AN INTEGRATED BUILDING SYSTEM

as envisaged for a

South Australian Institute of Technology

by

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Thesis Supervisor

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on Graduate Students

TABLE OF CONTENTS

ABSTRACT

AN INTEGRATED BUILDING SYSTEM

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Stephen Greville Brooke

Submitted to the Department of Architecture on June 17, 1968, in partial fulfillment of the requirements for the degree of Master of Architecture.

The purpose of this thesis was to develop a totally integrated reinforced concrete building system. The resulting structure being efficient in the transmission of structural forces throughout the overall structure, efficient in its usage of building volume when considering its necessary structural depth and the containment or integration of specific mechanical services, and functional in its capabilities of planning flexibility, structural expression, and space producing context.

The resulting system was a two-way precast reinforced concrete structure spanning 60'0" in both directions and utilizing a maximum component size of 10'0" with an overall structural depth of 4'0".

The thesis was oriented solely towards structural expression and overall functional integration and necessarily excluded architecture as a spirit or stimulating experience in terms of environment. It served to illustrate how a structural system could be derived from clear techniques of construction and underlying functions.

Thesis Supervisor: Eduardo F. Catalano

Title: Professor of Architecture

Dean Lawrence B. Anderson
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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, "An Integrated Building System" as envisaged for A South Australian Institute of Technology.

Respectfully,

Stephen G. Brooke

ACKNOWLEDGEMENTS

Eduardo F. Catalano,
Professor of Architecture, M.I.T.

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AN INTEGRATED BUILDING SYSTEM

INTRODUCTION

It has been estimated that within the next few years to cope with the ever-increasing earth's population, for man to maintain his present level of building occupancy, he will have to build more than the gross building cubage yet constructed by civilized man.

Significant technological advances in the building industry are imperative and those already realized must be augmented to their maximum extent if we are to attempt to cope with the future building requirements.

Implementation of a high degree of industrialization is undisputed. The architect, therefore, in collaboration with engineers and industry needs to formulate a vocabulary utilizing industrialization. As a consequence, both the construction cost and the erection time will be reduced. At the same time he should instigate orderly growth and flexibility in spaces within and without the building. Creativity is therefore necessary to attain variation in the proposed greater use of the mass-produced building components.

The concept of the architect as an architect becomes less acceptable. He must use logic and clarity to put his emotions on a level relative to construction.

PROGRAM

To develop a building system utilizing today's available building construction technology, integrating all of the environmental services within the structure such that the integrated system is inducive to spatial flexibility, usage flexibility, circulation, growth flexibility and variations in character.

In today's world of complex human requirements, architecture, if it is to remain under the control of the architect, must be capable of creating a harmonious juxtaposition of the various environmental complexities. This exercise, therefore, offers a unique opportunity for the study of architecture as integrated with its allied professions.

STRUCTURE

Structurally the system should be designed to have an inherent flexibility such that certain components may be removed from the structure during erection to give spatial variation in both the horizontal and vertical directions.

Construction technology is a major component of industrialization. Optimum industrialization may be successful if there is a straight-forward sequence to the component assembly. Therefore the technology employed for the components and the assembly procedure are of equal importance.

By using precast concrete techniques the advantages of both steel and concrete may be utilized. Reinforced concrete has inherent characteristics of being fireproof and extremely flexibly in its shaping possibilities.

Insitu connections enable a monolithic continuity of structure. Because of the simple monolithic connections a greater component tolerance is available with concrete than with steel.

Precast components may generally be more rigidly controlled under more controllable conditions during production than may insitu work. Also, because of a reduction in erection time, on site labour costs are reduced by using precast concrete. Precast concrete, in conjunction with post-tensioning techniques, enables structurally efficient large span bays. The components may be such that they express a modular planning grid thus affording a ceiling junction for subdivision partitions.

USAGE

It is most difficult to be able to predict building usage for a period beyond say 10 years. As the life of a building of this nature today is potentially 50 years, it can be seen that internal rearrangement of functions will be inevitable, especially for an educational complex. In the extreme, vertical circulation requirements may change.

CIRCULATION

In a building complex of this nature and size a hierarchy of circulation should exist to aid in orienting occupants. A system of easily understood major and minor orientation patterns is desirable.

The circulation system is composed of major and secondary arteries.[1]

Circulation arteries, in relation to the vertical circulation elements, offer an orderly direction in planning whilst serving as a means of both directing and orienting circulation throughout the system. Orientation is vital in a large complex and unless circulation of a multidirectional nature can be reduced to an obvious code, it is not valid. Corridor widths are considered sufficient if an individual can walk from point A to point B in the same period of time when walking alone as when others are using the same circulation space.

The planning module chosen was 5'0" x 5'0" with alternating modules reduced to two 5'0" x 2'6" modules.

GROWTH

Statistics available overwhelmingly prove that enrollment figures are on the increase and as such the building or buildings must exhibit such a geometry as to allow various systems of growth.

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[1]Refer plate, page 43.

It is critical that some doctrine of orderly growth be possible, both in large and small increments, to absorb future growth without disrupting the hierarchy of the building system.[1]

LIMITATIONS

A constant structural depth should be maintained to aid the placement of modular partitions, unify the design of the mechanical services and to reduce the complexity in the assembly sequence.

LIFE IN A BUILDING

Life in a building is analogous to interest and stimulation. Interest may be aroused because of curiousity and curiousity may be activated by the interplay of planes, volumes, and hence spaces. By creating voids a hierarchy of space may be obtained which may be of stimulating value. Variation in space is therefore the key to life in a building and this may be achieved readily in the two dimensional horizontal plane. The third dimensional vertical plane requires penetration of the horizontal structure and this may be achieved in a variety of positions restricted only by the column zones and multiples of the

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[1] Refer plate, page 45.

10'0" x 10'0" structural component and half structural component.[1]

Each faculty has varying requirements, and it is only by analysing and synthesizing these varying requirements that the structure may best collectively express them.

STATEMENT

The system is such that it may be employed for a specific building complex on a specific site. Interpolations of the system may also be used for varying complex criteria, although 60'0" appears to be the most efficient span for a precast concrete structure.

The fundamental requirements essential for health, comfort and safety would be governed by the South Australian Building Act and other appurtenant acts and codes having jurisdiction in the state of South Australia. Where specific restrictions have been unprocurable, reliance has been on the United States Uniform Building Code.

BUILDING FOOTPRINT

A footprint is the terminology given to an area within a building system which incorporates the

[1]Refer plate, page 43.

essentials for life within. These essentials include mechanical sources for return and supply air, exit egress, elevators where considered necessary, and possibly sanitary facilities.

SYSTEM NETWORK

A system network exhibits more than one building footprint in a relationship which is governed by various code requirements. A system network should be capable of growth in two directions by the addition of building footprints in a progression which continues to exhibit the initial code relationship.

CONCEPT OF SYSTEM NETWORK

For an educational complex the National Building Code requires that a fire-resisting exit stair be within 100'0" from a doorway opening to a corridor from any habitable room. For office areas this distance may be increased to 150'0". Should the building be installed with fire sprinklers these dimensions may be increased by 20%.

The position of exit stairs, therefore, determined the fixed element core frequencies. By considering the properties of scissor action with these fixed element cores it was possible to vary the relationship, one to another, from that of a square to an elongated rectangle. In this way the stair positions could be adjusted to coordinate with the best planning and circulation arrangements.

The National Building Code also stipulates that stair capacities vary for differing academic use within the same educational complex. It is possible, therefore, that each fixed element stair could vary in capacity requirements.

Three stair types were designed such that their capacities were rated as 2, 3 and 4 stair units respectively.[1] These stairs could then be grouped to give the appropriate stair combination required.

Foresight into the possibilities of future stair requirements in 2 unit increments could also be catered for by minor deviations to some of the structural elements at the initial construction stage. Thus it would be possible to remove these elements as further stairs became necessary.

The recommended elevator service for a five storey educational complex was two elevators, each rated at 2,500 pounds and each capable of carrying

[1] Refer plate, page 44.

15 persons per car per each 40,000 square feet of floor space.[1]

Lavatory accommodation is not permanent and hence had no bearing on the building footprint.

SELECTION OF STRUCTURAL SYSTEM

The two basic types of framing systems are rectangular one way and square two way. Study of one way systems for a 60'0" x 60'0" optimum sized bay found such systems illogical for this sized bay. Generally these systems allowed only one way flexibility and the components varied much in weight and proportion.

The two way framing system has been chosen for this study because of the following reasons:

(1) A constant beam depth in two directions, therefore providing an efficient functional continuity in structural depth.

(2) A structural system whereby loads may be transmitted to the columns via diagonal members more efficiently.

(3) An adequate two way system enables greater direction flexibility with mechanical services

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[1] Technical College Buildings, page 34
University Facilities Research Centre.

than does a one way system without excessive structural penetrations. As the percentage of costs of mechanical to overall building costs are considerable, this is a valid consideration.
(4) Smaller components, both in weight and physical size offer further advantages in both transportation and handling.

STRUCTURAL UNIT EVOLUTION

Because of the mechanical requirements and the desire to be unrestricted in the possible duct-work configurations, it became evident that the structural component would require a top and a bottom chord with as much free area as possible between.

For structural efficiency it was decided that the post-tensioning cables should run in an orthogonal direction in conjunction with the planning grid and the top reinforcement at 45° to this grid.

For handling purposes it was decided to limit the structural unit size to 10'0" x 10'0".

It was also essential that the resultant cast structural unit be as simple as possible to manu-facture and just as simple to assemble on the site.

Thus the limiting criteria was established for the evolution of the structural unit.

Phase one[1] was an attempt to simplify the casting technique. Its drawback was the fact that the connections all occured at the units' weakest points.

Phase two[2] attempted to strengthen these connections. The connection detail for the top and bottom chords was still complicated. The unit was also inefficient in the way in which diagonal lines of force were transmitted.

Phase three[3], while perhaps solving the foregoing problems, became complicated in form and restrictions began to occur with regard to possible freedom in direction for ductwork.

Phase four,[4] was considered to satisfactorily solve the problem. The structural unit, however, posed problems at the column connections. A

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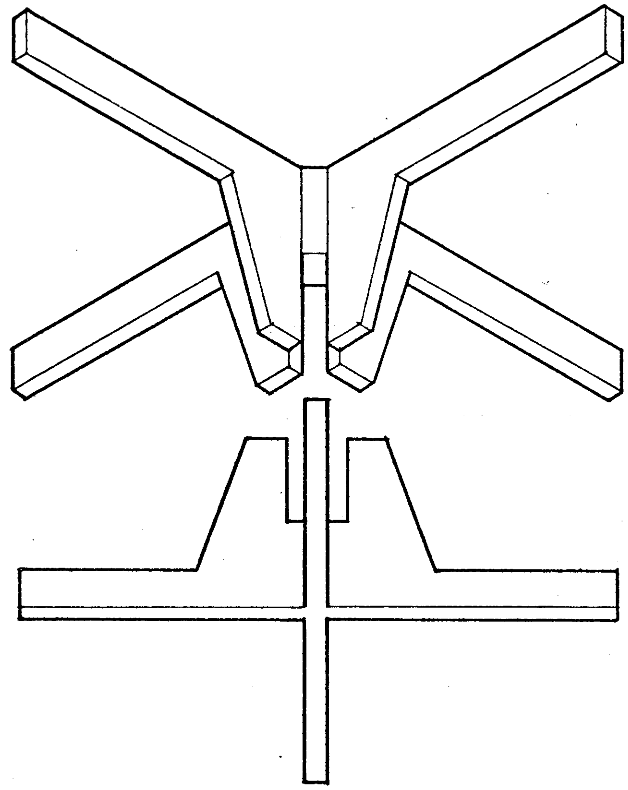
[1]Refer to page 16.

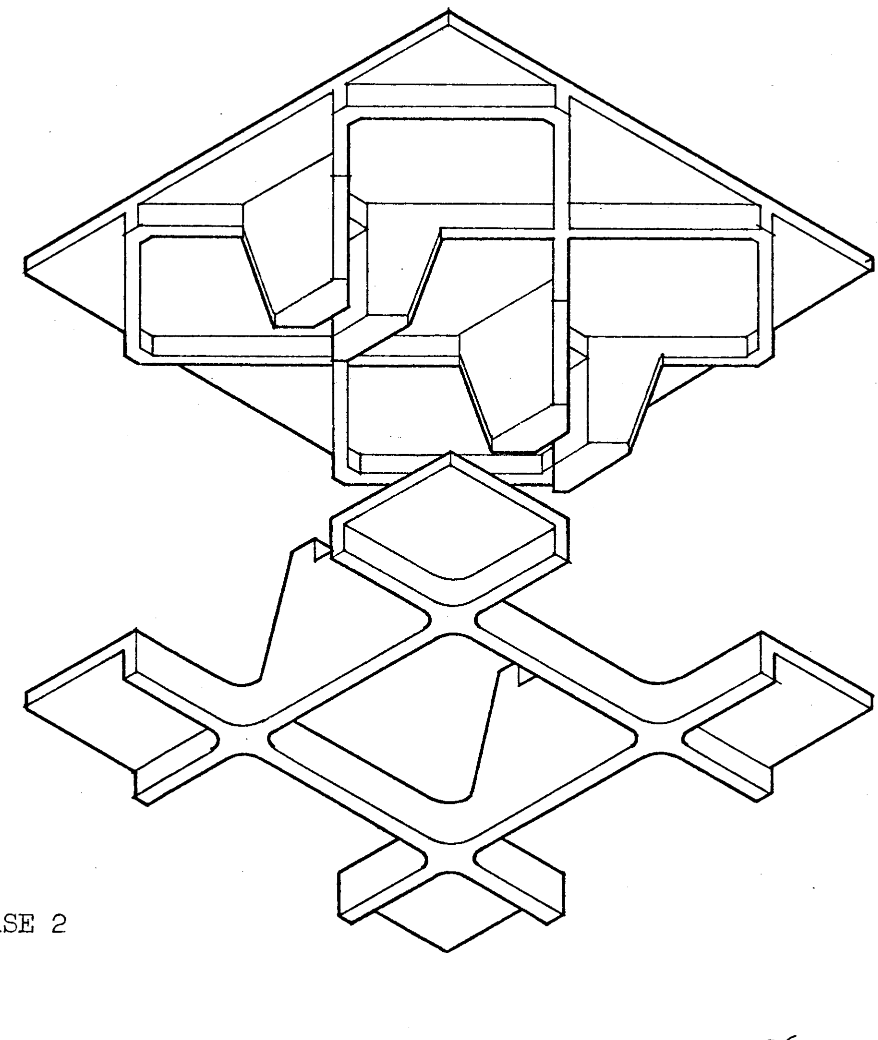
[2]Refer to page 16.

