BUILDING AS A SYSTEM

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 As A System "

Respectfully,

Isao Komatsuzawa

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THE AIM AND APPROACH OF THIS THESIS

THE AIM OF THIS THESIS IS 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 DEFIND.

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-EFFICIENCY OF EACH FOOTPRINT.

THEREFORE, THE SYSTEM WILL HAVE TO PROVIDE FOR MAXIMUM FLEXIBILITY IN INITIAL USE AND THE ADAPTABILITY TO CHANGING FUTURE USE THROUGH THE DEVELOPMENT OF LARGE UNINTERRUPTED FLOOR AREAS MODULALLY ORDERED FOR SUBDIVISION BASED ON CONSIDERATION OF OPTIMUM SPACE SIZE AND ENVIRONMENTAL CONTROL. IT WILL ALSO HAVE TO PROVIDE FOR SYSTEMATIC GROWTH OF BUILDING THROUGH GEOMETRIC ARTICULATION OF SPACE AND CONSTRUCTION TECHNIQUE.

IN ORDER TO MEET THESE REQUIREMENTS, THE MOST ADVANCED TECHNOLOGY AVAILABLE SHOULD BE CONSIDERED.

FOOTPRINT

(A) AS A GROWTH SYSTEM

TO SATISFY CONDITIONS OF GROWTH, THE FOOTPRINT TO BE DESIGNED SHOULD ACCOMPLISH THE FOLLOWING GENERAL OBJECTIVES:

(1) IN ORDER TO HAVE THE CAPACITY TO FACILITATE BUILDING GROWTH, A FOOTPRINT SHOULD BE SMALL ENOUGH, TO BE SELF-SUFFICIENT IN STRUCTURE, MECHANICAL DISTRIBUTION AND CIRCULATION.

(2) THE CIRCULAR EXPANSION SYSTEM IS A BETTER SOLUTION BECAUSE OF ITS POSSIBILITY TO EXPAND IN BOTH ORTHOGONAL AND DIAGONAL DIRECTIONS BASED ON THE CONDITION OF VARIOUS SITES.

(3) A MODULAR APPROACH TO SYSTEMS DESIGN IN ARCHITECTURE IS ADVANTAGEOUS NOT ONLY IN TERMS OF BUILDING GROWTH AND EXPANSION, BUT ALSO IN TERMS OF PARTITION DESIGN, PLANNING FLEXIBILITY, AND STANDARDIZATION OF STRUCTURAL ELEMENTS FOR MASS PRODUCTION.

(SEE DRAWING 1, 2 AND PHOTOGRAPHS)

(B) FOOTPRINT DIMENSION

THE FOOTPRINT IS COMPOSED OF FOUR STRUCTURAL UNITS, A MULTIPURPOSE CORE INCLUDING THE MAIN HORIZONTAL CIRCULATION, AND FOUR FIRESTAIRS.

EACH STRUCTURAL UNIT IS INDEPENDENT FROM THE OTHER BECAUSE OF THE SIMPLIFICATION OF STRUCTURAL CONDITIONS,

AND EACH UNIT IS COMPOSED OF A SLAB WITH FOUR COLUMNS. EACH UNIT HAS NORMALLY 10,000 SQUARE FEET OF FLOOR AREA CONSISTING OF A 60 FOOT SPAN AND A 20 FOOT CANTILEVER IN EACH DIRECTION.

LARGER SPANS CAN PROVIDE FOR GREATER FLEXIBILITY IN USE, BUT THEY ARE LIMITED BY ECONOMY AND STRUCTURAL TECHNOLOGY. ALTHOUGH THE SPAN OF 60 FEET IS QUITE LARGE, THE METHOD OF PRESTRESSING EMPLOYED HAS MADE IT POSSIBLE TO MAINTAIN A REASONABLY ECONOMICAL STRUCTURAL SECTION. THIS SPAN AND CANTILEVER COMBINATION GIVES A POSSIBILITY TO PROVIDE LARGE SPACES SUCH AS AUDITRIUMS AND LECTURE ROOMS, BECAUSE THE LARGEST FREE COLUMN SPACE IS 60 FEET BY 100 FEET WITHIN A SINGLE FOOTPRINT AND 60 FEET BY 200 FEET WHEN TWO FOOTPRINTS ARE COMBINED.

ALTHOUGH THE 20 FOOT CANTILEVER COMBINED WITH A 60 FOOT BAY DOES NOT REPRESENT AN OPTIMUM STRUCTURAL CONDITION, IT DOES PROVIDE A FUNCTIONALLY VALUABLE SPACE BETWEEN THE COLUMN LINE AND THE BUILDING PERIMETER. THIS SPACE MAY BE ORGANIZED WITH A 15 FOOT ROOM DIMENSION AND 5 FOOT BALUCONY OR SUNSHADE OR SIMPLY A20 FOOT ROOM DIMENSION.

THE 5 FOOT SUNSHADE CAN BE VERY INFLUENTIAL IN REDUCING PERIMETER MECHANICAL LOADS.

IN ORDER TO SATISFY THE REQUIREMENT FOR DIFFERENT SPATIAL QUALITIES AND CHARACTISTIES, THE SYSTEM USED PROVIDES THE OPTION OF A FLOOR PLANE WHICH IS SUPPORTED BY TWO COLUMNS ONLY, ALLOWING FOR MULTISTORY SPACES AND MEZANINES. THIS CANTILEVER PORTION USES EXACTLY THE SAME PRECAST MEMBERS

AND ERECTION PROCEDURE AS IS USED IN NORMAL CONSTRUCTION. THE DIMENSION OF THIS SPACE IS 40 FEET BY 100 FEET.

THE BASIC HEIGHT OF CEILING IS 14 FEET AND DOUBLE OR TRIPLE HEIGHT SPACES CAN BE CREATED WITHOUT ANY CHANGES IN THE STRUCTURAL AND MECHANICAL SYSTEMS.

THE POSSIBILITY OF ACHIEVING VARIOUS BUILDING SECTIONS AND GROWTH ARE SHOWN IN THE PHOTOGRAPHS OF THE MODELS INCLUDED WITHIN THE REPORT.

THEREFORE, EACH FLOOR OF A FOOTPRINT HAS 48,000 SQUARE FEET CONSISTING OF 40,000 SQUARE FEET OF FLOOR AREA AND 6,400 SQUARE FEET OF MULTIPURPOSE CORE AND 2,400 SQUARE FEET OF FOUR FIRESTAIRS.

(C) MODULAR SYSTEM

THE BEST MODULAR SYSTEM WAS TO HAVE THE SAME DIMENSION FOR PARTITIONING, MECHANICAL EQUIPMENT AND STRUCTURE; BUT SUCH AN IDEAL SYSTEM COULD NOT ECONOMICALLY BE ESTABLISHED, BECAUSE, WHILE SMALLER DIMENSIONS ARE MORE FLEXIBLE FOR PARTITIONING, THE MECHANICAL EQUIPMENT, SUCH AS LIGHTING FIXTURES AND AIR DEFFUSERS, AND STRUCTURE REQUIRES LARGER DIMENSIONS.

IN THIS PROGRAM, IT WAS ADVISABLE TO PROVIDE THE POSSIBILITY OF HAVING THE SMALLEST ROOM SIZE 10 FEET BY 10 FEET WITH 5 FEET FOR THE SMALLEST WIDTH FOR SECONDARY CIRCULATION. MANY DIFFERENT ROOM SIZES COULD BE OBTAINED BY USING A 5 FOOT MODULE, AND A FOUR FOOT FLUORESCENT FIXTURE, WHICH REPRESENTS AN ECONOMICAL INSTALLATION, COULD BE INSTALLED IN THE 5 FOOT SQUARE MODULE CONVENIENTLY.

ALTHOUGH THE 5 FOOT MODULE WAS MORE CONVENIENT IN TERMS OF LIGHTING AND PARTITIONING, THE 10 FOOT MODULE WAS SELECTED BECAUSE OF SUBSTANTIAL ADVANTAGES IN TERMS OF REDUCTION OF JOINTS, EFFECIENCY OF STRUCTURE, AND ACCOMODATION OF THE INTEGRATED MECHANICAL EQUIPMENT.

(D) CORE SYSTEM

THE CORES PROVIDE NOT ONLY THE UTILITY SERVICE AND VERTICAL CIRCULATION OF PEOPLE AND MECHANICAL SERVICES; BUT THEY ALSO DEFINE THE CENTER OF ACTIVITY AND THE HORIZONTAL CIRCULATION.

THEREFORE, THE CORE IS LOCATED AT THE CENTER OF EACH FOOTPRINT.

THE DIMENSION OF THE CORE IS 80 FEET BY 80 FEET, CONSISTING OF TWO TOILET ROOMS, TWO PASSENGER ELEVATORS, A FLEIGHT ELEVATOR WITH A STORAGE ROOM, A JANITOR'S ROOM, TWO TELEPHONE CLOSETS, TWO ELECTORICAL CLOSETS, TWO MAIN VERTICAL DUCTS FOR AIR-CONDITIONING, FOUR MAIN VERTICAL PIPE CLOSETS,AND TWO SPACES FOR PUBLIC TELEPHONE BOOTHS AND VENDING MACHINES WHERE REQUIRED.

A 15 FOOT MAIN CORRIDOR IS LOCATED AT THE PERIMETER OF THESE FACILITIES.

(1) FIRESTAIRS

ACCORDING TO THE CODE PREPARED BY THE NATIONAL FIRE PROTECTION ASSOCIATION, THE WIDTH OF FIRESTAIRS SHALL BE MEASURED IN UNITS, AND THE NUMBER OF UNITS ARE BASED ON THE OCCUPANCY OF AN ENTIRE FLOOR. THE OCCUPANCY SHALL BE DETERMIND ON THE BASIS OF 60 SQUARE FEET PER PERSON, WITH

ONE UNIT OF EXIT WIDTH BEING 22 INCHES. THE CODE ALSO REQUIRES THAT FOR OPEN PLAN BUILDINGS (CLASS D) THESE FIRESTAIRS SHALL BE WITHIN 125 FEET OF ANY POINT IN ANY ROOM.

