICE CORES.

3) ELECTRICAL SYSTEM

POWER AND COMMUNICATION WIRING ALSO MOVE WITHIN THE MAJOR STRUCTURAL ELEMENTS INTO THE FREE SPACE IN THE CEILING ABOVE THE DIAPHRAGM UNITS.

ELECTRICAL CLOSETS WOULD BE LOCATED IN THE CORES.

G. ACOUSTICS

THE ACOUSTIC CONTROL (SOUND ISOLATION, REVERBERATION, INTENSITY LEVELS, ETC.) IS SOLVED HORIZONTALLY BY PLACING THE REQUIRED MATERIALS TO ACHIEVE THE ABOVE ON TOP OF THE DIAPHRAGM UNITS. THIS ALSO SEALS OFF THE FREE SPACE TO PREVENT SOUND FROM PASSING OVER PARTITIONS.

H. LIGHTING

THE 6<sup>4</sup> X 4<sup>4</sup> MODULE ACCOMMODATES STANDARD FLOURESCENT FIXTURE DIMENSIONS, AND THE FREE SPACE ABOVE THE DIAPHRAGMS ALSO ALLOW FOR DEEP INCANDESCENT FIXTURES, TO BE PLACED IN EACH MODULE TO AFFORD UNIFORM LIGHTING LEVELS.

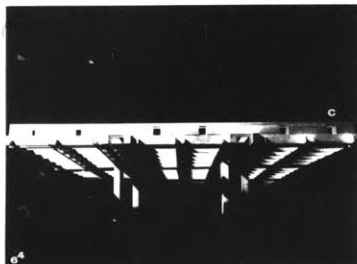
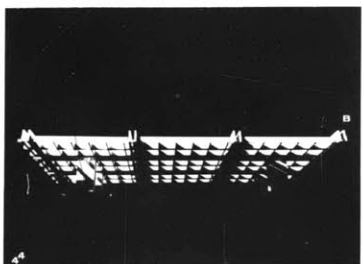
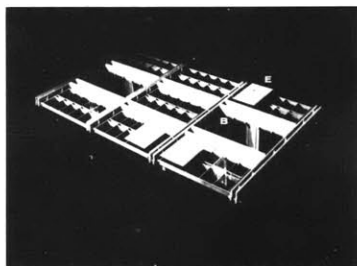
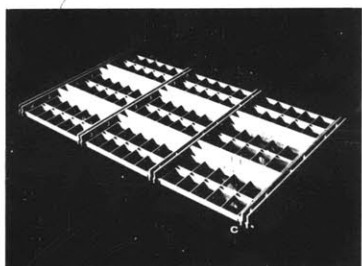
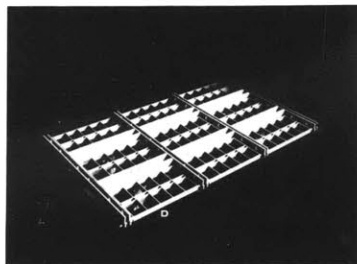
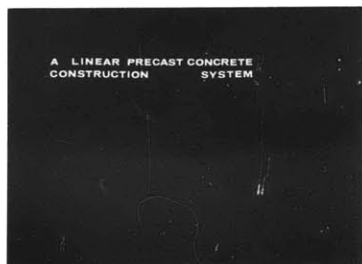
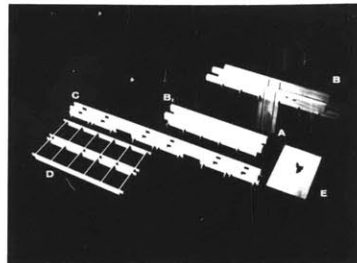
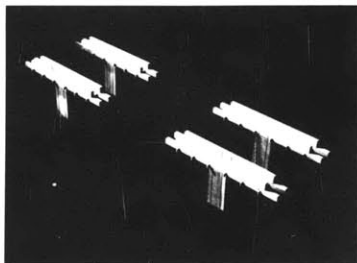
I PLANNING AND CIRCULATION

THE SYSTEM, WITH A UNIFORM FLUSH CEILING GRID WITH THE CAPACITY TO ADAPT TO A NUMBER OF MATERIALS, ALLOWS FOR A MULTITUDE OF PLANNING CONDITIONS FROM SMALL STORAGE DIMENSIONS TO LARGE SCALED SPACES, IN AN ORDERLY MANNER.