[3]Refer to page 18.

[4]Refer to page 18.



PHASE 1



PHASE 2

simple, but strong connection was required at the columns because of the maximum loading conditions. A modified three quarter structural unit was utilized for this purpose with increased strength in the line of action of the maximum forces.[1]

COLUMN EVOLUTION

The combined area required for maximum bearing structural concrete and mechanical services was such that it proved difficult to contain within a convenient structural module. Many configurations were attempted, the final selection being an integrated column plenum.[2] This fitted conveniently within a 10'0" x 10'0" module and did not disrupt planning possibilities. The riser ducts were reduced to two in number by using the column as a plenum.

The situation was now such that after leaving the column the air supply ducts could pass through the open structure parallel to the planning grid or at 45° to it.

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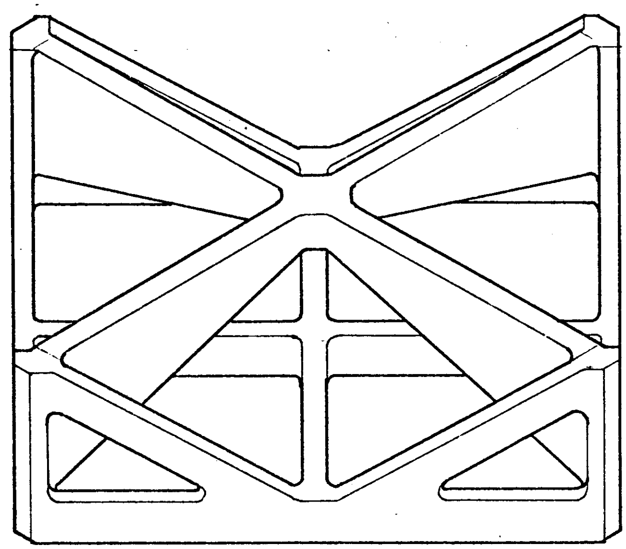
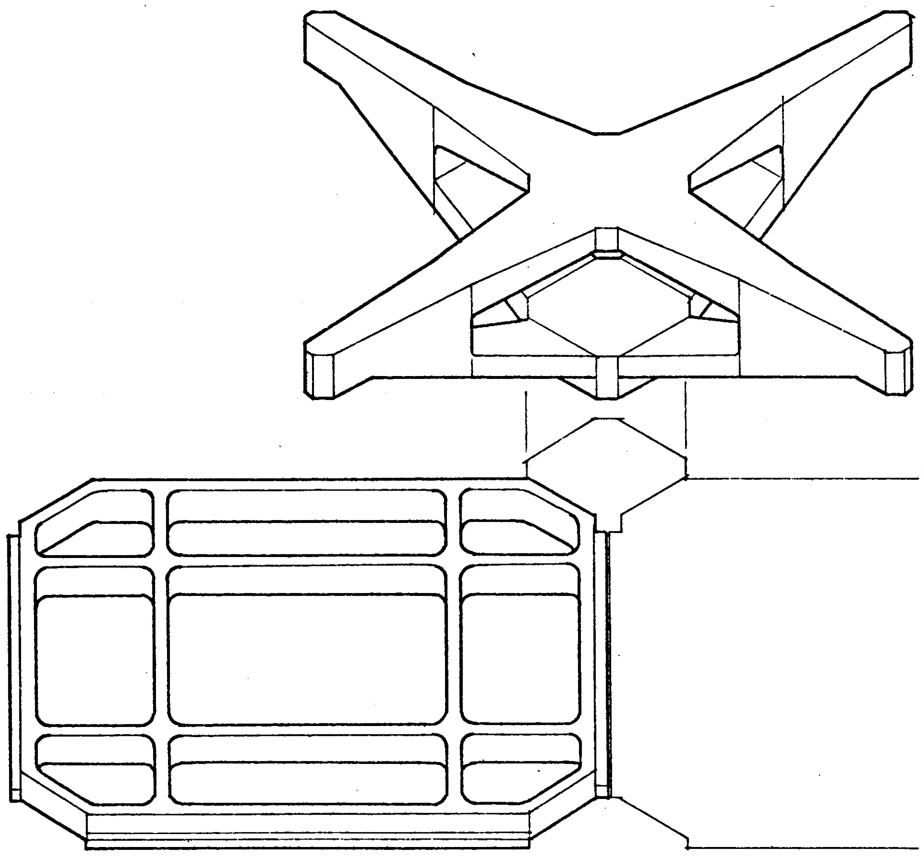
[1]Refer to page 19.

[2]Refer plate, page 42.



PHASE 3



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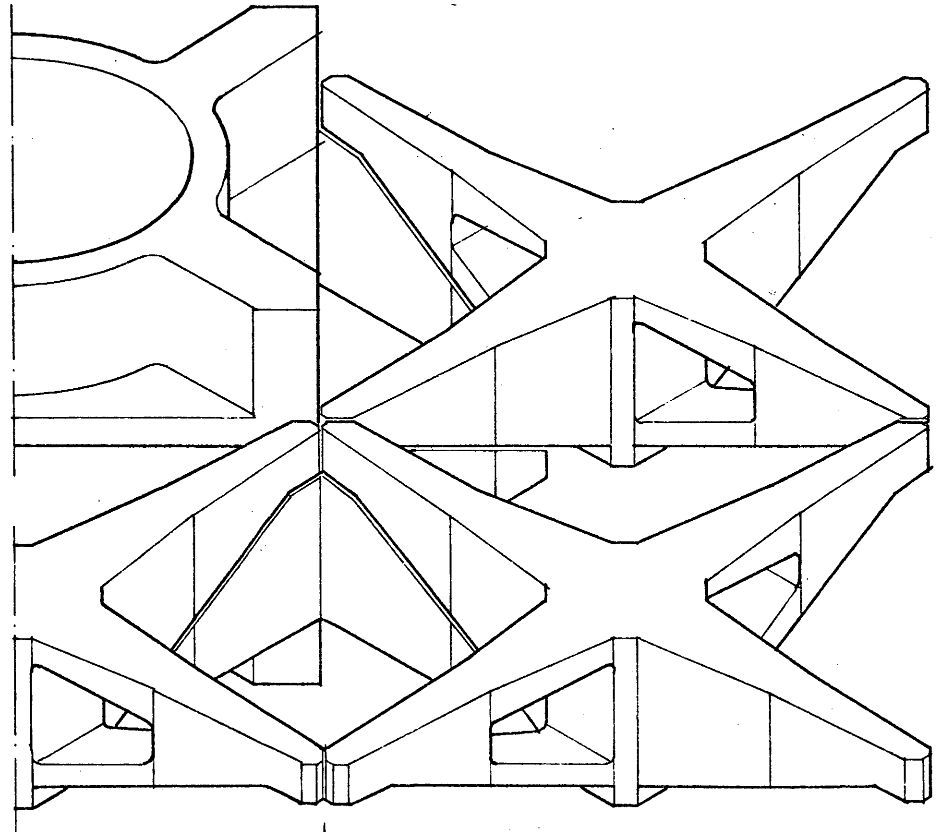
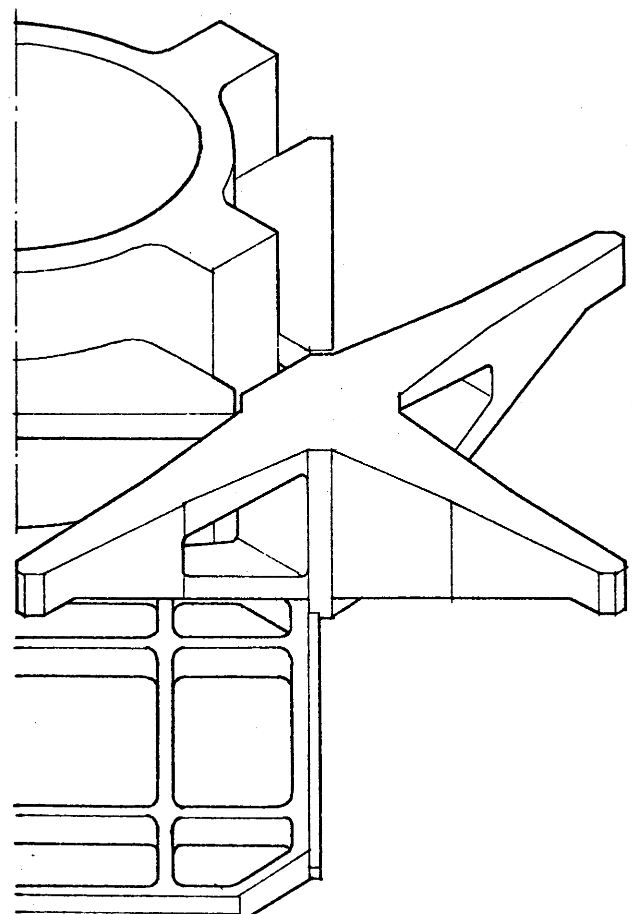


PRELIMINARY
COLUMN
CONNECTION



ADAPTED
THREE QUARTER
STRUCTURAL UNIT
AT COLUMN
CONNECTION

DESCRIPTION OF STRUCTURAL SYSTEM

A two way precast system based on a 5'0" structural module is proposed. The various functions of an academic institution, including classrooms, laboratories, offices and corridors may best be served by a 60'0" grid dimension. For two way flexibility a 60'0" x 60'0" bay seemed logical and was therefore utilized.

In reinforced concrete economic structural efficiency is possible with spans in the order of 60'0".

Each bay consists of 36 star-shaped structural components combined with 36 structural ceiling components.

The maximum size of a structural component, apart from the column sections, is 10'0" x 10'0" x 3'6", thus permitting unrestricted transport. The precast column has two reinforced concrete plates integral with it and 2'6" apart at its base. Each plate transmits forces from the diagonal loading positions around the circular column core rather than normal to it. The column component is 10'0" x 10'0" at the capital plates and 14'0" long. The precast floor panels are approximately 7'0" x 7'0" and have 4'0" x 4'0" recesses for absorptive acoustical material on the underside for use when no sealed ceiling panels are used.

The structural unit depth of 3'6" plus 3-1/2" precast floor panels and 2-1/2" of topping forms a total structural depth of 4'0".

The column weight per precast section is 52 kips or 23 tons.

The unit weight maximum is 4.8 kips or 2.15 tons.

The ceiling panels weigh 3 kips or 1.34 tons.

The system weight per 100 square feet is 15.3 kips or 6.8 tons.

The building edge can occur at the column line, although some continuity is preferred about the column. It may also occur in increments of 10'0" to a maximum of 20'0" if structural half units are employed. The 20'0" cantilever condition of the adjoining 60'0" bay spans enables the most efficient compromise in continuous beam moments. Three quarter units were employed at the column supports to provide greater shear depth. These units were further strengthened by being made solid in the directions of the diagonal lines of forces. The same basic star-shaped structural mold could be used for casting all of the subtle variations needed for column and edge conditions.

The overall dimensions of the units, whilst restricted because of transportation restrictions, are required to be as large as possible to give maximum flexibility within the component itself for mechanical distribution.

STRUCTURAL COMPUTATIONS

The member dimensions were determined by formulae provided in course 4.19.

Maximum loaded area acting at column from influence of one bay on finger of one diagonal structural unit:[1]

$$= \frac{25 \times 25}{2}$$

$$= 312.5 \text{ square feet}$$

Increase by 50% for safety factor

$$= 468 \text{ square feet}$$

[1]Refer diagram, page 24.

Decrease for continuation factor

$$= 468 \times 0.8$$

$$= 375$$

say 400 square feet

$= A^{t}$ maximum for

one finger of structural unit.

For diagonal member of slope 1:2

Area of concrete in compression

$$A^{cc} = \frac{A^{t} \times 1.5}{5}$$

$$= \frac{400 \times 1.5}{5}$$

$$= 120 \text{ square inches}$$

Area of steel

$$= \frac{A^{t} \times 1.5}{100}$$

$$= 6 \text{ square inches.}$$

Hence use 8 number 8 bars.

Maximum area for bottom compression chord:[1]

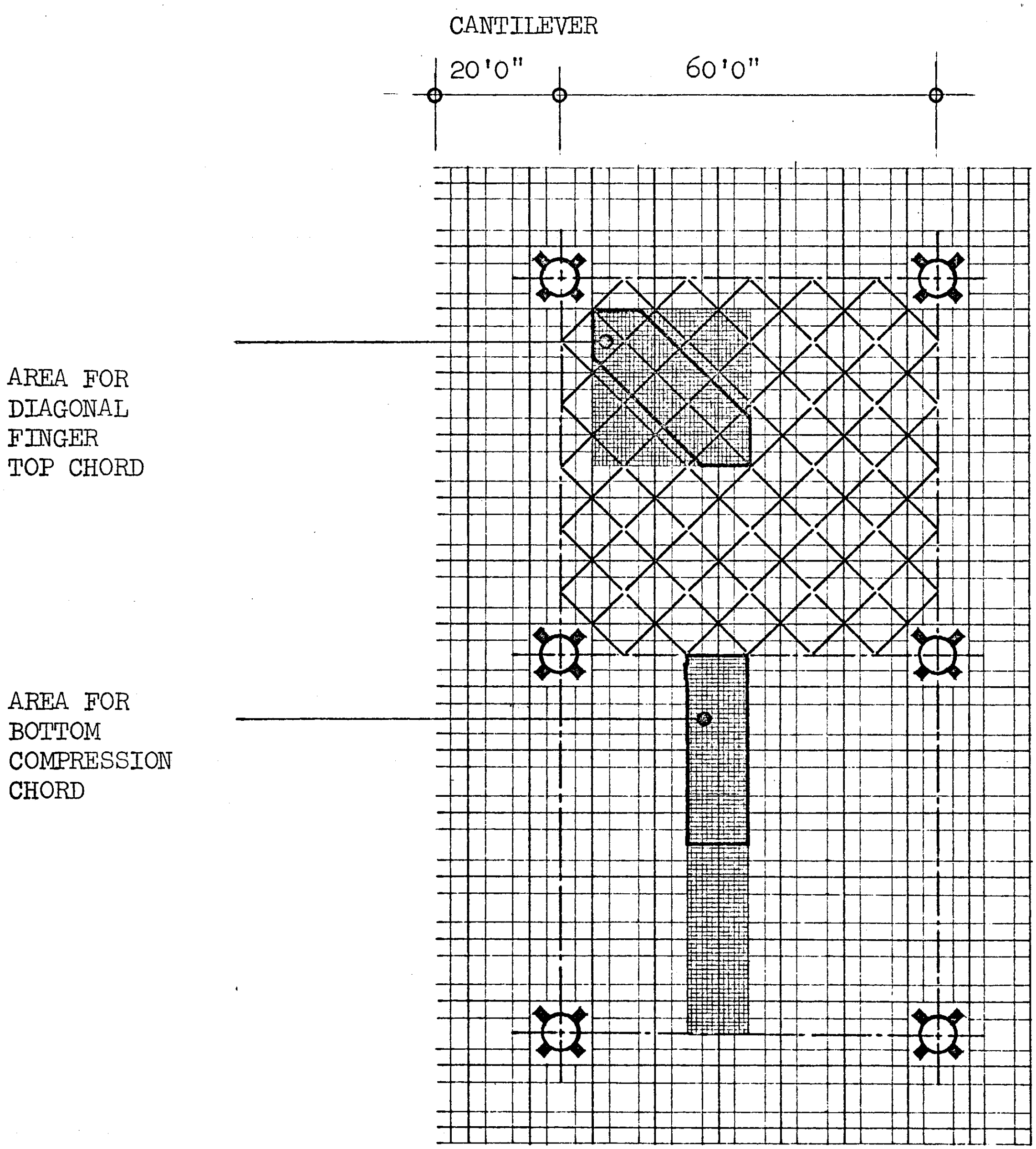
$$= \frac{60 \times 10}{2}$$

$$= 300 \text{ square feet.}$$

A^{cc} = area of concrete

$$= \frac{A^{t} \times L/}{50}$$

[1]Refer diagram, page 24.