AS A RESULT OF THE CODE REQUIREMENTS, EACH FLOOR OF A FOOTPRINT SHOULD HAVE NOT LESS THAN 12 UNITS OF FIRE-STAIRS, AND THEY ARE DIVIDED INTO FOUR THREE-UNIT ELEMENTS, WHICH ARE ORIENTED TO THE OUTSIDE TO TAKE ADVANTAGE OF NATURAL LIGHT IN THE EVENT OF ELECTRICAL FAILURE.

(2) TOILET

THE NUMBER OF WATER CLOSETS, URINALS AND LAVATORIES IS BASED ON THE ASSUMED OCCUPANCY OF EACH FLOOR. THE ASSUMPTION FOR CALCULATION OF THIS OCCUPANCY IS BASED ON 150 SQUARE FEET PER PERSON, WITH 50 PER CENT MALE AND 50 PER CENT FEMALE OCCUPANCY. THE TOTAL NUMBER OF FIXTURES FOR EACH FLOOR OF A FOOTPRINT SHOULD BE NOT LESS THAN:

	MEN	WOMEN
WATER CLOSETS	5	6
URINALS	2	-
LAVATORIES	4	4

(ACCORDING TO GRAPHIC STANDARD)

EACH CORE HAS TWO TOILET ROOMS, ONE FOR MEN AND ONE FORE WOMEN.

THE PARTITION BETWEEN THE TWO TOILET ROOMS CAN BE ADJUSTED TO ACCOMODATE ANY VARIATION IN THE PBOPORTION OF

MEN TO WOMEN OCCUPANTS.

(3) ELEVATORS.

ONE PASSENGER ELEVATOR WAS REQUIRED IN EACH FOOTPRINT ACCORDING TO CALCULATION BASED ON THE OCCUPANCY OF A FOOTPRINT, HOWEVER, IT WAS FELT TO BE ADVISABLE TO HAVE AT LEAST TWO ELEVATORS SIDE BY SIDE IN TERMS OF CONVENIENCE. THE CAR DIMENSION EACH ELEVATOR IS 5 FEET BY 7 FEET WITH A SPEED OF 350 FEET PER MINUTE.

ONE FLEIGHT ELEVATOR WITH FRONT DOOR OPENING WAS PROVIDED IN EACH FOOTPRINT. WHEN NOT REQUIRED, THE SPACE FOR THE ELEVATOR COULD BE COMBINED WITH THE STORAGE ROOM. THE CAR DIMENSION IS 6 FEET BY 8FEET WITH A SPEED OF 250FEET PER MINUTE.

(4) HORIZONTAL CIRCULATION

THE PRIMARY HORIZONTAL CIRCULATION OCCURS AROUND THE MULTIPURPOSE CORE WITHIN A 15 FOOT DIMENSION. THE CORRIDOR USED AS THE CENTER OF CIRCULATION FOR EACH UNIT; AND WAS USED FOR THE PLENUM SPACE ABOVE ITS HUNG CEILING FOR THE MAIN HORIZONTAL MECHANICAL DISTRIBUTION, LEADIND TO THE SECONDARY BRANCHES.

ALL OTHER CORRIDOR SPACES ARE DIMENSIONED AT EITHER 5 FEET OR 10 FEET ON THE BASIS OF CODE AND PLANNING REQUIREMENTS.

(SEE DRAWING 1)

STRUCTURAL SYSTEM

(A) INTEGRATION OF MECHANICAL AND STRUCTURAL SYSTEMS

THE TREND IN ARCHITECTURE TODAY IS TO INTEGRATE THE OVERALL PLANNING AND STRUCTURAL SYSTEM INTO THE MECHANICAL DISTRIBUTION SYSTEMS. THERE ARE MANY STRUCTURAL FLOOR SYSTEMS PRESENTLY AVAILABLE THAT PROVIDE FOR MECHANICAL DISTRIBUTION THROUGH STEEL, PRECAST CONCRETE, OR PREFORMED MEMBERS. SUCH DISTRIBUTION CAN EFFECTIVELY REDUCE MECHANICAL SPACE REQUIREMENTS, ESPECIALLY FLOOR-TO-FLOOR HEIGHT.

THEREFORE, THE STRUCTURAL VOID SYSTEM WAS SELECTED IN THIS THESIS.

(B) TWO-WAY SYSTEM

THE TWO BASIC CHOICES IN STRUCTURAL SYSTEMS ARE ONE-WAY AND TWO-WAY. IT IS HARD TO DEFINE WHICH REPRESENTS A BETTER SOLUTION.

IN THIS THESIS, THE TWO-WAY SYSTEM WAS CHOSEN FOR THE FOLLOWING REASONS;

(1) IN TERMS OF GROWTH, TWO-WAY SYSTEM HAS THE ADAPTABILITY TO EXOAND IN TWO DIRECTIONS WITH PERFECTLY EQUAL CONDITIONS.

(2) IN TERMS OF FLEXIBILITY IN THE PLANNING OF SPACES, THE MAXIMUM COLUMN FREE AREAS CAN BE DESIGNED IN TWO DIRECTIONS WITH CONSTANT CEILING HEIGHT.

(3) IN THE CASE OF CONCENTRATED LIVE LOADS WHICH WERE NOT EXPECTED BEFORE DESIGN, THE TWO-WAY SYSTEM IS SAFER THAN THE ONE-WAY SYSTEM, BECAUSE THE FORCE WILL BE TRANSMITED IN TWO DIRECTIONS.

(4) MECHANICAL DISTRIBUTION IS MADE MORE FLEXIBLE BY USING A TWO DIRECTIONAL VOID SYSTEM.

SOME OF THE DISADVANTAGES OF THE TWO-WAY SYSTEM, HOWEVER, ARE; TOO MANY JOINTS AND COMPLEXITY IN CONSTRUCTION.

(C) MATERIALS

PRECAST CONCRETE WAS SELECTED INSTEAD OF CAST-IN-PLACE WITH THE EXCEPTION OF THE COLUMN CAPITALS BECAUSE OF THE FOLLOWING ADVANTAGES;

(1) ERECTION SPEED IS EFFECTIVELY INCREASED.

(2) THE NUMBER OF CONSTRUCTION WORKERS REQUIRED IS REDUCED.

(3) ECONOMY IN MOULDING IS ACHIEVED ESPECIALLY FOR THE TYPE COMPLICATED SHAPES WHICH BEST FACILITATE THE PASSAGE OF MECHANICAL EQUIPMENT.

(4) A REDUCTION IN SCAFFOLDING IS ACHIEVED.

(5) THE PRODUCTION OF PRECAST MEMBERS IN THE FACTORY IS ON A 24 HOUR BASIS AND INDEPENDENT OF WEATHER CONDITIONS.

(6) FACTORY CONTROL OF MATERIALS, PLACEMENT OF REINFORCEMENT AND CONTROLLED CURING ASSURES HIGHER QUALITY AND BETTER SURFACE CONTROL.

THERE ARE ALSO SOME INHERENT DISADVANTAGES IN PRECAST CONCRETE. THEREFORE, SOME DEVICES ARE REQUIRED TO SOLVE THESE PROBLEMS.

(D) THE BASIC STRUCTURAL UNIT

THE BASIC STRUCTURAL UNIT IS COMPOSED OF A SLAB AND FOUR COLUMNS, INDEPENDENT FROM THE OTHER STRUCTURAL UNITS.

THE FLOOR SYSTEM DESIGNED WAS A TWO-WAY ORTHOGONAL GRID WITH PERFORATIONS IN THE VERTICAL MEMBERS. THE SLAB IS NORMALLY A PLATE 100 FEET LONG ON EACH SIDE AND EQUALLY STRESSED BOTH WAYS, THE PLATE RESTS ON SUPPORTS LOCATED AT THE FOUR CORNERS OF A SQUARE 60 FEET ON A SIDE AND 20 FEET FROM THE PERIPHERY. THE EFFECTIVE DEPTH IS 3 FEET 6 INCHES INCLUDING A $2^{1/2}$ INCH TOPPING SLAB. THE BASIC FLOOR-TO-FLOOR HEIGHT IS 14 FEET.

FOR THE STRUCTURAL MODULE, A 10 FOOT MODULE WAS SELECTED. THE REASONS WERE THAT, THE NUMBER OF CRITICAL JOINTS COULD BE REDUCED, AND IT WAS MORE FLEXIBLE TO DISTRIBUTE MECHANICAL SERVICES, AND IT WAS EASIER TO INSTALL MECHANICAL EQUIPMENTS.

(E) <u>PRECAST MEMBERS</u>

(1) COLUMNS

EACH PRECAST COLUMN HAS AN OCTAGONAL SECTION AND A LENGTH OF 14 FEET. A DIAMETER OF 4 FEET WAS SELECTED BECAUSE OF NOT ONLY THE OCCURRENCE OF LARGE BENDING MOMENTS BY THE ECCENTRIC LOADS OR WIND FORCES IN THE COLUMNS, BUT ALSO TAKING THE PHYCHOLOGICAL EFFECTS ON LARGE CANTILEVERS INTO CONSIDERATION. BUT IT IS TOO LARGE FOR COMPRESSION SO THAT EACH COLUMN HAS A VERTICAL HOLE WITH A DIAMETER OF ONE FOOT FOR RAIN DRAIN.

IN ORDER TO STAND COLUMNS STRAIGHT, FOUR TURNBUCKLES BETWEEN TWO COLUMNS CAN BE USED.

