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Search For Economic and Universal Housing Systems -- Some Design and Construction Experience

Zenon A. Zielinski

SEARCH FOR ECONOMIC AND UNIVERSAL HOUSING SYSTEMS - SOME DESIGN AND CONSTRUCTION EXPERIENCE

By

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1. INTRODUCTION - INCREASING DEMAND VERSUS INSUFFICIENT HOUSING SUPPLY

An increasing demand for better, cheaper and faster housing construction stems from natural increase of population, and rapid urbanisation. This is true for both developing and developed countries.

Although new inventions and techniques, mechanisation and automatisation are being adopted in other fields of human activity, the housing industry, which after food production is of first priority, continues to lag behind. Only recently, during the last decade, the need for better organised housing planning and construction has been recognised. New prefabrication and industrialised housing systems have been tried out in some countries. As yet, they are employed only on an individual and limited basis and their development has been very slow, especially by contrast with progress made in other fields.

Still today, even in developed countries, only a small percent of housing is done by professional man - an architect or engineer. Most are done by private citizens - villagers or towns folk - and developers, according to traditional and time-worn structural concepts.

Under these conditions the cost of housing remains very high and prohibitive for the financially weaker section of population who make-up the majority of the population in developing countries. The result has been tragic housing shortages, the growth of unhealthy slums, and the deterioration of whole cities.

The Calcutta Metropolitan District with its population of 7.5 million can be taken as an example of a huge, rapidly growing, urban complex where the lack of housing has long since past the critical point. According to the basic Development Plan prepared in 1966, by the Calcutta Metropolitan Planning Organisation and Ford Foundation Advisory Planning Group, the housing need in Calcutta Metropolitan District, only to satisfy the increased population and absorb slum dwellers, is 67,000 units per year upto 1986 whereas the yearly production figure stands between 10,000 to 30,000 units per year. As each year passes the housing situation becomes still worse. Calcutta is not the only example. Similar problems are being faced in many other places.

It is the "science of housing" that should now be given more attention, for the house is the basic element of modern urban planning, whether it be the planning of new cities, expanding the old, or the rehabilitation of populations already ill-housed.

How our cities will look tomorrow depends on how we build our houses today, in what number, how fast and at what cost.

2. SYSTEMS APPROACH - A NECESSITY IN HOUSING DESIGN

The need for a shelter is common to all human beings irrespective of their origin, culture or geographic location. Cultural, environmental or economic factors, however may cause shelters to be different in form.

The analysis of functions and components of what we call 'shelter' or 'house' would demonstrate that there are some basic, structural components which are common to all shelters (examples: structure of wall, structure of floor or roof, door units, etc.), and secondary or optional components which may appear or not, depending on cultural, environmental or economic factors (examples: water-proofing, thermal insolution, decoration, special appliances, etc.).

As basic components appear in every shelter, a shelter composed only of them would represent structure of minimum possible cost. These components could be developed on universal global basis. The supplementary components would be introduced only where they may be required or whenever they could be afforded economically or, in some instance, they might be installed on a self-help basis.

Such an approach places first priority on the development of new materials and techniques and secondly on disciplines of house design. This would be in contrast to present practice.

A systems design approach appears to be a necessity of future housing development including definition of main housing components, applicable on a universal, global basis; the production of basic shelter's durable structure in the fastest, possible way and at a minimum cost; the adaptation of the structure to different cultural and environmental conditions through use supplementing components.

The development of modular, industrially-produced, flexible, housing components and their organisation into individual custom-built housing units, blocks, or townships, will be the future of architectural and engineering professions.

3. SOME ELEMENTS OF ECONOMIC HOUSING DESIGN

The total cost of housing development consists of several elements including land development, instalations (water, sewerage, electricity), construction of buildings and maintenance.

We intend to limit our discussion here only to costs of building construction and maintenance which constitute the largest part of housing cost. Having in mind the fact that production of housing has to be accelerated in existing conditions of always limited financial resources we must look for new and more appropriate housing systems and design concepts.