CANTILEVER
20'0"
60'0"
AREA FOR
DIAGONAL
FINGER
TOP CHORD
AREA FOR
BOTTOM
COMPRESSION
CHORD

$$= \frac{300}{50} \times \frac{50}{4}$$

= 75 square inches

Area of post-tensioning cable

$$= \frac{A^t \times L/}{2,500}$$

$$= \frac{300}{2,500} \times \frac{60}{4}$$

= 1.8 square inches.

Hence use 37 number 2 high strength steel cables.

Area of column for five storey building in square inches

= A^t in square feet.

Area of column = $\frac{3600}{144}$ square feet

= 25 square feet.

Structural continuity of the flooring system is achieved by a combination of post-tensioning cables at the bottom of the structural units and overlapping reinforcement at the top such that when grouted in position this reinforcement develops bond and thus continuity.

The post-tensioning cables may terminate at, or continue through, the columns.

The main precast structural unit employed was a logical development of an integration of structural members following the lines of forces inherent in a two way structural system. Because of the transfer of forces diagonally to the orthogonal planning grid it is possible to incorporate floor penetrations utilizing this feature, whether by necessity or implementation of some spatial variation concept.

Removal of redundant material from the structural unit enabled voids to be formed such that the various services could be made more integral with the structure.

By combining the star-shaped structural units with the structural ceiling components a functional two way diagonal member truss system was formed. The addition of the precast floor panels and floor topping further integrated the structural units into a harmonious structural system.

The junction of these units, although occurring at the weakest point of the individual unit, is such that four units are combined to give rigidity at that point.

CONSTRUCTION SEQUENCE

A. PREPARATION

(1) Commence precasting of all structural component types.

(2) Form, reinforce and pour column and core footings.

B. COLUMNS

(3) Grout precast column sections in position to terminate one inch below R.L. of underside of suspended floor structure.

(4) Place second storey column sections in position to terminate one inch above supporting column sections.

C. FLOOR SYSTEM

(5) Erect scaffolding for first floor.

(6) Bolt 3/4 star-shaped units to column cleats and weld.

(7) Place precast ceiling panels in position.

(8) Place star-shaped units in position.

(9) Thread post-tensioning cables to bottom of structure.

(10) Grout between units at bottom of structure.

(11) Post-tension 50%.

(12) Place precast floor panels in position.

(13) Place reinforcement, electrical and telephone services and pour topping slab.

(14) Post-tension bottom cables to required stress and grout and pressure grout as necessary for steel protection.

(15) Weld column reinforcement of second storey unit which had been left free from first storey column sections for movement during post-tensioning so as not to induce moment into the column section supporting it, then grout.

(16) Remove scaffolding.

The system should follow an orderly and logical construction sequence which allows for the break-down of the various trades.

FORMWORK

Because of the large number of repetetive units, and the high cost of forms, it would seem advisable that steel forms be used, especially for the star-shaped units. These star-shaped units incorporate a void which may be formed by using either:

(a) seven solid component pieces which may be installed in the mold as a single solid but which would then have to be dismantled into seven pieces for removal.

or

(b) a heavy duty pneumatic infill which may simply be deflated for easy removal. The voids in the model castings were formed using a flexible removable infill analogous to the industrial process outlined above.

Insitu concrete formwork would create no particular problem as the required insitu concrete work is almost negligible.

A disadvantage in the erection procedure is that cumbersome scaffolding is necessary. In certain one way systems scaffolding is not required.

HORIZONTAL PENETRATIONS

In a two way structural system there are no main supporting elements as divorced from secondary elements.

With the exception of an area of approximately 400 square feet assymetric about each column there is no restriction as to where penetrations may occur. Due consideration should be given, however, to severing post-tensioning cables and to maintaining the required proportion of structural continuity.

Penetrations for elevators and stairwells would be in 10'0" square increments such that continuation of the post-tensioning cables is maintained wherever possible.

MECHANICAL

"Environmental control is the maintenance of atmospheric factors such that the combination of proper temperature, humidity, air motion and radiant temperature are so balanced that the body can dissipate, at the correct rate, the excess heat generated."[1]

The incorporation of a mechanical system in a large building is normally a necessity for the supply of fresh air in places which would otherwise prove uncomfortable. Comfort then is the main criteria.

With a functional depth of 4'0" for a structure spanning 60'0" it was found that a certain free area penetrating this structure remained after the component structural members were sized. This free area posed a limitation on the maximum sized duct work that could penetrate the structure

1 The ABC's of Air Conditioning, pages 2-3.

and at the same time somewhat control the ductwork layout.

For maximum flexibility the area served by each supply run should be small so as to warrant small ducts.

Therefore there evolved a condition whereby correlation between structure and mechanical became necessary if an efficient and functional system was to evolve. Various structural unit configurations were assessed during this juxtaposition period.

The parameter for the mechanical air supply was established at 2 c.f.m. per square foot of floor area served. This quantity determined the upper limit of the system flexibility. However, the system should be capable of unlimited variation in both air quantities below 2 c.f.m. and direction. For this to be feasible the system had to be readily accessible without necessitating any change in the members of the permanent structural system.

The location of basic services should be such that it would always be possible to meet unforeseen requirements promptly and economically.

A core supply restricts internal planning flexibility in that cores are required at reasonably frequent intervals because of the incapability of the functional two way structure to integrate supply and return ducts of a larger nature than those required when using column plenums.

A column supply is static and enables a repetitive and therefore economic ductwork layout.

To give maximum internal flexibility for the layout of ducts within a structure expressing diagonal lines of force it became obvious that the ductwork would require to be as small as possible whilst at the same time exhibiting the environmental control required in an efficient and economical way. For simplicity and hence economy, the ductwork should be repetitive.

As large penetrations would occur frequently through the floor structure in a variety of positions it became obvious that certain duct layouts would be inefficient.

Whilst seemingly impossible to attain a duct layout which would maintain environmental control without some duct variations it was possible to achieve duct layouts which, although on rare occasions may require minor adjustments, would never necessitate overloading the standard ductwork layout.

Two duct layouts were submitted, one of which exemplified the structural concept to the maximum in that it is almost entirely hidden by the structural members. This system supplies air from one column and returns the same air at an adjacent column. The second alternative ductwork was based on a radial supply and return system independent to each column.[1]

The most functional mechanical system to employ catering for the preceding criteria would be a single duct all air cooling system with electrical reheat units.[2] This system would require a reheat unit at each small subdivision where individual control was required. This situation

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[1]Refer plate, page 44.

[2]The ABC's of Air Conditioning, page 4.

would be in the minority. The electric reheat units may easily be repositioned as necessary. Each zone would cover one half bay in area, or alternatively, with the diagonal supply system, one quarter bay in area.

Because of the differential heat load on the perimeter wall surfaces of the building as compared with internal areas it is advisable to incorporate supplementary convection units.

A 3-pipe fan coil system, incorporating chilled water supply, hot water supply and a common return, could be used such that both heating and cooling would be available at separate units at any one time.[1]

The ceiling panel design is such that the orientation of both the supply and return registers may be oriented through 90 degrees about the central lighting fixture to best suit the particular planning arrangements.

Studies of the area required for both the column support and the air supply and return ducts indicated that for both supply and return to

[1] The ABC's of Air Conditioning, page 8.

occur at the columns 3 riser ducts would normally be required. These would have to be satisfactorily enclosed to reduce the sound being transmitted to the surrounding areas by the high velocity ductwork and also to sustain possible damage from impact. It was considered, therefore, that the integrated column plenum used was functionally acceptable.[1]

The vertical air supply has a maximum velocity of 4,000 feet per minute. Horizontal air distribution has an initial velocity of 1,200 feet per minute and a final velocity to the air supply register of 700 feet per minute. The high velocity air supply would leave the column at 4,000 feet per minute, reduce in velocity by means of a control valve and then pass through an attenuator system combined with a reheat unit where applicable.

Eighty percent of the supplied air would then be returned to the column at a maximum velocity of 1,200 feet per minute. At the column this would be increased to approximately 1,850 feet per minute. An insulated high velocity supply duct would be positioned centrally within this column plenum.

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[1]Refer plate, page 44.

The columns also contain plumbing risers, vents, various water services and gas runs. Main electric feeds, including telephone cable risers would be incorporated in the permanent core elements.

MECHANICAL ROOM

Because of the vibration usually associated with refrigeration machine compressors, it was considered wise to position this heavy equipment along with the boiler in the basement. The preheater, filters, dehumidifier, humidifier and fan would be positioned on or near the roof at the air supply source. The unfortunate fact about column supply from the roof is that large ducts have to traverse the area of the building to feed the individual columns. Smaller air treatment plants serving smaller zones would therefore be logical.

FIXED ELEMENTS

Permanent fixed elements other than columns include stairs and elevators. These are self-supporting and are not used structurally. Spatial changes are augmented by the initial removal of permanent elements from the structural system context. Concentration of stairs for all major occupancies in education facilities, with the exception of office areas, is such that no entrance from any habitable room is more than 100'0" from an escape stair. Should the occupancy of an area change, further minimum width stairs may be added without undue complications.

Three stair sizes have been incorporated in this particular system such that where initial stair concentration is required larger stair sizes may be used rather than an unwanted buildup of minimum sized stair units.

In general elevators should be considered for buildings of four storeys and over, with operation restricted to those floors above the first and second floors. A generally acceptable basis for determining the number of elevators needed is that they should be sufficient to carry peak traffic to the upper floors within thirty minutes with an average waiting time per passenger of about thirty seconds.

Freight elevators are normally provided where there is likelihood of constant vertical transportation being required for heavy or bulky equipment.

ENVIRONMENTAL CONSIDERATIONS

A. ILLUMINATION

The system should be flexible in its intensity in order to achieve the desired environment for a given function. Special square fluorescent lighting fixtures, only recently developed by lighting manufacturers, have been incorporated in this system. These units, being square in shape, functionally harmonize with the structure irregardless of the required lighting intensity.

B. ACOUSTICS

Concrete has little absorptive value. The integrated structure has penetrations above the partition junction with the underside of the structure which readily allows the transmission of sound from one space to another. Essentially the system should be flexible enough to cater for different functional requirements. Large areas requiring no restriction to sound transmission would have an absorptive panel integral with the underside of the precast floor panels to help reduce the reverberant sound. Thus the fully integrated system is expressed to the occupants below.

In cases where sound transmission should be restricted, sealing by means of panels at ceiling level is necessary. This may be done either by: (a) removable precast coffer panels placed into the structural ceiling panels and sealed,[1] or (b) precast panels placed vertically within the ceiling construction and caulked at all junctions insitu.

CONCLUSION

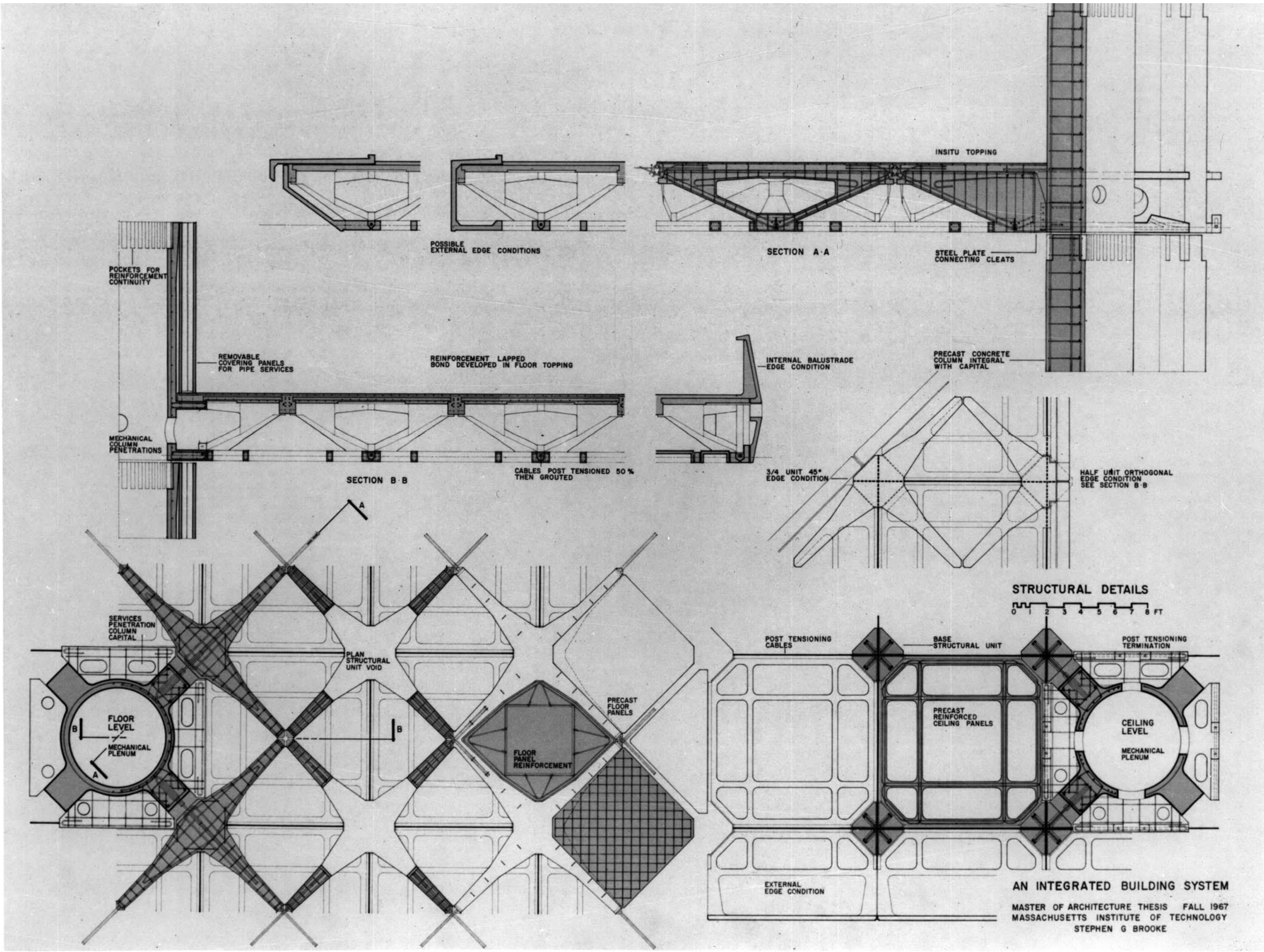
With few reservations the reinforced concrete two way integrated building system fully exploits function and structural and economic efficiency.

