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I TITLE

AM INTEGRATED BUILDING SYSTEM

KURT E. ROGNESS

B. ARCH UNIVERSITY OF MINNESOTA

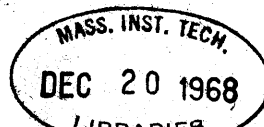
SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER IN
ARCHITECTURE AT THE MASSACHUSETTS INSTITUTE
OF TECHNOLOGY, CAMBRIDGE, MASSACHUSETTS,
17 JUNE, 1968

SIGNATURE OF AUTHOR

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II SUBMISSION LETTER

CAMBRIDGE 39, MASSACHUSETTS
17 JUNE, 1968

DEAN LAWRENCE B. ANDERSON
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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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CAMBRIDGE 39, MASSACHUSETTS

DEAR DEAN ANDERSON,

IN PARTIAL FULFILLMENT OF THE REQUIRE-
MENTS FOR THE DEGREE OF ARCHITECTURE,
I HEREBY SUBMIT THIS THESIS ENTITLED
"AN INTEGRATED BUILDING SYSTEM".

RESPECTFULLY,

KURT E. ROGNESS

III ABSTRACT

AN INTEGRATED BUILDING SYSTEM

KURT E. ROGNESS

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF
ARCHITECTURE 17, JUNE, 1968

THE INTENT OF THIS THESIS WAS TO DEVELOP
AN INTEGRATED BUILDING SYSTEM FOR AN URBAN
UNIVERSITY, UTILIZING THE MOST ADVANCED
TECHNOLOGY AVAILABLE. THE BUILDING WAS
CONCEIVED OF AS AN ALL ENCOMPASSING SYSTEM
OF SPACE, CIRCULATION, LIFE, GROWTH CHANGE,
STRUCTURE, AND MECHANICAL SERVICES. THE
COMPREHENSION OF THE VARIOUS GEOMETRIES
COMPRISING THE INTEGRATED SYSTEM BECAME
THE ESSENCE OF THE PROBLEM.

THE SYSTEM PROPOSED CONSISTS OF A ONE-WAY
PRE-CAST CONCRETE STRUCTURE SUPPORTED ON
COLUMNS FORMING A 36' x 69' BAY. BEAMS
ARE PLACED ALTERNATELY 6' x 12' APART WITH
MECHANICAL SERVICES ENCLOSED IN THE 6' DI-
MENSION. A TOTAL STRUCTURAL DEPTH OF 4'-0"
ALLOWS PRIMARY MECAHNICAL CIRCULATION OUT
OF THE COLUMNS INTO THE GIRDER.

THESIS ADVISOR: EDUARDO CATALANO
PROFESSOR OF ARCHITECTURE
MASSACHUSETTS INSTITUTE OF
TECHNOLOGY

IV ACKNOWLEDGEMENTS

THE AUTHOR WISHES TO THANK THE FOLLOWING
WHOSE ASSISTANCE AND ADVICE CONTRIBUTED TO
A TERM OF TECHNICAL ENLIGHTENMENT.

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INTRODUCTION

THE ARCHITECTURAL PROFESSION TODAY IS THREATENED. THE WORLD'S URBAN MASSES ARE DEMANDING UNPRECEDENTED VOLUMES OF PUBLIC BUILDINGS. THE ARCHITECT, MEANWHILE, DUE TO HIS TRADITIONAL TRAINING PRIMARILY AS AN ARTIST, LACKS THE FACILITY OF COMMUNICATE WITH THE ENGINEERING PROFESSIONS AND HAS LITTLE OR NO KNOWLEDGE CONCERNING THE METHODS AND MANUFACTURING PROCESSES WHICH ARE OBVIOUSLY VITALLY NECESSARY IF THE ARCHITECT IS TO MAKE ANY CONTRIBUTION TO THE MASS PRODUCTION OF BUILDINGS. AS A RESPONSE TO HIS BACKGROUND, THE ARCHITECT IS STILL DESIGNING INDIVIDUAL BUILDINGS AS INDIVIDUAL EXPRESSIONS FOR SPECIALIZED FUNCTIONS.

ACCOMPANYING SOCIETY'S DEMAND FOR INCREASED BUILDING VOLUMES, HAS BEEN THE NEED FOR INCREASED FLEXIBILITY. FUNCTIONAL REQUIREMENTS ARE CONSTANTLY IN FLUX AND MAY WELL OFTEN CHANGE BEFORE AN ENTIRE BUILDING PROGRAM CAN BE COMPLETED. THEREFORE, FRAMEWORKS MUST BE PROVIDED WITHIN WHICH FUNCTIONAL, ENVIRONMENTAL, AND SPATIAL CHANGE CAN OCCUR, WHILE ORDERLY PATTERNS OF GROWTH CAN BE PROJECTED WITHOUT DISTURBING THE PREVIOUSLY COMPLETED STRUCTURE.

THIS THESIS PROPOSAL EXPLORES THE POTENTIALS OFFERED BY ADVANCED ENGINEERING PRACTICE, AND INDUSTRIALIZED CONSTRUCTION TECHNIQUE. WHILE THE THESIS PROPOSAL MAY NOT BE THE ULTIMATE ANSWER TO THE PROBLEM, THE DESIGNER EXPERIENCED A WELL DEVELOPED SEARCH INTO THE PROBLEM WHICH WILL POSITIVELY SERVE HIM IN PRACTICE.

OBJECTIVES

THE OBJECTIVES OF OUR RESEARCH WERE CLARIFIED THROUGH THE EVALUATION OF VARIOUS BUILDING SYSTEMS COMPLETED OVER THE LAST FIVE YEARS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, AND AN ANALYSIS OF CONTEMPORARY BUILDING PRACTICE. THE STUDY OF PAST THESIS PROBLEMS CONCENTRATED ON THE FOLLOWING:

- A. GEOMETRICAL PATTERNS OF THE VARIOUS SYSTEMS COMPRISING A BUILDING, i.e. STRUCTURAL, MECHANICAL, ILLUMINATION, AND PLANNING MODULES IN SEARCH OF PARALLELS AND POINTS OF CONFLICT BETWEEN THE PATTERNS
- B. CONSTRUCTION TECHNIQUES AS RELATED TO AN ADVANCED TECHNOLOGY OF PREFABRICATION AND ASSEMBLY
- C. PARAMETERS DICTATING DIMENSIONS WITHIN A BUILDING TO INTEGRATE FUNCTIONAL AS WELL AS STRUCTURAL AND COMFORT SYSTEMS
- D. GROWTH POTENTIAL AND INTERNAL CHANGE FLEXIBILITY

AN ANALYSIS OF EXISTING OR CONTEMPORARY FLOOR CONSTRUCTION WAS DONE TO JUDGE ITS ADEQUACY FOR FUTURE BUILDING NEEDS. THIS ANALYSIS INDICATED THAT ALTHOUGH MOST FLOOR SECTIONS INCORPORATED A COMBINATION OF STRUCTURAL AND NON-STRUCTURAL ELEMENTS, THERE EXISTS LITTLE OR NO INTEGRATION BETWEEN THEM.

THE MOST TYPICAL MEANS USED IN DEALING WITH THESE UNRELATED ELEMENTS CONSISTED OF ASSIGNING EACH A WORKING DEPTH WITHIN THE FLOOR THICKNESS. THE STRUCTURE IS ASSIGNED TO THE TOP PORTION, DUCTS ALLOCATED TO THE CENTER, AND LIGHTING LOCATED AT THE BOTTOM. WHILE IN DESIGN AND CONSTRUCTION, THIS LAYERED SECTION PROVIDES A LOGICAL SEPARATION OF THE WORK; IT DOES HAVE THE FOLLOWING DRAWBACKS.

1) INORDER TO LIMIT THE TOTAL DEPTH OF THE FLOOR CONSTRUCTION, A MINIMUM STRUCTURAL DEPTH IS SOUGHT, OFTEN RESULTING IN AN UNECONOMICAL STRUCTURE AND DEFINITELY LIMITING THE SPANS.

2) SINCE MECHANICAL COMPONENTS BECOME MORE COMPLEX AND SPACE CONSUMING WITH THE ADDITION OF MORE SERVICES OVER THE COMING YEARS, THE FLOOR THICKNESS INCREASES INORDINATELY OR IS FORCED INTO AN INADEQUATE DEPTH.

3) THE CEILING PROVIDED DOES NOT LEND ITSELF TO FLEXIBLE PARTITION PLACEMENT AND ACOUSTICAL PRIVACY. BLOCKING, INSTALLED ABOVE PARTITIONS TO INSURE STABILITY AND ACOUSTICAL CLOSURE, BECOMES AN UNTIDY PROCEDURE THAT OFTEN HAS UNSATISFACTORY RESULTS.

AS A RESPONSE TO THE INITIAL RESEARCH DESCRIBED ABOVE, THE FOLLOWING DESIGN CRITERIA WAS FORMULATED. IT SERVED AS A GUIDE THROUGH SEVERAL INVESTIGATIONS PRESENTED AT INTERIM REVIEWS, AND FINALLY TO A THESIS PROPOSAL.

DESIGN CRITERIA

A. SPATIAL

SPACE GENERATED BY STRUCTURAL AND MECHANICAL DETERMINANTS SHOULD PERMIT SMALL AND LARGE SCALE USE OF SPACE BOTH HORIZONTALLY AND VERTICALLY.

THEREFORE, THE SYSTEM MUST POSSESS INHERENT STRUCTURAL FLEXIBILITY WHEREBY COMPONENTS OF VARYING SIZES CAN BE REMOVED OR ADDED WITHOUT AFFECTING THE BASIC STRUCTURE.

B. FUNCTIONAL

DIVERSE REQUIREMENTS FOR AN EDUCATIONAL INSTITUTION MUST BE SATISFIED WHICH WOULD INCLUDE DIMENSIONS FOR AUDITORIUMS, LECTURE HALLS, LABORATORIES, WORK SHOPS, SEMINAR ROOMS, AND OFFICES.

PLAN FLEXIBILITY SHOULD BE REALIZED THROUGH THE LOCATION OF PARTITIONS ON A FLEXIBLE GRID SYSTEM INTEGRAL WITH THE STRUCTURE.

VERTICAL FLEXIBILITY SHOULD BE PROVIDED BY UTILIZING THE INHERENT HIERARCHY OF PERMANENCE IN THE COMPONENTS COMPRISING THE FLOOR STRUCTURE.

THE DESIGN PROPOSAL WILL NOT BE AN ANSWER FOR ANY "PARTICULAR" FUNCTION, BUT RATHER FOR A BASIC FUNCTIONAL ABILITY TO ACCOMMODATE CHANGE.

C. GEOMETRICAL

STRUCTURAL COMPONENTS SHOULD VISUALLY SERVE TO EXPRESS THE ORDER OF THE INTEGRATED SYSTEMS, i.e. MECHANICAL, CONSTRUCTION SEQUENCE, PLANNING, AND CIRCULATION.

D. MECHANICAL

BASICALLY THE MECHANICAL SYSTEM HAS TWO ZONES, INTERIOR AND PERIPHERAL, WHILE VARIETIES OF CONTROL MUST BE PROVIDED TO SERVE DIVERSE NEEDS.