FOUR CONTINIOUS PRESTRESSING CABLES RUN FROM THE FOOTING TO THE ROOF WITHIN THE COLUMNS USING GROOVES FOR PARTITIONS.

(2) SLABS

THE SLAB STRUCTURE WAS COMPOSED OF THE PRECAST VERTICAL MEMBERS CONSISTING OF FOUR DIFFERENT SIZES AND SHAPES, THE PRECAST SLAB PANELS AND THE TOPPING SLAB. THE DIMENSION OF THESE MEMBERS WERE DETERMINED ON THE BASIS OF THE TRANSPORTATION PROBLEM, THE CONSTRUCTION TECHNIQUE, THE REQUIREMENTS OF SPATIAL QUALITIS AND THE ANALYSIS OF THE STRUCTURE SYSTEM. BOTH THE VERTICAL MEMBERS AND THE SLAB PANELS ARE SO PLANE THAT IT IS POSSIBLE TO TRANSPORT THEM WITH THE MAXIMUM CARRYING CAPACITY OF TRUCKS AND ALSO TO REDUCE THE REQUIRED SPACES TO KEEP THEM AT A SITE. THE HEAVIEST MEMBERS, THE 40 FOOT VERTICAL MEMBERS, ARE APPROXIMATELY 9 KIP. ACCORDING TO THE CALCULATION, THERE IS NO PRO-BLEM TO LIFT THEM UP BY A CRANE, EVEN DURING ERECTION THEIR EFFECTIVE STRUCTURAL DEPTH IS 1 FEET 4 INCHES. IN TERMS OF SATISFACTION TO THE SPATIAL QUALITY REQUIREMENTS, THESE STRUCTURAL COMPONENTS PROVIDE ENOUGH FLEXIBILITY TO CREATE THE INTERESTING SPACES.

THE SLAB PA NELS OF A SQUARE 9 FEET 7 INCHES WITH A THICKNESS OF 3.5 INCHES ARE PLACED ON THE VERTICAL MEMBERS. THE CONTINUITY OF THESE PRECAST MENBERS IS PROVIDED BY THE CONCRETE OF THE TOPPING AND REINFORCING STEELS PLACED WITHIN THE 5 INCH WIDE GROOVES BETWEEN THE SLAB PANELS.

IT WAS ADVISABLE TO AVOID VIERENDEEL TRUSSES IN TERMS OF THE STRUCTURAL INEFFECIENCY. THEREFORE, THE VERTICAL MEMBERS WERE REINFORCED DIAGONALLY AND HORIZONTALLY IN ORDER TO BE ABLE TO ACT IN A MORE TRUSS-LIKE MANNER, PROVIDING ENOUGH OPENING SIZE FOR MECHANICAL DISTRIBUTION.

THE TWO-WAY SYSTEM CAN BE PROVIDED BY THE COMBINATION OF THE LOWER CHORD MEMBERS AND THE UPPER CHORD MEMBERS . THE LOWER CHORD MEMBERS HAVE THE CONTINUITY IN THEMSELVES AT THE LOWER PART OF THE MEMBERS, SO DO THE UPPER CHORD MEMBERS. THE MUTUALPPOSITION CAN BE DETERMINED ON THE BASIS OF CONDITIONS OF POSITIVE OR NEGATIVE BENDING MOMENTS.

(3) MEMBERS FOR PARTITIONING

AS A RESULT OF THE 10 FOOT MODULE FOR STRUCTURE, SOME ADDITIONAL MEMBERS WERE REQUIRED IN ORDER TO PROVIDE THE 5 FOOT MODULE FOR PARTITIONING. THE CROSS MEMBERS WERE DESIGNED, AND LIGHT-WEIGHT CONCRETE WAS SELECTED AS THE MATERIAL, BECAUSE THEY ARE NOT THE STRUCTURAL COMPONENTS. THE JOINTS WITH THE STRUCTURAL MEMBERS ARE NOT SO CRITICAL THAT AN EASY JOINT WITH A SIMPLE FIRE-PROOFING COULD BE CONSIDERED.

THE MEMBERS FOR PARTITIONING NOT ONLY PROVIVE THE PARTITIONING MODULE, BUT ALSO MAKE

IT POSSIBLE TO PROVIDE THE SECONDARY MECHANICAL DISTRIBUTION WITHIN THE PARTITIONS THROUGH THE VERTICAL PERFORATIONS WITHIN THEM.

(F) STRUCTURAL ANALYSIS

THE STRUCTURE IS ANALYZED AS A FLAT SLAB AT THE FIRST STAGE. THE ANALYSIS PRESENTED IS NOT INTEND TO BE FINELY DETAILED,BUT RATHER TO INDICATE THE ACTION OF THE FLOOR.

ERECTION PROCEDURE

THE FOLLOWING IS THE ELECTION SEQUENCE;

(1) PLACEMENT OF FOOTINGS, FOUNDATIONS, BASEMENT.

(2) CORE ERECTED INDEPENDENTLY OF FLOORS.

(3) PLACEMENT OF COLUMNS OF ONE FLOOR HEIGHT.

(4) ERECTION OF SCAFFOLDING.

(5) PLACEMENT OF 40 FOOT PRECAST LOWER CHORD MEMBERS ON THE SCAFFOLDING.

(6) PLACEMENT OF 40 FOOT PRECAST UPPER CHORD MEMBERS.

(7) GROUTING OF ALL JOINTS WITH EXPANSION MORTAR.

(8) POST-TENSIONING OVER THE UPPER CHORD MEMBERS.

(9) PLACEMENT OF COLUMNS OF NEXT FLOOR HEIGHT.

(10) PLACEMENT OF STEEL REINFORCING AT THE COLUMN CAPITALS.

(11) POURING OF COLUMN CAPITALS.

(12) PLACEMENT OF 20 FEET UPPER CHORD MEMBERS AT CENTER SECTIONS.

(13) PLACEMENT OF 40 FOOT UPPER CHORD MEMBERS AT CENTER SECTIONS.

(14) FILLING OF ALL JOINTS WITH MORTAR.

(15) PLACEMENT OF CROSS MEMBERS FOR PARTITIONING.

(16) PLACEMENT OF STEEL REINFORCING WITHIN THE GROOVES BETWEEN SLAB PANELS.

(17) PLACEMENT OF ANY MECHANICAL EQUIPMENT, ELECTRICAL RACEWAYS AND THE LIKE WHICH ARE REQUIRED IN THE SLAB.

(18) POURING OF TOPPING SLAB.

(19) REPETITION OF PROCEDURE FROM (3) TO (18)

(SEE DRAWINGS NO.3 AND NO.4, AND THE PHOTOGRAPHS OF STRUCTURAL MODEL)

MECHANICAL SYSTEM

(A) AIR-CONDITIONING SYSTEM

MANY AIR-CONDITIONING SYSTEMS ARE AVAILABLE FOR ARCHITECTURAL DESIGN.

GENERALLY, THE MOST EFFECTIVE WAY TO CONTROL SPACE TEMPERATURE IS TO SUPPLY A CONSTANT VOLUME OF AIR, WHILE VARYING THE AIR TEMPERATURE AND HUMIDITY CONTENT IN ACCORDANCE WITH THE DEMANDS OF CHANGING INTERIOR AND EXTERIOR LOADS.

THE SIMPLER ONE-DUCT AIR SYSTEMS, WHICH REQUIRE A LARGE AMOUNT OF SPACE, ARE NOT CAPABLE OF SERVISING A GREAT NUMBER OF SMALL ZONES. BECAUSE OF THE LOW PRESSURES AVAILABLE, AND THE LARGE DUCT SIZE; THE LENGTH OF DUCT SYSTEMS, IS RELATIVELY SHORT AND ACOUSTICAL TRANSMISSION IS PROPAGATED. THIS TYPE OF SYSTEM CAN SUPPLY THE TOTAL REQUIREMENTS OF ONLY A SMALL AND SIMPLE BUILDING. MULTIPLICITY OF THESE SYSTEMS FOR A LARGER, MORE COMPLEX BUILDING RESULTS IN A MAZE OF MECHANICAL DIVICES REQUIRING MAINTENANCE AND LARGE SPACE REQUIREMENT. THE ONE-DUCT SYSTEM USING HIGHER PRESSURES TO INCREASE VELOCITY AND REDUCE DUCT SIZE, GENERALLY WITH VARYING VOLUME CONTROL, ATTEMPT TO OVERCOME THOSE DISADVANTAGES. THEY ARE, HOWEVER, LIMITED MAINLY TO INTERIOR SPACES HAVING NO HEATING REQUIREMENTS. THE PROBLEM WITH VOLUME CONTROL IS THAT IN PERIMETER ZONES REQUIRING HEAT, MAXIMUM HEATING EFFECT OCCURS CONCURRENTLY WITH MAXIMUM VENTILATION EFFECT; THEREFORE, AS HEATING REQUIREMENTS

DIMINISH, SO DOES AIR VOLUME AND VENTILATION. THE REASON FOR LESS HEAT REQUIREMENT IS USUALLY INCREASED POPULATION OR SOLAR PENETRATION., SO THAT REDUCTION IN VENTILATION RATE UNDER THESE CONDITIONS IS OPPOSITE TO THE EFFECT DESIRED. FOR COOLING-ONLY SPACES, HOWEVER, THE VARYING VOLUME SYSTEMS HAVE GREAT MERIT.

