

H I G H D E N S I T Y H O U S I N G
O N S T E E P S L O P E S

Submitted in partial fulfillment of the requirements
for the degree of Master in Architecture
at the
Massachusetts Institute of Technology

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Dipl. Ing. Arch. Univerza v Ljubljani, 1957

U O
| A |
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June 1967



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Massachusetts Institute of Technology
Cambridge, Massachusetts
June 1967

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

Dear Dean Anderson:

In partial fulfillment of the requirements for the
degree of Master in Architecture, I hereby submit this
thesis entitled "High density Housing on Steep Slopes".

Respectfully

Janez Lajovic

(U U

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

The Author wishes to thank the following
who's assistance contributed substantially
to the included thesis projects.

1. Prof. Waclaw P. Zalewsky
2. Prof. Eduardo F. Catalano
3. Members of the MIT faculty
and the guest jurors who participated
in the thesis jury, June 1967.

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

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HIGH DENSITY HOUSING ON STEEP SLOPES

INTRODUCTION

Among the world metropolitan areas, several enclose vast tracts of land, often in very central positions, which because of excessive inclination could never have been used for any urban need, not even for recreation. The cities have spread around these obstacles, usually in an inconsistent and badly organized suburban pattern. As soon as their newly acquired mobility had enabled the well-to-do people to move further away, many hilly lots around the centers began to decline. There is not enough money left to support the development and modernisation of the existing facilities, and obsolescence in turn repels those who have the money and would be interested in proximity to the center. This vicious circle is perceptible in every large city in the plains as well, and the known solutions are either the change of use or redevelopment, i.e., tearing down or rebuilding the obsolete, and constructing new housing and communal facilities. This represents an activity which no private capital would normally undertake. It is therefore financed by government or public authorities, and accompanied by all restrictions in standards and design which mark the social housing in all but a few Scandinavian countries.

2.

The existence of unusable land, which up to now in several ways has hampered the development of cities in hilly regions, may offer another solution: to open up the slopes for the kind of high density housing that would attract both private capital and the occupants with a good average income. This problem is studied in the case of Pittsburgh, Pennsylvania, USA.

THE CASE OF PITTSBURGH

Pittsburgh has all the general characteristics mentioned above. Founded in the valley at the junction of Monongahela and Allegheny Rivers, the city has had to expand into extremely hilly surroundings, and claims today that 85% of the land within the city boundaries is unusable for building purposes.

The project suggests a means to improve conditions and trigger the further redevelopment of the southern part of Pittsburgh by building up the southern eastern and western slopes of Mt. Washington and Mt. Oliver, which because of the inclinations between 35° and 50° could not be used before. The whole area lies within 3.0 miles (4.8 km) radius from the central business district called the Golden Triangle. There are several housing developments in the valleys and on the hill plateaus, with good roads and several rail connections to the center. The project provides for a total of over 100,000 new inhabitants in an area of about 10 km^2 (1000 ha) thus raising the overall density by about 100 inh./ha.

3.

The added number and buying potential of new population will doubtless stimulate the construction of new, and rehabilitation of older, shopping centers, schools, playgrounds and other urban facilities, on the ground appropriate for that kind of use. Although this will raise the values of existing properties, there will be less pressure on them because the bulk of new housing will be constructed on previously unusable land. As a result there is a good chance that a great deal of flat land can and will in the future be converted into uses which enhance the way of living and improve the quality of a community.

BASIC PROBLEMS

There are several specific problems of building on a hillside, resulting from the limited accessibility and reduced stability of inclined terrain, which play a part in the economy, construction, and operation of buildings.

The recent developments of terrace houses on slopes, which are the only types used heretofore on inclinations above 30° , are :

1. Expensive because of the preparation of site and complicated handling of building materials,
2. In danger of landslide because of vertical foundations,
3. Limited in the density (cca 1000 - 1.200 inh./ha) at a total coverage of a 45° slope).

4.

In comparison, this project proposes a safe use of slopes of any inclination, for all kinds of (economy class and more expensive) apartments, achieving thereby a density of over 2000 inh./ha, with most of the existing vegetation preserved.

The proposed housing utilizes:

- a) the rigidity of a large structure which inherently transfers vertical loads to the foundations at the bottom of the hill, thus loading the slope only with forces perpendicular to its surface,
- b) the construction sequence where each part of the finished construction forms the working platform for the preparation of the next section of the slope
- c) the recent developments in prefabrication of building parts and in the lifting capacities of helicopters.

THE REASONS FOR THE SPECIFIC FORM

The development of the basic structural idea is explained on the introductory sheet. The project changes the simple form of a straight slab on a slope into a curved one, as a result of the need for :

1. Increased stability of the structure (especially at the bottom of the slope where it is the highest),
2. Proper sunlighting of all apartments at higher density of the housing development. According to the sunlight regulations of the British Standard Code of Practice every window in the principal living rooms and several bedrooms and kitchens receive sunlight for at least one hour daily from Feb-

5.

ruary to November most of them during the whole year.

3. Enough crossventilation of apartments. Most of them utilize the air currents which rise during the day and descend at night along the slope.
4. Correct proportion between the apartments of different sizes or proper locations for them. There is a large amount of flats with the easy access to the ground and visible proximity to the slope: these are the only ones which correspond to the needs of the families with children.
5. Flexibility of flats and their arrangements. This calls for the provision of internal staircases in rather small intervals. Only the circular form provides enough space for them without excessive sacrifices in the sunlighted façade. (The indicated distances between the housing units and columns are also required by fire protection codes).
6. The social linkage of single elements into larger groups: the corridor levels and especially the "streets" run continuously through the elevator towers and enable communications among the people from the same corridor level, and among those of a group without excessive vertical movements to the ground floor and back.
7. The sense of urbanity. The vertical communication towers, which with this solution can stand separately, not only serve as visual and functional linkages between the members of a group, but also form the basic life-generating nodes at the

6.

ground floor level. Since their outer skin is semitransparent, their function is clearly visible. Accompanying them the protruding and adjacent higher parts of the structure give a definite feeling of an intense urban space which is greatly released by the receding circular lower parts on the slope. While the total effect still enables one to get the feeling of the slope and of proximity to nature, there is nevertheless a strong impact of a cultivated environment, particularly if the space in the housing circle is intensively landscaped and well kept.

To reach all these goals a certain degree of the structural idea had to be sacrificed. The compression member, which in the case of a straight slab could be poured sequentially as the rest of the structure grows, has to be prepared separately before any substantial loads are imposed on it, since it cannot transmit any forces to the foundations at the bottom of the slope until it is completed in the form of a horseshoe. In most cases it means a rather insignificant technical inconvenience which is more than compensated by the gains shown above.

URBAN RELATIONSHIPS

The resulting urbanistic solution is based on former observations and on some rather generally accepted premises. Since only sun exposed slopes can be effectively used for housing, there is always an unobstructed view on untouched northern slopes of the valleys from all apartments. To avoid the traffic hazards and

noise and to utilize the narrow bottomw of the valleys, these are covered by one or more parking and access levels above which there is a safe and peacefull pedestrian platform, where all more extensive communal life can take place. It gives the access to all housing, to the different working places that can be built on top of it, and to other institutions such as shopping centers, schools, playgrounds, swimming pools, etc. The platform covers only parts of the traffic surfaces and the bottom of the valley. Spaces can be left in their natural form according to need, particular features and morphology. There is a similar flexibility in the housing structures. Although their basical shapes are identical, they can vary widely in the diameter, height of different parts, position of the vertical communications and the extent of gap in the building circle. The mutual result is hence much more adaptable to different natural conditions than it seems at first.

In the plans presented only a most general situation is shown. The housing structures are leaning against steep slopes and most of the communal functions asking for more space are put on the ground floor platform or on the bottom of the valley. Nevertheless, the housing units are not put together into an unarticulated massing of flats. A sense of social belonging is created by access levels, which in each fifth floor enable the inhabitants to reach (mostly private) staircases to their apartments. These levels are open terraces used on one side for

8.

for small apartments for older people (so they do not need to climb the staircases) who, being at home most of the time, simultaneously monitor the public areas. This gives a sense of security and makes possible use of the terraces in many different ways: as places for small storage boxes (for e.g. bicycles, baby carriages, skis, etc. which do not have place in the flats), as chatting corners provided with some benches, as playgrounds for the smallest children, using small plastic sandpits, etc. There is space for mail boxes at the entrances to the elevator towers, drinking fountains, vending machines, public telephones, etc.

More of these different facilities are concentrated in the "street" level which does not contain any flats. A communal laundry, dry cleaning, small reading rooms or small libraries, some of the club rooms and public toilets can be found there, together with more benches and sandpits, and, where possible, the access to the slope, thus connecting the street with the ground.

If the slopes allow, a much larger amount of communal life can be plugged into the housing structures; e.g. nurseries, lower grades of the elementary school. Additional natural playgrounds and sandpits can be arranged on some less steep parts of the hillside. If this is levelled or already inhabited, as is often the case in Pittsburgh, the new housing can give a new and better access to the old housing colonies. They in turn can

allow for further extension of schools and playgrounds, the new housing development thus becoming a link between the hill top and the valley, which today are completely separated.