MAXIMUM AIR-HANDLING REQUIREMENTS WERE PRESCRIBED BY THE CONSULTING MECHANICAL ENGINEER TO BE 2 CFM PER SQ. FT. THE INTERIOR ZONES COULD BE SUPPLIED BY A DUAL DUCT OR A SINGLE DUCTED SYSTEM. A DUAL DUCT SYSTEM IS MORE ECONOMIC TO OPERATE AND IS MORE SENSITIVE TO CONTROL. HOWEVER, THE SINGLE-DUCT SYSTEM COSTS LESS TO INSTALL DUE TO LESS COMPLEX DUCT WORK, AND CONSEQUENTLY TAKES LESS SPACE. ON THE PERIPHERY EITHER INDUCTION OR FAN-COILED UNITS COULD BE USED.

THE FLOOR SLABS SHOULD ALLOW FREE MOVEMENT FOR AND ACCESS TO AIR-CONDITIONING DUCTS, WATER, SANITATION, AND ELECTRICAL SERVICES. THE MECHANICAL SYSTEM AND THE SPACE PROVIDED TO ENCLOSE IT, MUST BE DESIGNED TO ANTICIPATE FUTURE CHANGES FOR

THIS SYSTEM IS INHERENTLY LESS PERMANENT THAN THE STRUCTURE.

E. STRUCTURAL

IN ORDER TO FACILITATE FUNCTIONAL CHANGE WHICH WAS PROJECTED TO OCCUR EVERY TEN YEARS, THE MECHANICAL SYSTEM SHOULD BE INCORPORATED INTO THE STRUCTURAL DEPTH. A MINIMUM SPACE, e.g. 10' x 10', 12' x 12', ETC., SHOULD BE PROVIDED WITH ALL SERVICES. THE ADVANTAGE WILL BE UNIFORMITY, FLEXIBILITY, DURABILITY, AND LESS COST IN ALTERATIONS.

ADDITIONALLY, THE STRUCTURE IS RELIED UPON TO GIVE THE BUILDING LIFE - WHICH IS SPATIAL INTEREST. EDGE VARIATION, AS WELL AS A VARIETY OF VOID POSSIBILITIES, SHOULD BE FEASIBLE IN DESIGN IN ADDITION TO CHANGE POTENTIAL TO ACCOMMODATE FUTURE DEMANDS.

F. CORES

CORES ARE ORGANIZATION POINTS CONCENTRATING VERTICAL CIRCULATION, UTILITY SERVICES, AND POSSIBLY MECHANICAL SHAFTS. THE COMPONENTS, HOWEVER ARRANGED, SHOULD PROVIDE FOR A RANGE OF BUILDING TYPE AND OCCUPANCIES. THE CORE SHOULD ACCOMMODATE ALL OR PART OF THE FOLLOWING ELEMENTS: TOILETS, ELEVATORS, STAIRS, CLOSETS FOR JANITOR, TELEPHONE EQUIPMENT, AND ELECTRICAL EQUIPMENT.

SQUARE FOOTAGE REQUIREMENTS FOR
THESE ELEMENTS ARE AS FOLLOWS:

TOILETS (WOMEN): 1 W.C. / 45
1 LAV. / 100

PASSENGER

ELEVATOR: 1 5 x 7 ELEVATOR
PER 50,000 SQ. FT.

FREIGHT PROVIDED TO REACH
ELEVATORS: EACH FLOOR & LO-
CATED TO SERVE SPE-
CIAL FUNCTIONS.

JANITOR CLOSET: 25 SQ. FT. /
30,000 SQ. FT.

TELEPHONE

CLOSET: 100 SQ. FT. /
30,000 SQ. FT.

ELETRICAL

CLOSET: 100 SQ. FT. /
30,000 SQ. FT.

G. CODE

THE NATIONAL BUILDING CODE WAS USED
AS A BASIS FOR SAFETY AND CIRCUL-
LATION REQUIREMENTS. THE CODE
PRESCRIBES FIRE-STAIR FREQUENCIES
AND WIDTHS BASED ON DIFFERING
OCCUPANCIES. OCCUPANCIES IN-
CLUDED ARE:

BUSINESS: 1 PERSON PER
40 SQ. FT.

EDUCATIONAL 1 PERSON PER
LECTURE: 40 SQ. FT.

OFFICE: 1 PERSON PER
100 SQ. FT.

HIGH

HAZARD:

EXIT CAPACITY IS MEASURED IN 22 INCH UNIT WIDTHS. THE NUMBER OF OCCUPANTS PER STORY PER UNIT OF EXIT STAIRWAY WIDTH IS THE FOLLOWING:

BUSINESS: 60 PERSONS
EDUCATIONAL: 60 PERSONS
HIGH HAZARD: 30 PERSONS

THE MAXIMUM DISTANCE TO EXIT DOOR FROM ANY POINT ON A FLOOR AREA, MEASURED ALONG THE LINE OF RUN SHOULD NOT EXCEED:

BUSINESS: 150 FEET
EDUCATIONAL: 100 FEET
HIGH HAZARD: 75 FEET

CONCLUSION

IN CONCLUSION, THE ARCHITECT MUST ATTEMPT TO COORDINATE ADVANCED ENGINEERING PRACTICE WITH INDUSTRIALIZED PRODUCTION IN SEARCH OF A NEW ORDERING OF OUR ENVIRONMENT. THE EXPERIENCE GAINED IN THIS FIRST ATTEMPT AT EVOLVING A SYSTEM UNDOUBTEDLY WILL BROADEN THE CREATIVE PERSONALITY OF THE ARCHITECT; AND, HOPEFULLY AS A RESULT OF THIS SEARCH, IT WILL FACILITATE HIS COMMUNICATION WITH THE ENGINEERING PROFESSION.

INITIAL
INVESTIGATION

CONCRETE CONSTRUCTION SYSTEMS, WHETHER PRE-CAST OR CAST IN PLACE, ARE COMMONLY CLASSED AS EITHER ONE OR TWO-WAY STRUCTURAL SYSTEMS. THE DISTINCTION WOULD BE BETTER CLARIFIED IF THEY WERE DIVIDED INTO:

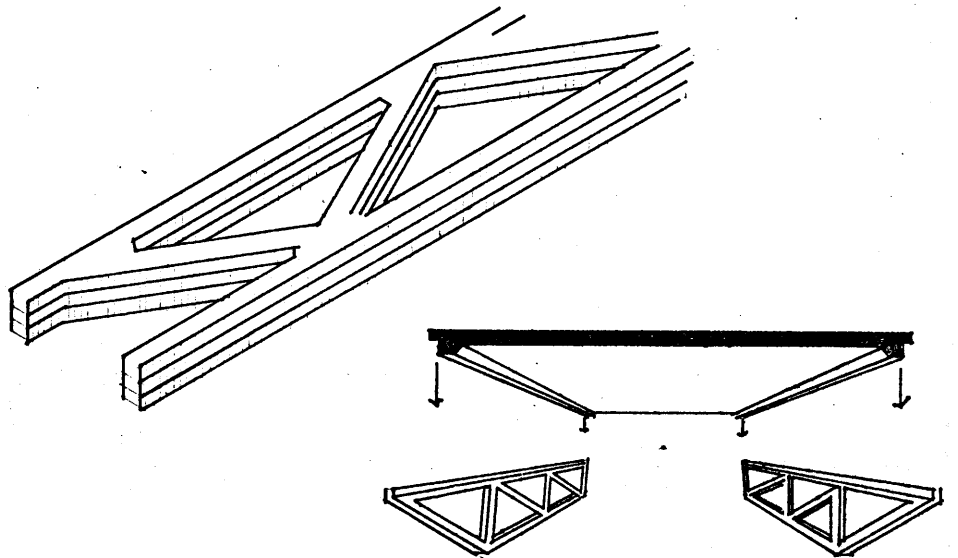
- 1) SYSTEMS THAT TRANSMIT FORCES IN ONLY ONE DIRECTION FROM A GIVEN POINT, AND,
- 2) THOSE CAPABLE OF TRANSMITTING FORCES IN MORE THAN ONE DIRECTION DEPENDING ON THE CONFIGURATION.

THE TECHNOLOGICAL ADVANCES IN CONCRETE THAT HAVE HAD CONSIDERABLE IMPACT ON STRUCTURAL CAPABILITY ARE PRE-STRESSING AND POST-STRESSING. PRE-STRESSING IS GENERALLY USED ON LONG STRUCTURAL MEMBERS ASSOCIATED WITH ONE-WAY STRUCTURES. POST-STRESSING IS USUALLY A PART OF THE PROCESS INCORPORATED IN TWO-WAY STRUCTURAL SYSTEMS WHICH GENERALLY CONSIST OF SMALL STRUCTURE UNITS LINKED TOGETHER BY CABLES IN TENSION.

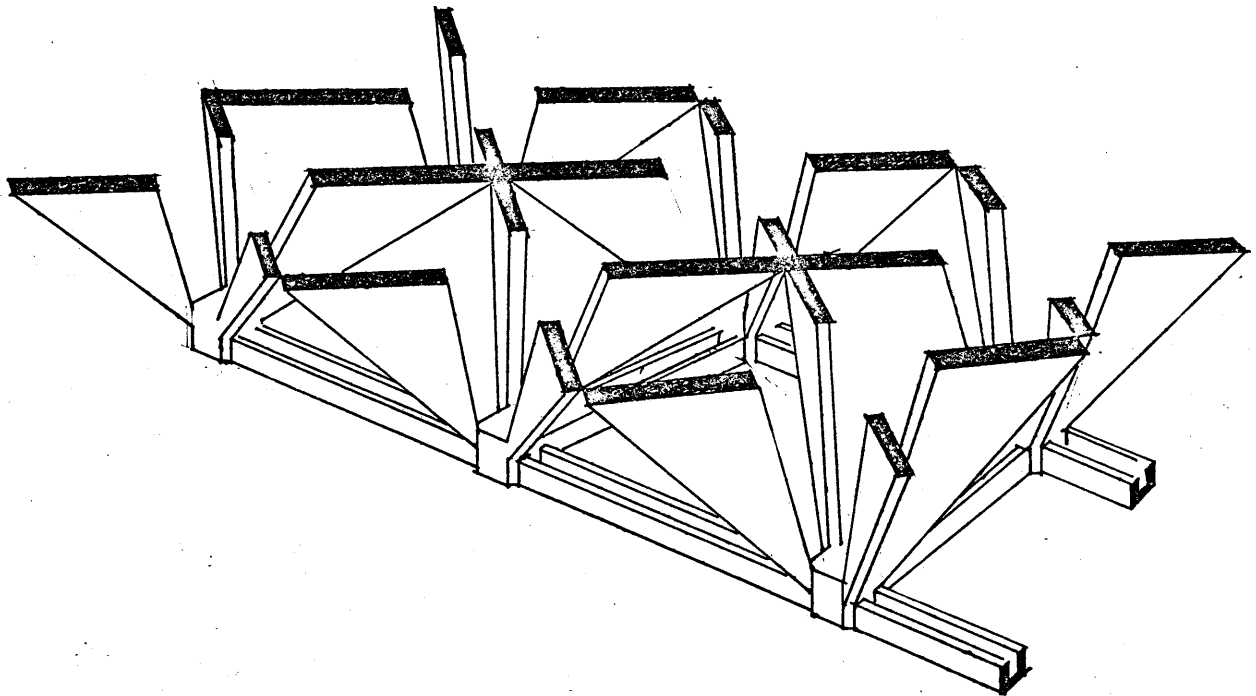
ONE AND TWO-WAY STRUCTURAL SYSTEMS LEAVE DIFFERING VOID CHARACTERISTICS THROUGH WHICH MECHANICAL RUNS ARE MADE. THE ONE-WAY SYSTEM PROVIDES LONG UNINTERRUPTED CHANNELS, ACCOMMODATING A NATURAL SEQUENCE OF PRIMARY AND SECONDARY RUNS OF AIR DISTRIBUTION. THE TWO-WAY SYSTEM CONVERSELY PROVIDES A UNIFORMITY OF SPACE WHICH IS MORE CONDUCIVE TO RADICAL CHANGE IN THE OVER-ALL PATTERN AT SOME FUTURE DATE.