THE MAJOR CIRCULATION PATTERN IS DEFINED BY THE GIRDER SYSTEM WHICH WOULD RELATE TO CORES AND WOULD ALSO BEGIN TO ESTABLISH CIRCULATION SYSTEMS FOR GROWTH.

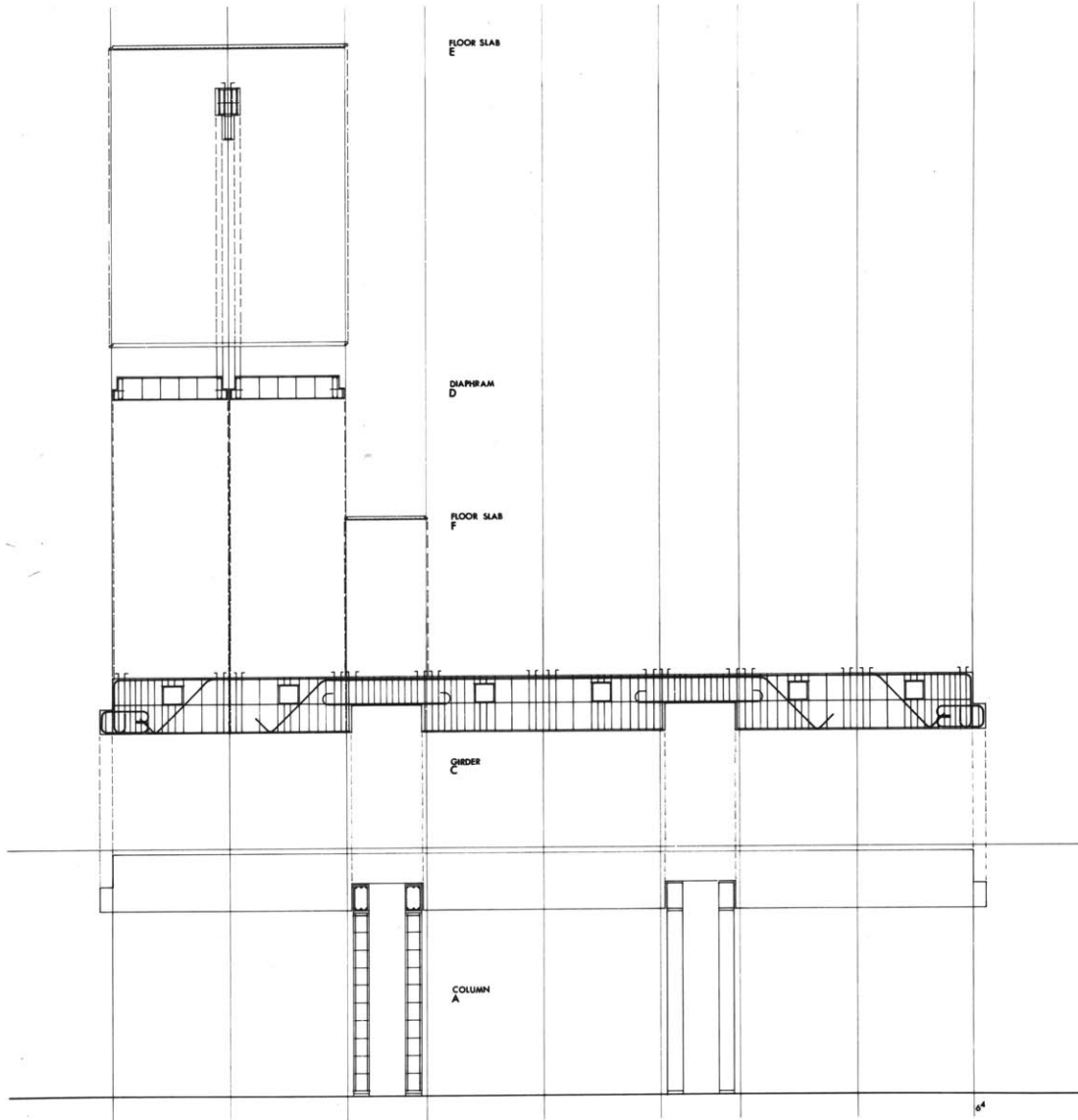
THE STRUCTURE ALLOWS FOR AUTO STORAGE AND MOVEMENT AND SERVICING WHICH MAY BECOME REQUISITES IN FUTURE LARGE SCALE PLANNING.