The interaction of several elements can result in an economic housing design. Some could be listed as follows:

a) Standardisation and modular coordination - Economy of housing development can be achieved by standardising of housing space (building height, size of rooms, kitchen, toilettes) and of building elements (wall elements, floor or roof elements, doors, windows, appliances, etc.) Space norms - in square footage per person - have been enforced in several countries with centralised planning as first means of economic housing development.

b) Economic site planning and house designing - This includes adopting of proper housing densities, housing types (single family houses or apartment blocks of defined heights), and economic architectural and structural house designs. Standard house designs have been introduced quite often,

c) Selection of proper structural materials - Time of brick as basic structural material seems to be gone. With cost of labour going up brick construction has become too costly.

Timber as basic structural material underwent evolution from a log house to a baloon frame. The baloon frame was an economic house structure and became very popular and, especially in the USA, it revolutionised housing industry. It is still a popular system, both standardised and flexible, it allows freedom of design and use of variety of supplementing elements (wall panels, insolution and finishing materials).

Unfortunately, in most cases, timber is now in short supply and expensive. For some building types timber is not sufficiently strong, fire-proof, or durable. Timber houses deteriorate fast and they cannot be rehabilitated as easily as durable brick or stone houses can be. There is probably truth in often-heard statement that timber construction of houses, presumably for one generation, but used in deteriorated state for two or more generations, is one of the contributors of urban deterioration and even of segregation in existing American cities.

Structural steel cannot be considered as principal structural material for mass housing either. It is too expensive.

Concrete or rather reinforced concrete appears to be today's best structural material. It has all required characteristics. It can be produced locally, is available almost anywhere. It is durable, fireproof, earthquake-resistant, flexible in use and provides scope for various aesthetic treatment.

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Wider and better use of concrete should be considered for mass housing construction today. Prefabrication and industrial production of concrete modular units should be recognised as the right answer.

Obviously new materials as they are developed, including plastics or new compositions of traditional materials, should not be neglected in future.

d) Economic use of structural materials - Selection of proper structural material may not produce economic housing if material is wastefully and improperly used. Better knowledge of materials structural properties, and use of proper structural systems contribute to economic structural design.

Time does not permit to give examples of how savings could be made by proper use of structural materials. Simplicity, elimination of unnecessary decorative elements, thin wall structures, hollow core elements, shells and box type systems, are some examples of economic structural design. But even box systems can be wasteful and expensive if not properly designed. "Habitat 67" at EXPO 67, in Montreal, was a bad example in this respect.

e) Industrialised production of housing components - The introduction and acceptance of industrially-produced building components, based on standardisation and modular coordination, will be probably the single-most important element of universal and economic housing design.

In case of reinforced concrete industrialised production means mass-prefabrication of housing elements.

4. EXPERIENCE OF INTRODUCTION OF UCOPAN INDUSTRIALISED HOUSING SYSTEM

4.1 - Description of the System

On the basis of the requirements discussed above this author developed a new Universal Concrete Panel System, called "UCOPAN" in short, which facilitates the construction of aesthetic, durable, fireproof, flexible and economic housing.

UCOPAN is a modular structural system allowing for the construction of any size single or multi-storey houses that consist of rectangular rooms.

Walls and floors (or roofs) are constructed out of the same type of modular prefabricated panels. There are only two basic modular panels -- one for walls and the other for the floor/roof -- or only one type of panel for both walls and floors or roofs if the reinforcement of the panels is changed according to different loading requirements.

Panels can be made to any chosen modular size, in accordance with specific space requirement and available mechanisation. For rural construction condition, where only simple tripods and pulleys can be used, minimum modular size of panel can be assumed -- about 9'x3' or 10'x3' as it was done in India. Models of such panels are illustrated in Figs 1 and 2.

The height of 9 or 10 feet, chosen here, conforms to normal room height. The width of panel equal 3 feet provides space necessary to accommodate normal door. Chosen length of 10 feet for roof panel conforms to basic rooms width of also 10 feet.

The UCOPAN system has been developed for rapid construction of durable housing units at minimum cost and with the least possible quantity of basic structural materials.