ACCORDING TO PEOPLE WORKING IN ARCHITECTURAL RESEARCH AT M.I.T., LABOR COSTS HAVE RISEN DISPROPORTIONATELY OVER MATERIAL COSTS DURING THE PAST FIVE YEARS. RECOGNIZING THIS FACTOR, A DECISION WAS MADE TO MINIMIZE THE NUMBER OF PARTS AND CONNECTIONS AS WELL AS THE EXPENSE OF SCAFFOLDING.

THE PURPOSE OF THE SECOND INVESTIGATION WAS TO ALLEVIATE THE ERECTION PROBLEMS OF THE INITIAL PROPOSAL. THIS SECOND PROPOSAL UTILIZED LARGE ONE-WAY BEAM COMPONENTS TO ASSEMBLE A TWO-WAY CONCRETE SPACE FRAME. THE VALIDITY OF THIS APPROACH LAY IN THE SIZE OF ITS COMPONENTS AND THE MEANS OF PRODUCTION, i.e. THE BEAM COULD BE CAST IN A STACK ON THE GROUND.



FOR THE FIRST PRELIMINARY REVIEW, A TWO-WAY STRUCTURAL SYSTEM WAS EXPLORED. TO OBTAIN A GREATER STRUCTURAL ADVANTAGE, THE UPPER CORD WAS ROTATED 45 DEGREES. THE RESULT WAS A DIAGONAL STRESS TRANSFER TO THE COLUMNS. OTHER ADVANTAGES WERE ITS CONTAINMENT OF SERVICES AND ITS APPEARANCE.



DRAWBACKS TO THIS PROPOSAL WERE CONCENTRATED IN ON-SITE LABOR, POST-TENSIONING, SCAFFOLDING, AND JOINTING COMPLEXITY. ADDITIONALLY, MECHANICAL RUNS TENDED TO BE SHORT AND TORTUOUS, INCREASING THE COST OF MECHANICAL EQUIPMENT INSTALLATION.

SERIOUS DRAWBACKS APPEARED AT THE GIRDER LINES. CONNECTION WAS VERY TRICKY AND THE GEOMETRY OF THE BAYS BECAME VERY RESTRICTIVE. VERTICAL PENETRATION WAS LIMITED TO THE DELETION OF A 10' x 50' AREA DUE TO THE SIZE OF THE COMPONENTS. THE STRUCTURE WAS NOT A MOST ECONOMICAL ONE DUE TO A LACK OF CONTINUITY OVER THE SUPPORTS.

THESE FIRST PROPOSALS, THOUGH EXTENSIVELY DEVELOPED WERE DISCHARGED BECAUSE THEY DID NOT SATISFY IMPORTANT DESIGN CRITERIS, i.e., THREE-DIMENSIONAL CHANGE, SPATIAL FLEXIBILITY, AND EASE OF CONSTRUCTION. THE TWO-WAY SYSTEM WAS, IN PRINCIPLE, VERY ATTRACTIVE; HOWEVER, ON PRACTICAL GROUNDS IT WAS DISCARDED. SUCH SYSTEMS MIGHT BEST BE REALIZED BY A CAST-IN-PLACE CONSTRUCTION TECHNIQUE, UTILIZING SOPHISTICATED SHUTTERING PROCEDURES, RATHER THAN INCURRING PRECASTING EXPENSE COMPOUNDED BY THE HIGH COSTS OF ON-SITE ASSEMBLY OF SO MANY PARTS.

PROPOSAL

A ONE-WAY STRUCTURAL SYSTEM WAS CHOSEN PRIMARILY FOR ITS SPATIAL FLEXIBILITY AND EASE OF CONSTRUCTION. THE FOLLOWING ARE ADVANTAGES OF THE SYSTEM PROPOSED AND GENERALLY APPLICABLE TO ALL ONE-WAY SYSTEMS.

- A. CONSTRUCTION ECONOMY FOUND IN JOINT SIMPLICITY AND THE DELETION OF SCAFFOLDING.
- B. FRAMING PATTERN WHICH FACILITATES THREE-DIMENSIONAL CHANGE.
- C. VOID POSSIBILITIES IN LARGE AND SMALL SCALE.
- D. PROVIDES NATURAL SEQUENCE FOR LONG UNINTERRUPTED PRIMARY AND SECONDARY AIR DISTRIBUTION RUNS.
- E. TWO-WAY CANTILEVER ACHIEVED.
- F. PLANNING GRID FORMED IS FIXED IN ONE DIRECTION (THE DIRECTION OF THE LONG FRAMING MEMBER) AND FLEXIBLE IN THE OTHER.

STRUCTURE

THE STRUCTURAL FRAMING PATTERN CONSISTS OF BEAMS ALTERNATELY SPACED 6' & 12' APART. THE 6' SPACING FORMS A MECHANICAL CHANNEL IN WHICH AIR AND PLUMBING SERVICES ARE ENCLOSED. THE 12' SPACING IS FREE OF PRIMARY MECHANICAL RUNS ALLOWING VERTICAL SHAFTS OR VOIDS TO CONNECT ONE LEVEL TO THE NEXT. GENERALLY, HOWEVER, IT IS INFILLED WITH 6' x 12' PRESTRESSED SLABS. THIS PATTERN THUS ALLOWS THE CORE ELEMENTS TO BECOME PART OF THE STRUCTURAL BAY SYSTEM, ALLOWING MORE FLEXIBILITY IN DESIGN AS WELL AS CHANGE.

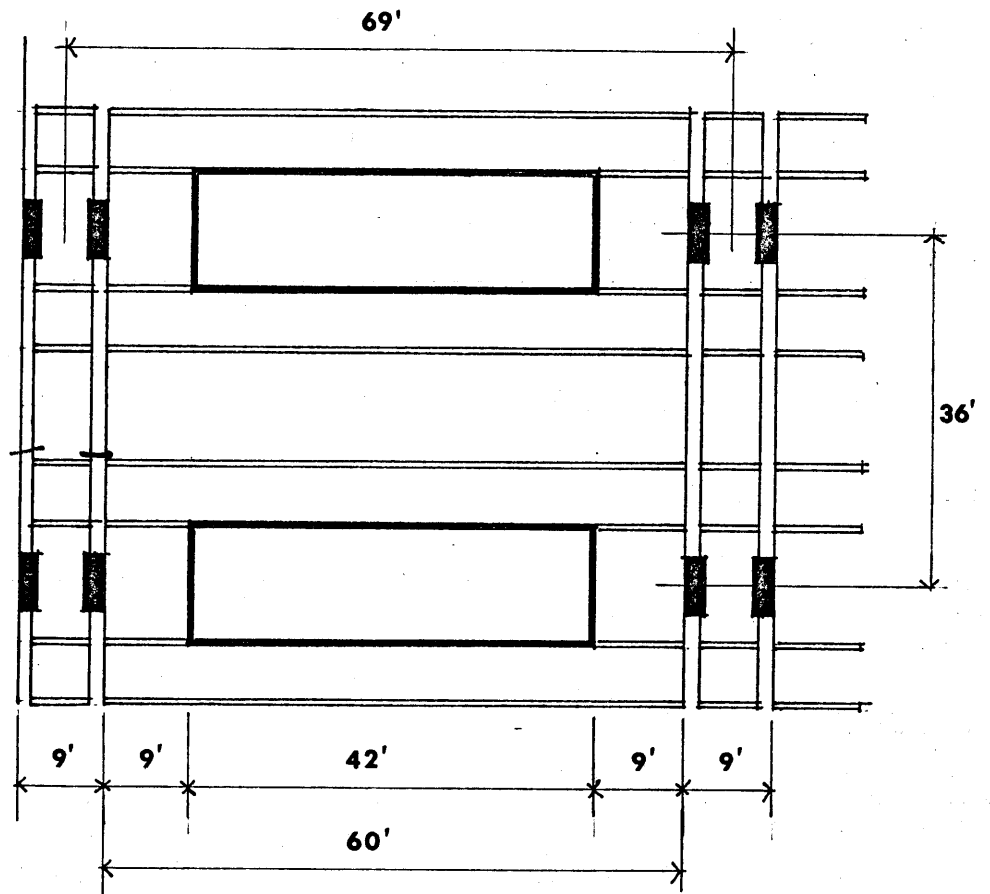
CHANGE IS EASILY ACCOMODATED WITHOUT AFFECTING
MAIN SUPPORTING ELEMENTS. (SEE PLATE 3)
THE COMPONENTS ARE THE FOLLOWING:

- A. COLUMN- PRE-CAST, REINFORCED, AND
MADE CONTINUOUS THROUGH THE WELDING
OF RODS AT MATING PLATES. CAST INTO
THE COLUMNS. (WEIGHT 14.2 KIPS)
SEE PLATES 2 & 3)
- B. GIRDER - ASSEMBLED AT POINTS OF
ZERO MOMENT BY WELDED CONNECTION
PROVIDING GENEROUS OPENINGS FOR
MECHANICAL RUNS. (WEIGHT 9.5 KIPS)
- C. CANTILEVERED BEAMS - STRADDLE THE
DOUBLE GIRDER PROVIDING FLEXIBILITY
IN THE SYSTEM DUE TO POSSIBILITIES FOR
REASONABLE ASYMMETRY. (WEIGHT 5.5 KIPS)
(SEE PLATE 2)
- D. INFILL BEAMS - SIMPLY SUPPORTED BEAR-
ING, SPANNING BETWEEN THE ENDS OF
THE CANTILEVERED BEAMS.¹ (weight
11.5 KIPS) (SEE PLATE 2)
- E. INFILL SLABS - 4" PRE-CAST SLAB UNIT
COMPLETE THE SYSTEM WITH A LEVELING
SLAB POURED OVER THE ENTIRE STRUCTURE.
- UNTIL THIS PROCEDURE IS ACCOMPLISHED,
GIRDER RESISTANCE IS NOT AT FULL
STRENGTH. (WEIGHT 3.6 KIPS) (SEE PLATE 3)

THE TOTAL STRUCTURAL WEIGHT OF THE FLOOR CON-
STRUCTION IS 120 POUNDS PER SQUARE FOOT USING
150 POUNDS CONCRETE.

1. MARIO SALVADORI AND ROBERT HELLER,
STRUCTURES IN ARCHITECTURE (ENGLEWOOD CLIFFS,
NEW JERSEY: PRENTICE - HALL, INC., THIRD
EDITION, 1964) P.