THE TWO-DUCT SYSTEMS USUALLY ORIGINATE FROM A HIGH-PRESSURE FAN. TWO HIGH-VELOCITY DUCTS CARRY COLD AND HOT AIR TO POINTS OF USE. FINAL CONTROL FOR AN INDIVIDUAL ZONE, WHICH MAY EFFICIENTLY BE AS SMALL AS 100 SQUARE FEET, IS ACCOMPLISHED BY MIXING AIR FROM EACH MAIN DUCT TO SATISFY THE REQUIREMENTS OF A SPACE THERMOSTAT. THIS SYSTEM IS CAPABLE OF HEATING AND COOLING SIMULIANEOUS AND, IF ARCHITECTURAL SPACE CAN BE FOUND FOR THE DUCT SYSTEMS, IS VERY ADAPTABLE TO MODERATE SIZE BUILDINGS. AS WITH THE ONE-DUCT AIR-SYSTEMS, A COMPLETE RETURN-AIR SYSTEM IS REQUIRED. THE COMBINATION OF TWO SUPPLY MAINS PLUS A RETURN MAIN REQUIRES A LARGE AMOUNT OF SPACE. THESE SYSTEMS, WHICH ARE USUALLY CONSTANT IN VOLUME, ACHIEVE RESULTS THAT ARE CLOSE TO IDEAL-- WITH EXCEPTION OF CLOSE HUMIDITY CONTROL.

FOR THE REASONS NOTED ABOVE, THE HIGH-VELOCITY TWO-DUCT SYSTEM FOR SUPPLY AND THE LOW-VELOCITY SYSTEM FOR RETURN WAS USED.

THE VERTICAL SUPPLY AND RETURN AIR-DUCTS FROM THE PENT-HOUSE ABOVE THE CORE, TAKE PLACE WITHIN THE CORE. THE MAIN HORIZONTAL DUCTS RUN OVER THE HUNG CEILING OF THE CORRIDOR AND AROUND THE CORE, AND ARE DIVIDED INTO NUMBERS OF SMALL

DUCTS. THESE SMALL DUCTS THEN PENETRATE INTO THE FLOOR STRUCTURE AND ARE CARRIED TO THE PERIMETER OF THE BUILDING THROUGH THE STRUCTURAL VOID SYSTEM. THE REQUIRED SIZE OF OPENING IN THE STRUCTURE CAN BE REDUCED BY THIS METHOD OF DISTRIBUTION OF DUCTS.

IN THE INTERIOR ZONES, THE MIXING BOXES ARE PLACED BETWEEN HOT AND COLD AIR-DUCTS WHICH ARE PROVIDED ALTERNATELY EVERY 10 FEET. A MIXING BOX CAN BE INSTALLED EVERY 5 FEET ALONG THE DIRECTION OF THE DUCTS AND EVERY 10 FEET IN A PERPENDICULAR DIRECTION AS REQUIRED.

CONDITIONED AIR BLENT TO THE REQUIRED TEMPERATURE THEN FLOWS FROM THE MIXING BOX INTO THE SPACE THROUGH CONTINIOUS DIFFUSERS, WHICH RUN ALONG THE BOTTOM OF EACH LOW-VELOCITY SUPPLY DUCT AND ARE INTEGRATED ALONGSIDE THE LIGHTING FIXTURES.

IN THE PERIMETER ZONES, A DIFFUSER FROM THE FLOOR IS INSTALLED EVERY 10 FEET ALONG THE WINDOWS, AND NO OVERHEAD DUCTWORK IS NECESSARY, BECAUSE THE DISTANCE TO WHICH THE EFFECTS OF EXTERNAL CONDITIONS PENETRATE A BUILDING IS APPROXIMATELY 20 FEET.

THIS SYSTEM MAKES IT POSSIBLE TO PROVIDE THE SMALLEST ROOMS--- 10 FEET BY 10 FEET IN THE INTERIOR ZONES AND 10 FEET BY 15 FEET IN THE PERIMETER ZONES, WITH INDIVIDUAL CONTROL AIR-CONDITIONING.

CALCULATION OF AIR DUCT SIZE

THE FOLLOWING ARE THE ASSUMPTIONS LEADING TO THE CALCULATION OF AIR DUCT SIZE;

(1) THE HIGH VELOCITY OF 4,000 FPM FOR SUPPLY AND THE LOW VELOCITY OF 1,000 FPM FOR RETURN WERE SELECTED.

(2) EACH FLOOR HAS 48,800 SQUARE FEET OF FLOOR AREA.

(3) THE AVERAGE CEILING HEIGHT IS MEASURED 12 FEET.

(4) A FIVE STORY BUILDING WAS ASSUMED.

(5) THE AIR CHANGES WITH AT LEAST 6 TIMES PER HOUR ARE REQUIRED.

(6) THE RATIO OF HOT-AIR VOLUME TO COLD-AIR VOLUME MAY BE 7 TO 10.

(7) THE REQUIRED AIR VOLUME FOR RETURN MAY BE 70 PER CENT OF THE SUPPLY AIR VOLUME.

(8) A SPACE FOR ONE INCH ISOLATION MATERIAL AROUND THE SUPPLY DUCT AND A FEW INCHES TO PLACE AND TO SUPPORT THE DUCTS FROM THE STRUCTURE ARE REQUIRED.

CALCULATION OF VERTICAL MAIN DUCT SIZE

ACCORDING TO THE TABLE OF AIR-DUCT DIMENSION, THE DUCT SIZE OF 14.8 SQUARE FEET PER FLOOR THE TOTAL SUPPLY AIR AND 42.2 SQUARE FEET PER FLOOR FOR RETURN AIR ARE REQUIRED. THEREFORE, FOR THE FIVE STORY BUILDING 74 SQUARE FEET FOR THE SUPPLY DUCTS AND 211 SQUARE FEET FOR RETURN DUCT AT THE MAXIMUM POINT, ARE REQUIRED.

CALCULATION OF HORIZONTAL DUCT SIZE

EACH HORIZONTAL MAIN DUCT PROVIDES FOR THE FLOOR AREA OF 20,000 SQUARE FEET SO THAT THE RETURN DUCT AREA OF 16.1 SQUARE FEET AND THE TOTAL SUPPLY DUCT AREA OF 6.2 SQUARE FEET WHICH CONSISTS OF 3.6 SQUARE FEET FOR COLD AIR AND 2.6 SQUARE FEET FOR HOT AIR ON A BASIS OF THE ASSUMPTION NO.6 ARE REQUIRED.

IN ORDER TO PENETRATE INTO THE FLOOR STRUCTURE, THESE HORIZONTAL MAIN DUCTS ARE DIVIDED INTO NUMBERS OF THE SMALL DUCTS, THE FOLLOWING IS THE NUMBER OF THE DUCTS WITHIN A STRUCTURAL UNIT;

HOT AIR DUCTS	5
COLD AIR DUCTS	6
RETURN DUCTS	8

THESE SECONDARY DUCTS, THEREFORE, ARE SO SMALL THAT THE REQUIRED OPENING WITHIN THE FLOOR STRUCTURE COULD BE REDUCED. THE DIMENSION OF EACH HOT AIR, COLD AIR AND RETURN AIR DUCT IS 0.26, 0.30, AND 1.00 SQUARE FEET.

(B) PLUMBING

THE MAIN VERTICAL PIPES FOR HOT AND COLD WATER, VENT, AND WASTE ARE LOCATED IN FOUR PARTS OF THE CORE. THE MAIN HORIZONTAL PIPES FOR VENT AND WASTE RUN PARALLEL WITH THE AIR-DUCTS THROUGH THE STRUCTURAL VOID SYSTEM WHICH IS PROVIDED ONLY FOR PIPES AT EVERY 20 FEET. THE HORIZONTAL PIPES FOR HOT AND COLD WATER ARE LOCATED OVER THE AIR DUCTS.
THE SIZE OF THOSE HORIZONTAL PIPES IS;

	DIAMETER	REMARKS
WASTE PIPES	3"	WITH THE SLOPE OF 1" IN 12'
VENT PIPES	2"	
HOT-WATER PIPES	1"	WITH 1" ISOLATION MATERIAL AROUND THE PIPES.
COLD-WATER PIPES	1"	

BY THE USE OF NON-STRUCTURAL MEMBERS, ALL RISES OF THESE PIBES ARE LOCATED WITHIN THE PARTITIONS, AS IT IS SHOWN IN DRAWING NO.8.

THIS SYSTEM IS ALSO CAPABLE OF PROVIDING MAXIMUM FLEXIBILITY IN THE INSTALLATION OF FIXTURES SUCH AS DRINKING FOUNTAINS, JANITOR'S SINKS, LAVATORIES,ETC.
RAIN DRAINS ARE PROVIDED WITHIN THE COLUMNS. EACH DRAIN SERVES APPROXIMATELY 2,500 SQUARE FEET OF ROOF AREA.

(C) LIGHTING

THE LIGHTING FIXTURES ARE LOCATED AT THE BOTTOM OF THE SUPPLY AND RETURN AIR-DUCTS. THE FLUORECENT TUBES USED ARE FOUR FEET LONG, WITH TWO IN EVERY 5 FOOT MODULE, AND ARE ARRANGED IN A LINEAR MANNER.

ACOUSTICAL TREATMENT.

ENVIRONMENTAL ACOUSTICAL CONTROL IS ONE OF THE INDISPENSABLE REQUIREMENTS. THE PURPOSE FOR CREATING ENCLOSED SPACES IS TO PROVIDE ENOUGH PRIVACY BETWEEN DIFFERENT SPACES. FOR EXAMPLE, THE PARTITIONS SHOULD PROVIDE BOTH VISUAL PRIVACY AND ACOUSTICAL PRIVACY. IF THE ACOUSTICAL PROBLEM COULD NOT EFFECTIVELY BE SOLVED BY PARTITIONING, THE WHOLE SYSTEM WOULD LOSE A GREATE PERCENTAGE OF ITS VALIDITY.