A thin wall concept has been adopted for panels. Walls are made of 1" to 1.5" thick concrete, reinforced with mesh or wire. The required strength and rigidity of the panels and of the entire building is provided by means of reinforced ribs at the perimeter and in-between two panels. Thus, a system has been introduced where the total consumption of reinforced concrete for wall or floor structure, when considered as a layer of concrete spread flat on the floor, could be of only 2" to 3" thickness. The depth of the ribs, which impart rigidity and strength to the wall or to the floor, could be determined according to the design (8" or more). An example of a roof panel -- its dimensions and reinforcement -- is given in Fig.3.

A universal single form has been designed for wall panels. Different types of panels can be produced in the same form, made according to basic template as shown in Fig.4. There are solid or open panels (with door or window) as well as panels with extensions on either side or on the top. All of them are produced in the same form with special inserts, depending on requirements of the panel.

Because of their reasonable size, panels can be produced industrially under mechanised factory conditions or directly on the building site using simple concrete moulds or forms made of timber or steel.

Concrete moulds as well as timber and steel forms have been tried in India and Nepal. An example of timber form for wall panels is shown in Fig.5 and of steel form for roof panels - in Fig.6.

Simple site-prefabrication and natural open air curing may be the cheapest solution where weather conditions permit. In India for example panels are cast in an open air. The day after casting they are removed from forms, turned upside down, filled with water and left exposed for natural curing for about 7 days. Panels during such a curing process can be seen in Fig.7.

UCOPAN has been designed as an universal system. It can be used for any house-plan and for single as well as multi-storey (up to 8 floors) construction. Model schemes of UCOPAN construction of single- and multi-storey buildings are shown in Figs 8 and 9 respectively.

The perimeter ribs on UCOPAN panels are at an obtuse angle to the panel membrane and are shaped in such a way that,when the panels are placed side by side,gaps exist between the ribs along vertical and horizontal lines. The gaps can be filled in with additional reinforcement and concrete which ties seperate panels into a solid and monolithic structure so that the rooms or even the whole finished building itself becomes a box-like structure -- strong and rigid in spite of its thin walls. This is an extra advantage that makes UCOPAN buildings durable and especially suitable for weak soil conditions, seismic zones and flood-prone areas. The obtuse angle perimeter also makes forms simpler and removal of panels from forms easier and faster.

The perimeter ribs in wall panels are arranged in such a way that the fixing of joints is simple. It is done just by filling the cavity with concrete from the top. After hardening the concrete acts as a lock. Special and expensive connecting elements such as plastic or rubber gaskets, which are normally used in joints in other systems, have been eliminated. Detail of joints betwen panels can be studied in Figs 10 and 11.

Examples of the reinforcement in the joints between roof panels on a corner segment of a house with a cantilever of one panel width can be seen in Fig.12.

The UCOPAN panels in place, connected along the perimeter with roof waterproofed, constitute a low-cost housing unit ready for immediate occupancy in mild climatic conditions. Under conditions of extreme heat or cold, however, additional insulation is required. It can be placed inside the hollow, formed by the panel's perimeter ribs. In order to obtain better acoustics or to achieve a higher level of amenity extra finish or better lining can also be given to a UCOPAN house. Any material -- additional concrete panels, dry gypsum boards, plywood, plastic, metal, bricks, wall-paper, etc., -- can be used for this purpose. Such lining, if desired, can be given to the panels at the time of their production or on the assembled structures after erection. Many such improvements inside a house can even be effected later by the occupants themselves on a self-help basis.

The small size of panels has been chosen in India in order to limit the weight of panels only to 300-350 kg. That weight allows the panels to be handled manually if conditions demand. This is a very important factor for economy in some countries and permits a wide use of the system.

In order to make assembly of panels easier and to conserve labour, especially in case of multi-storey building construction, a very simple, mobile, but manually operated, hoist has been also designed. The hoist is shown in Fig.13. A model of similar hoist can also be seen in Fig.8.

The hoist consists basically of 4 units -- pulley or lifting hoist, a stand frame, bracing elements and a base frame with wheels. All the units are simply connected with bolts which can be removed. Each hoist-unit can be easily manually transported to new position or to the next floor -- in case of multi-storey construction.