THE COLUMN GRID MODULE RESULTED FROM SEVERAL PARAMETERS. FIRST A LARGE ENOUGH SPAN WAS REQUIRED TO ACCOMODATE PARKING ON A SUB-LEVEL; WHILE SECONDLY, THE STRUCTURE HAD TO BE OF SUFFICIENT DEPTH TO ALLOW THE PASSAGE OF MECHANICAL SERVICES. THIRDLY, IT HAD TO CONFORM TO A GEOMETRY EXPLOITING STRUCTURAL CONNECTIONS AT POINTS OF ZERO MOMENT, WHICH IN TURN, GENERATED A FRAMING PATTERN ALLOWING THREE DIMENSIONAL FLEXIBILITY. THE DIMENSIONS DETERMINED ARE 36' x 69', CENTER TO CENTER.



POINT OF 0 - MOMENT = 15% OF SPAN. 2.

2. IBID., PP.

AS SEEN IN THE PREVIOUS DIAGRAM, THE ELEVATOR AND STAIR CORES PENETRATE THE SYSTEM BUT WITHOUT DISRUPTING IT. CORRIDORS STRADDLE THE CORES Laterally (6' OR 9' WIDTH) AND MAY PENETRATE BETWEEN OR ALSO STRADDLE LONGITUDINALLY. (6' OR 12' WIDTH) LATERAL STABILITY IS DEPENDENT ON THE CORE SHAFTS AND THE IMPLEMENTATION OF DIAPHRAGMS INSTALLED BETWEEN THE COLUMNS. THE BUILDING FORM IS HORIZONTAL WITH A MAXIMUM HEIGHT LIMIT OF SIX STORIES.

MATERIALS AND TECHNIQUES

CONCRETE WAS CHOSEN BASED ON ITS INHERENT FIRE PROOF QUALITIES, EVEN THOUGH SCIENCE MAY EVENTUALLY FIREPROOF STEEL OR PROVIDE US WITH A LIGHT WEIGHT CERAMIC MATERIAL FOR MORE EFFICIENT SPANNING. AT PRESENT, HOWEVER, CONCRETE IS MOST SUITABLE FOR EXPOSED USE IN THE BUILDING TYPE STUDIED.

PRE-CASTING AND PRE-STRESSING TECHNIQUES WERE CHOSEN OVER CAST-IN- PLACE CONSTRUCTION FOR THE FOLLOWING REASONS.

- A. FACTORY PRODUCTION MAY FORM MORE COMPLEX SHAPES
- B. QUALITY CONTROL OF MIXES AND DIMENSIONS.

- C. ECONOMY OF FABRICATION WILL FOLLOW AN EXPANDING MARKET
- D. PRODUCTION AND ERECTION NOT AFFECTED BY WEATHER CONDITIONS
- E. ON-SITE LABOR COSTS HAVE RISEN DIS-PROPORTIONATELY TO MATERIAL COSTS OVER THE PAST FIVE YEARS-INDICATING THAT CAST IN PLACE MAY WELL BECOME OBSOLETE ECONOMICALLY

A CONCERTED EFFORT WAS MADE TO GREATER SIMPLIFY THE FORMING OF THE STRUCTURAL COMPONENTS. THE LONG-SPANNING MEMBERS ARE DESIGNED TO BE CAST HORIZONTALLY IN STACKS. THIS METHOD WILL ELIMINATE IN-PLANT HANDLING PROBLEMS AND MAKE GREATER PRODUCTION POSSIBLE.

CONSTRUCTION
SEQUENCE

- STEP 1) COMPONENTS ARE ASSEMBLED AT A PRE-CASTING PLANT UNDER CLOSE QUALITY CONTROLLED CONDITIONS SPECIFIED BY THE DESIGNER.
- STEP 2) FOOTINGS ARE POURED IN PLACE WITH STEEL LEVELING BLOCKS TO ALLOW FOR GROUTING AFTER PRE-CAST COLUMNS ARE LOWERED INTO PLACE.
- STEP 3) PRE-CAST COLUMNS ARE PLACES IN DESIRED POSITIONS BY CRANE.
- STEP 4) ON EACH COLUMN IS PLACED A CANTILEVERED GIRDER SECTION AND WELDED TO THE COLUMN.

- STEP 5) THE INFILL GIRDER IS LOWERED INTO PLACE BETWEEN THE CANTILEVERED SECTIONS AND WELDED.
- STEP 6) THE CANTILEVERED BEAMS STRADDLING THE GIRDER ARE LOWERED INTO PLACE AND WELDED.
- STEP 7) PRE-STRESSED INFILL BEAMS ARE LOWERED INTO PLACE BETWEEN CANTILEVERED CHANNELS AND WELDED.
- STEP 8) PRE-STRESSED SLABS ARE LAID INTO POSITION SPANNING BETWEEN THE BEAMS.
- STEP 9) THE FLOOR TOPPING IS POURED AND ALL WELDED JOINTS ARE GROUTED WITH EXPANDING GROUTS. THE PROCEDURE CAN THEN BE REPEATED FOR THE NEXT FLOOR.
(SEE PLATE 3)

STRUCTURAL JOINTS IN ALL CASES ARE LOCATED AT POINTS OF ZERO MOMENT. THESE LOCATIONS FACILITATE CONTINUITY AND ARE STRUCTURALLY ADVANTAGEOUS.³.

ERECTION CAN BE ACCOMPLISHED WITH A LIELSHEER TOWER CRANE. ITS MAST HEIGHT IS 148', ADEQUATE FOR THE BUILDING MASS DESIGNED. WITH A 100' REACH, THE HEAVIEST COMPONENT (GIRDER 14.2 KIPS) CAN BE EASILY HANDLED BY THE CRANE. THE COMPONENTS ARE NEARLY EQUAL IN WEIGHT, A FACTOR WHICH OPTIMIZES THE EFFICIENCY OF THE CRANE.

MECHANICAL

THE PURPOSE OF THE MECHANICAL SYSTEM IS TO PROVIDE FOR HUMAN COMFORT WHICH IMPLIES A NATURAL DISSIPATION OF BODY HEAT. FACTORS AFFECTING THIS DISSIPATION ARE HUMIDITY, TEMPERATURE, AND AIR MOTION.⁴

THE PROPOSED STRUCTURAL FRAMING PATTERN VERY CLEARLY AND RIGIDLY PRESCRIBES THE LOCATION AND DIRECTION OF MAIN MECHANICAL RUNS. INHERENT IN THE ONE-WAY SYSTEM IS A HEIRARCHY OF VOIDS FOR THESE RUNS WHICH TEND TO FACILITATE INSTALLATION, AND COINCIDE WITH THE HEIRARCHY OF PRIMARY AND SECONDARY ELEMENTS OF A SIMPLE AIR-DISTRIBUTION SYSTEM. WHILE THE TWO-WAY STRUCTURAL SOLUTION PROVIDES A UNIFORMITY OF SPACE FOR MECHANICAL RUNS, INSTALLATION TENDS TO BE MUCH MORE COMPLEX AND CONSEQUENTLY MORE EXPENSIVE.

THE SINGLE DUCT SUPPLY SYSTEM WITH TERMINAL REHEAT WAS CHOSEN, OVER THE DUAL DUCT SYSTEM. WHILE THE DUAL DUCT SYSTEM HAS CONTROL AND OPERATING EXPENSE ADVANTAGES, THE SINGLE DUCTED SYSTEM HAS A SIMPLIFIED INSTALLATION AND MAINTENANCE, THUS MAKING IT MORE SUITED TO AN INTEGRATION WITH THE STRUCTURE.

IN THE SINGLE DUCT SYSTEM, COOL AIR IS SUPPLIED AND CONTROLLED BY VARIABLE VOLUME AND REHEAT COILS. MAJOR VERTICAL SUPPLY IS DELIVERED TO EACH FLOOR AT 4000 FPM IN ROUND CIRCULARLY WOUND DUCTS. AT EACH FLOOR LEVEL BRANCHES TAKE OFF AND THE HIGH VELOCITY AIR IS ROUTED THROUGH A VALVE WHICH PRECEEDS

4. CARRIER AIR CONDITIONING CO. THE ABC'S OF AIR CONDITIONING, NEW YORK 1966, P.4.

A SOUND ATTENUATION BOX. MAIN HORIZONTAL RUNS ARE ENCLOSED IN THE STRUCTURAL CHANNELS AND RUN AT 1500 FPM, WITH AIR FINALLY SUPPLIED TO THE DIFFUSER VIA FLEXIBLE DUCT AT 700 FPM.

RETURN AIR DUCTS INTERLOCKS DIMENSIONALLY WITH THE SUPPLY DUCTS WITHIN THE CHANNEL. SEVENTY-FIVE PER CENT OF THE AIR IS RETURNED TO THE COLUMN AT 1200 FPM.

VERTICAL SUPPLY AND RETURN IS ENCLOSED IN ALTERNATE COLUMNS. CORE SUPPLY WAS REJECTED BECAUSE CORES HAD TO BE SPACED AT CLOSER INTERVALS THAN WOULD BE NECESSARY FOR FIRE STAIR SAFETY. CORE SUPPLY AND RETURN REQUIRED LARGER DUCTS THAN COULD BE INTEGRATED INTO THE STRUCTURAL DEPTH.

DUE TO THE HIGH VENTILATION REQUIREMENTS (2 CFM PER SQUARE FOOT), THE RETURN AIR DUCT DIMENSION BECAME THE MOST CRITICAL DUCT TO ENCLOSE. SIZING BY CONSTANT FRICTION, THE RETURN AIR NEAR THE BASE TRAVELS NEARLY 2000 FPM.

HEAT LOADS OF THE PERIPHERY OF THE BUILDING ARE MUCH MORE UNSTABLE THAN THOSE IN THE INTERIOR. THEREFORE, IT BECAME ADVISABLE TO INCORPORATE A SUPPLEMENTARY PROVISION TO CONTROL THIS ZONE. A THREE PIPE FAN COIL SYSTEM WAS RECOMMENDED UTILIZING CHILLED WATER SUPPLY, HOT WATER SUPPLY, AND A COMMON RETURN. CONSEQUENTLY, HEATING AND COOLING COULD BE AVAILABLE AT A SEPARATE UNIT AT ANY ONE TIME. ^{5.}

5. CARRIER, THE ABC'S OF AIR CONDITIONING, P.8.

FOOTPRINT

THE FOOTPRINT IS DEFINED AS A PATTERN OF BUILDING WITHIN WHICH ALL THE ESSENTIALS FOR LIFE ARE ENCLOSED.

SYSTEM NETWORK

THE SYSTEM NETWORK IS AN ASSEMBLANCE OF FOOTPRINTS COMPLYING WITH THE REQUIREMENTS OF CODES AND EXTERIOR EDGE CONDITIONS. THE EDGE CONDITION SHOULD BE SUCH THAT THE BUILDING CAN UNDERGO AN EXPANSION OF THE INDIVIDUAL FOOTPRINTS IN COMPLIANCE WITH THE NETWORK PATTERN.

THE PERMANENT FIXED ELEMENTS OF THE SYSTEM NETWORK OTHER THAN COLUMNS ARE THE STAIRS AND ELEVATORS. THESE ELEMENTS ARE SO GROUPED TO ACT AS ORGANIZED POINTS IN THE PLANNING SCHEME. THE FREQUENCY OF THESE CORES ARE REGULATED BY FIRE STAIR FREQUENCY AS PRESCRIBED BY THE NATIONAL BUILDING CODE.