STRUCTURAL AND FUNCTIONAL CONSIDERATIONS

The main goal with the design of the housing structures was to reduce the impact of obsolescence, which ruins so many of the present developments. Since the obsolescence is influenced by three sets of factors: a) abuse of materials, b) constant technical innovations and c) changing spatial standards, it is very unlikely that any solution could guarantee a complete protection against it.

The proposed solution tries to resolve these conflicts by the consequent division of elements of housing in the structural parts with the long term usage cycle and the housing units themselves with the relatively short term cycles. For the first there are only concrete or rustproof (Corten) steel - the proper materials. There is no evidence that in principle these materials will be changed much in next decades. The long cycled carrying structure is for the case of Pittsburgh conceived as a simple steel grid of vertical frames 5 floors high, with horizontal wind bracing every 5th floor at their junctions, connected with horizontal beams serving as support for the plugged-in housing units.

10.

For the housing units there is a greater choice of materials, (the main objective being reasonable fireproofing,) much faster development of new building and equipment techniques and much less stable requirements on their properties and spatial standards from the side of user. Some dimensions and the weight of the proposed units are the result of the present motor vehicle code and lifting capacities of helicopters. (While the lifting capacity of a Sikorsky S-64 Skycrane is 8.773 kg, the weight of a completely furnished unit will not exceed 7.000 kg). The proposed organisation of the plan corresponds to the demands of a middle-class American family but can as well be rearranged as to meet very special needs.

HOUSING UNIT

The construction of the unit as shown is an outer skin of glass-fiber-reinforced polyester plastic, wrapped on a light metal frame. The interior siding is thin formica-like plastic (uninflamable and much cheaper than formica), the space between inner and outer shells being filled with a sort of a very light concrete (154 kg/m^3) reinforced with thin wire mesh. All installations are poured into the bottom of the unit (they are easily accessible since the concrete is very soft) and symmetrically arranged around the axis of the unit so that the latter can be used in both orientations. Every main pipe and sewer is doubled so as to make possible connection on the left and the right side of the vertical ducts. The completely prefabricated bathrooms (see Habitat) together with kitchen elements and closets, are the

11.

only partitioning, completed with a door unit, which fits into the joints of all these elements. Since every unit rests on rubber pads, and there are only soft materials used for horizontal connections between two adjoining units, there is no major acoustical problem. With the prospect of electric resistance heating, there is provision for a temporary installation of nearly any type of central heating or individual heating units in use today. All ventilating ducts are connected to risers which end above the roof terraces. The windows have special metal outer blinds to prevent excessive heating loads on the glass surfaces. All colors and interior fittings can in the case of a mass production be selected by purchaser just as it is possible with an automobile purchase today.

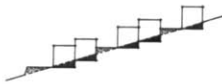
FLEXIBILITY

Small size of the unit, sufficient variety (although essentially the derivation from only one type) of elements and the possibility of accesses between each pair of units give a wide variety of possible arrangements of apartments. The main feature however is the possibility of transporting an even occupied unit by helicopter into some other position without disturbing the rest of the housing structure. This means not only the unoccupied units can be put together in a way which would please the user but also the much better average utilisation of the total dwelling space in the structure. This could be constantly checked and the unrealised preferences of residents remembered by a computer, so that at any time the proper use of vacancies and read-

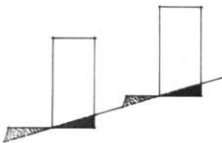
12.

justment of tenants that wish to move could be arranged. By the same technique, a renovation program on an individual basis can take place. There should be basic norms regarding the size, form, fenestration and colouring of the units but interior design and equipment can change substantially. Thus one could buy a new, improved type of a unit, in exchange for the old one, in much shorter cycles than today is the case with the houses. There is not much spatial leeway in this direction. The only real improvement would be doubling the present size from 3.6 m (12 ft) to 7.20 m (24 ft) when the lifting capacities will allow it. But even then, it is quite likely that many smaller units will still persist, thanks to their greater flexibility. They already today would allow to greatly reduce or increase the population density in a structure. Since not only every housing unit but those with the corridor platforms are interchangeable as well, it is possible to shift whole portions of the structure into higher category of space and communication standards by moving the access corridor from each fifth floor to e.g. each third one, and (or) to "thin out" the density by simply substituting the housing units with terraces or double height open spaces. Since this process is possible in both directions, it will always be possible to satisfy specific needs.

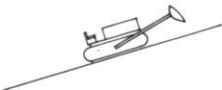
TRADITIONAL METHOD OF BUILDING ON THE SLOPE REQUIRES CUTTING INTO IT



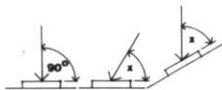
AND BECOME VERY COSTLY FOR LARGER BUILDINGS



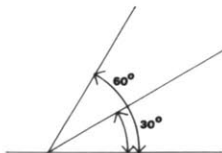
BECAUSE OF THE EXPENSE OF USING HEAVY MECHANIZED EQUIPMENT ON SLOPES



good worse

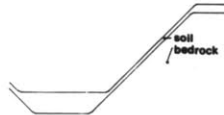


AND BECAUSE OF SMALLER RESISTANCE OF SOIL TO FORCES NOT PERPENDICULAR TO THE SURFACE

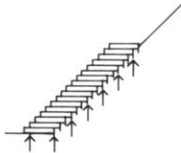


AS A RESULT, SLOPES OVER 30° HAVE SELDOM BEEN UTILIZED IN THE PAST, IN THE LAST 8 YEARS, HOWEVER, SEVERAL TERRACED HOUSING PROJECTS ON SLOPES BETWEEN 30°-40° HAVE BEEN PROVIDED.

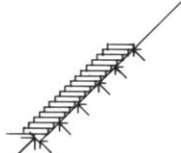
SINCE THE REGION IN THE PAST MEXICANA CALLED AWAY MOST OF THE SOFT SURFACE MATERIAL, THE SLOPES - ESPECIALLY THE STEEP ONES - HAVE IN GENERAL ONLY A THIN LAYER OF SOIL ABOVE THE BEDROCK OR SOLID GROUND (THE ONE THAT RETAINS THE FORM OF THE SLOPE). TO REMOVE THE EARTH COVER FROM THE SLOPE - I.E. TO PREPARE IT FOR PLACING THE FOUNDATIONS - IS THEREFORE A MINOR OPERATION.



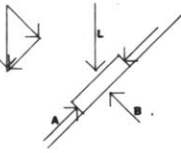
IN SOME SPECIAL CASES OF HARD ROCKY GROUND IT IS POSSIBLE TO USE IT FOR SUPPORTING STRUCTURES WITHOUT ANY ADDITIONAL MEASURES



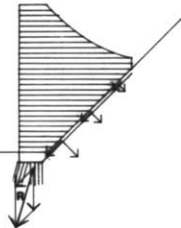
BUT MOST OF SLOPES ARE TOO WEAK TO CARRY A VERTICAL LOAD WITHOUT THE DANGER OF A LANDSLIDE. THE STRUCTURE NEEDS ADDITIONAL SUPPORT FROM BELOW. THE PROBLEM REMAINING TO BE SOLVED IS HOW TO PROVIDE IT ECONOMICALLY.



THE ULTIMATE DENSITY OF THIS KIND OF DEVELOPMENT, EVEN IF THE WHOLE AREA OF THE SLOPE WERE BUILT UP, DOES NOT EXCEED 1 SW UNITS/HA.

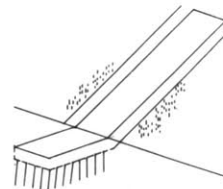


THE IDEA OF THE PROPOSED STRUCTURE IS TO RESOLVE THE VERTICAL LOADS INTO THE COMPONENT PERPENDICULAR TO THE SLOPE AND THE ONE PARALLEL TO IT AND TO TRANSMIT TO THE SLOPE ONLY THE PERPENDICULAR COMPONENT.

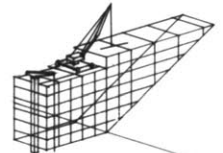


THIS IS ACHIEVED BY THE COMPRESSION MEMBER WHICH CARRIES THE PARALLEL COMPONENT TO THE BASE OF THE SLOPE, WHILE IN COMBINATION WITH A LARGE VERTICAL LOAD EXERCISED BY A SPECIFIC FORM OF THE BUILDING, THE RESULTANT FORCE IS NEARLY VERTICAL AND CAN EASILY BE SUPPORTED BY A SIMPLE FOUNDATION. THIS STRUCTURE NOT ONLY AVOIDS THE HIGH COST OF EXTENSIVE SOIL HILL EARTH WORK AND FOUNDATIONS, BUT ALSO PROVIDES SECURITY FROM LANDSLIDES CAUSED BY THE WEIGHT OF THE STRUCTURE. BY ITS PRESENCE THE STABILITY OF THE HILL IS IN FACT IMPROVED.

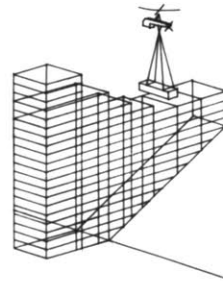
THE SYSTEM ALSO MAKES POSSIBLE THE USE OF A RELATIVELY UNDEMANDING CONSTRUCTION METHOD. ALTHOUGH THE FOUNDATION AT THE BOTTOM OF THE SLOPE MAY REQUIRE PILING TO REACH THE SOLID GROUND THROUGH THE SOFTENED SEDIMENTS IT IS LIMITED TO A VERY SMALL AND EASILY ACCESSIBLE AREA.