In construction reinforced concrete allows for a tolerance factor unmatched in systems of equal performance in other materials.

The efficient spans allow maximum planning flexibility in two directions.

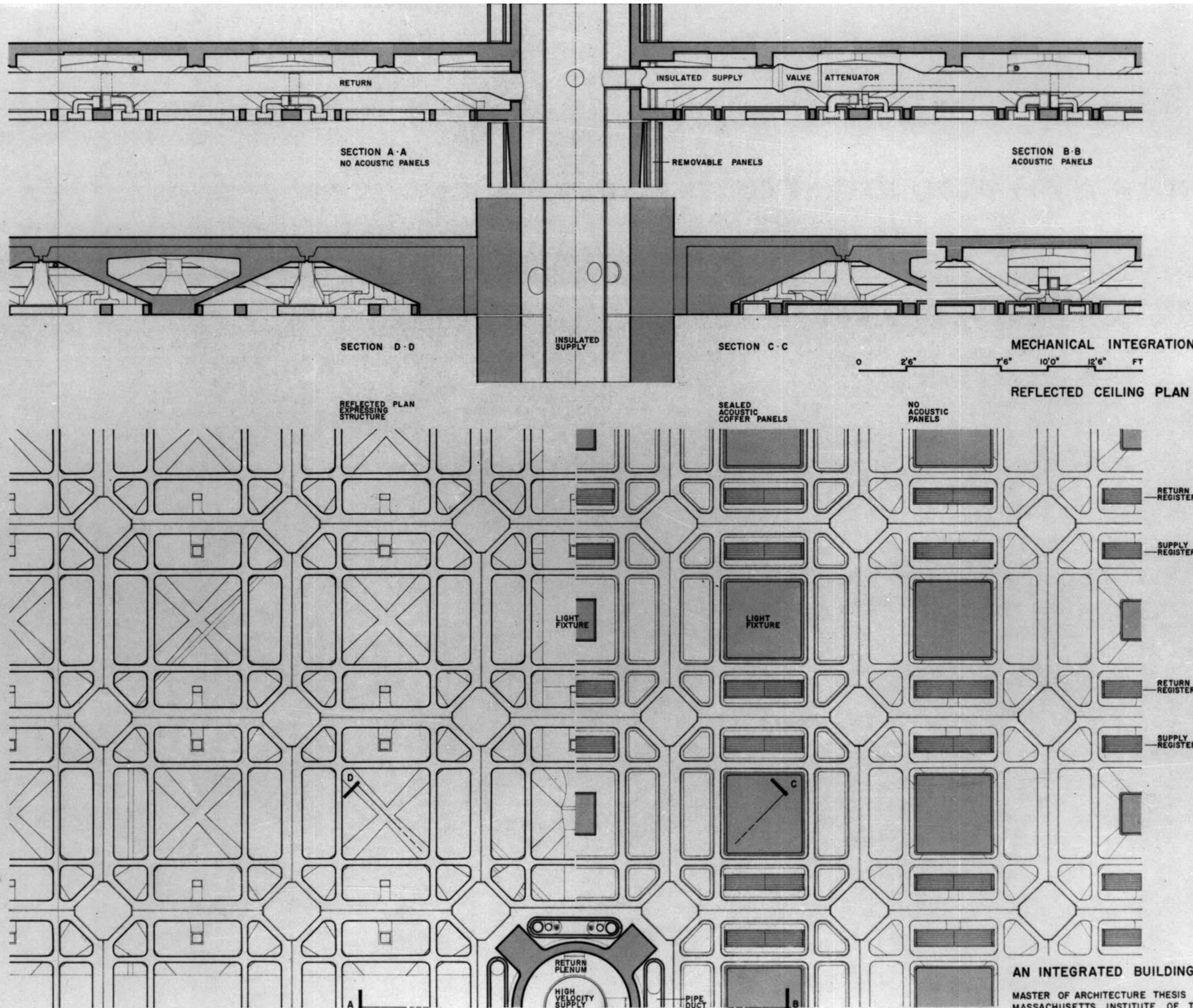
A reinforced concrete system provides a sense of human scale which is not so readily available with other structural materials in buildings for human use.

Overall, the concept of possible endless growth in two directions, whilst at the same time adhering to a basic theme which would, at all times, be evident in the building complex, must provoke excitement, approval, and agreement as to its inherent necessity.



AN INTEGRATED BUILDING SYSTEM

MASTER OF ARCHITECTURE THESIS FALL 1967
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
STEPHEN G BROOKE



AN INTEGRATED BUILDING SYSTEM

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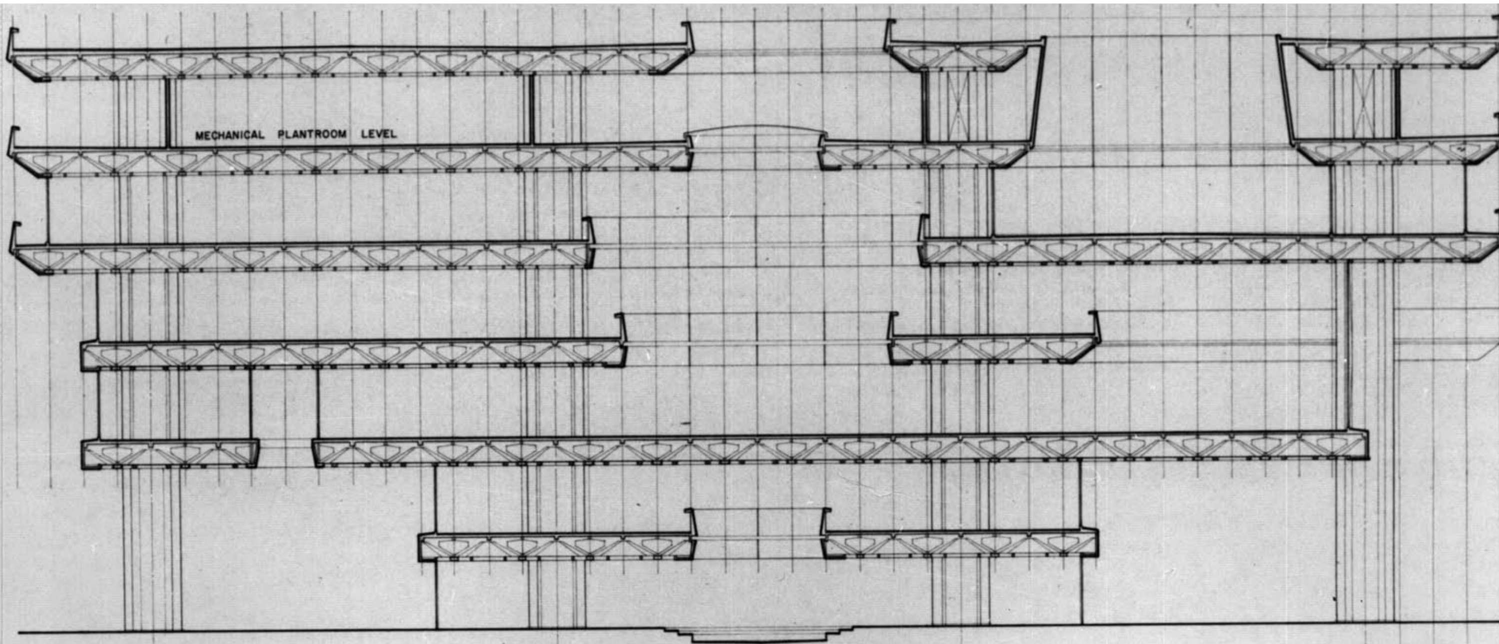
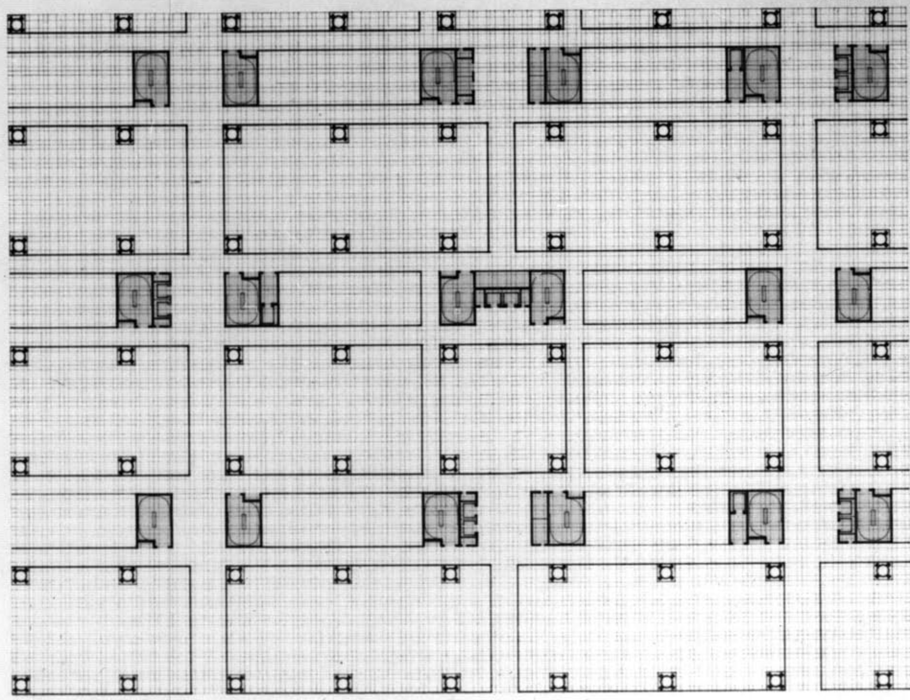