ELEVATOR AND STAIR SHAFTS REST ON THE STRUCTURAL FRAMING IN THE 12' SPACING BETWEEN THE BEAMS. THEREFORE, IF IN THE FUTURE, ELEMENTS ARE TO BE ADDED OR DELETED, THE RENOVATION CAN OCCUR WITHOUT DISRUPTING MAJOR STRUCTURAL ELEMENTS OR PRIMARY MECHANICAL RUNS.

THE RECOMMENDATION BY THE OTIS CORPORATION FOR ELEVATORS SERVING A 6 STORY GENERAL EDUCATIONAL BUILDING IS TWO CARS PER 30,000 SQ. FT. EACH CAR IS TO HAVE A 2500 POUND

6. AMERICAN INSURANCE ASSOCIATION, THE NATIONAL BUILDING CODE (NEW YORK, CHICAGO, & SAN FRANCISCO: ENGINEERING & SAFETY DEPT. 1967)

RATING AND A CAPACITY OF 15 PERSONS PER CAR.

FREIGHT ELEVATORS ARE PROVIDED TO REACH EACH FLOOR LEVEL. FUNCTIONALLY, THEY SHOULD BE LOCATED WHERE IT WOULD BE MOST ESSENTIAL TO SERVICE THOSE AREAS REQUIRING A TRAFFIC OF HEAVY OR BULKY GOODS.

TOILET ROOMS MAY OR NOT BE LOCATED AT THE CORES. ALTHOUGH IN THE MOST GENERAL CASE, IT MAKES PLANNING SENSE TO GROUP TOILETS. WITH A VERTICAL CIRCULATION, ANY PARTICULAR SOLUTION TO LOCATING TOILETS ANYWHERE ON THE SLAB CAN BE ACCOMODATED,

PLUMBING

PLUMBING RUNS ARE ENCLOSED IN THE SAME 6' CHANNELS AS AIR DISTRIBUTION. PLUMBING RUNS PROVIDED ARE HOT WATER, COLD WATER, WASTE, GAS, AND ROOF DRAINS. MAXIMUM FALL IS REALIZED WHEN THE PIPES ENTER THE CHANNEL FROM DIRECTLY ABOVE. A POTENTIAL 21" FALL IS PROVIDED. IF THE PIPE PENETRATES INTO THE 12' SPACING, THE PIPE MUST BE RUN INTO THE 6' CHANNEL THROUGH ONE OF BEAM PENETRATIONS.

MODULE AND LIGHTING

A FLEXIBLE MODULE IS FORMED BY THE STRUCTURAL FRAMING. THE BASIC MODULE IS 3' IN THE DIRECTION OF THE LONG SPAN WITH MULTIPLES OF 6' IN

THE DIRECTION OF THE DOUBLE GIRDER.

ASSUMING A 6' x 6' MODULE, TWO ARRANGEMENTS MAY ACHIEVE A MINIMUM ILLUMINATION OF 70 FC, (1) 3-40 WATT LAMPS IN EACH MODULE OR (2) 6 - 40 WATT LAMPS IN STAGGERED MODULES.⁷ (SEE ALSO COMPUTER PRINT OUT.)

A MINIMUM HABITABLE SPACE WAS CONSIDERED TO BE 12' x 12'. ALL SERVICES, FRESH AIR, EXHAUST, LIGHT, AND PLUMBING COULD SERVE THIS SPACE.

ACOUSTICS

ACOUSTIC TREATMENT MUST BE FLEXIBLE ENOUGH TO ACCOMMODATE VARYING LEVELS OF ABSORPTION OR REFLECTIVITY DEPENDING ON THE FUNCTION OF A PARTICULAR SPACE. THE RECTILINEAR CHARACTER OF THE STRUCTURAL MEMBERS FACILITATES THE INSTALLATION OF SUCH TREATMENT AS WELL AS THE INSTALLATION OF ACOUSTICAL CLOSURE.

SPECIAL ATTENTION MUST BE MADE TO MECHANICAL NOISE PROBLEMS. THE HIGH VELOCITY AIR HANDLING SYSTEM MUST BE CAREFULLY SEALED VALVES ATTENUATED AND DUCTS SUFFICIENTLY LINED TO MAINTAIN AN NC 35 CURVE.⁸