BASIC UNIT



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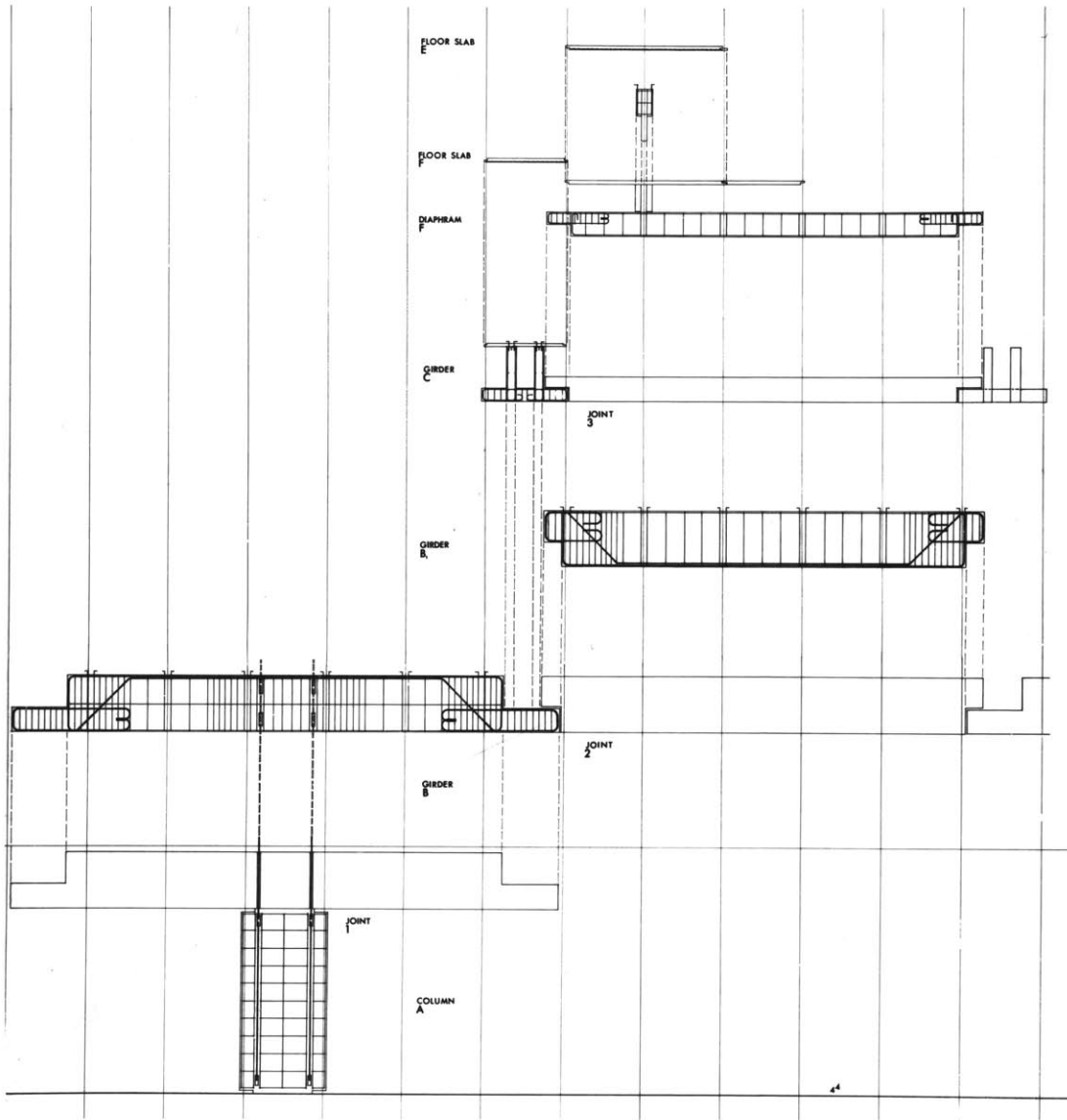