THE EXPOSED STRUCTURE WITH THE EXPOSED MECHANICAL EQUIPMENTS SUCH AS AIR-CONDITIONING DUCTS AND PIPES IS VERY ADVANTAGEOUS NOT ONLY TO ELIMINATE THE COST OF USING A SUSPENDED CEILING, BUT ALSO TO CREATE INTERESTING SPACES.

IN ACOUSTICS, HOWEVER, CEILINGS ARE ONE OF THE MOST EFFICIENT PARTS OF A BUILDING TO REDUCE THE NOISE INTENSITY LEVEL BY USING ACOUSTICAL MATERIALS. IN THIS SENCE, THE CONCRETE SURFACE WITHOUT ANY ACOUSTICAL TREATMENT IS CRITICAL. ALSO, THE EXPOSED PIPES, ESPECIALLY THE WASTE PIPES, MAKE UNCOMFORTABLE NOISE.

IF THE CONTINIOUS AIR DEFFUSERS ARE INTRODUCED, THE THE SOUND TRANSMISSION BETWEEN THE SPACES WOULD BE SO CRITICAL THAT SOME DIVICES ARE REQUIRED.

THEREFORE, THE CEILING PANELS WERE DESIGNED IN ORDER TO PROVIDE SUFFECIENT SOUND ABSORPTION AND SOUND TRANSMISSION LOSS BY USING SANDWICH PANELS CONSISTING OF THE PERFORATED ALUMINUM PLATE AND SOLID STEEL PLATE WITH 1/2" GLASS-FIBER.

THE CONTINIOUS DEFFUSERS FOR RETURN AND SUPPLY ARE COM-

POSED OF PERFORATED ALUMIMUM PLATE AND ONE INCH OF ISOLATION MATERIAL FOR HEAT ADIABATIC AND SOUND ABSORPTION MATERIAL.

THE INTERIOR PARTITIONS ARE REQUIRED TO BE THE MOST FLEXIBLE ELEMENT IN THE BUILDING. IN THIS SENCE, IT SHOULD BE DESIGNED MORE LIGHTLY IN ORDER FOR PEOPLE TO BE ABLE TO MOVE IT, BUT ON THE CONTRARY HEAVIER PARTITIONS ARE BETTER IN TERMS OF THE SOUND TRANSMISSION LOSS. AS A RESULT OF THESE OPPOSITE REQUIREMENT, GYPSUM BOARDS OF 6 INCHES THICK WITH ENOUGH INSIDE OPEN SPACE FOR THE RUNNING OF THE PIPES WERE SELECTED. THE DIMENSION OF THE PARTITION IS 5 FEET WIDE AND 11 FEET 6 INCHES HIGH. IT COULD EASILY BE MOVED BY TWO PERSONS.

IT IS ALSO REQUIRED TO SOLVE AN IMPACT NOISE THROUGH SLABS. IT IS ADVAISABLE TO DESIGN THE SPAN BETWEEN TWO RIBS AS SMALL AS POSSIBLE AND THE THICKNESS OF SLAB AS THICK AS POSSIBLE, IN TERMS OF THE REDUCTION OF THE IMPACT NOISE INTENSITY. THE SLAB OF 6 INCHES THICK DESIGNED IS A LITTLE TOO THICK FOR THE STRUCTURAL REQUIREMENT, BUT IT DOES PROVIDE SUFFECIENT REDUCTION OF IMPACT NOISE INTENSITY.

ACCORDING TO PROFESSOR NEWMAN, THE SELECTIONS OF THE GYPSUM BOARDS FOR PARTITIONS, THE SANDWICH PANELS AND THE SLAB GIVE ALMOST THE SAME EFFECTS ON THE NOISE REDUCTION AND THE SOUND TRANSMISSION LOSS. IT MAY BE SAID THAT THE ACOUSTICAL TREATMENT USED IS QUITE ECONOMICAL.

THE MAIN MECHANICAL ROOMS ARE LOCATED ON THE TOP FLOOR AND AT THE BASEMENT OF CORES. THE CORE HAS AN INDEPENDENT STRUCTURE ITSELF, SO THAT STRUCTURE BORNE NOISE DOES NOT TRANSMIT INTO THE SPACES.

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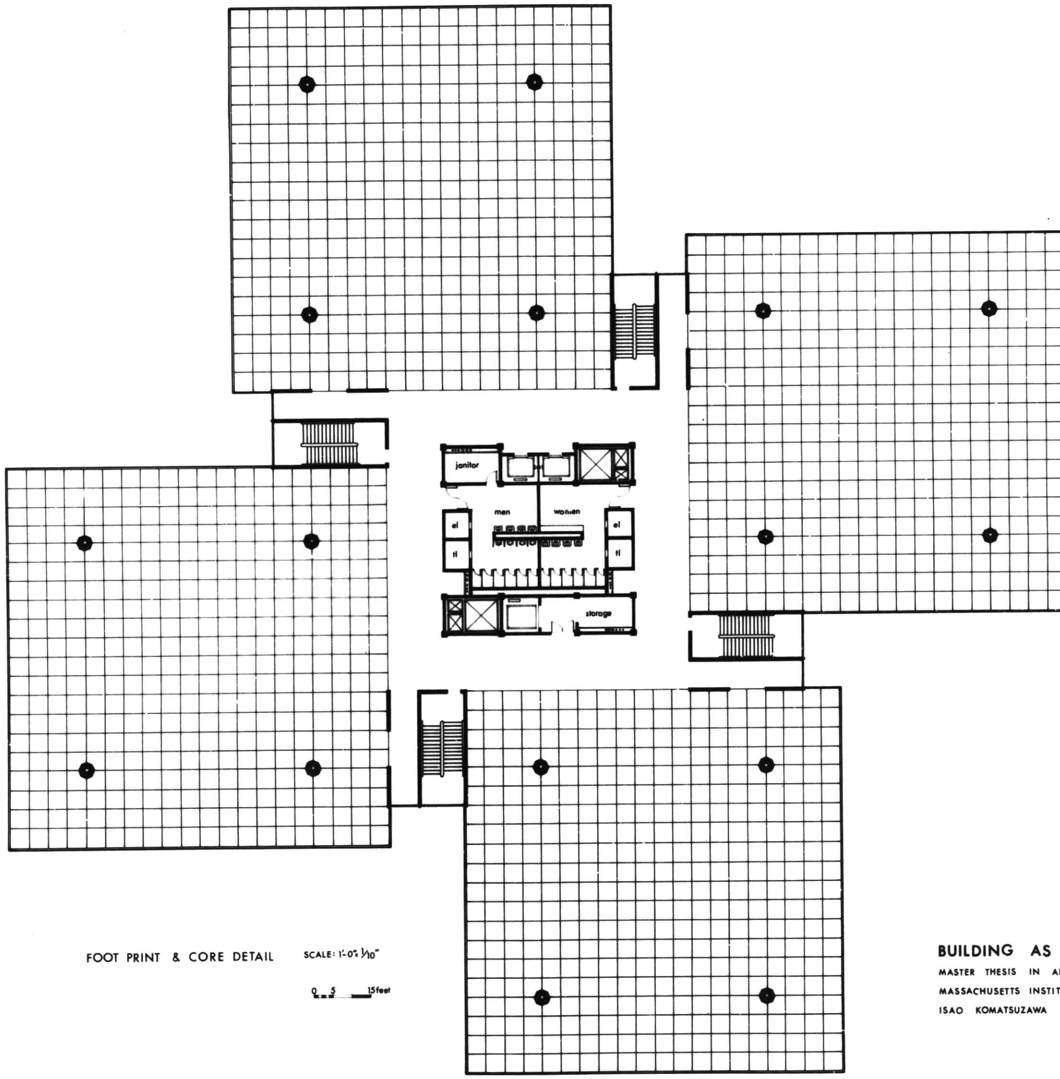


FOOT PRINT & CORE DETAIL

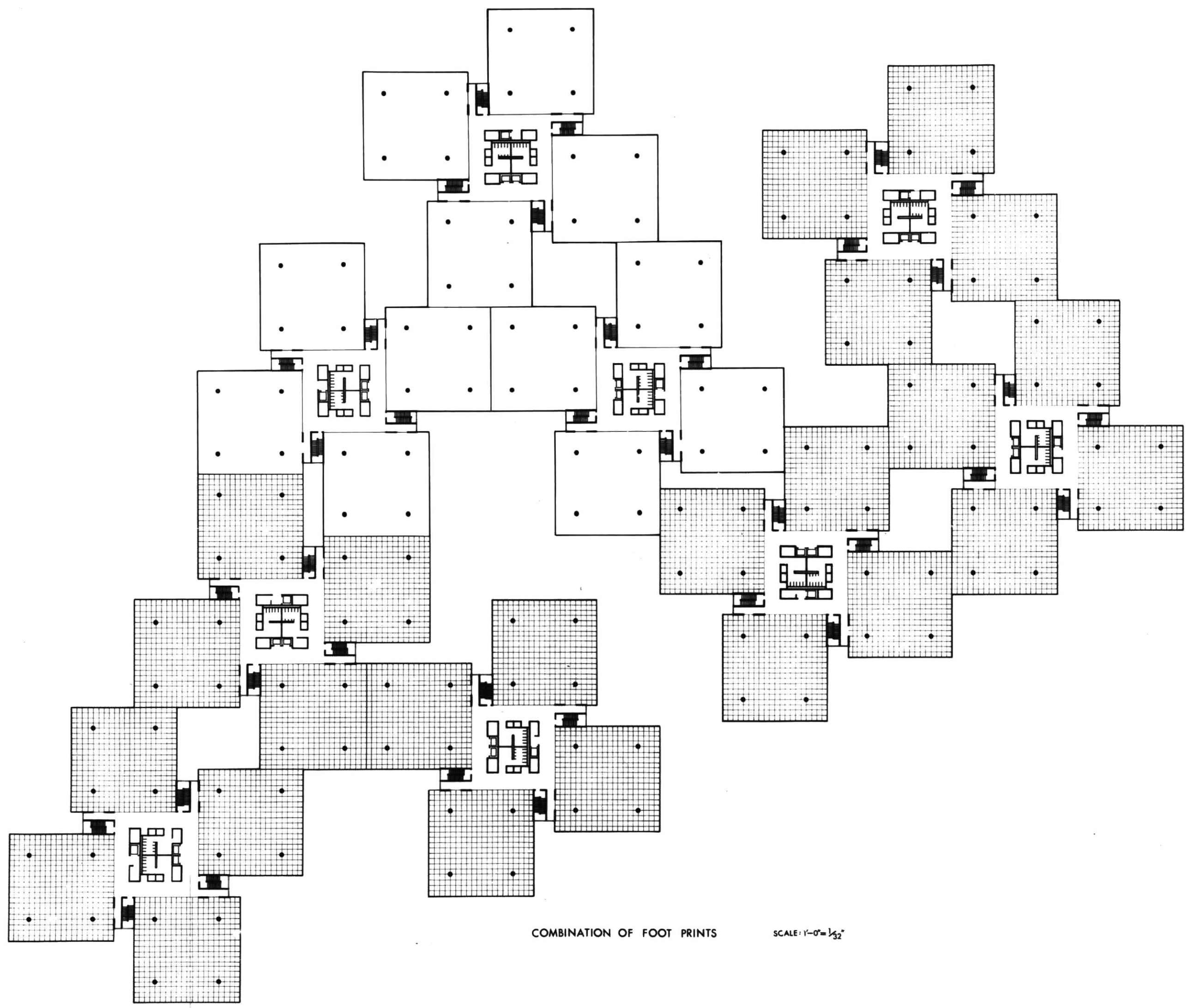
SCALE: 1'-0" = 1/10"