7. WESTINGHOUSE, LIGHTING HANDBOOK (BLOOMFIELD, NEW JERSEY: WESTINGHOUSE ELECTRIC CORP., 1964 P. 41.

8. V.O. KNUDSEN & C.M. HARRIS, ACOUSTICAL DESIGNING IN ARCHITECTURE, (NEW YORK: WILEY & SONS, 1963) P. 286.

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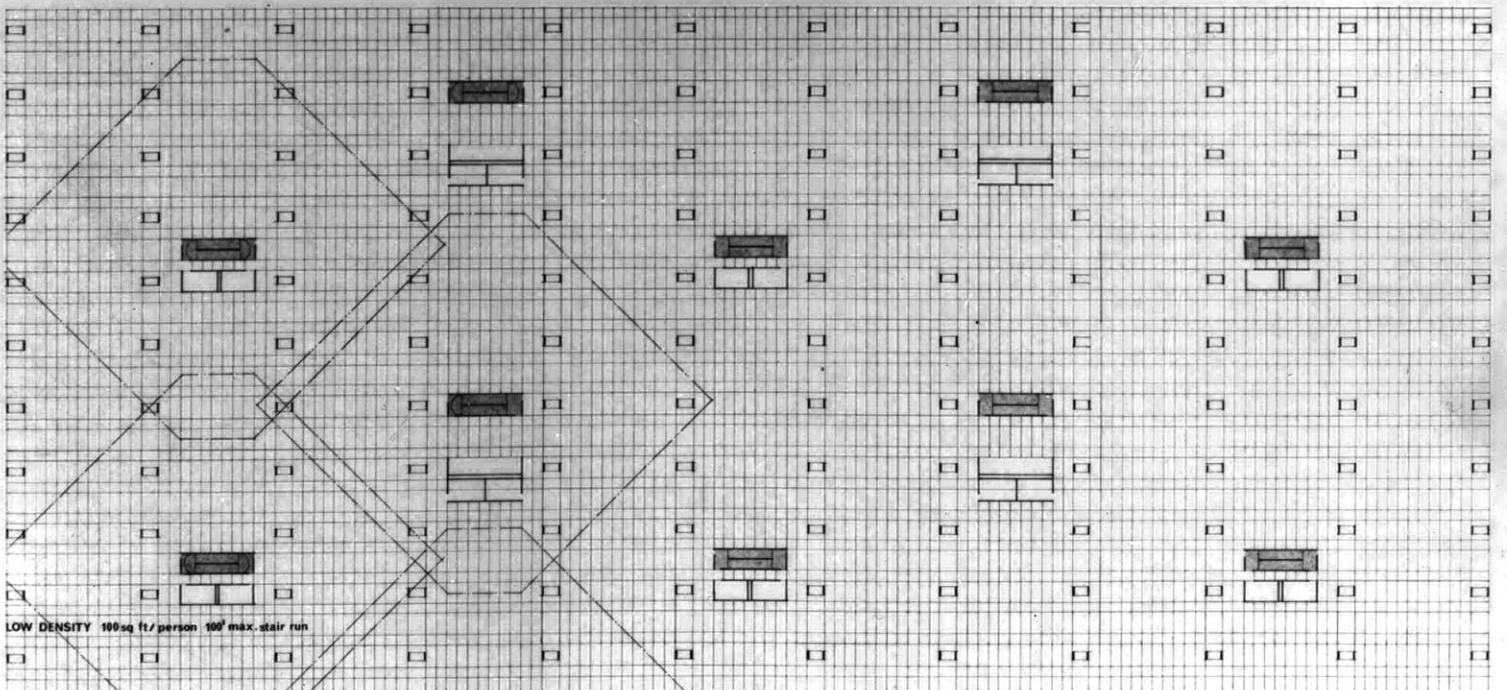
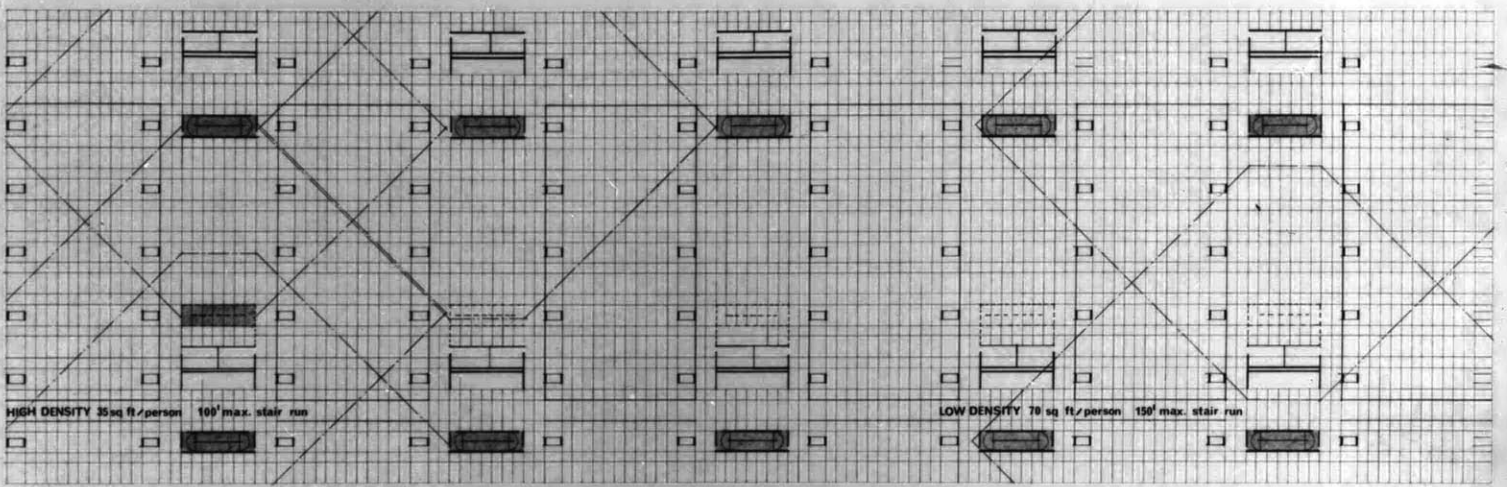
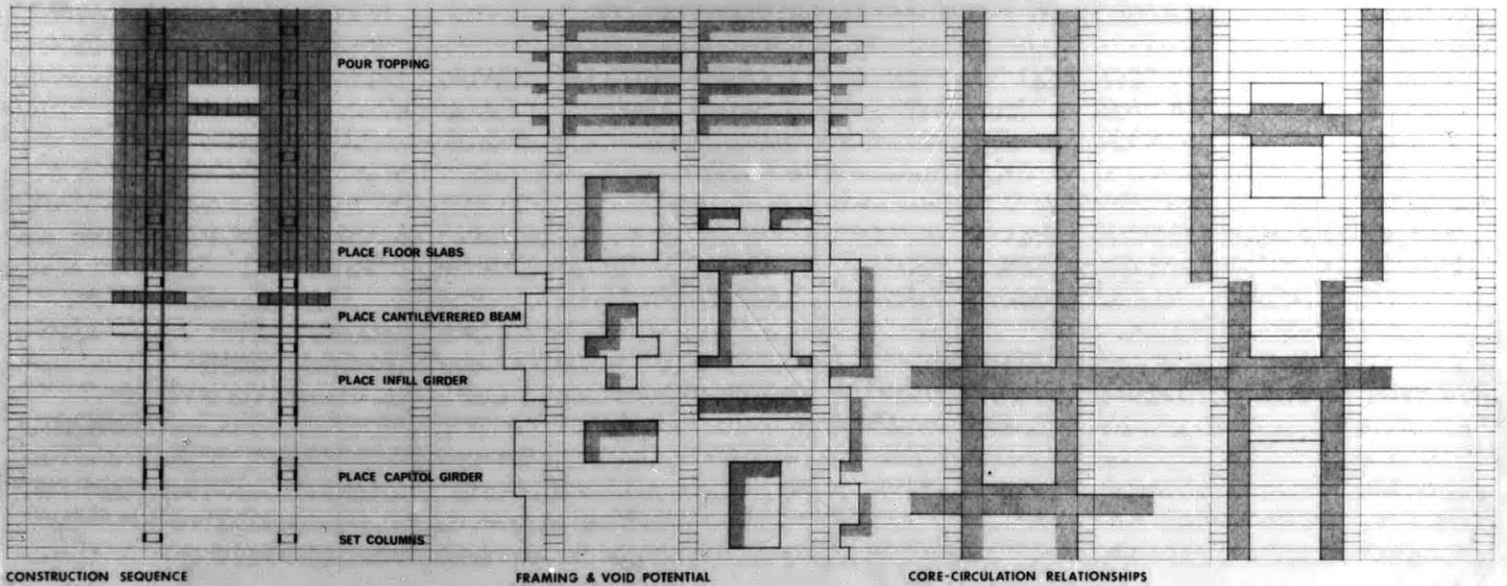
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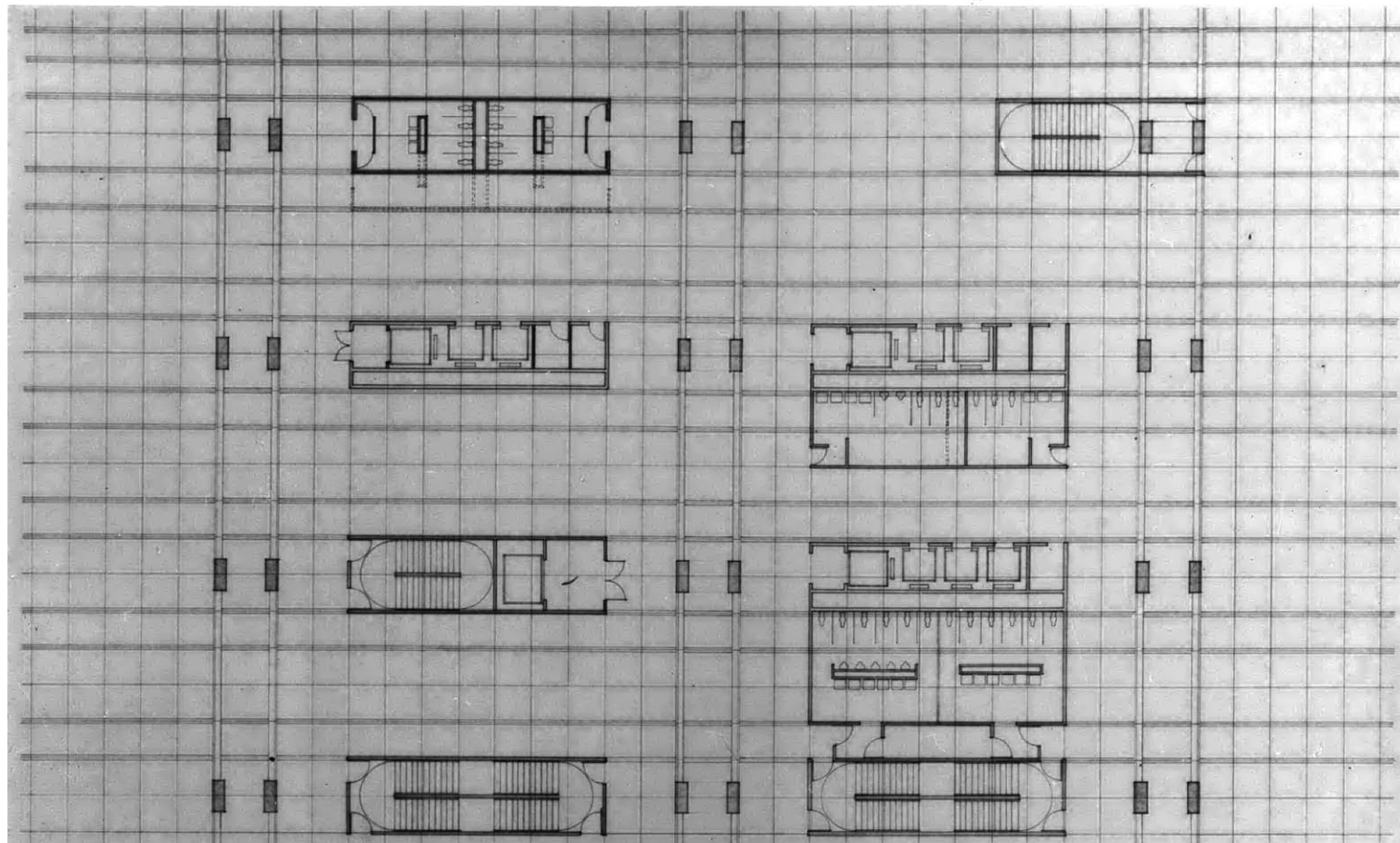
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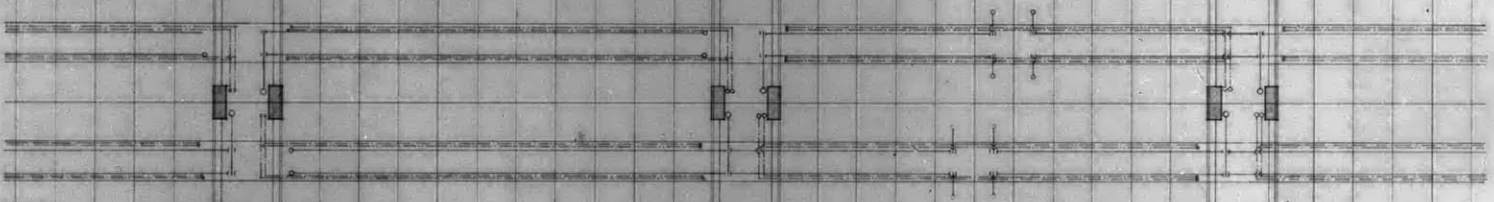
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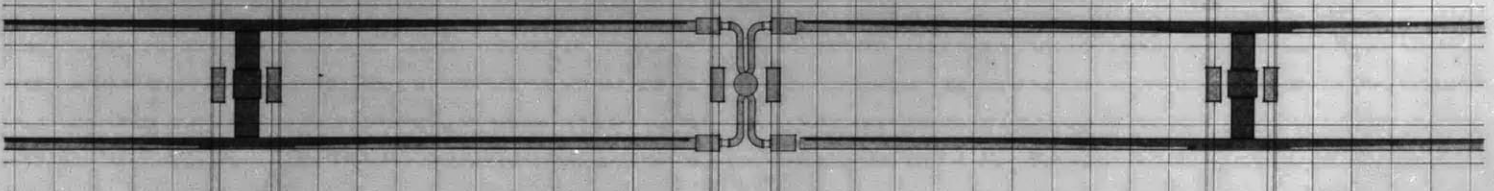