THE PREPARATION OF THE SLOPE AND RAISING OF THE FOUNDATION (SIMULTANEOUSLY THE INCLINED COMPRESSION MEMBER) STEP CAN BE DONE SEQUENTIALLY AS THE STRUCTURE GROWS, USING EACH FINISHED FLOOR AS WORKING PLATFORM FOR THE NEXT ONE.

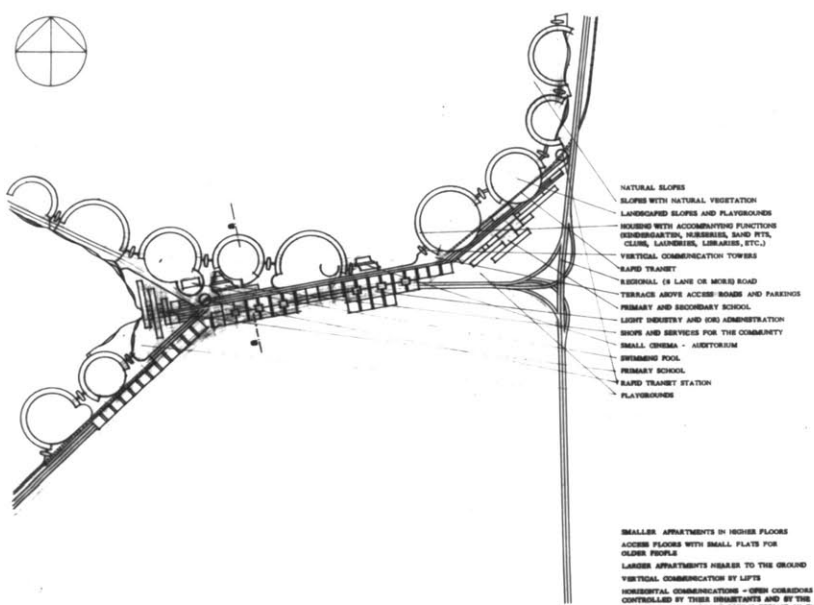


INTO THE FINISHED STRUCTURE, VERTICAL DUCTS AND PREFABRICATED STAIRCASES ARE INSERTED AND AFTER THAT



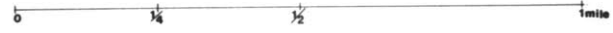
COMPLETE PREFABRICATED HOUSING UNITS (STORED TO THE BUILDING LOT AS TRAILERS) ARE LIFTED AND INSERTED INTO THE STRUCTURE BY A 5-44 SIKORSKY HELICOPTER. ITS CARRYING CAPACITY IS OVER 4000 KG AND THE UNITS (SINCE LIMITED IN WIDTH BY THE MOTOR VEHICLE CORD) CAN BE PRODUCED WELL UNDER THIS WEIGHT. THEY CAN ALSO BE MOVED OR EXCHANGED BY THE SAME TECHNIQUE.

DEVELOPMENT OF THE STRUCTURE



- NATURAL SLOPE
- SLOPES WITH NATURAL VEGETATION
- LANDSCAPED SLOPES AND PLAYGROUNDS
- HOUSING WITH ACCOMPANYING FUNCTIONS (COMMUNICATION, RECREATION, SAND RYLA, CLIMB, LAUNDRY, LIBRARIES, ETC.)
- VERTICAL COMMUNICATION TOWERS
- RAIL TRANSIT
- REGIONAL (3 LANE OR MORE) ROAD
- TERRACE ABOVE ACCESS ROADS AND PARKINGS
- PRIMARY AND SECONDARY SCHOOL
- LIGHT INDUSTRY AND JOB ADMINISTRATION
- SHOPS AND SERVICES FOR THE COMMUNITY
- SMALL CINEMA - THEATRE
- SWIMMING POOL
- PRIMARY SCHOOL
- RAIL TRANSIT STATION
- PLAYGROUNDS

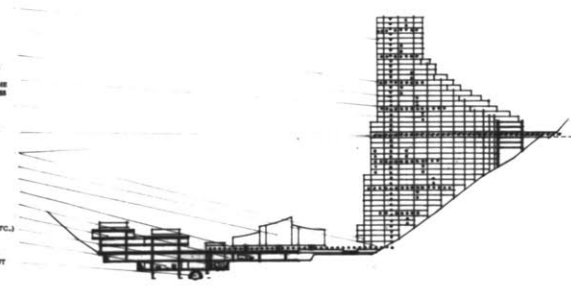
development unit for 25000 inhabitants
scale 1:5000



view

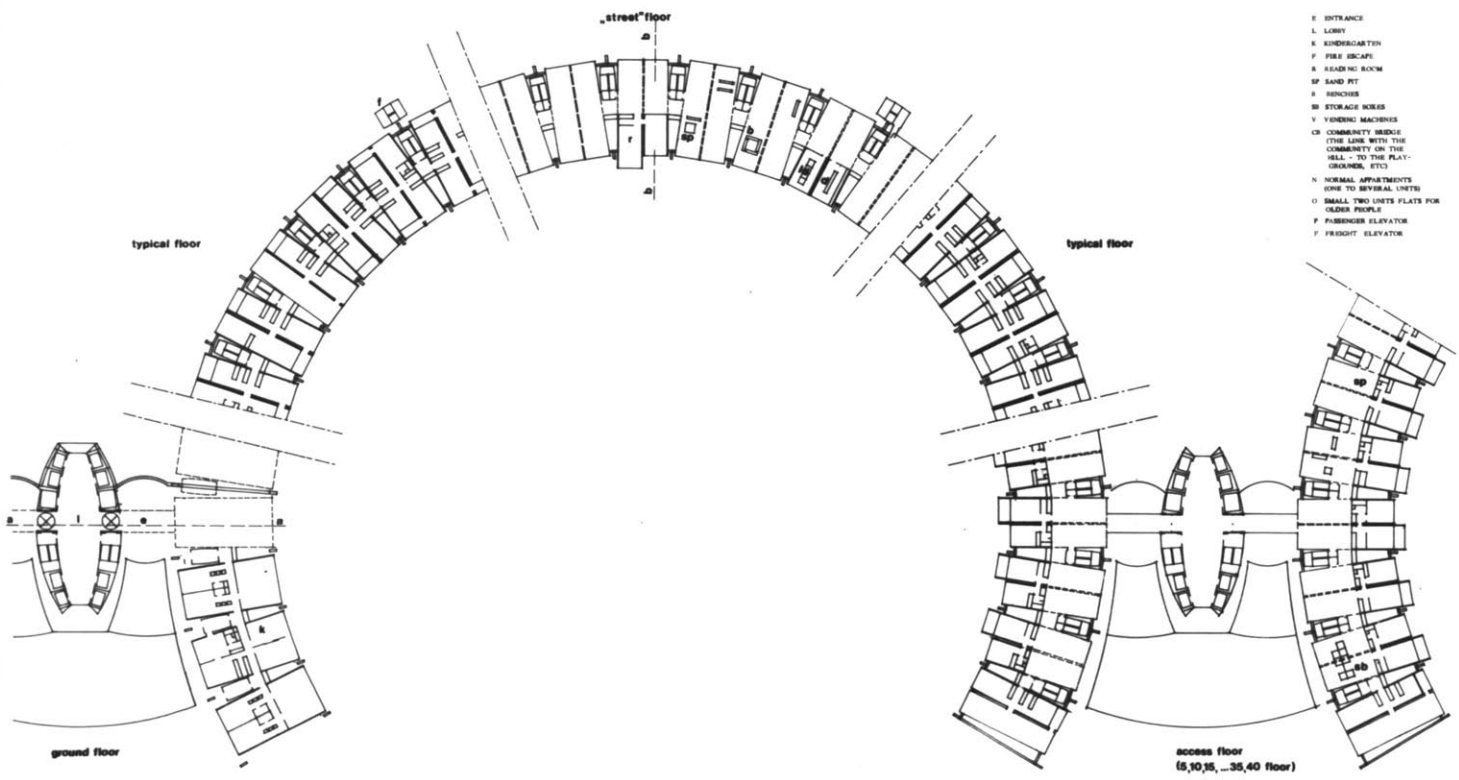
new developments in Pittsburgh
scale 1:50 000