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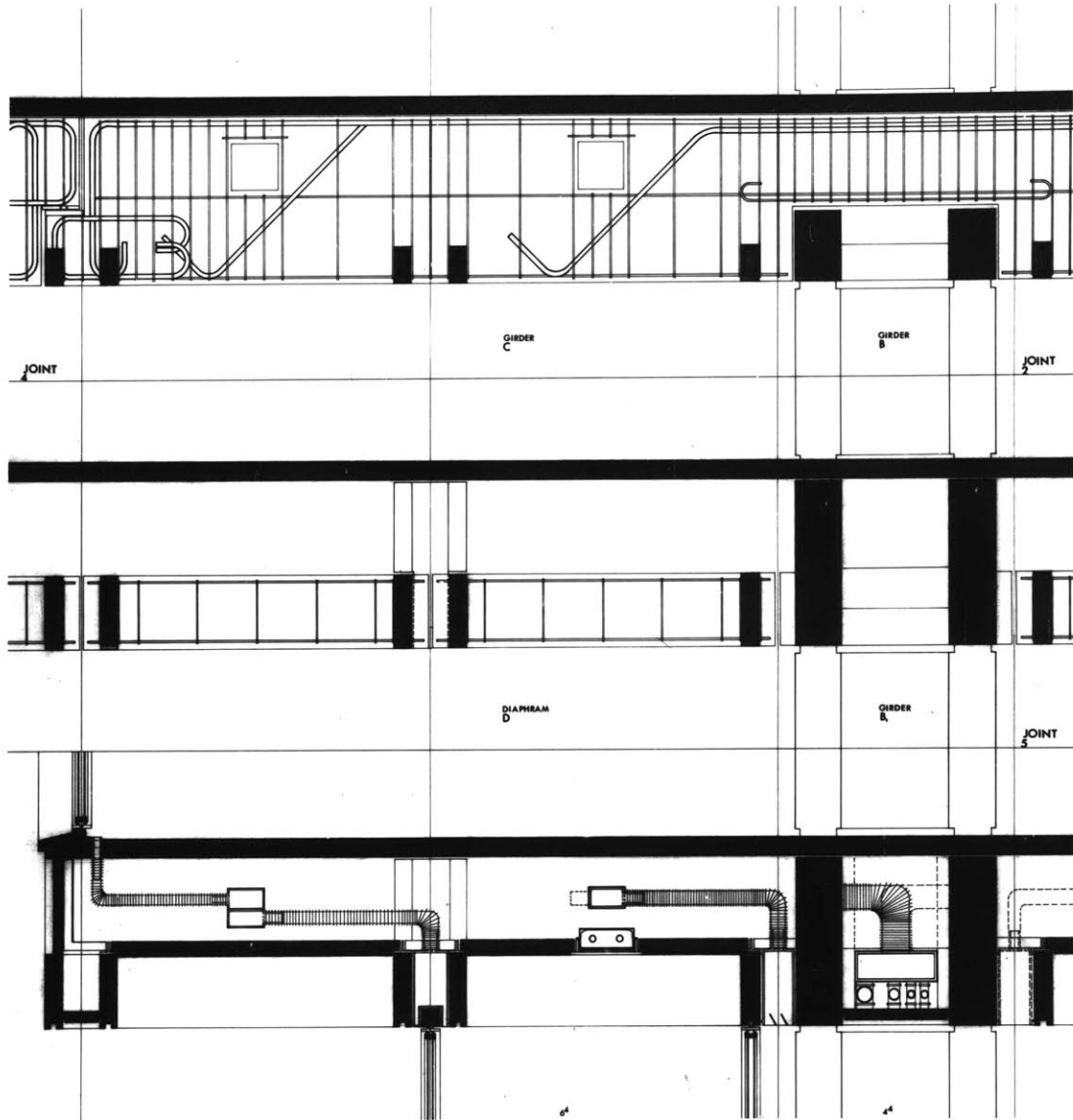
DETAILS