4.2 Application Examples

Since its introduction in early 1969, UCOPAN system have been used on many projects. Several standardised application designs have been developed including single and multi-storey housing units, schools, health centers, university buildings, etc.

Basically, two application alternatives have been popularised: first -- where only roofs and floors are made out of panels but walls remain of traditional materials, second -- where floors, roofs and walls are made out of panels.

Selected examples of standard designs and applications are given below.

Figs 14, 15 and 16 illustrate a single-storey row-type housing design, developed in the Calcutta Metropolitan Planning Organisation. This demonstrates use of smallest size house units consisting of two rooms with toilet and bath and of total plinth area of approximately 299 sq.ft. Estimated cost of single house unit of this type is approximately Indian Rupees 3500 means Rupees 11 per sq.ft. (Indian Rupees 7.50 to US $).

Fig.17, shows design of a house for flood victims in North Bengal prepared in the Siliguri Planning Organisation. Three such houses were built for demonstration purpose. It took approximately 5 days to build complete house of this type including preparing of ground and foundations. Panels were cast earlier in an open yard shown in Fig.5. After panels achieved their strength they were transported on trucks to the sites located in a distance of 30 miles (16 panels load per truck). Transport of panels and different stages of assembly are illustrated in Fig.18. Completed houses can be seen in Fig.19.

Fig.20, shows how interiors of these houses were made more attractive by painting of traditional Indian alponas on panels between ribs. In these houses both roofs and walls are made of precast panels, no wall lining was introduced.

Fig.21, shows another type of one-storey house designed for tea plantation workers. A bigger, split level, three-room house can be seen in Fig.22.

The illustrations of Fig.23, show the construction of series of low-cost houses on Tribuvan University Campus in Kathmandu, Nepal. Exposed, brick is used here for walls and UCOPAN panels for roofs.

An example of standardised multi-storey apartment block design, developed in the Calcutta Metropolitan Planning Organisation, is presented in Fig.24. The whole structure is designed here out of standard panels, including balcony railing, and foundations. Houses up to 8 stories could be built this way. Illustration of construction of two storey similar house built in Calcutta are shown in Fig.25. A colony of 50 UCOPAN houses is now in advanced stage of assembly at Durgapur City Center.

UCOPAN system has been adopted lately for several bigger projects all over India including 4000 apartment units to be erected at new township of Borivili in Bombay, apartment blocks for military personnel, mine workers etc.

The illustrations given above demonstrate the simplest way in which modular thin wall concrete panels can be used. The same panels may be used in more sophisticated, in structural terms, conditions - as part of composite structures, including also precast or cast-in-situ beams or frames or for creation of structural space systems like shells, folded plates or so.

The design of the Center for Economic Development and Administration at Tribuvan University in Kathmandu can be taken as a good example in this respect. This project is in construction now and will be completed during one construction season.

As it can be seen from illustrations of Figs 26, 27 and 28 this project consists of series of buildings including four-storey dormitory block, big auditorium hall, lecture rooms and office blocks. All these buildings have different structural spans from 9 to 50 ft. However, all roofs and floors on the whole complex will be made out of one modular UCOPAN panel of 9x3 feet. Bigger span structures will be created by using the same panels in composition with precast or cast-in-situ beams. All supporting elements -- pillars and walls -- will be made out of factory produced, exposed bricks. It appeared here that even ground floor slabs, made of the same panel, are cheaper than traditional floor, made of earth filling and cast-in-situ concrete.

Even the dome type roof, spanning about 50 feet in the big seminar hall will be made out of modular panels. This structure is illustrated in Fig.27. Separate panels of 3x9 feet will produce a monolithic dome after joineries between panels will be filled in with cast-in-situ concrete. Approximately, 2½ thousand of panels will be used on all buildings in this project. The same panels are being marketted from now on for use in other buildings now under design in the Kathmandu Valley.