- SMALLER APARTMENTS ON HIGHER FLOORS
- ACCESS FLOORS WITH SMALL FLATS FOR OLDER PEOPLE
- LARGER APARTMENTS NEARER TO THE GROUND
- VERTICAL COMMUNICATION BY LIFTS
- HORIZONTAL COMMUNICATIONS - OPEN CORRIDORS CONTROLLED BY THESE STRUCTURES AND BY THE PASSENGERS - A COMMUNAL LIFE IS FORMED BY THE LIMITED NUMBER OF OCCUPANTS USING ONE ACCESS STAIRWAYS TO THE FLATS
- "STREET" LEVEL: THE FLOOR CONNECTING ALL TOWERS OF A GROUP AND PROVIDING ACCESS TO THE COMMUNITY ON THE HILL, IF IT EXISTS
- CLIMB AND OTHER COMMUNAL FACILITIES
- EDUCATION CENTER
- SHOPPING CENTER
- HIGH ACCESS LEVEL
- ACCESS ROADS AND PARKINGS
- WORKING PLACES
- RAIL TRANSIT (SUBWAY, MONORAIL, CAPSULE, ETC.)
- REGIONAL ROAD
- SEWER CONTAINING ORIGINAL SEWERS POLLUTED BY MINING - THE CENTRAL SEWAGE TREATMENT PLANT IS SITUATED AT THE RIVER



section as
scale 1:1000

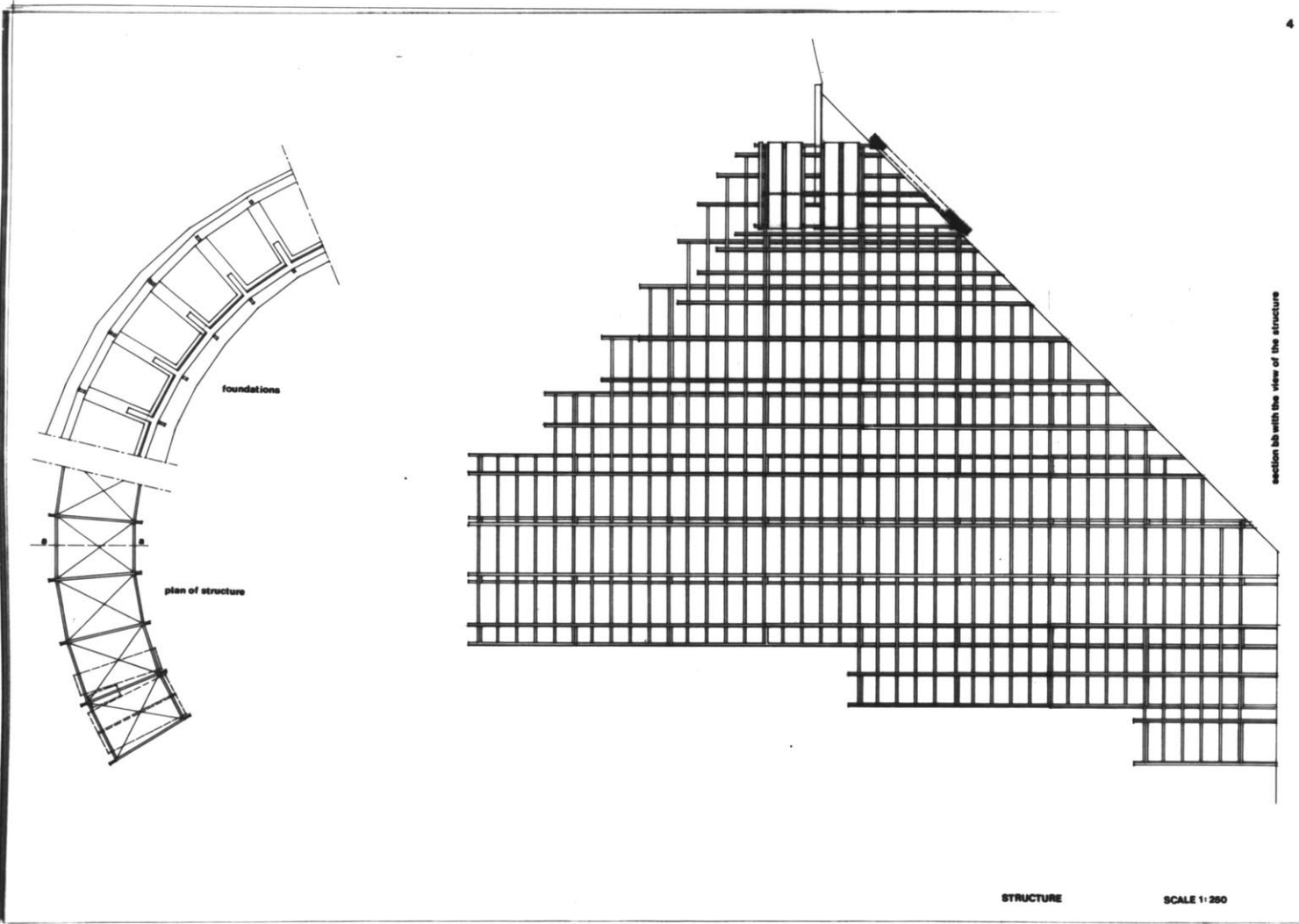
URBAN RELATIONSHIPS



FLOOR PLANS SCALE 1:250

HIGH DENSITY HOUSING ON STEEP SLOPES

MASTER OF ARCHITECTURE THESIS
 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
 JANEZ LAJOVIC SPRING 1966-67



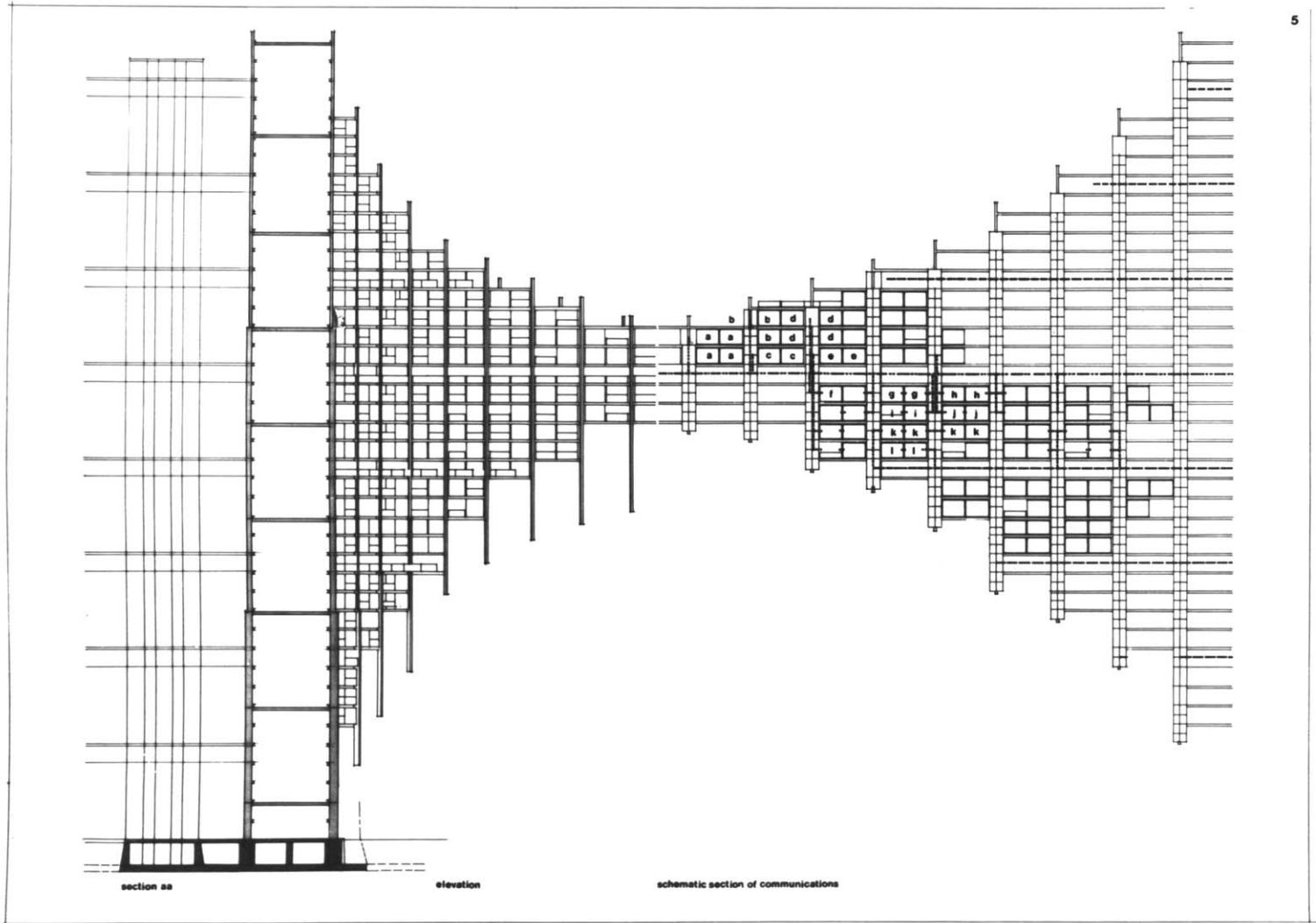
section bb with the view of the structure