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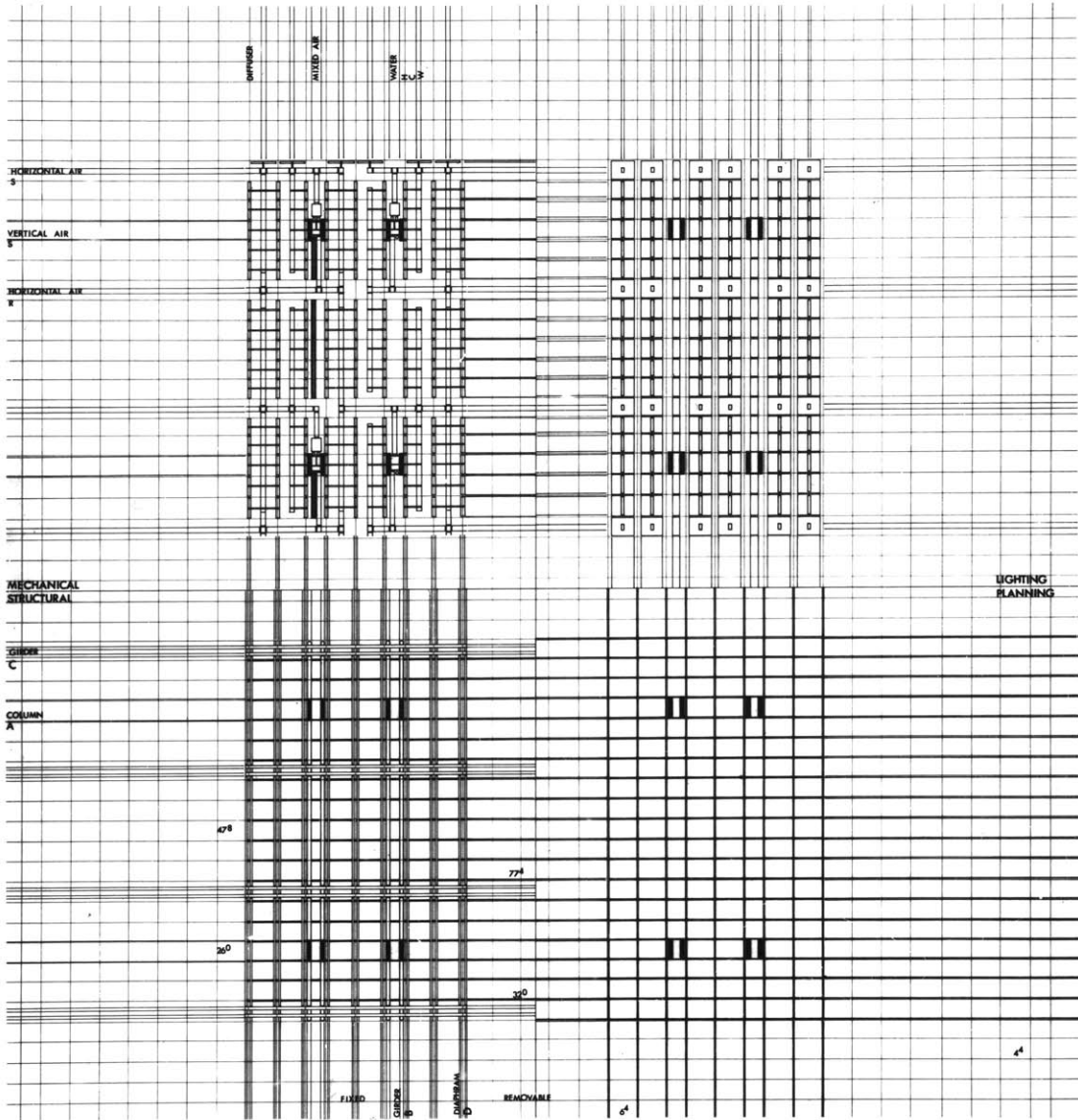