CORE COMPONENTS

CORES



PIPING

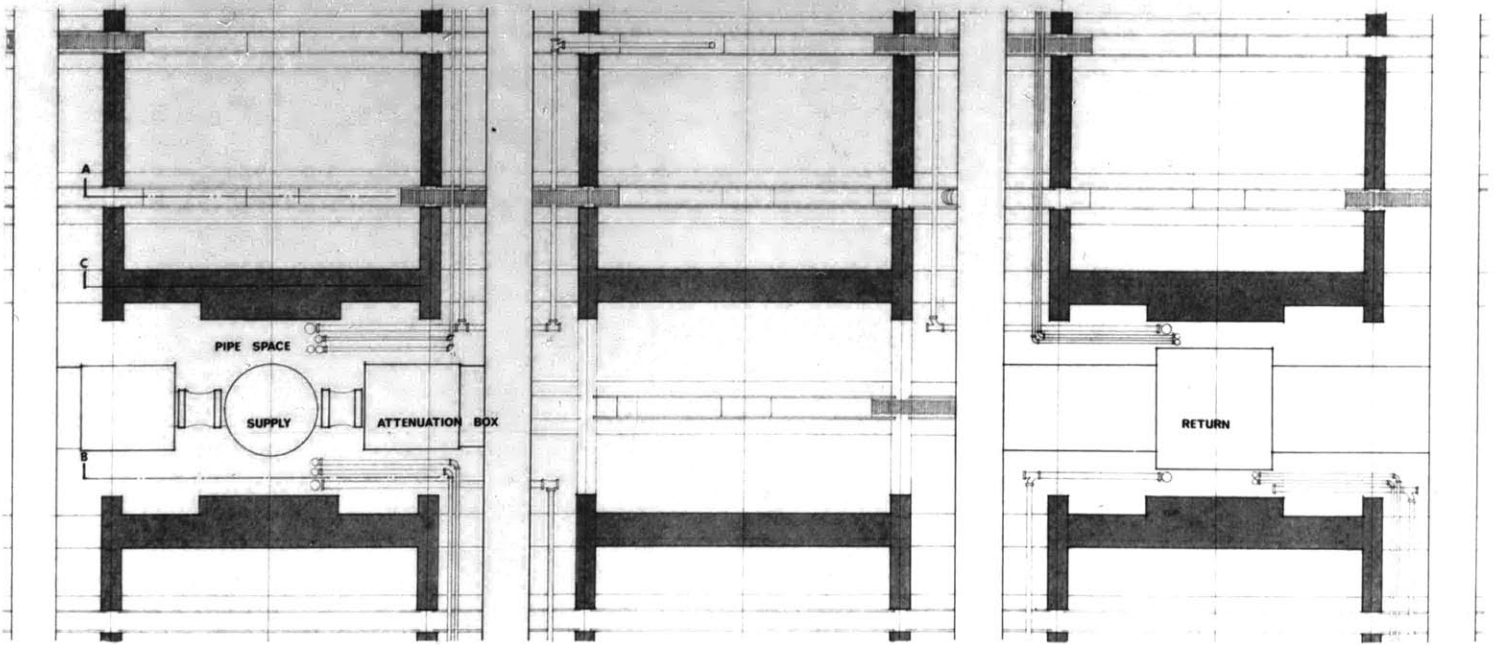
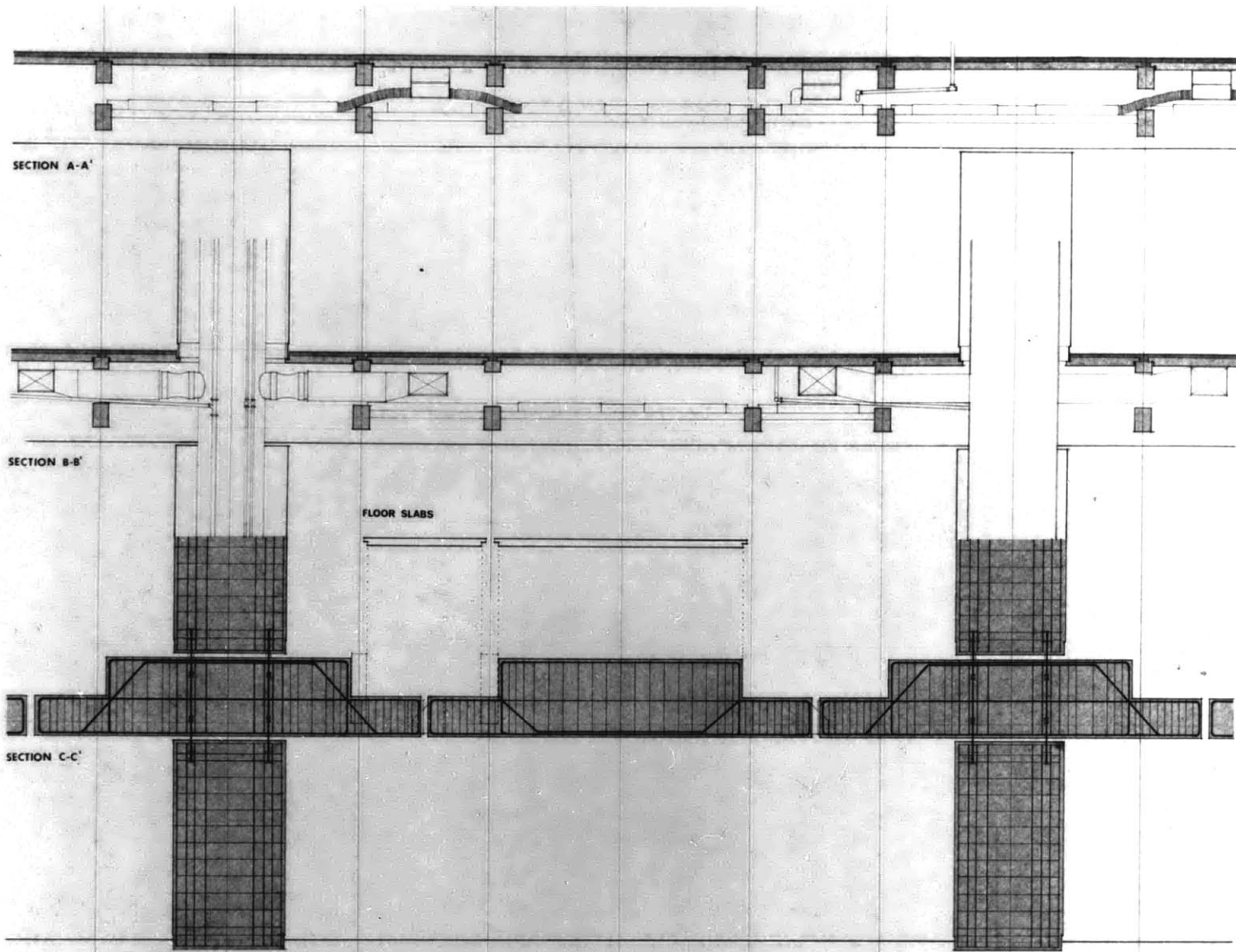


AIR DISTRIBUTION

ENVIRONMENTAL SERVICES

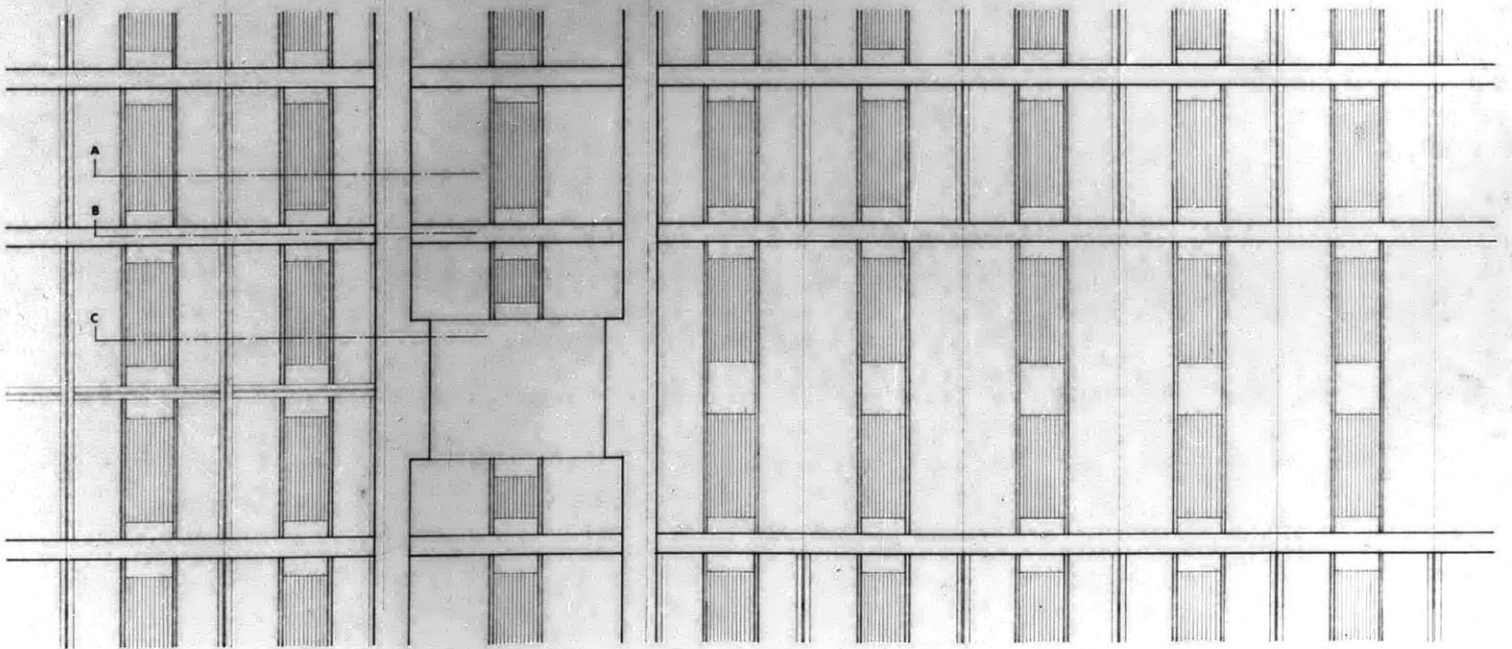
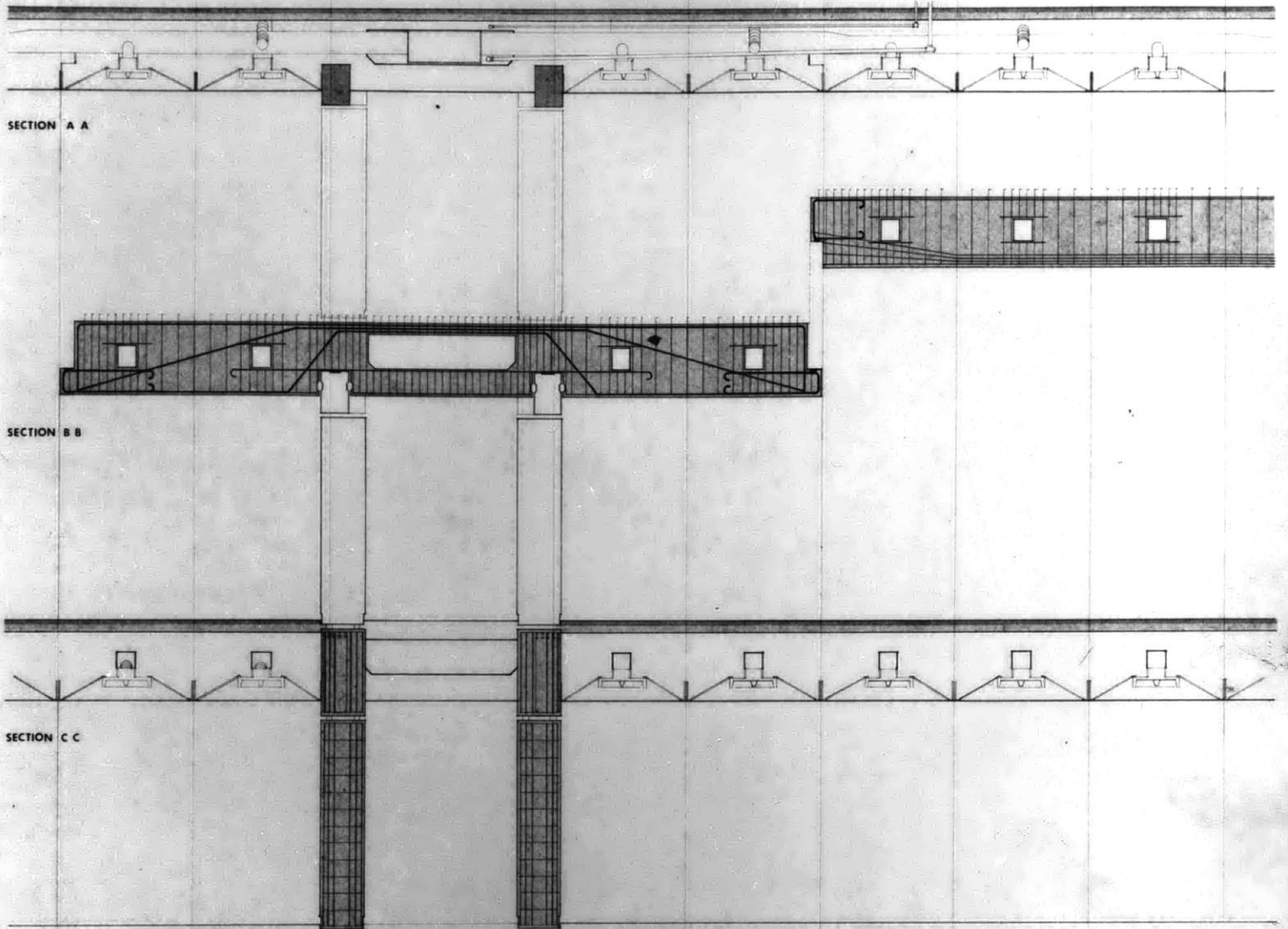
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MECHANICAL PLAN