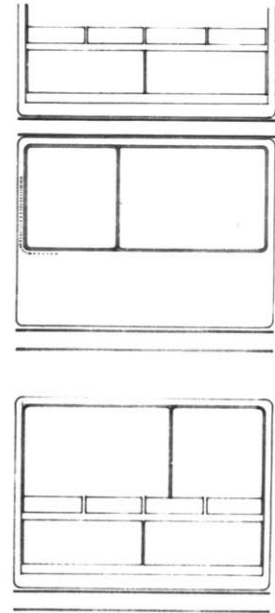
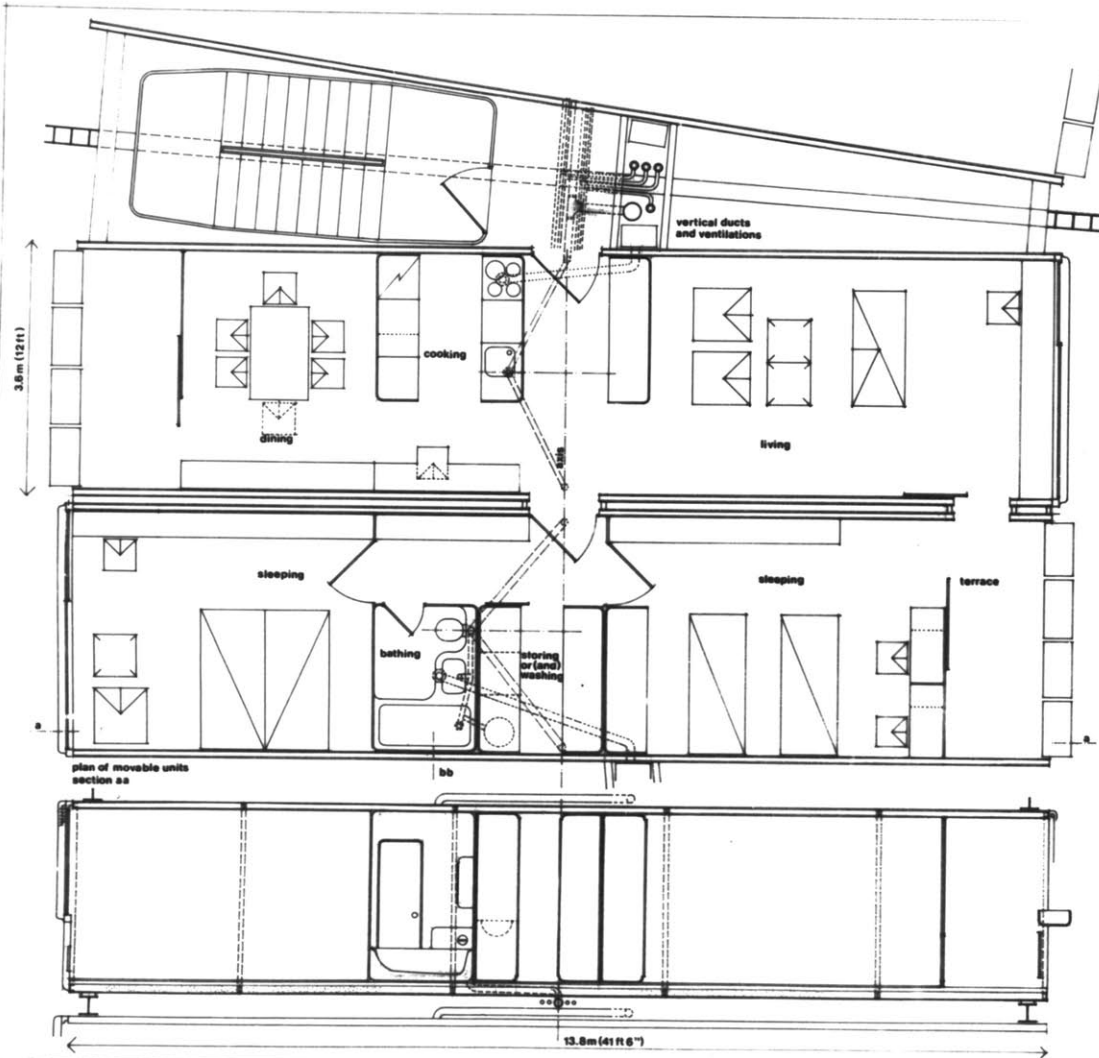
STRUCTURE

SCALE 1: 250

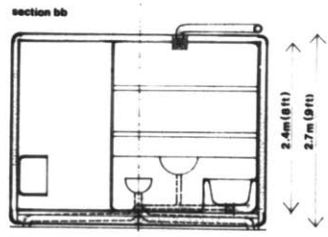
HIGH DENSITY HOUSING ON STEEP SLOPES

MASTER OF ARCHITECTURE THESIS
 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
 JANEZ LAJOVIC SPRING 1966-67





elevations

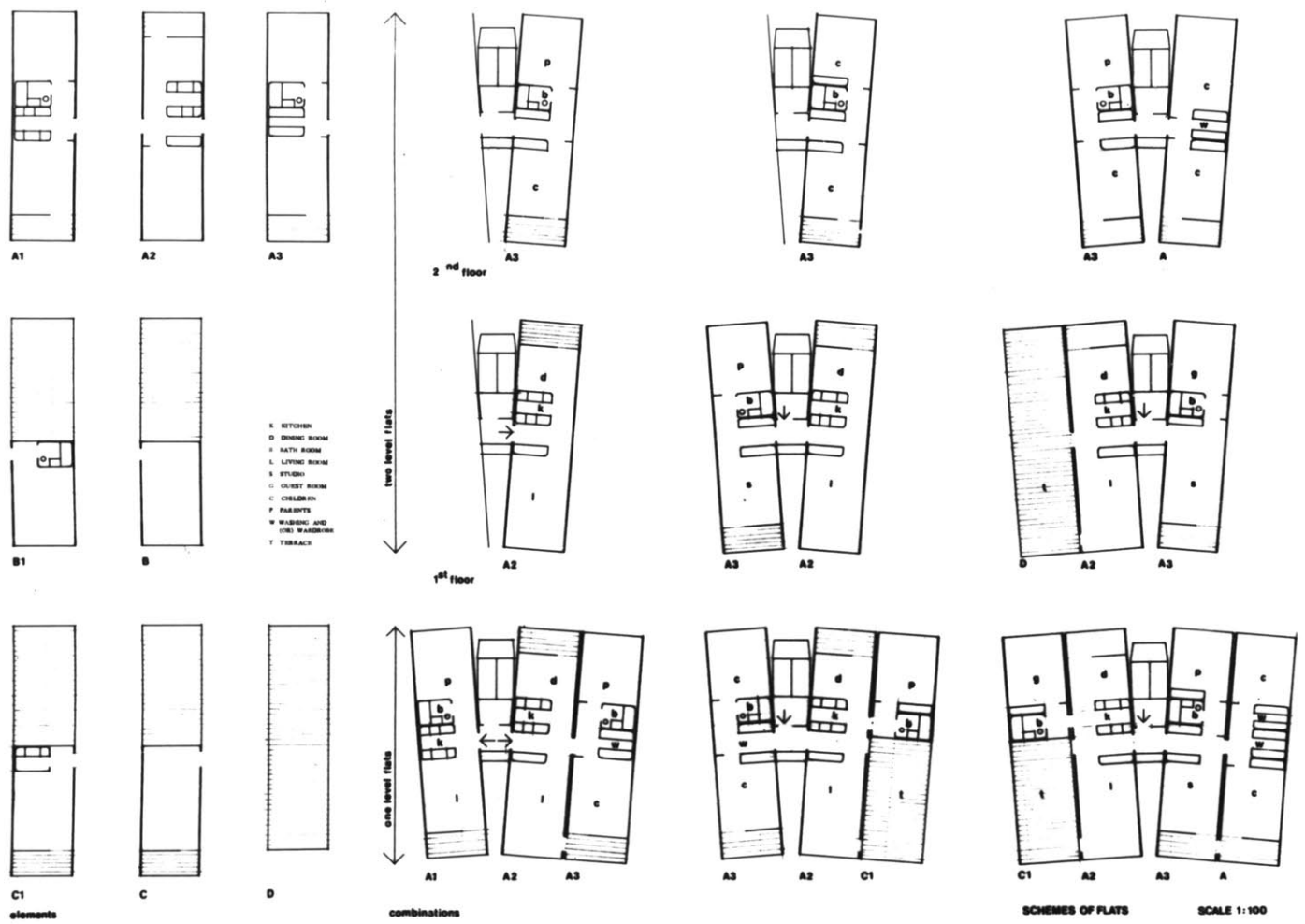


HOUSING UNIT 2 x 44 m² SCALE 1:25

HIGH DENSITY HOUSING ON STEEP SLOPES

MASTER OF ARCHITECTURE THESIS
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JANEZ LAJOVIC SPRING 1966-67



OBJECTIVES

Besides general goals set for the structure system as multipurpose use and unlimited flexibility on a chosen module, this structure aims at:

- a) reasonable building economy
- b) increased vertical flexibility - i.e. possibility to cut as large openings in floors as possible during the use of the building
- c) good acoustical isolation of spaces, and
- d) justified full utilisation of ceiling plenum.

As starting point precast concrete was selected for basic building material as the only initially fire-proof material that bridges large spans and that can be produced and assembled regardless of outside temperature. Though much more voluminous and heavier than steel it has in comparison to the latter certain advantages allowing for a structural expression which can not be attained by steel because of necessary additional fireproofing.

There are several technical and economical conflicts among requirements:

multipurpose use - building economy

5 ft module flexibility - vertical flexibility (large openings in floors)

good acoustical isolation - full utilisation of ceiling plenum

expression of structure - concealed distribution of pipes and ducts.

The analysis of the work done in previous years on the same problem and of projects going on in this term shows that simultaneous satisfaction of all these demands has not been achieved as yet and is probably impossible.

1) The claim for building economy excludes proposals that demand a lot of work on the construction site and a superfluous quantity of material. The majority of two-way systems falls in this category.