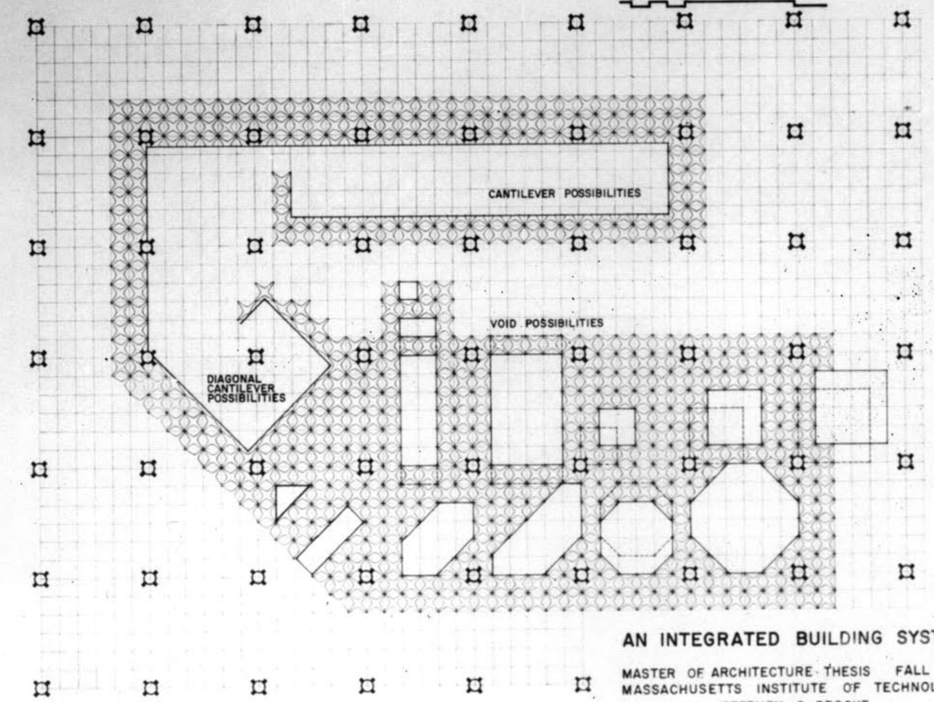
SECTION VARIATIONS
0 5 10 15 25 FT

SYSTEM NETWORK

EXAMPLE
BASED ON
CLASSROOM OCCUPANCY
20 SQU FT NET
PER PERSON



EDGE CONDITIONS
0 15 75 FT



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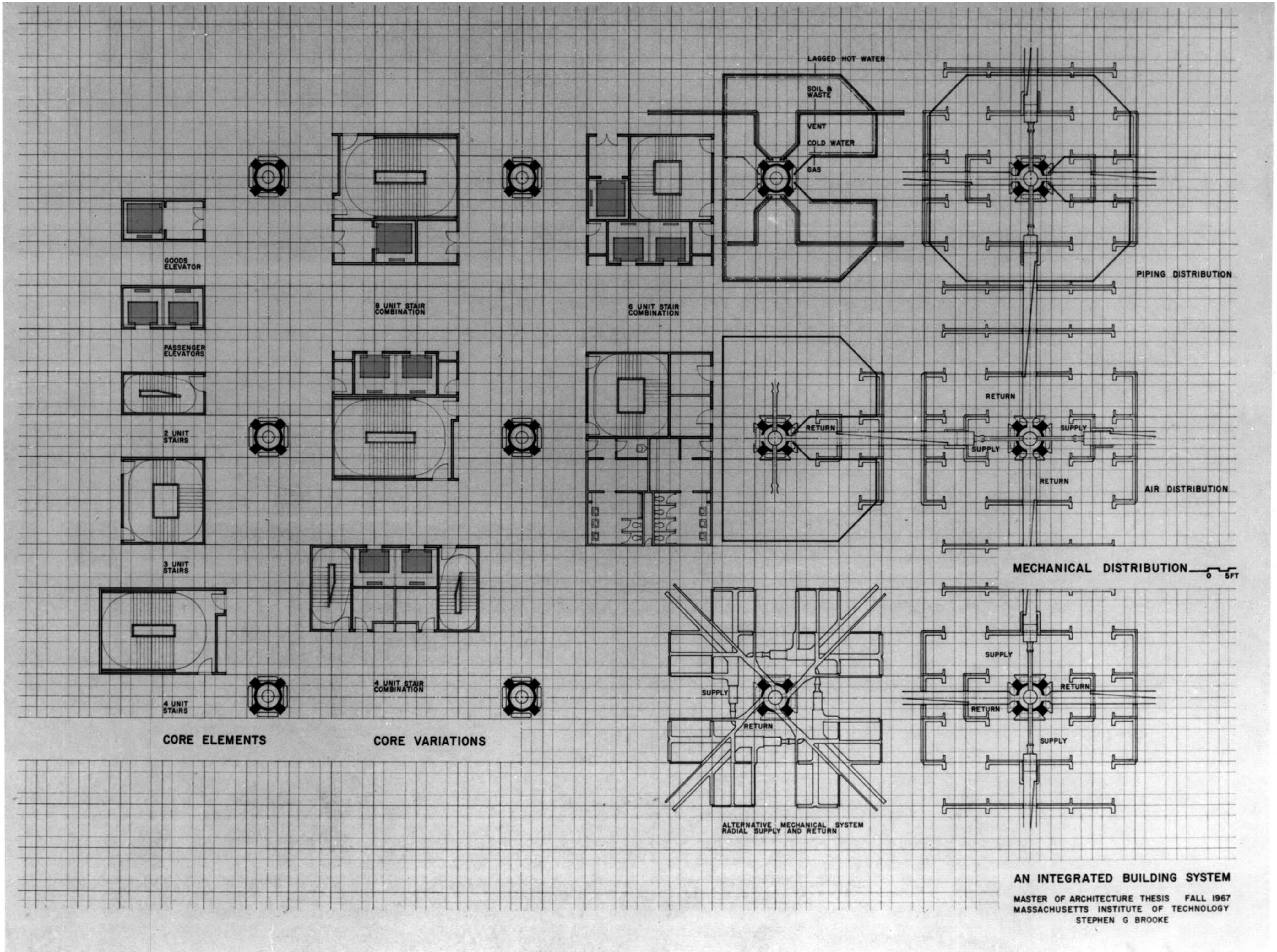

GOODS ELEVATOR
PASSENGER ELEVATORS
2 UNIT STAIRS
3 UNIT STAIRS
4 UNIT STAIRS
8 UNIT STAIR COMBINATION
6 UNIT STAIR COMBINATION
4 UNIT STAIR COMBINATION
CORE ELEMENTS
CORE VARIATIONS
LAGGED HOT WATER
SOIL & WASTE
VENT
COLD WATER
GAS
PIPING DISTRIBUTION
RETURN
SUPPLY
RETURN
SUPPLY
RETURN
AIR DISTRIBUTION
MECHANICAL DISTRIBUTION
0
5FT
SUPPLY
RETURN
ALTERNATIVE MECHANICAL SYSTEM
RADIAL SUPPLY AND RETURN
SUPPLY
RETURN
RETURN
SUPPLY
AN INTEGRATED BUILDING SYSTEM
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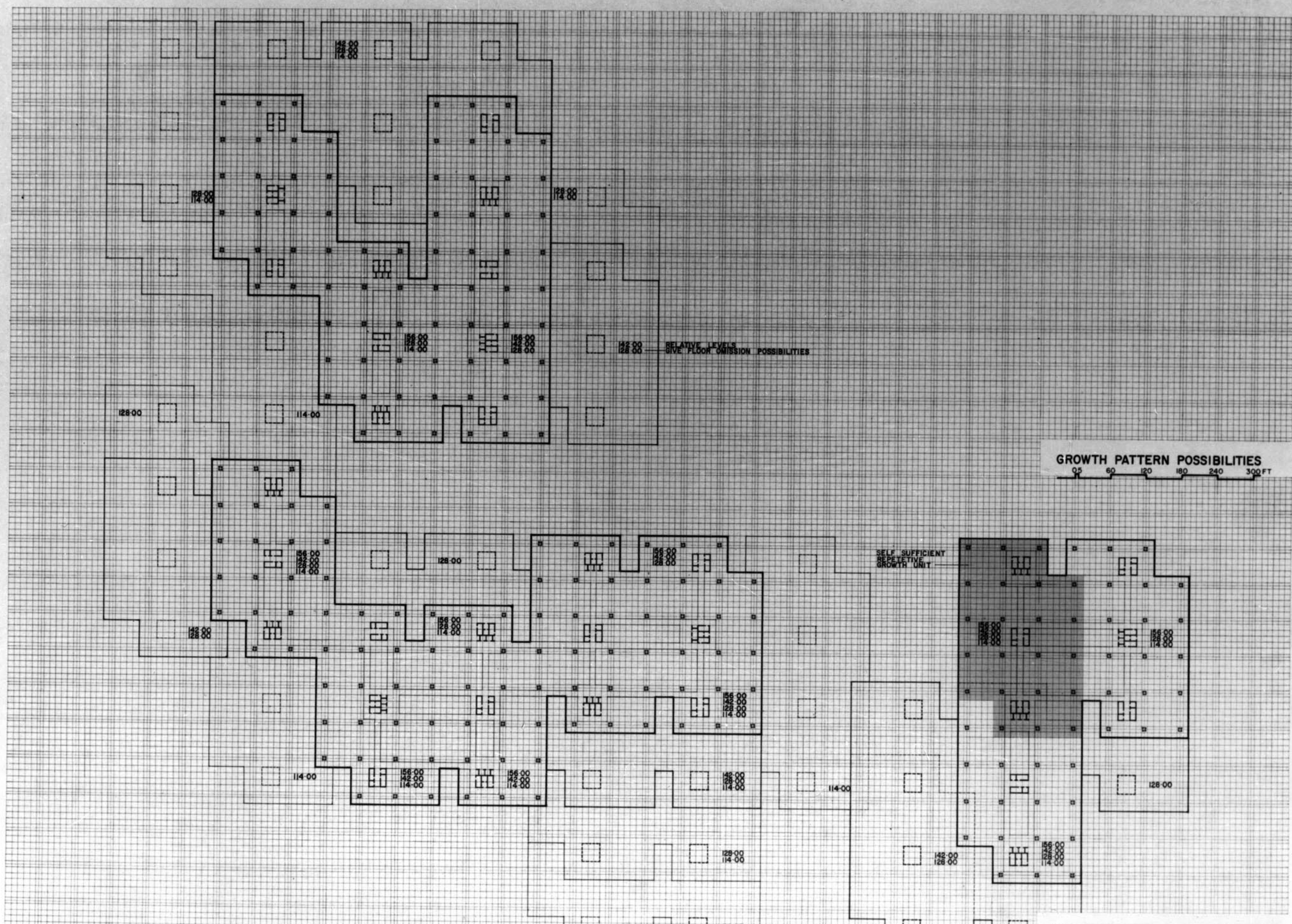

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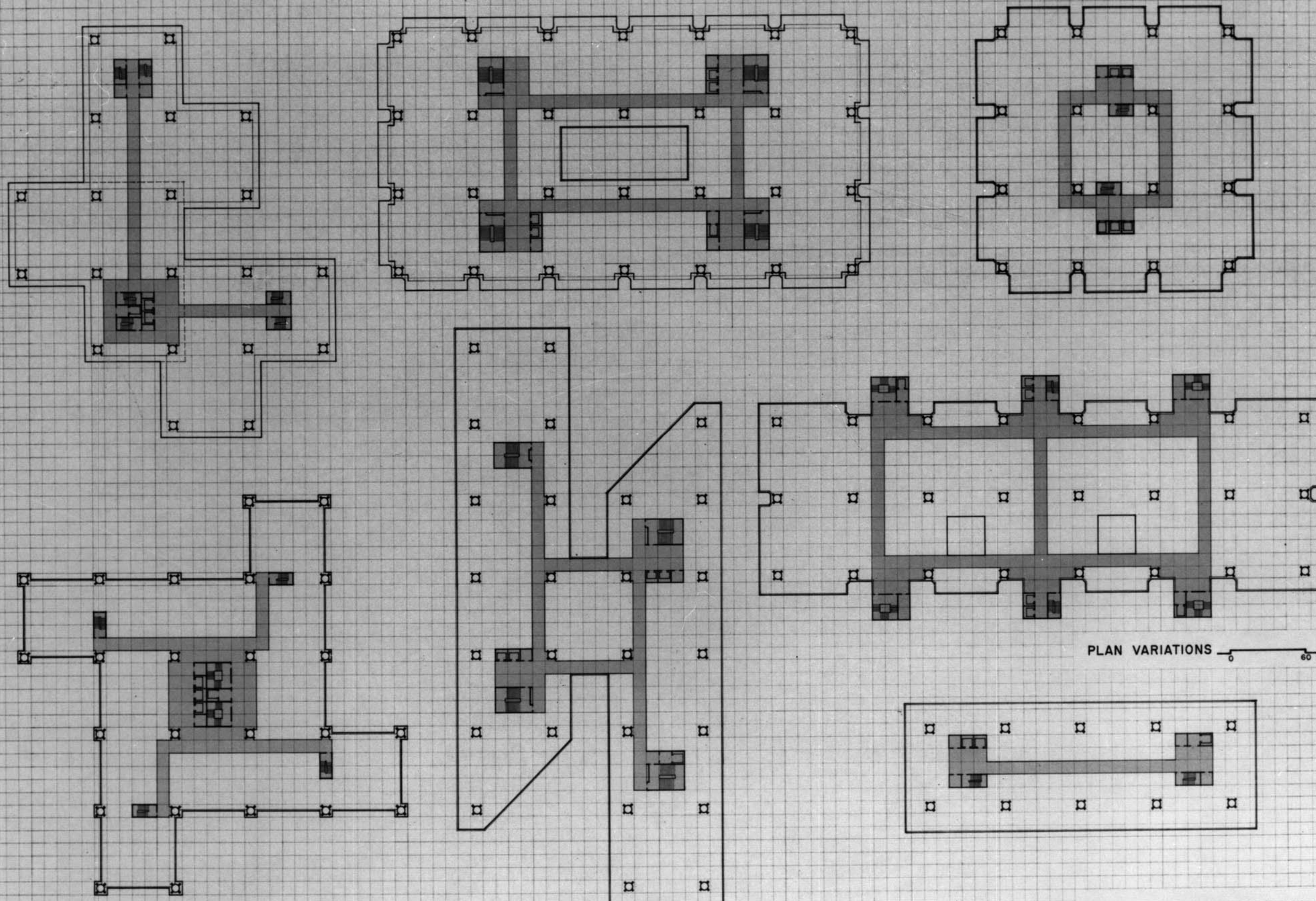

PLAN VARIATIONS

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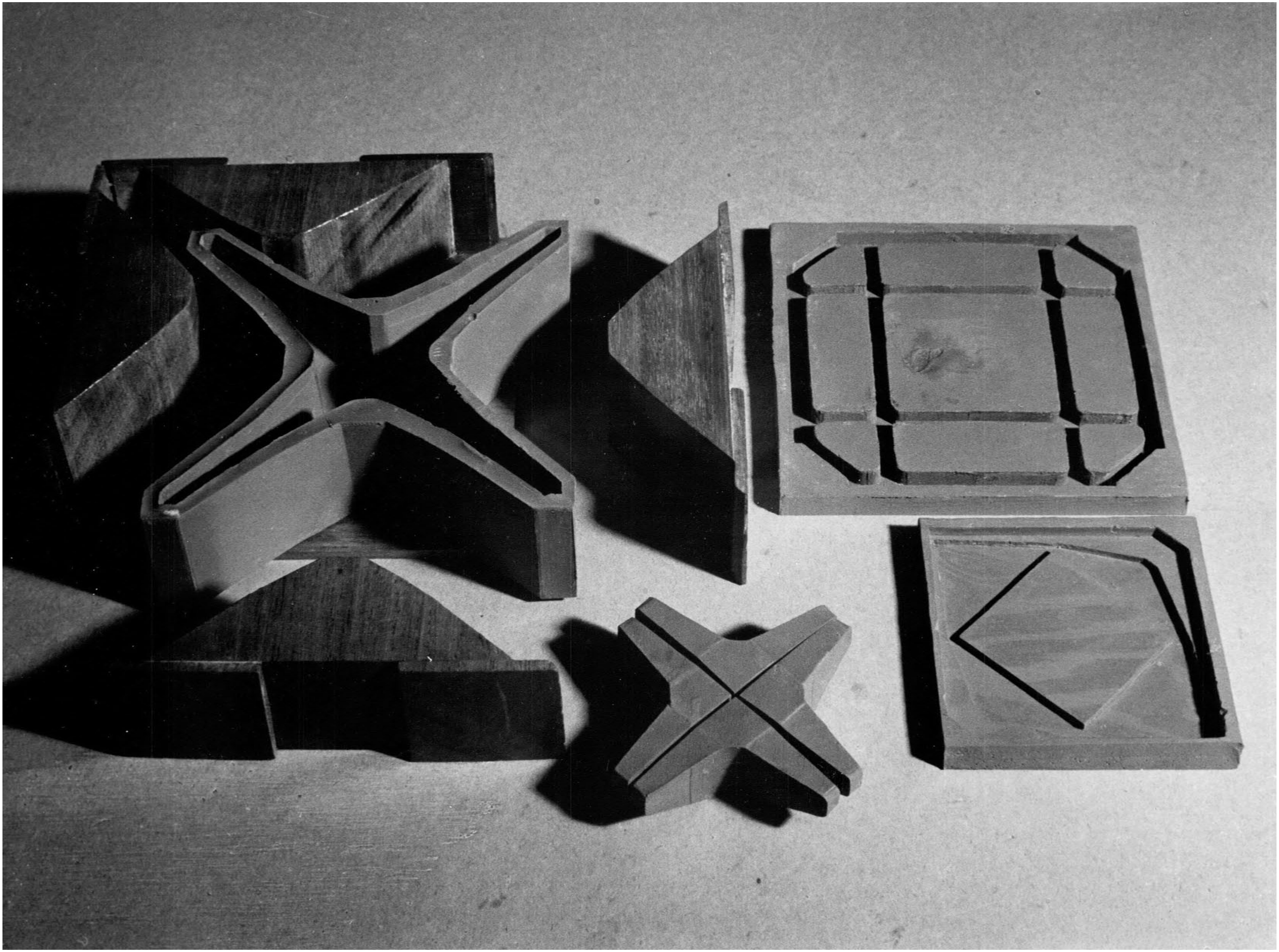