0 5 15feet

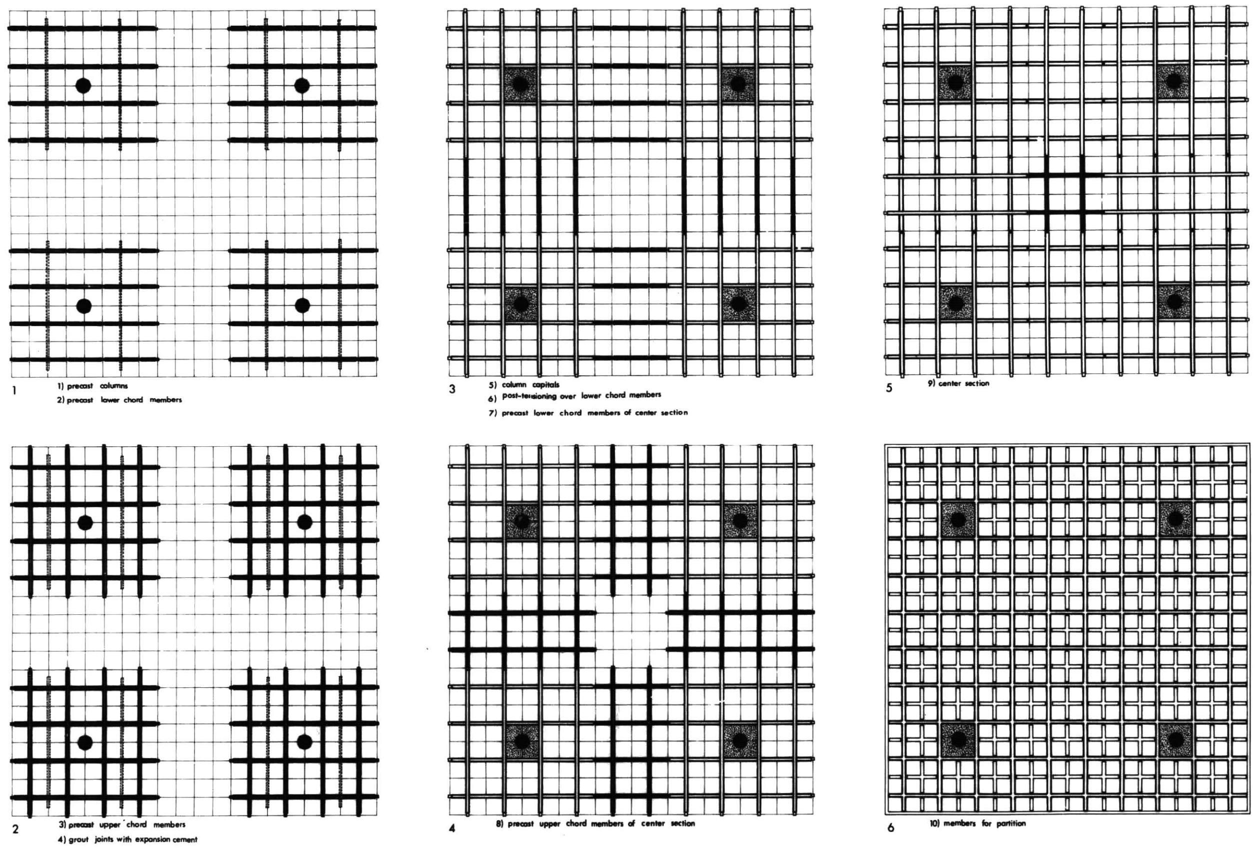
BUILDING AS A SYSTEM

MASTER THESIS IN ARCHITECTURE. 1966

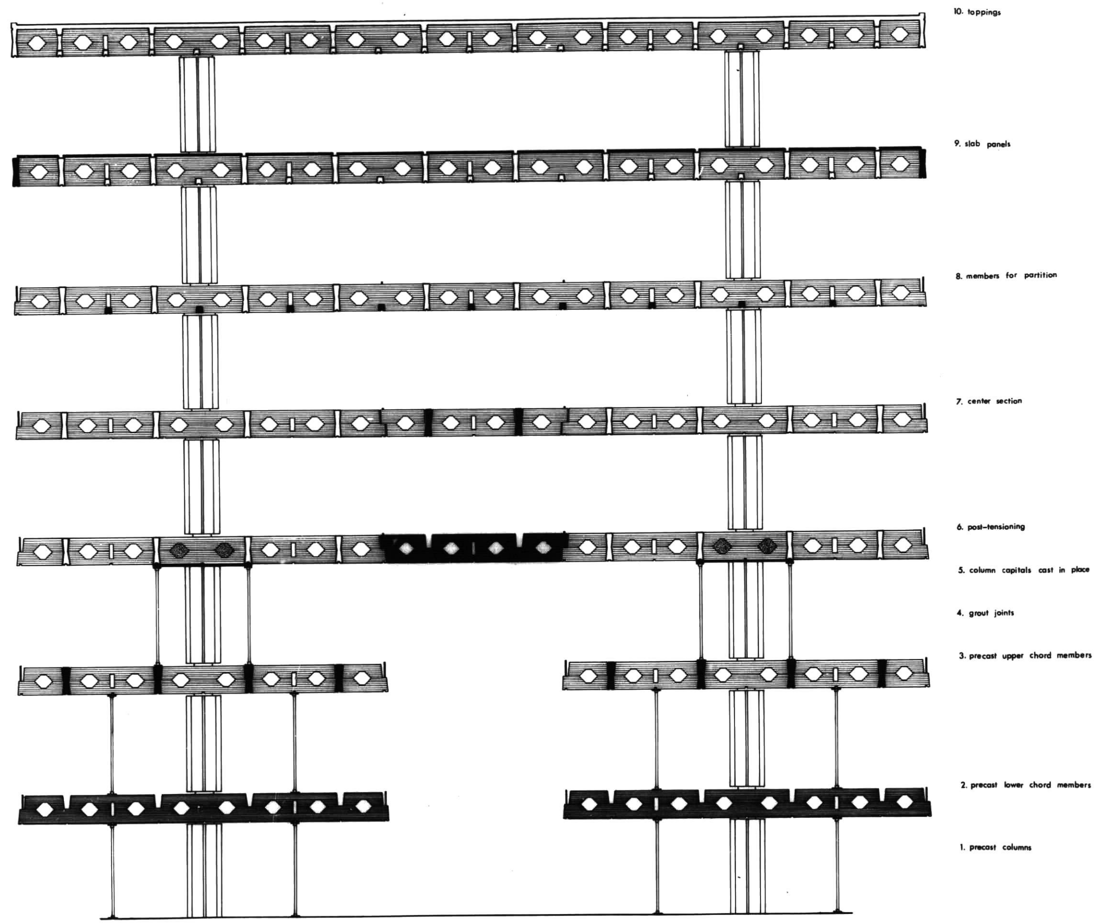
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
ISAO KOMATSUZAWA