2) The requirement for good and economically feasible acoustical isolation, with the need for concealed piping, leads to a horizontal closing of structure which puts in question all efforts for an elaborate and expensive - though nevertheless very charming - construction of floors. Closing of vertical (or oblique) holes in beams and girders for acoustical reasons is much more expensive and still does not solve the problem of concealing ducts and pipes. For both - building economy and acoustical isolation - as well as for the sake of structural expression, the one-way systems give much better, cheaper and simpler solutions (e.g. with ducts between a double T beam). There too are some problems as penetrating of beams for plumbing in transverse direction, wiring for lighting and visual uniformity of - especially smaller - spaces where the recesses between double beams produce a visual effect of irregularity rather than regularity as in larger spaces where more ceiling units can be perceived with one glance.

3) The requirement for extensive vertical flexibility of the structure - for opening of different sizes in floors - and especially the claim for flexibility of this kind during the use excludes even the so far only successful double T beam one-way system. The present technology of concrete does not allow removal of parts of this construction after they have been set in place. The only way that would make it possible should resemble more the steel construction.

SOLUTION

Starting from the objectives the proposed system tries to satisfy - at least technically - the majority of the demands. To achieve maximal vertical flexibility a two-way system of simple shaped precast concrete girders is used as primary load carrying grid 32 x 32 ft o.c. supported by precast columns one floor high with 16 ft

cantilevers. The columns raise in a square 64 o.c. grid. The fields between primary girders are halved so that uniform alternately oriented 16 ft span remains. This is bridged by Sanvel Spancrete prestressed floor slabs. The primary members are partially prestressed and partially post-tensioned so that a sufficient continuity of the whole structure is achieved. The columns and cantilevers are normally reinforced. Since each column is formed by four parts they are put together on the ground somewhere on the building lot, protruding reinforcement is welded together and the middle part poured in, so that a complete balanced four cantilever column is lifted and set in place.

The secondary girders are as well normally reinforced and have metal joints with the primary members or cantilevers respectively. These joints make possible the removal of secondary members during use without difficulties which would occur if any cast in place joints were used. All girders have necessary openings for ducts and pipes.

As the system of primary and secondary girders reaches to the bottom of the ceiling plenum only in a grid of 16 x 32 ft o.c. a secondary 5'4" x 5'4" o.c. system of metal ceiling coffers with metal strips for attachment of partitions between them was developed. The 3 ft high coffers are parabolic shaped with the 1' x 1' lighting panel in the focus so that all light is reflected straight down and does not disturb the eye until an angle of 45°. They can be produced of stainless steel 1/8" thick which gives an exquisite acoustical insulation between each adjoining modules. The upper part of coffers is perforated and backed with 1" glass wool blanket and additional steel sheet for sound absorbing reasons. The coffers are attached to the floor slabs, the metal strips between them to the girders. Both coffers and strips are soundproof gasketed and tightly clipped together forming a soundproof

ceiling plenum. The metal stripes can be left out where necessary: it allows e.g. in laboratories to connect lab benches with the pipes and ducts running in the ceiling plenum and to access and control the latter; in drafting rooms additional light sources can be installed in the slits thus raising the illumination level from 100 fcdl to 200 fcdl or more. All this can be achieved without changing the basic visual impact of the ceiling.

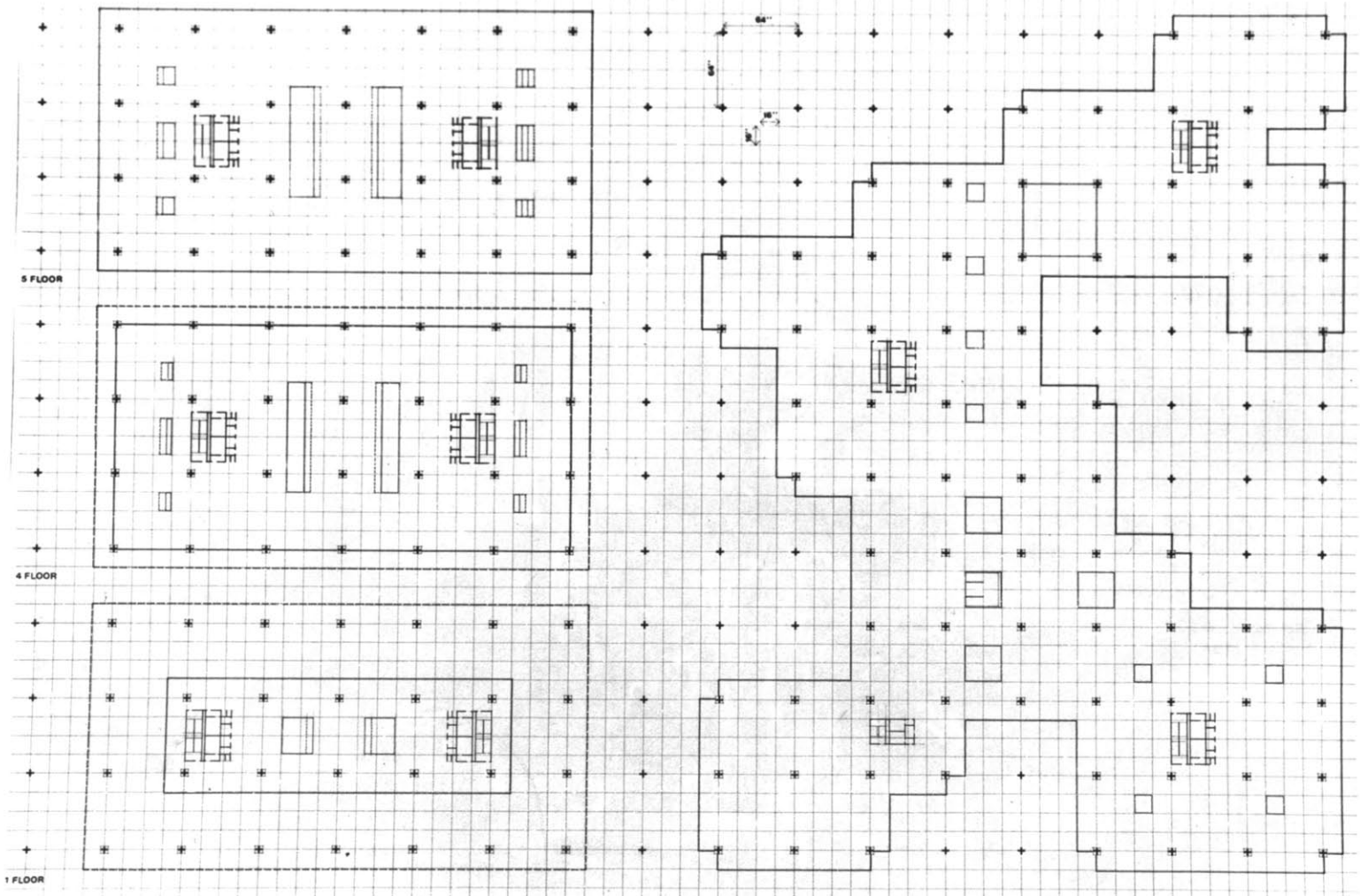
The pyramidal coffers touch the floor slab only at approximately 1 x 1 ft surface thus leaving roughly half of the ceiling plenum for ducts and pipes and allowing drains to pierce through the ceiling slab at nearly every point in the space. Since there is enough space any kind of air conditioning can be used. For the sake of space economy of risers which run at every column and are shielded by metal panels, the high velocity single duct constant volume system was used. The necessary temperature control with electrically heated reheat units is either in terminal box attenuators or at the outlets. These are placed alternately along metal strips between coffers. The exhaust ducts are connected to the tops of the coffers thus exhausting air at the highest points of the space, removing the heat load of lighting units and simultaneously prolonging the life of lighting fixtures.

In total this system represents a sort of hung ceiling where the load bearing structure is only partially visible. However the coffers very uniformly show the depth of the ceiling, their depth being really justified by the parabolical form needed for good seeing conditions in space. The sharing of the ceiling plenum between the functions of lighting and partitioning which are visible from below and the functions of air conditioning and other services which are invisible but accessible, combined with the possibility to dismantle any member of ceiling units without disturbing the user, seems to justify this particular combination

of concrete and metal elements. The expression of structure is limited to bottom parts of girders and outer trims of columns. More structure can be seen only where the floor is pierced or where columns are serving only for supporting with air being distributed from above (see sections).

ERECTION SEQUENCE

- 1) foundations poured
- 2) preassembled four-cantilever columns set in place
- 3) main girders attached to the cantilevers
- 4) posttensioning of the main girders
- 5) secondary girders inserted
- 6) prestressed precast floor slabs put on girders
- 7) all installations attached and distributed
- 8) ceiling coffers with complete lighting units mounted
- 9) lighting units and exhaust ducts connected
- 10) metal strips clipped to girders and coffers
- 11) floor topping and cover sheet applied
- 12) partitions installed.