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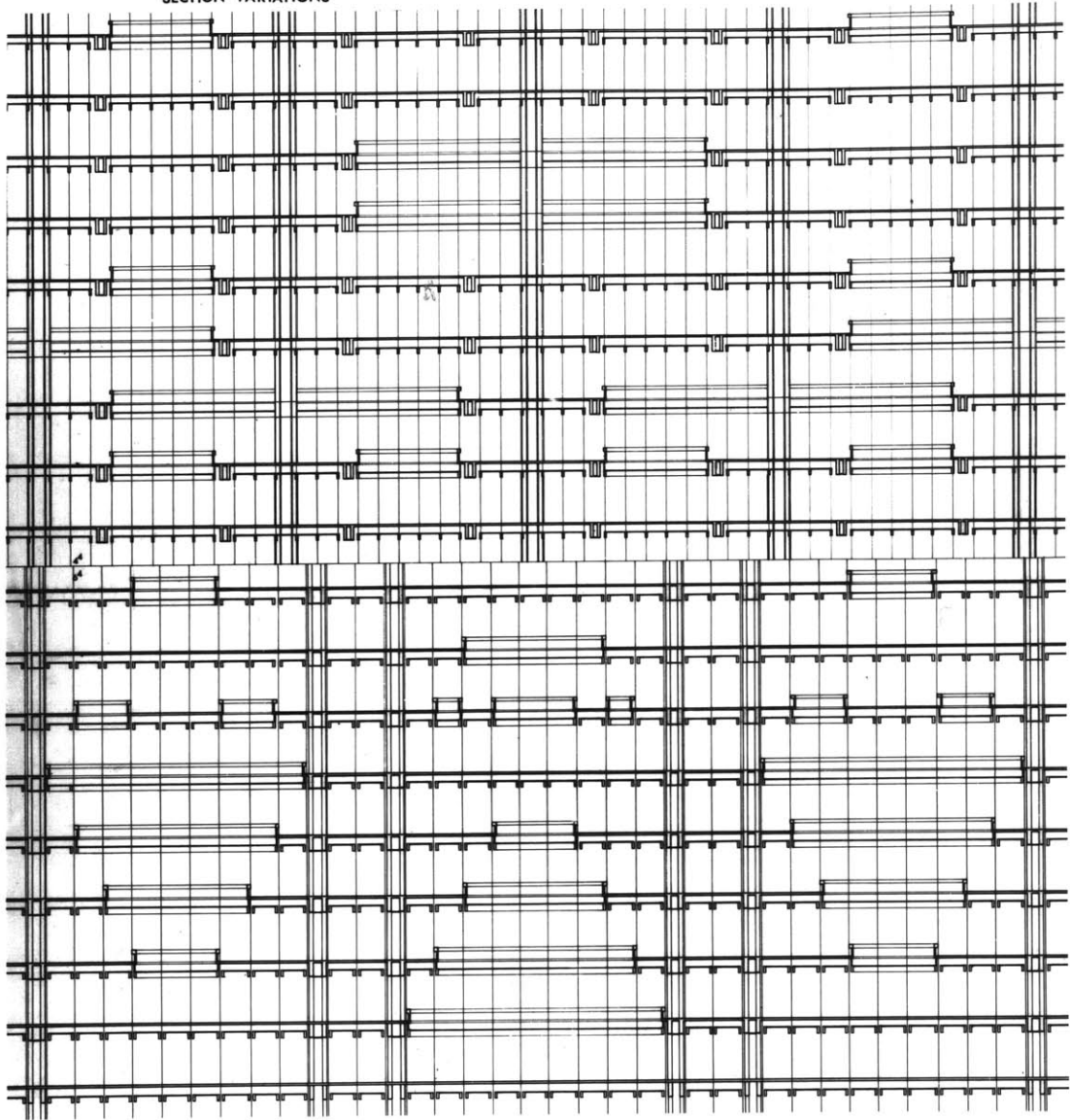