STRUCTURAL - MECHANICAL SECTIONS

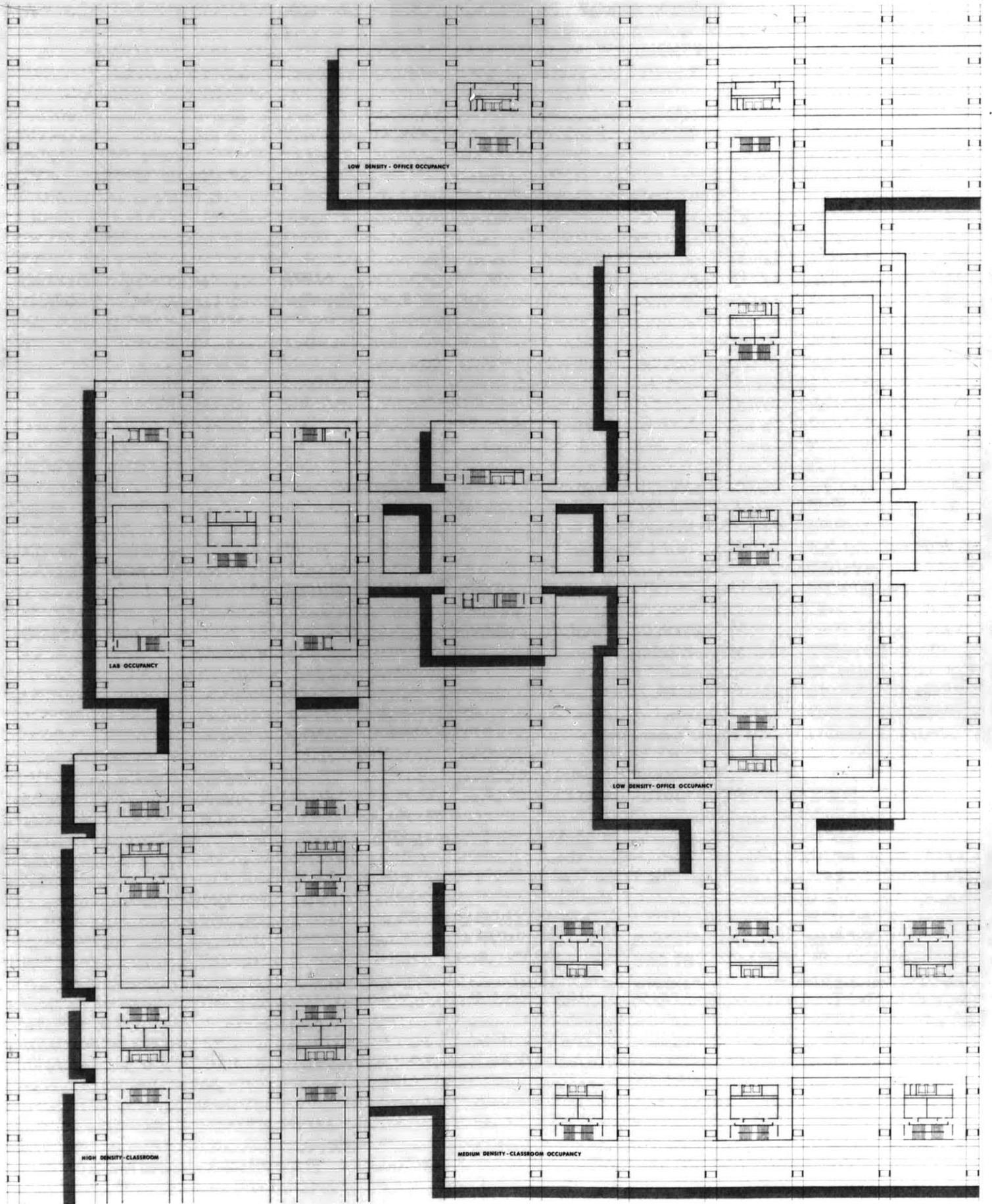


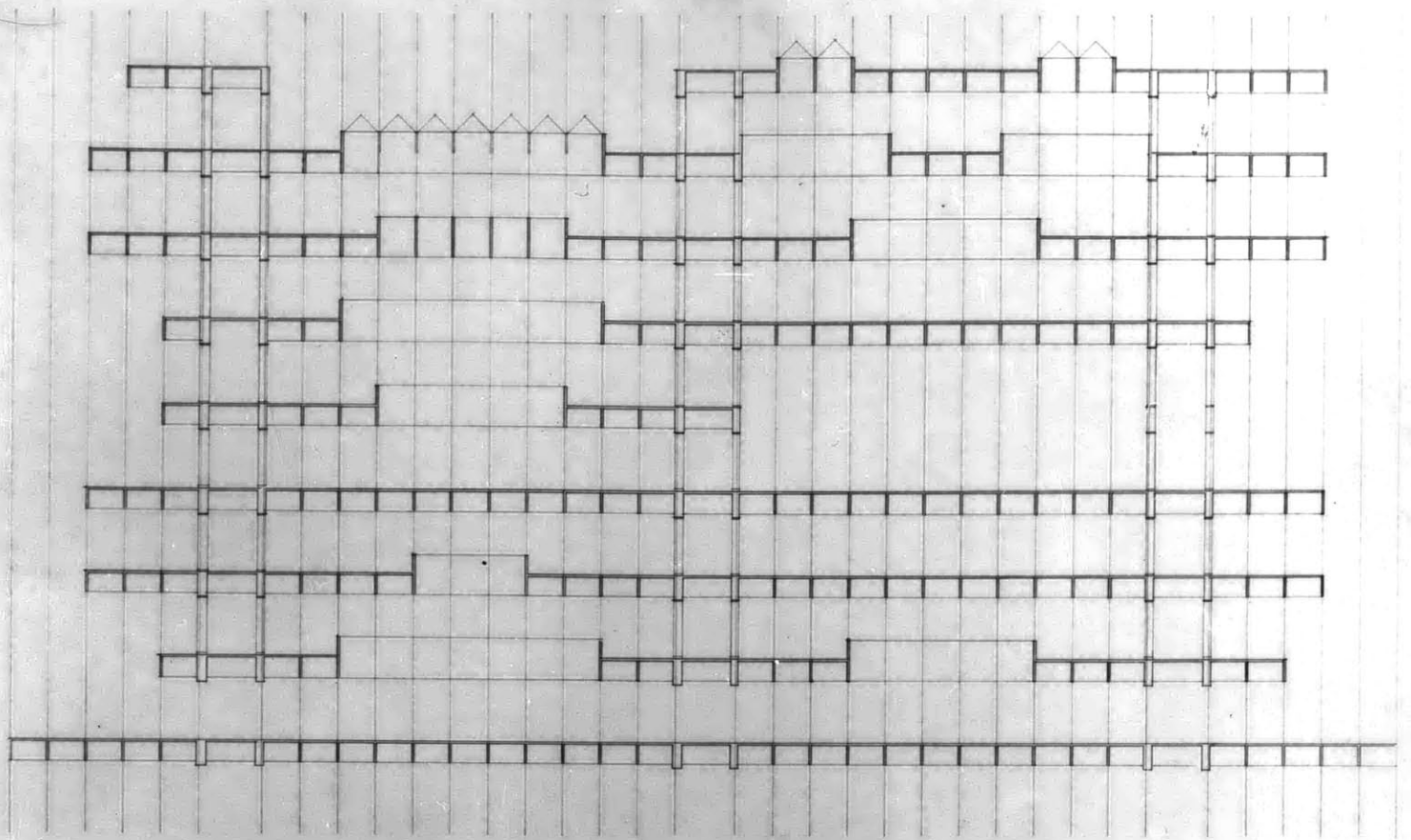
REFLECTED CEILING PLAN

STRUCTURAL - MECHANICAL SECTIONS

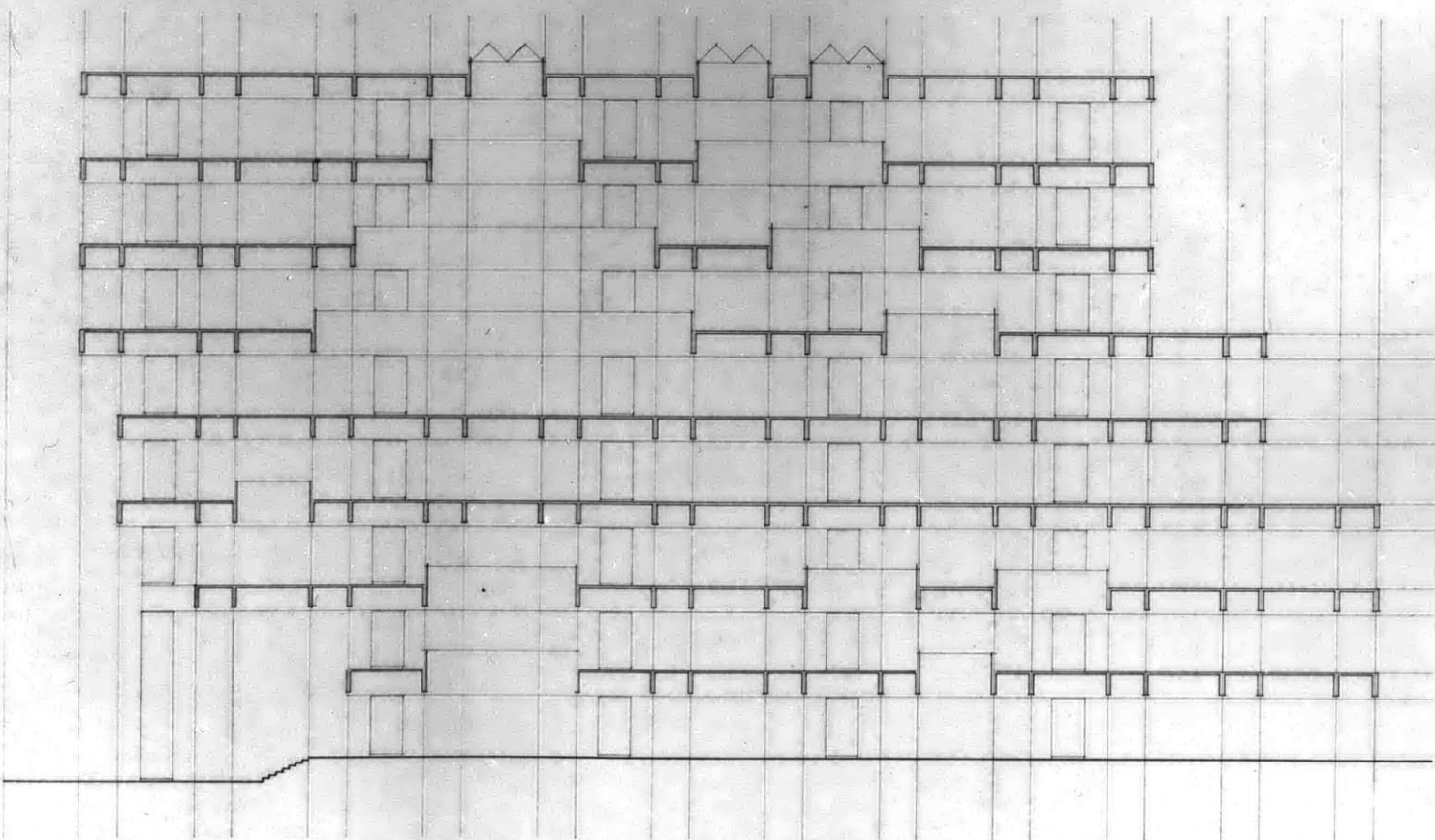
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LONGITUDINAL SECTION



TRANSVERSE SECTION

SECTION VARIATIONS

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