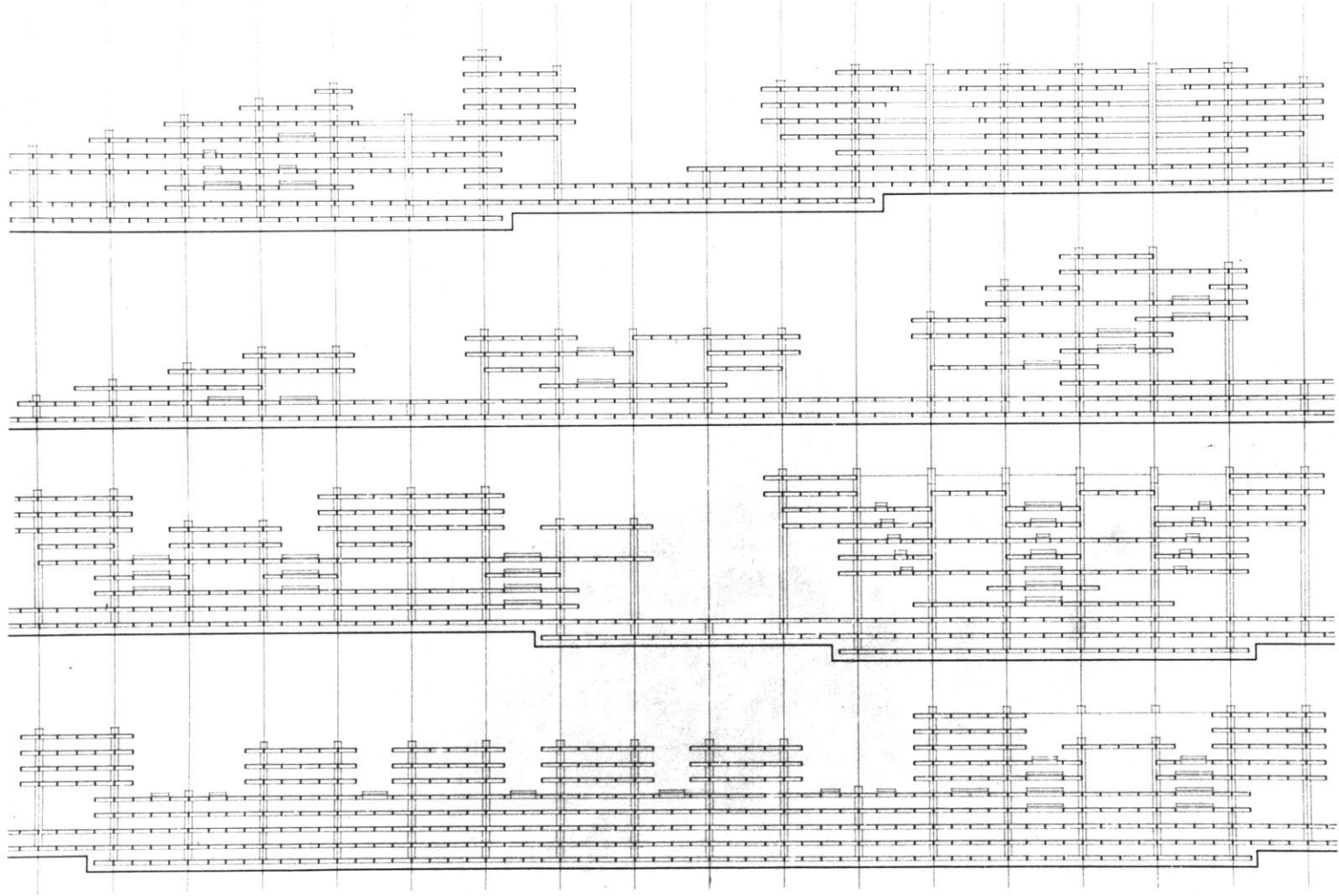
5 FLOOR

4 FLOOR

1 FLOOR

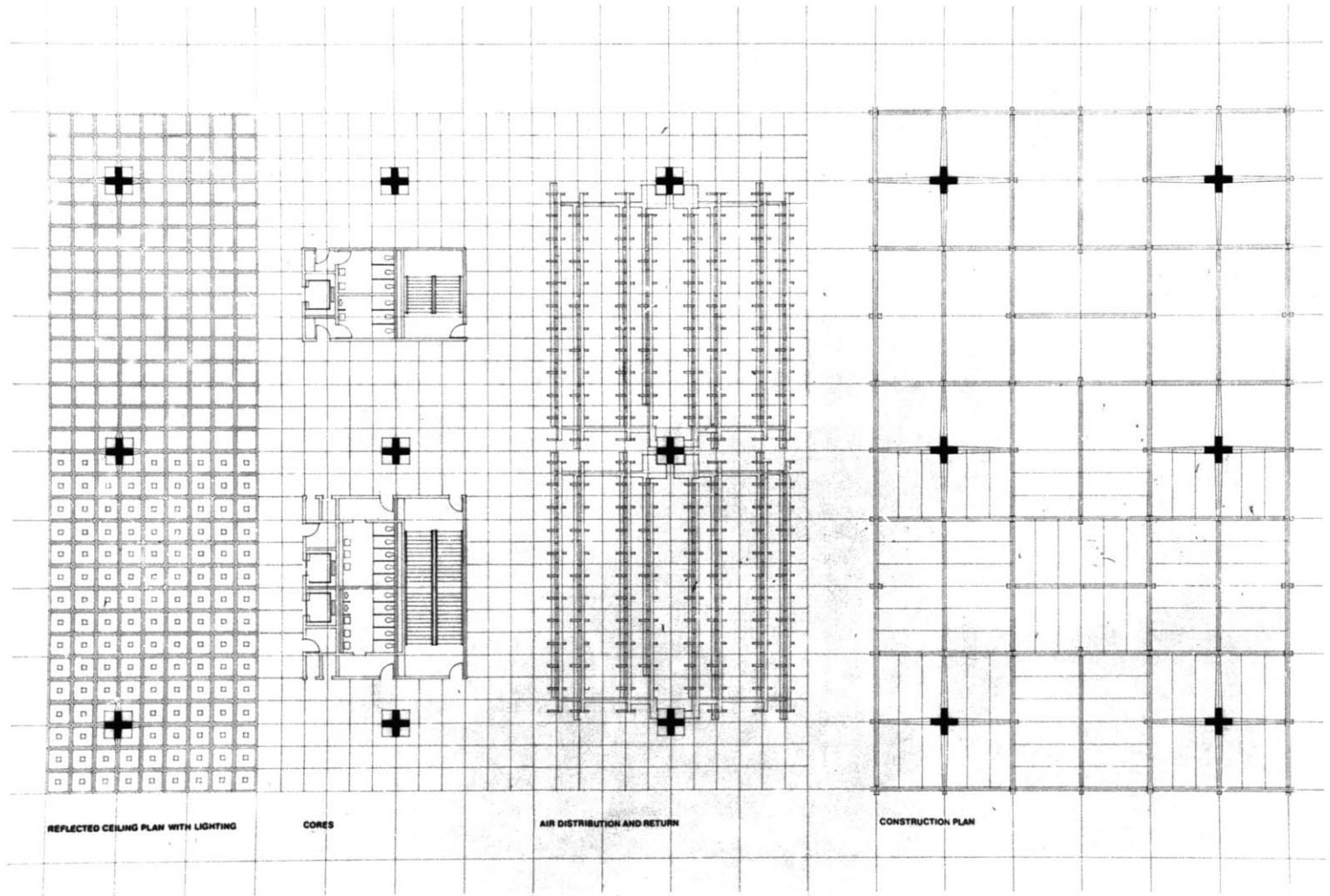
PLAN VARIATIONS

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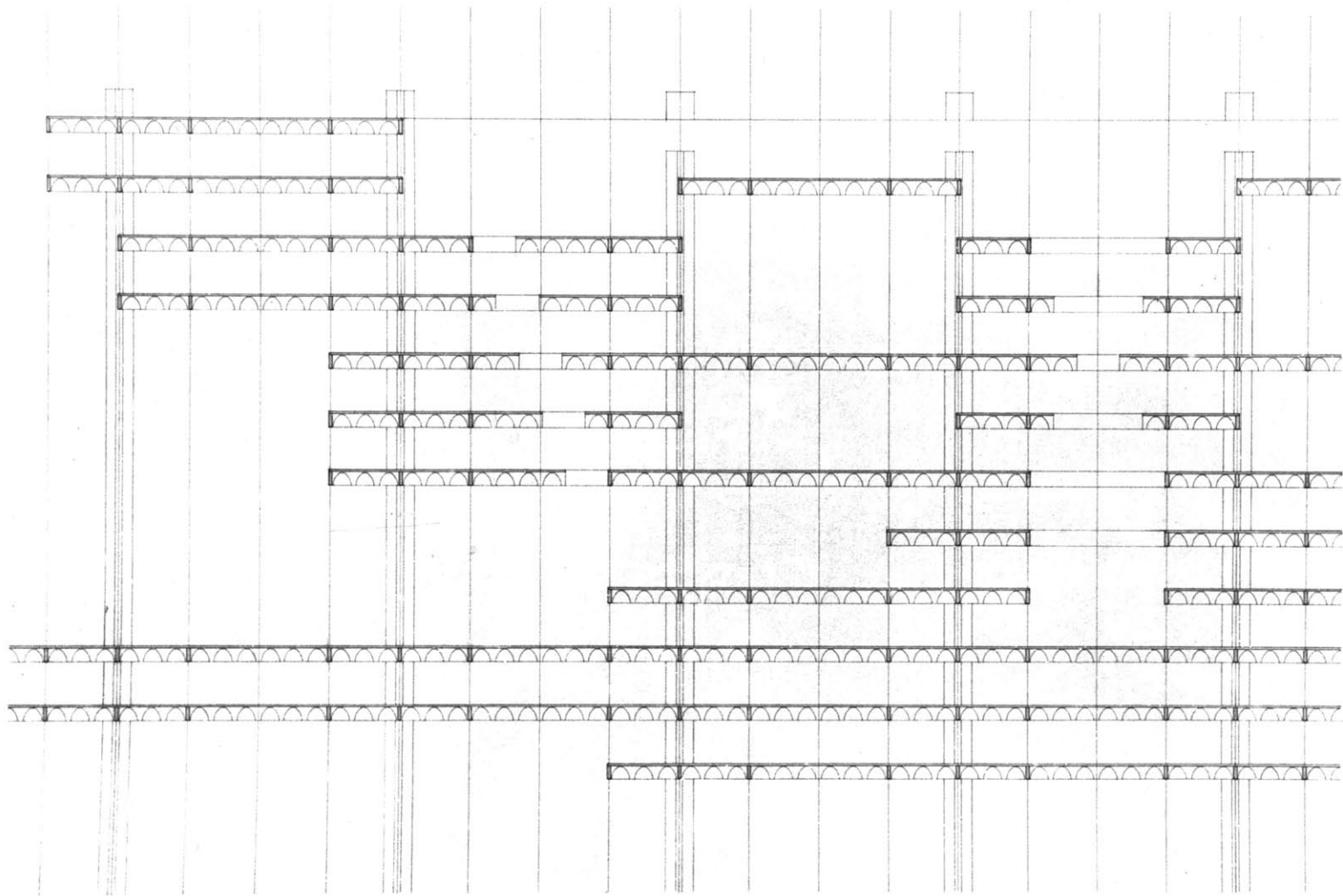