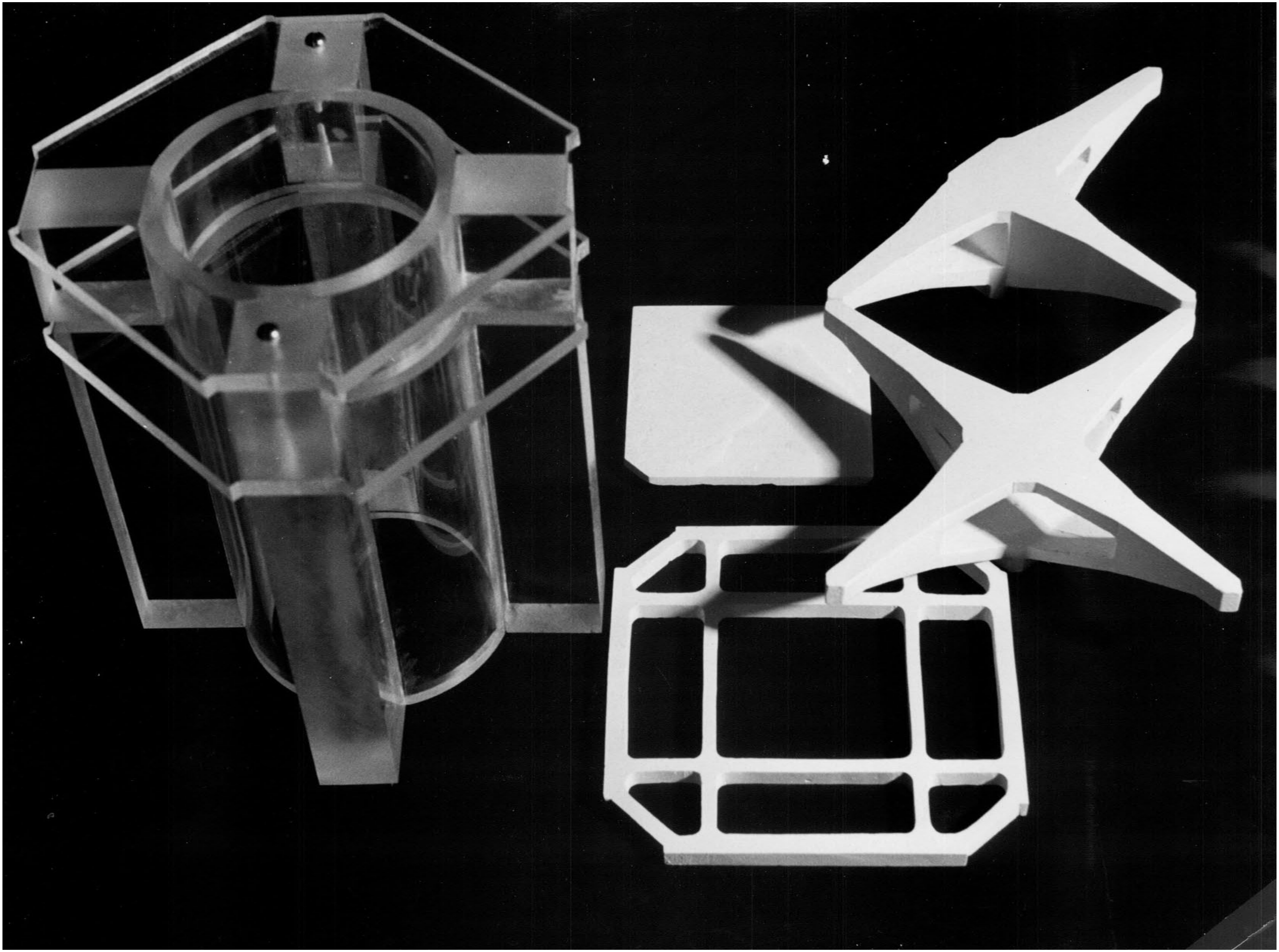

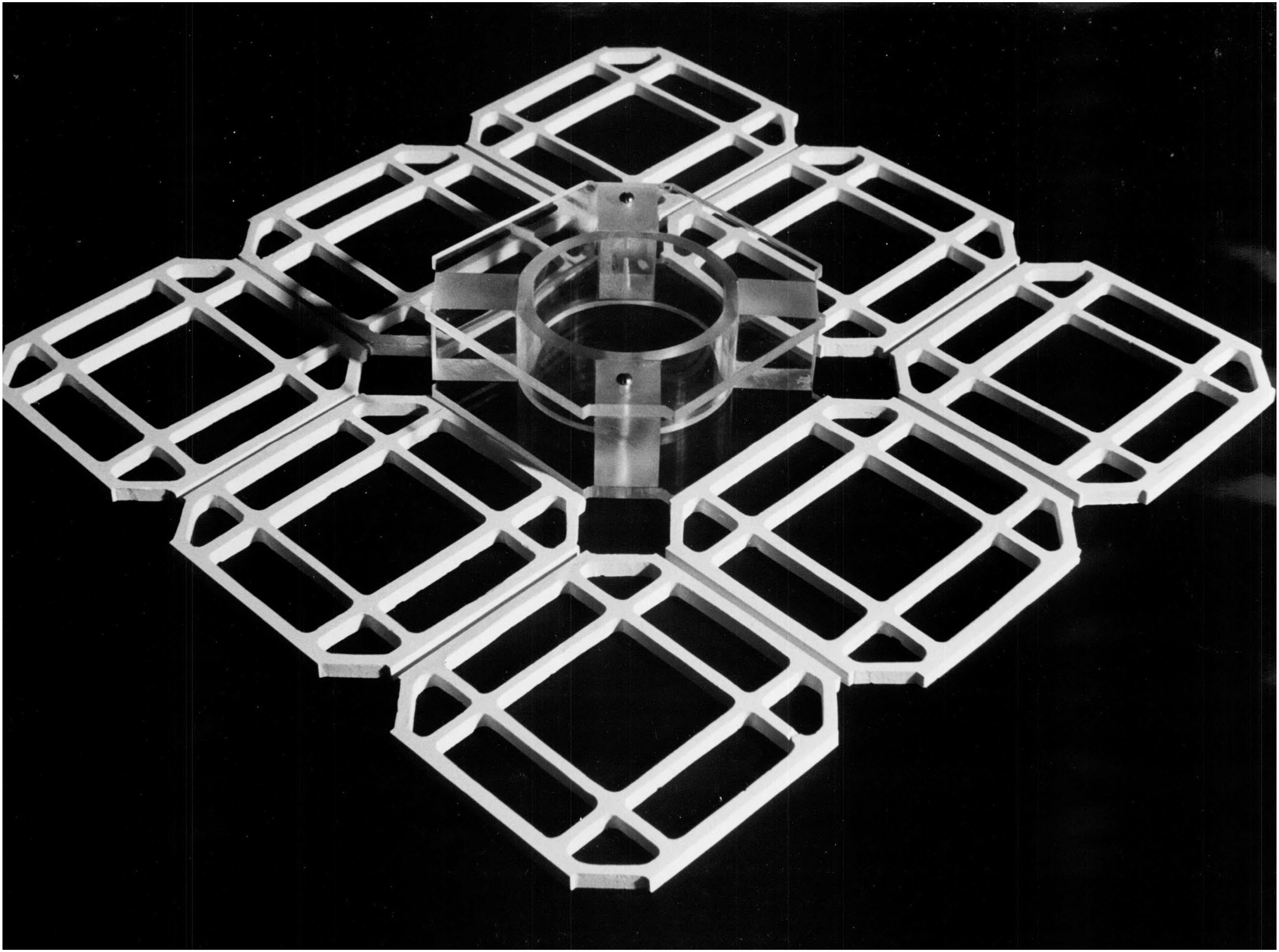

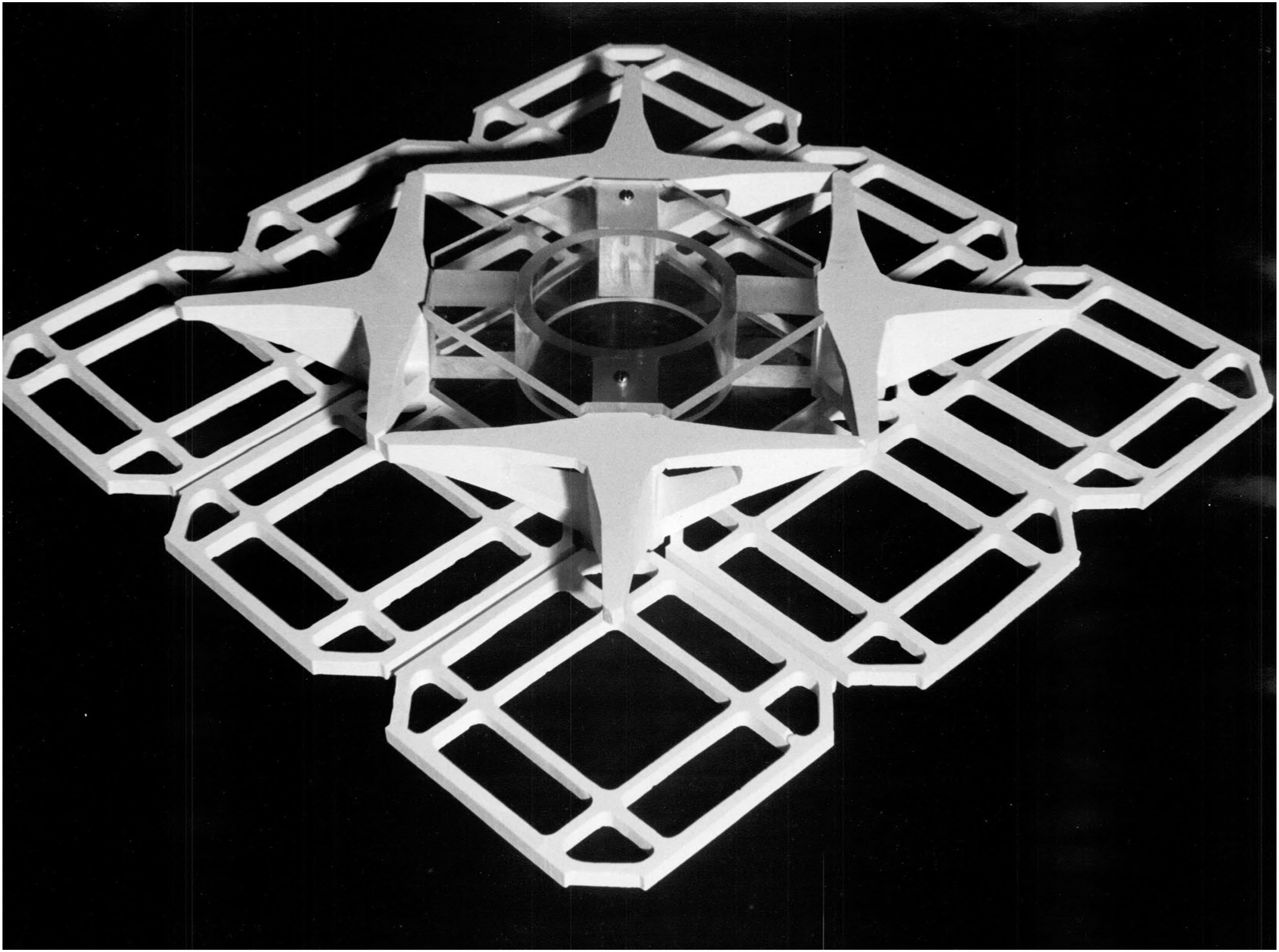

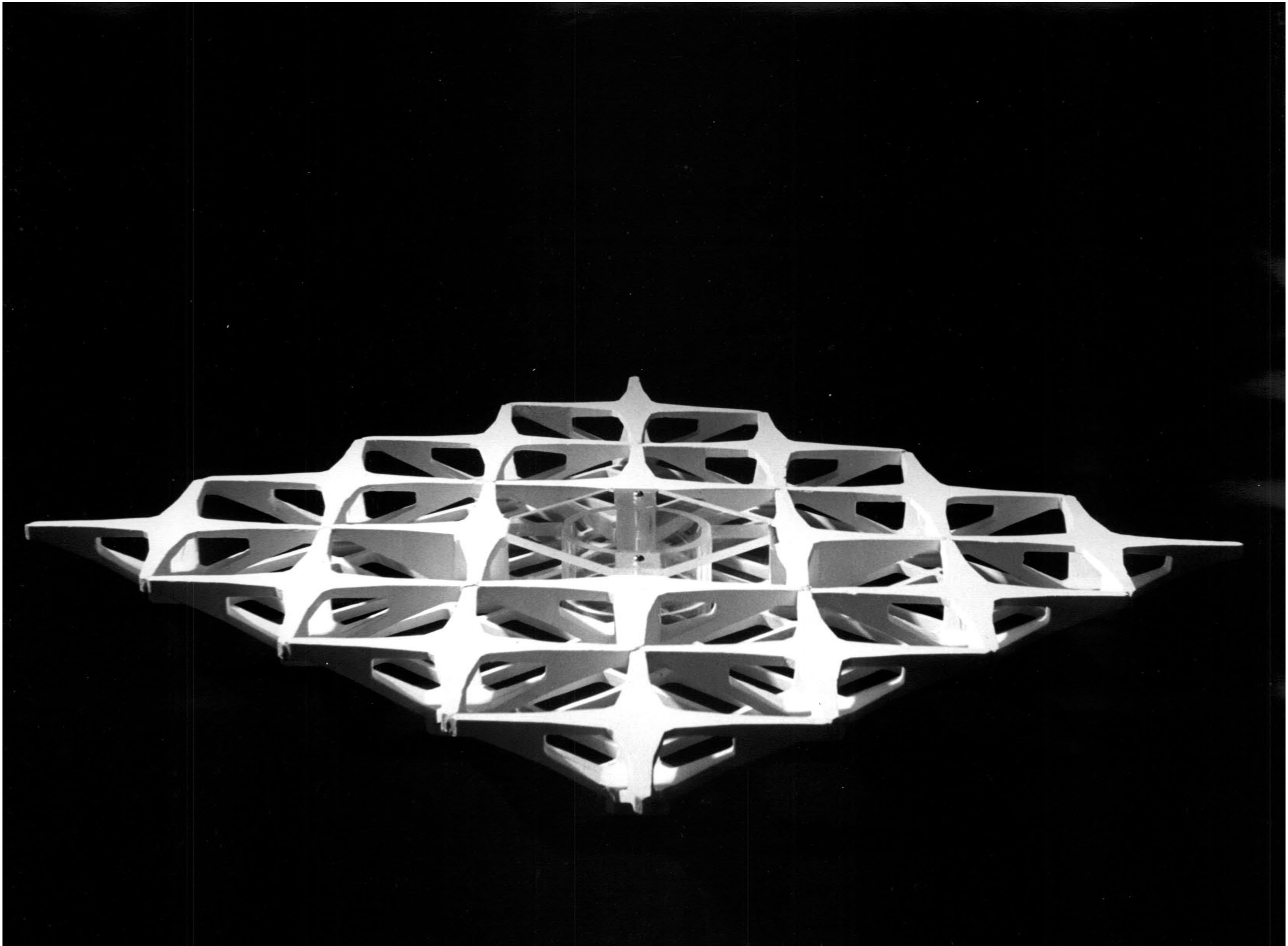

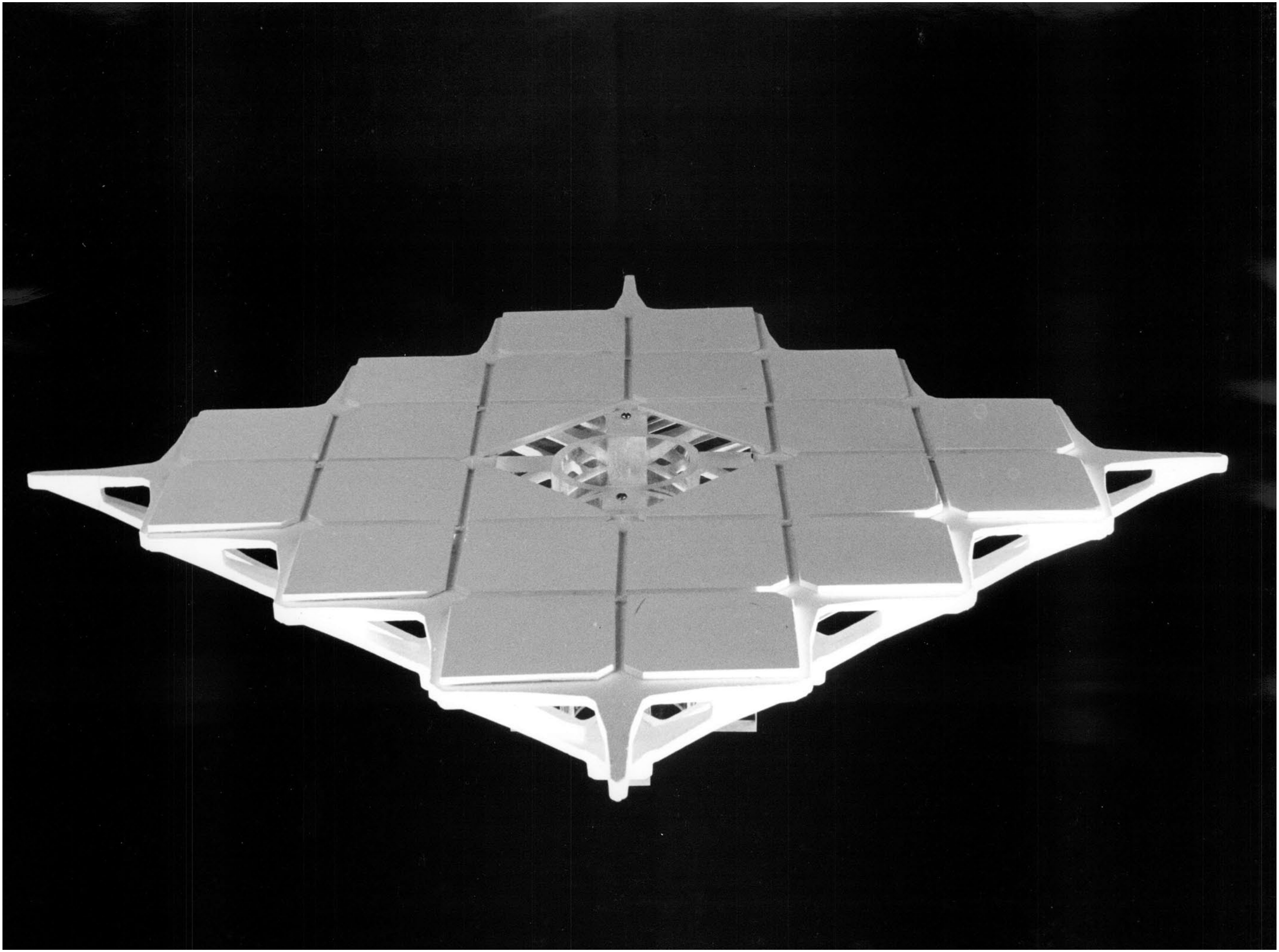

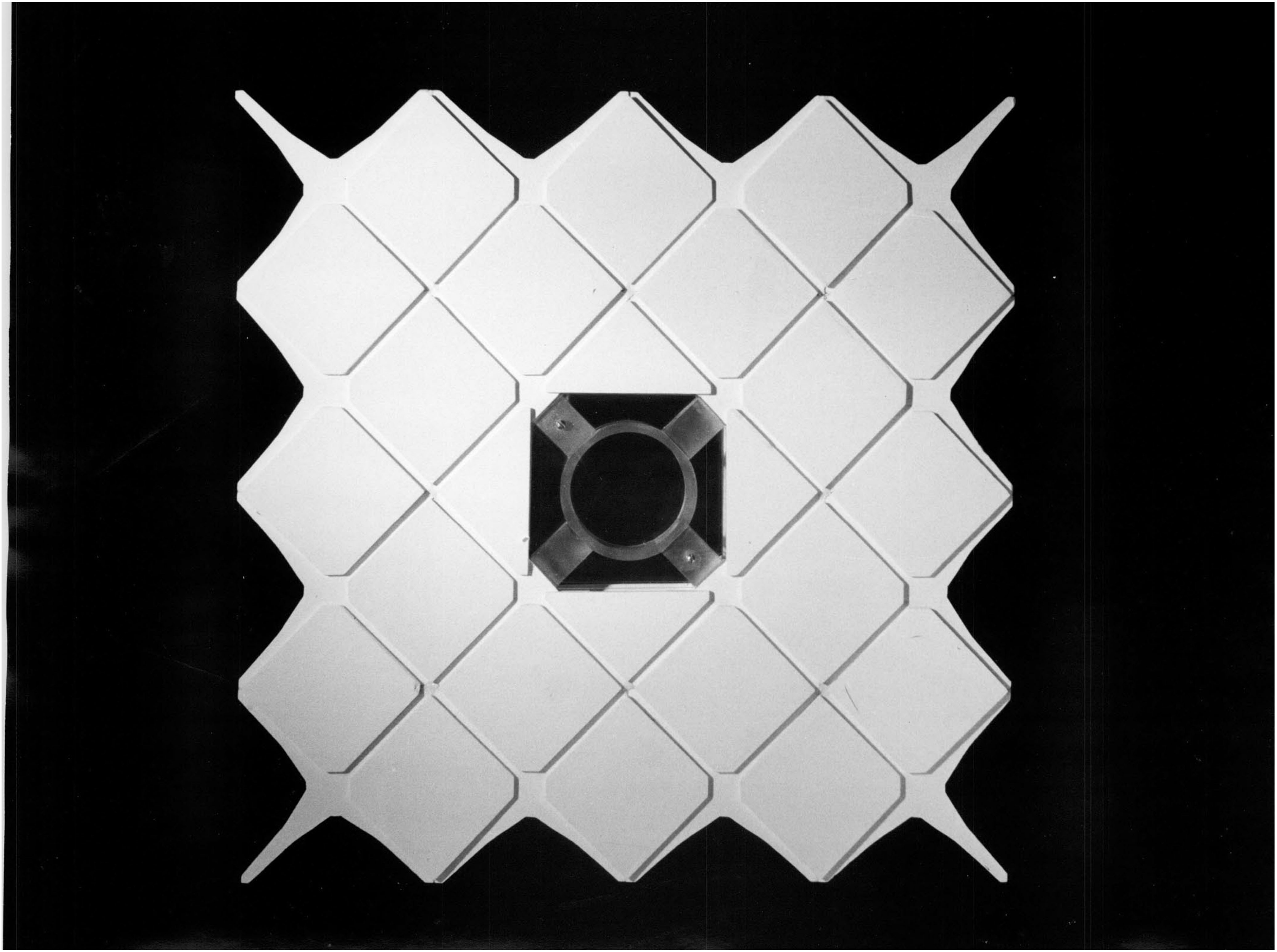

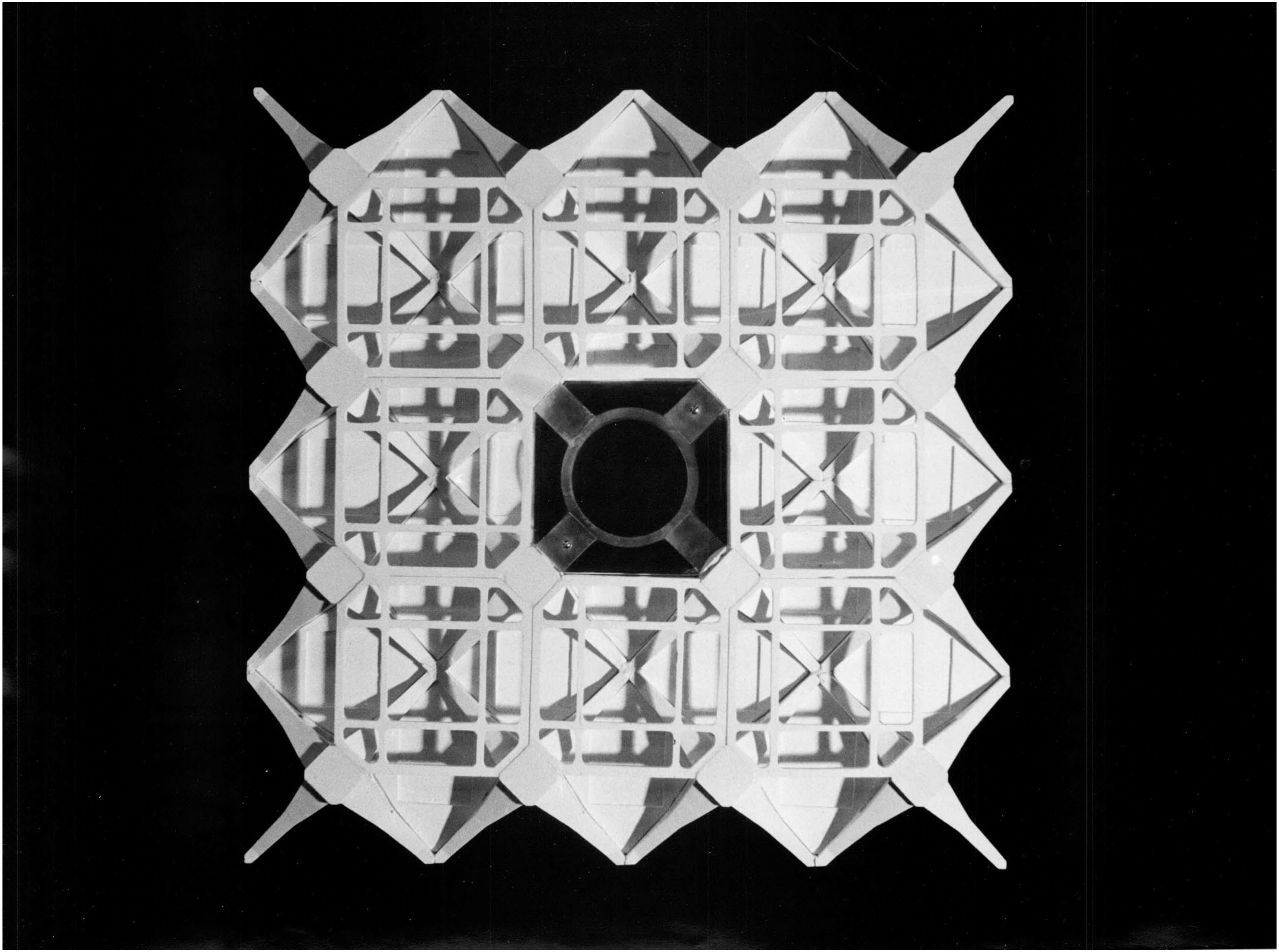

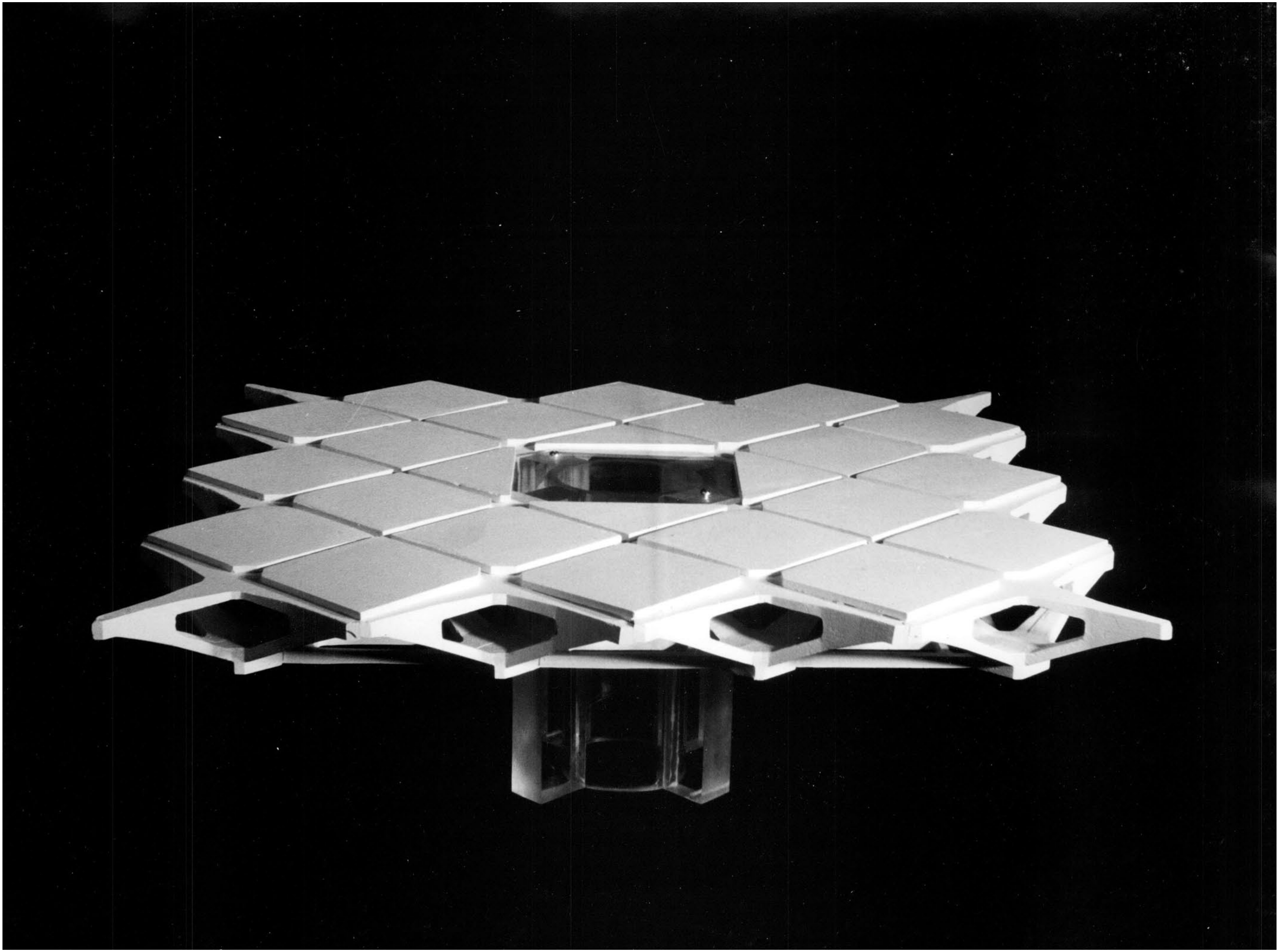