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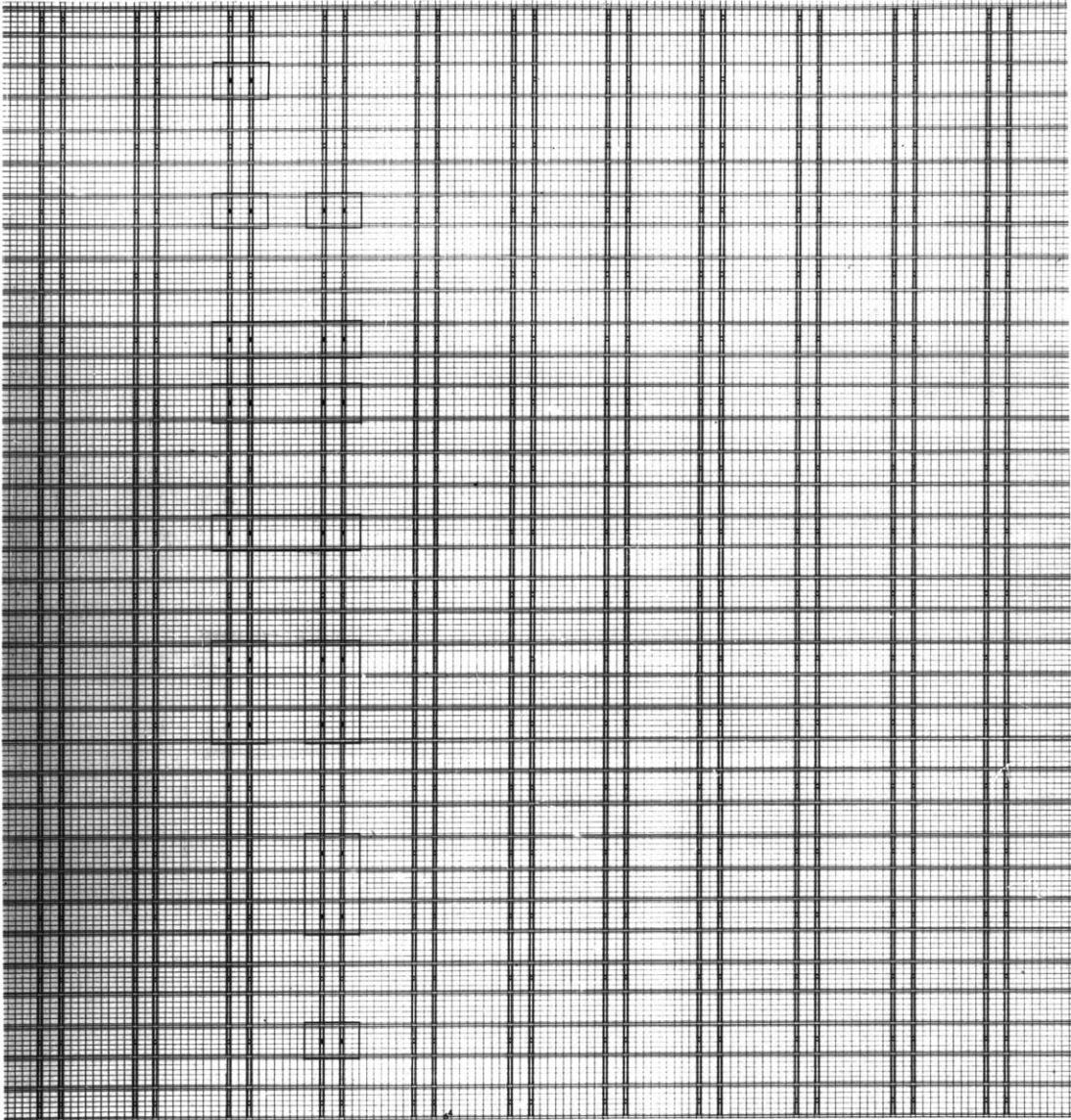
BASIC UNIT PLANS