SECTION VARIATIONS

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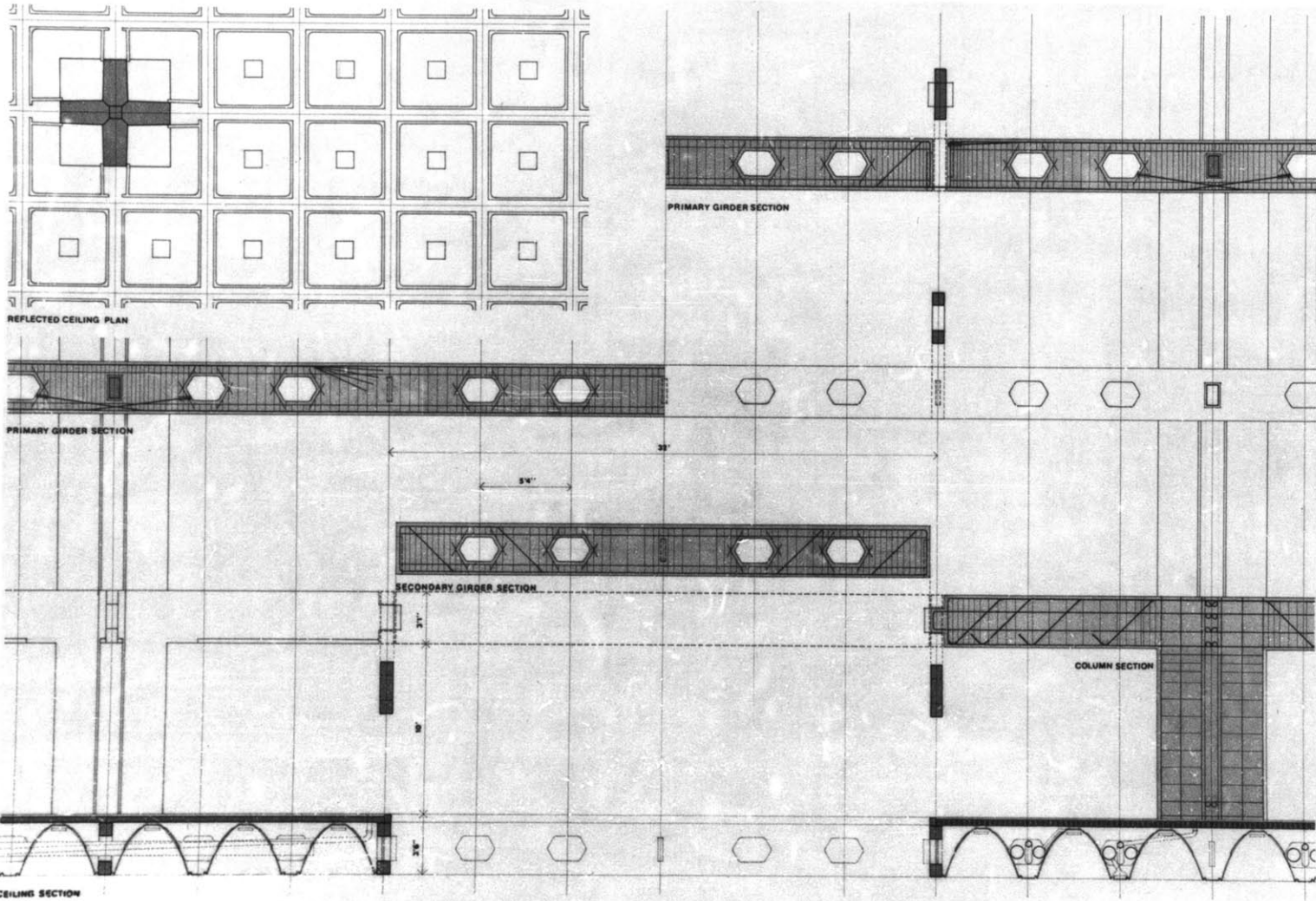


COMPONENT BUILDING SYSTEMS



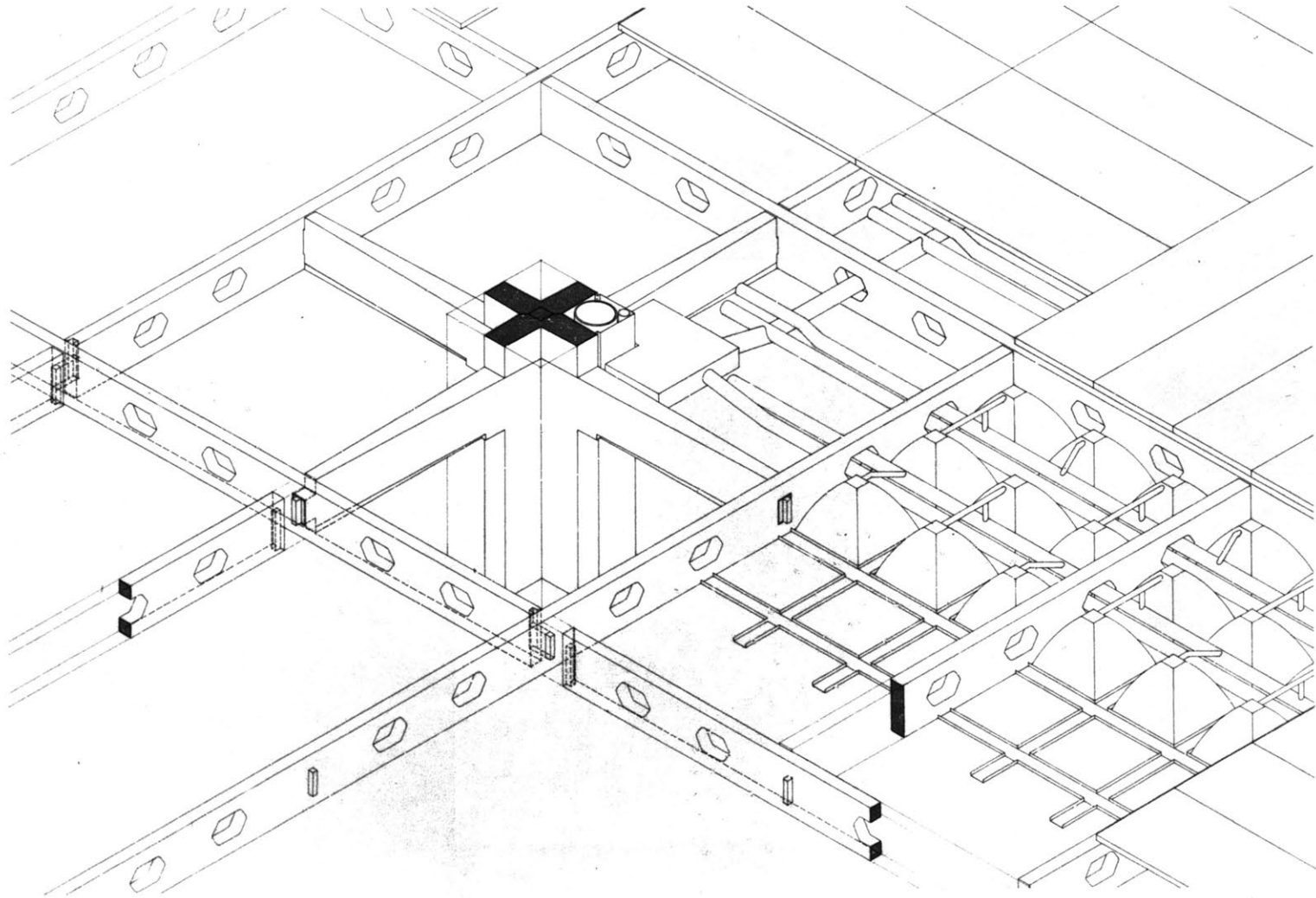
BUILDING SECTION

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STRUCTURAL DETAILS

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SYSTEMS ISOMETRIC

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