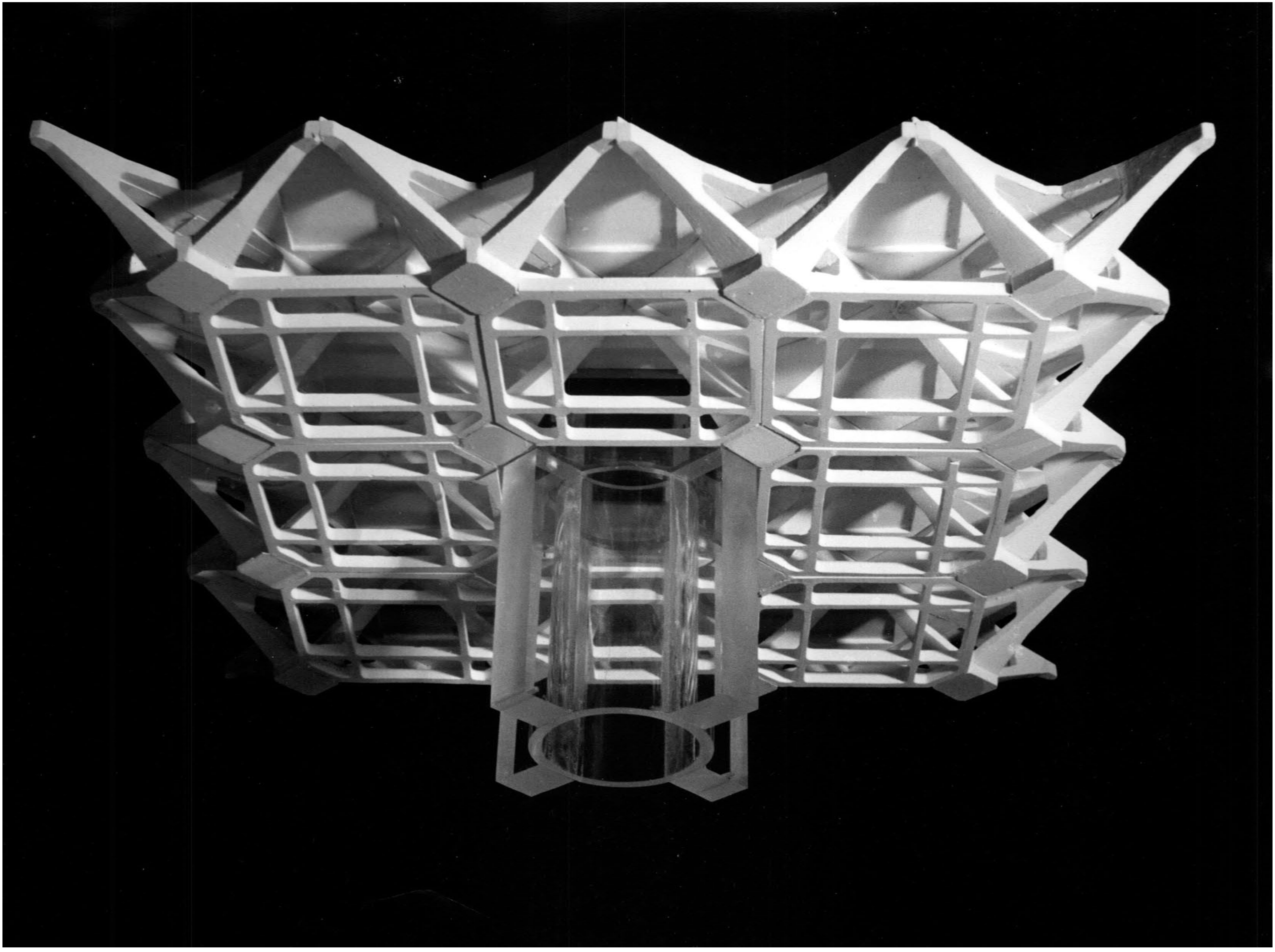

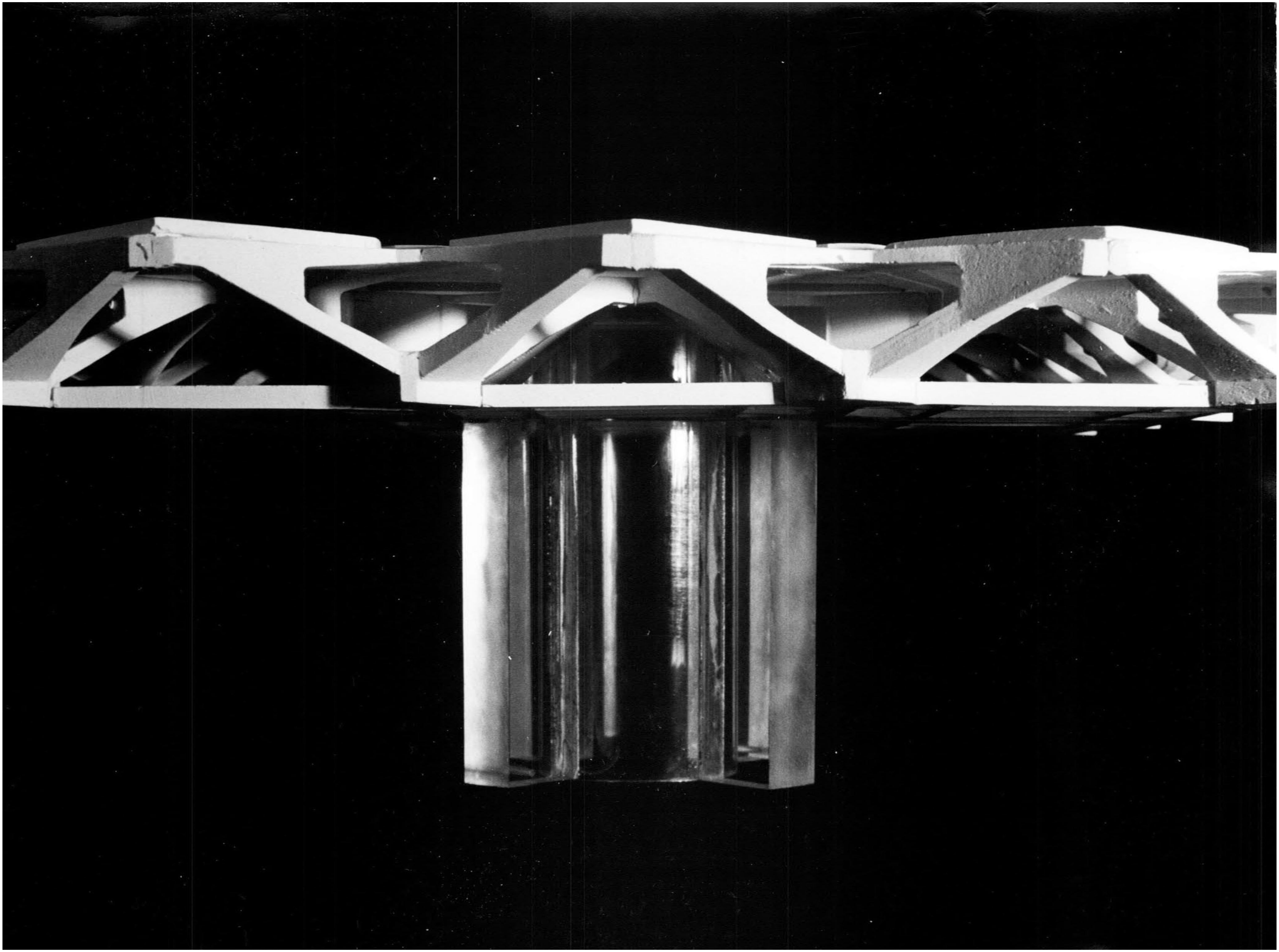

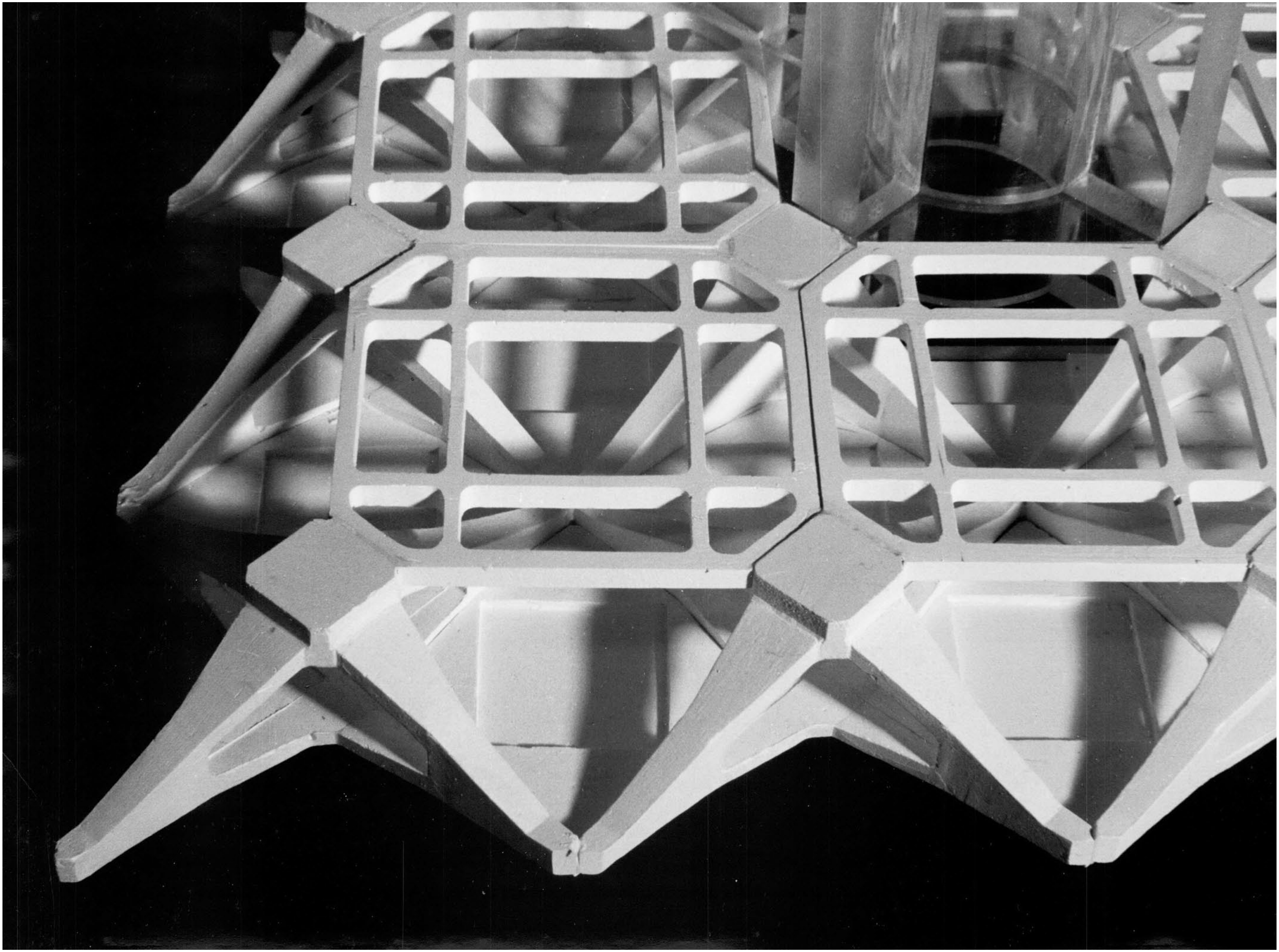

APPENDIX

As a class project a computer program was formulated, the aim of which was to enable the design of an integrated building system by feeding into the computer varying information criteria.

The program was capable of producing either a one way or two way system, each dependent on the initial information criteria.

A copy of the program entitled: "Computer Supplement for Integrated Building System Prototypes, 1968," will be available for reference from the school library.