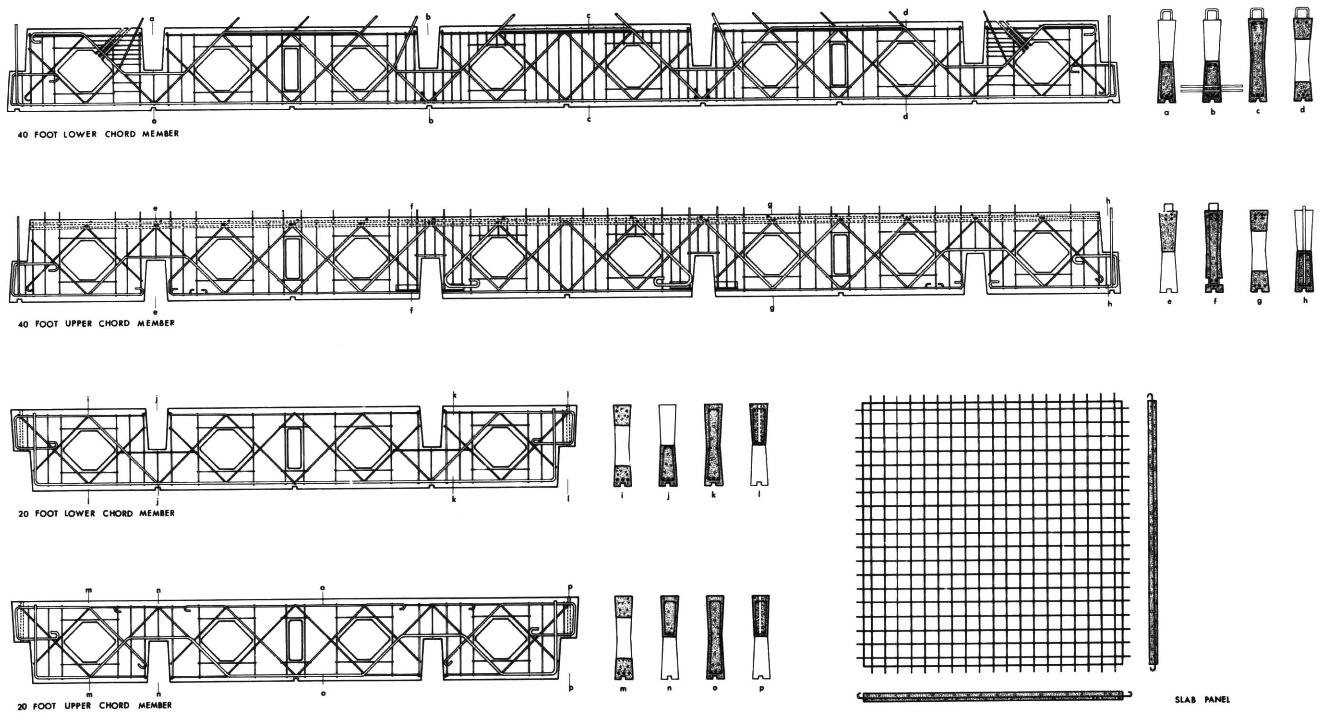
COMBINATION OF FOOT PRINTS SCALE: 1'–0" = 1/32"



ERECTION PROCEDURE PLAN SCALE: 1'–0" = 1/10"

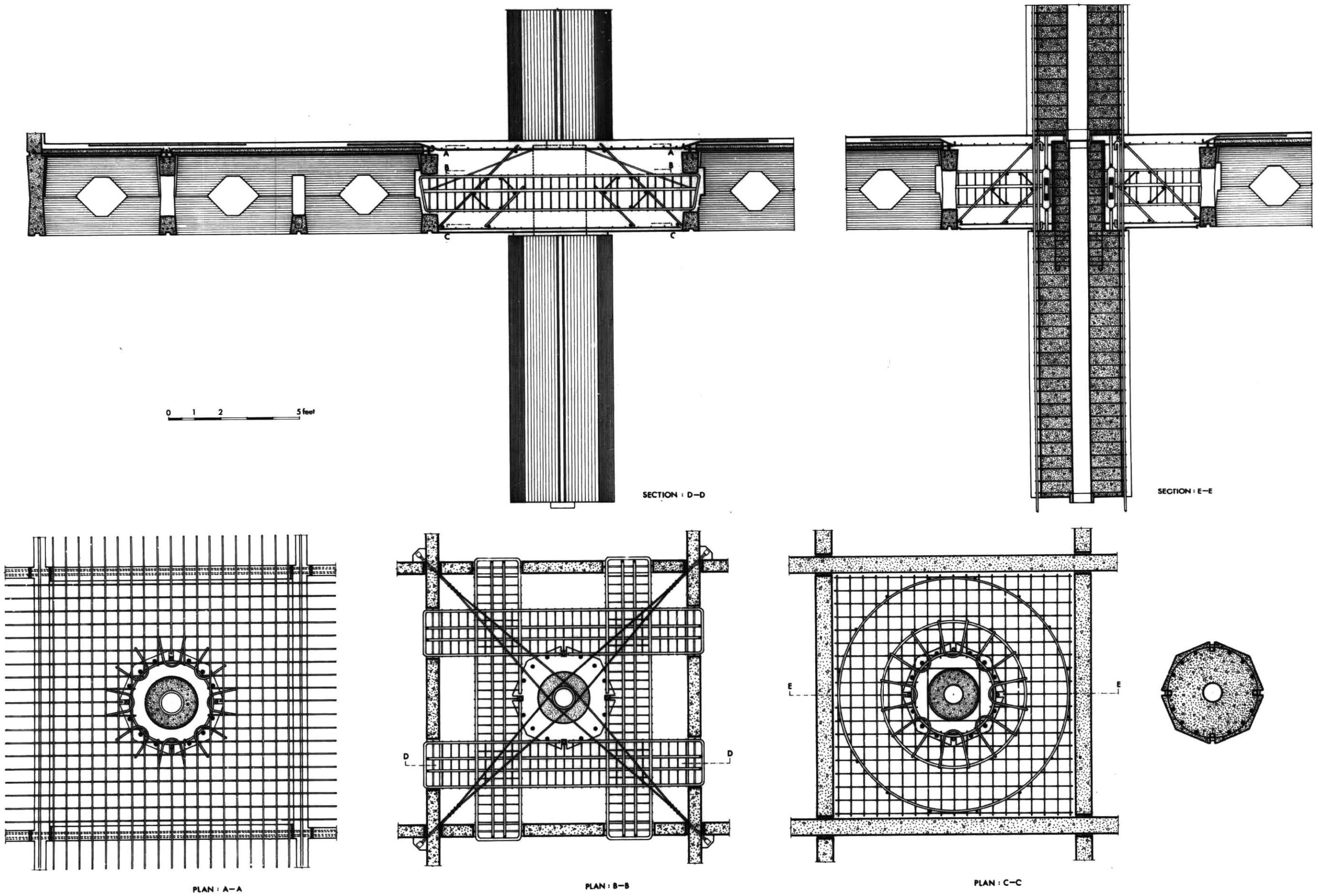


ERECTION PROCEDURE SECTION SCALE: 1'-0" = 1/2"