SECTION VARIATIONS



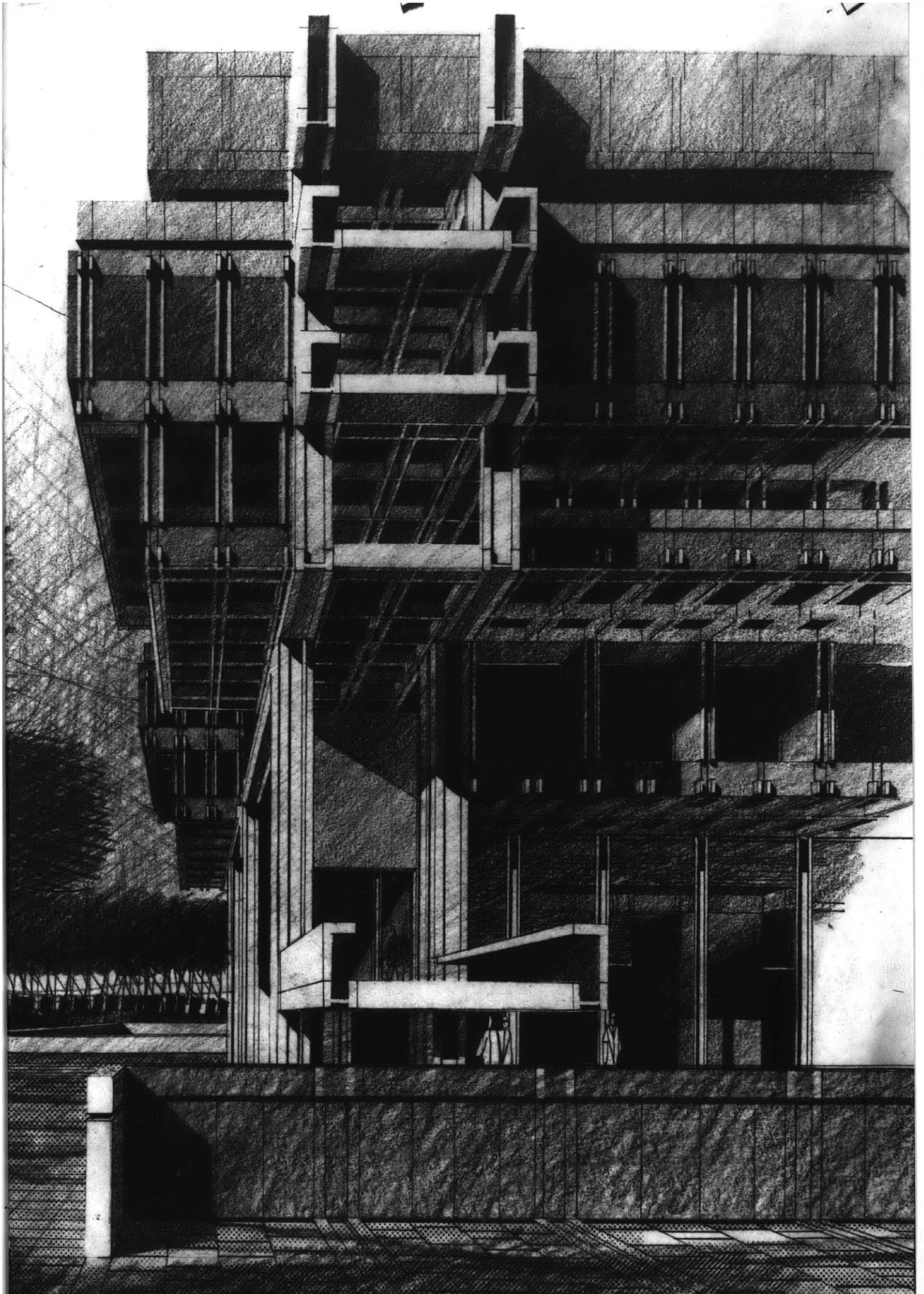
MODULAR FIELD



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XI BIBLIOGRAPHY

AMERICAN CONCRETE INSTITUTE, A.C.I. STANDARD-BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE. (ACI 318-63) DETROIT, MICHIGAN, 1963.

\_\_\_\_\_, FORMWORK FOR CONCRETE, (SP-4), DETROIT, MICHIGAN, 1963.

\_\_\_\_\_, A.C.I. STANDARD-RECOMMENDED PRACTICE FOR CONCRETE FORMWORK. (ACI 347-63) DETROIT, MICHIGAN, 1963.

BURNS, RUDQUIST, AND KUPRITZ, PRECAST FLOOR SYSTEMS, UNPUBLISHED MASTERS THESIS, MIT, 1962.

HORNHOSTEL, CALEB, MATERIALS FOR ARCHITECTURE. NEW YORK: REINHOLD PUBLISHING CO., 1965.

MCGUINNESS, WILLIAM J., STEIN, BENJAMIN, MECHANICAL AND ELECTRICAL EQUIPMENT FOR BUILDINGS. NEW YORK: WILEY, 1964.

NERVI, P. L. AESTHETICS AND TECHNOLOGY IN BUILDING CAMBRIDGE, MASS.: HARVARD UNIVERSITY PRESS, 1965.

PARKER, H. SIMPLIFIED DESIGN OF REINFORCED CONCRETE, NEW YORK: WILEY, 1964.

WESTINGHOUSE ELECTRIC CORPORATION, LIGHTING HANDBOOK, BLOOMFIELD, N.J., 1963.