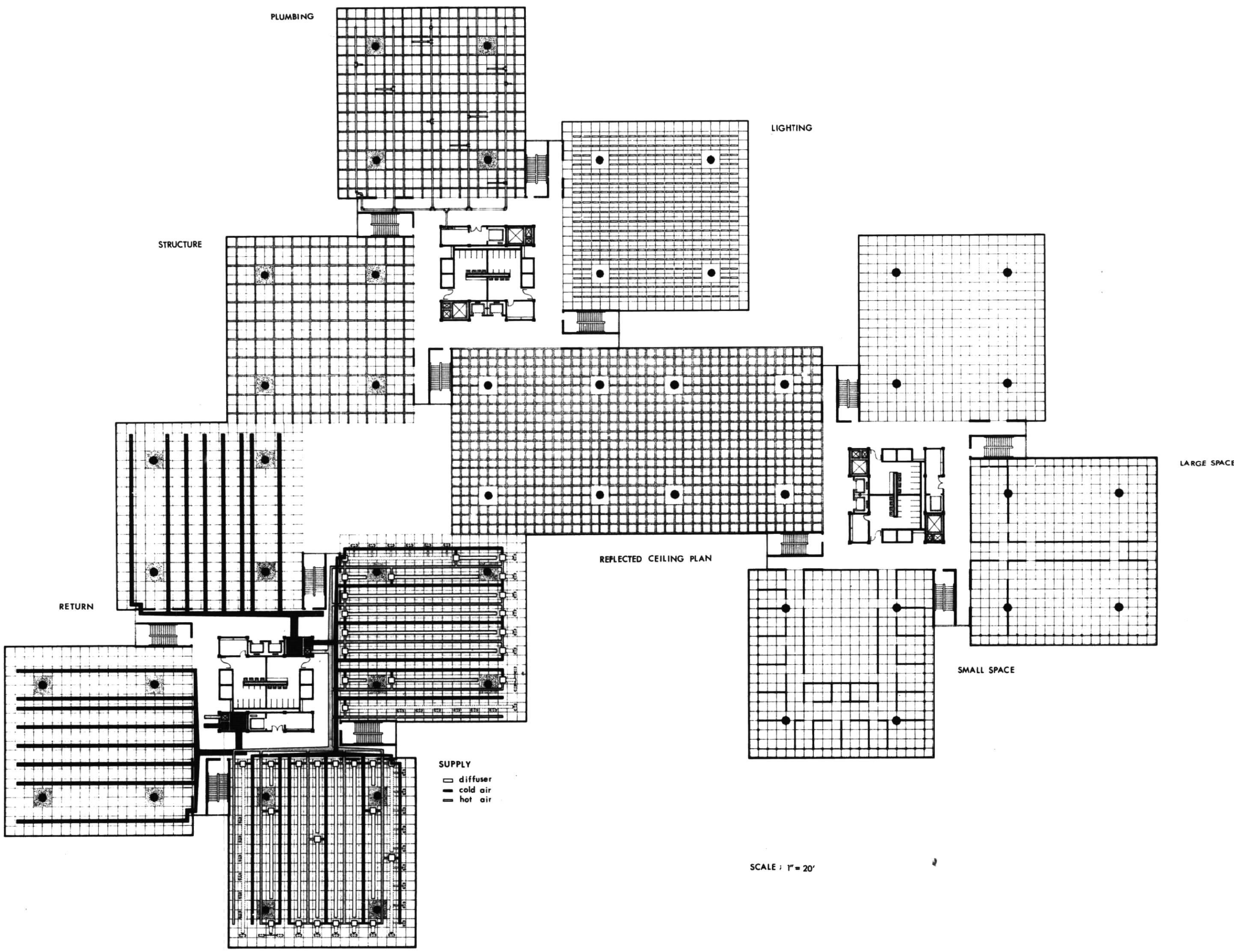


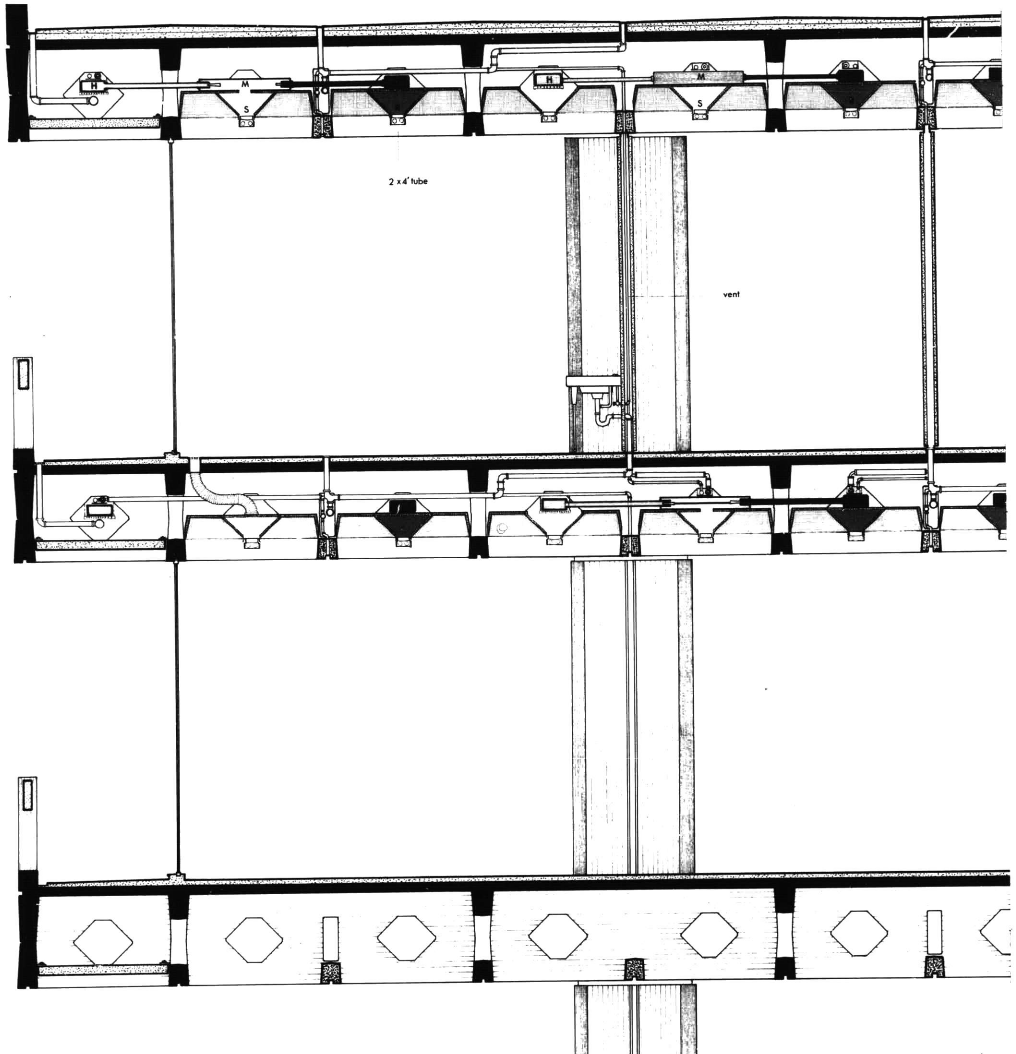
PRECAST MEMBERS REINFORCEMENT SCALE: 1'-0"=3/4"

0 1 2 3 feet

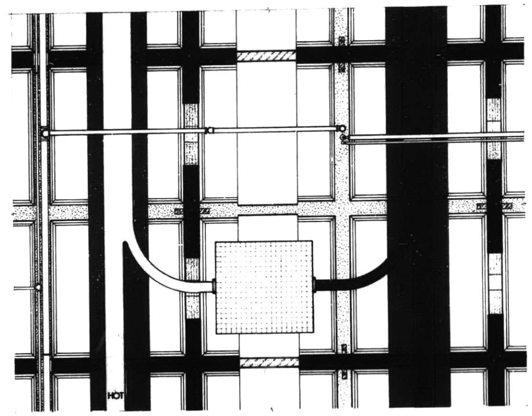


COLUMN CAPITAL REINFORCEMENT SCALE: 1'-0" = 3/4"

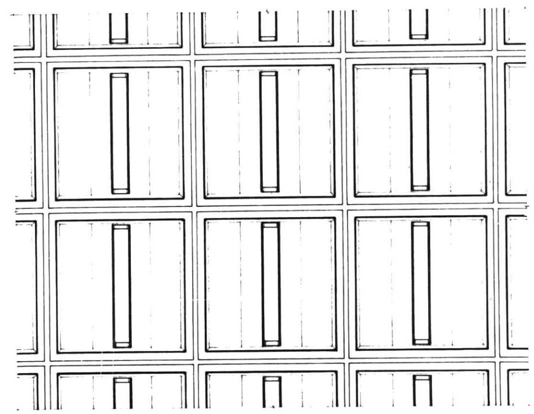

PLUMBING
LIGHTING
STRUCTURE
LARGE SPACE
REFLECTED CEILING PLAN
RETURN
SMALL SPACE
SUPPLY
diffuser
cold air
hot air
SCALE: 1" = 20'



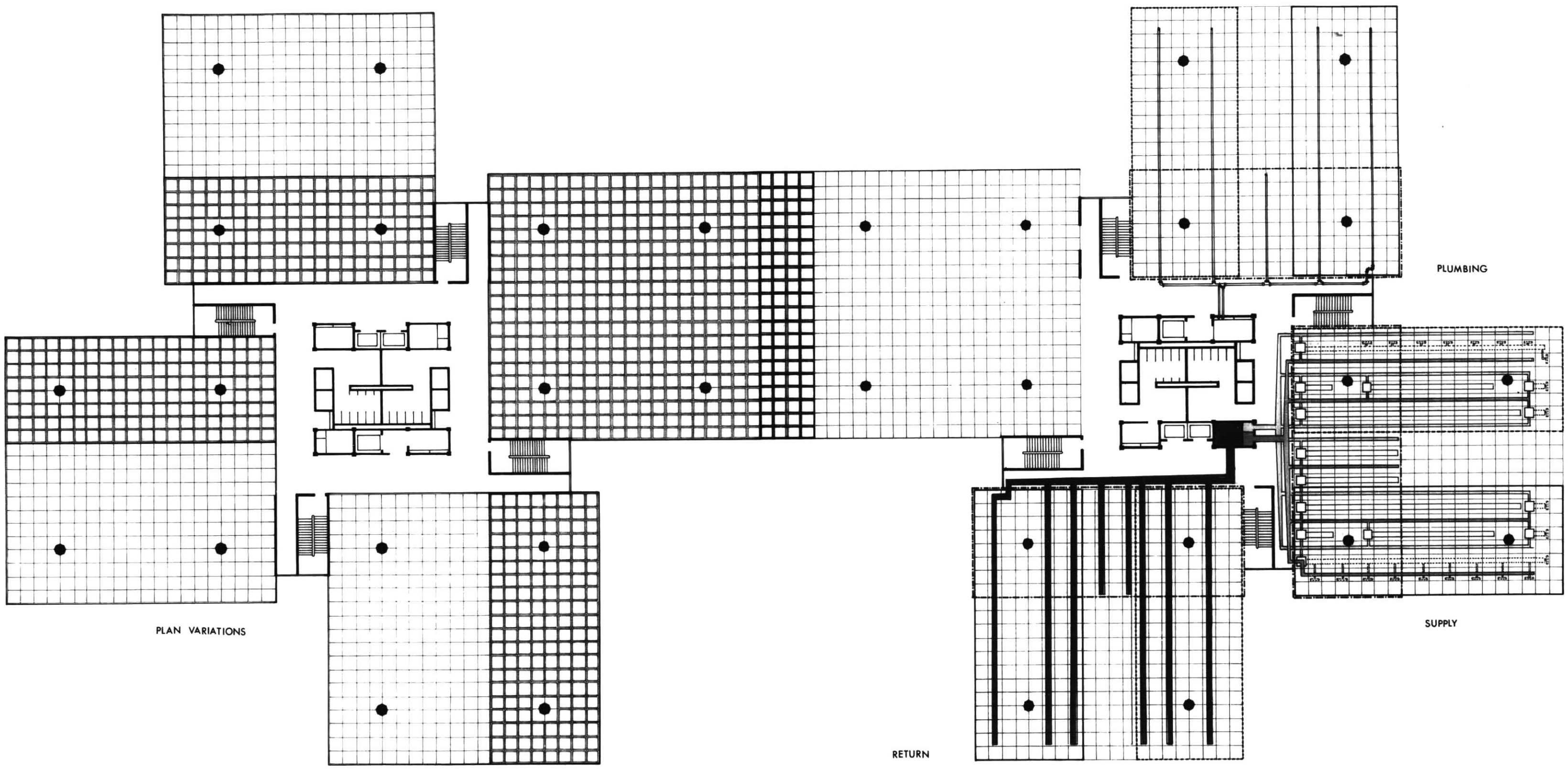
MECHANICAL DETAIL 3/4" = 1'-0"



MECHANICAL DETAIL SCALE: 3/4" = 1'-0"



CEILING DETAIL 3/4" = 1'-0"



SYSTEM VARIATIONS SCALE: 1'-0" = 1/16"