5. OTHER EXAMPLES OF USE OF UNIVERSAL INDUSTRIALISED HOUSING SYSTEMS

The industrialised modular panel structural system has been employed also on other occasions. For example in 1965, a similar system to the one described above was introduced by the author in the design of the new City of Asswan in Egypt. (See Figs 29 and 30). Here again two basic panels - one for walls and one for roofs were introduced. In Asswan, with its desert climate, and high diurnal temperature variations (cold at night and very hot in the daytime), it was desirable to utilise a structural system having heavy thick wall and roof elements able to store heat and cold. This would appear to be in conflict with our concepts of minimum cost and minimum consumption of structural materials. In this case a double panel external wall, of minimum thickness, with desert sand poured between the panels allowed minimum cost while providing the desired heat storage capacity. A system of single panel with a thick desert sand cover on the top was the cheapest solution for the roof. Minimum panel thickness with no water proofing on flat roofs is acceptable in Asswan, a "never-rain" condition.

This structural system has been adopted for the design of the whole new City, even though different house types have been included - all of them made of the same two type panels.

The planning concept here was to compose a city out of urban units, those units out of standard housing blocks, those blocks out of different dwelling units and finally the dwelling units out of the same standard structural panels.

In advanced, urbanised and developed centres where lack of mechanisation is not a problem, for example, in America, it is necessary to think in terms of a universal system, using larger size units, which would conserve labour. Here the size of the panels does not have to be limited by the strength of a men, or by the size of door size, but may be chosen on a highway clearance basis. However, even in mechanised countries, where labour is more costly than material, the element of minimum consumption of materials will remain valid, since consumption of labour is in proportion to the amount of material used.

An universal large scale concrete panel housing system, called 'LUCOPAN', has been proposed in 1967, for urban renewal in Detroit area and Montreal which is illustrated in Fig.31, 32 and 33. Dimensions of 8x8 feet (or 10x10) was suggested here as basic module. This equals room's height what also equals to highway clearance. A double module units of 8x16 feet (or 10x20 feet) or triple module units of 8x24 feet (or 10x30 feet) were possible. Only one universal panel, able to work in walls as well as in floors or roofs was adopted. When making these panel out of reinforced concrete, the reinforcement in itself could be different for wall and roof panels. By using of only six panels of 10x20 feet (as it is shown in Fig.31), it would be possible to produce a basic house unit of 600 sq.ft. thus accomodating a medium size apartment. A minimum number of three panels for walls and only three panels for the roof produce a "rigid box" - a very effective and practical structural system. Such a "box" can be used for the production of free standing or row type houses of any shape (Fig.33). It is also suitable for different types of multistorey houses.

Through proper structural arrangements of blocks, it will be possible to produce attractive compositions of arching or even overhanging houses - in effect the whole new housing environment.

The panels themself produce instantly, a basic durable and fireproof shell of a house. Light weight partition segments, window or door segments as well as home appliances would follow (many are already available on the market as standard products.) Using this system it is possible to think in terms of mobile and rearrangeable partition elements, eventually functionally combined with the furniture and introduced on "plug-in" and "plug-out" (even "trade-in") basis. The panels could also be equipped with prefabricated insulations and could be finished in any desired way in the factory or later, on a "do it yourself" basis. The producer of panels could offer the delivery and their immediate assembly on the site, in the same fashion as ready-mixed concrete producer is offering today both delivery and placing of concrete on the site.

6. ACKNOWLEDGEMENTS

The construction of houses out of universal modular concrete panels represents an extension of similar concept used by the author earlier for industrial buildings (1), (2), (3).

The development work dealt with in this paper was carried out during the period of 1965-1970 within the Ford Foundation consultancy and in association with: Asswan Devolopment Planning Office, School of Design, University of Detroit, Siliguri Planning Organisation and Calcutta Metropolitan Planning Organisation.

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8. LIST OF FIGURES

Figure 1 - UCOPAN - precast reinforced concrete wall panels 9x3 feet (solid panel, ventilation panel and window panel).

Figure 2 - UCOPAN - precast reinforced concrete floor and roof panels 10x3 feet. Weight of single panel 800 lbs.

Figure 3 - Precast roof panel RP 10x3 - dimensions and reinforcement.

Figure 4 - Different wall panels which can be produced in the same universal form.

Figure 5 - Example of timber form for wall panels used in North Bengal. In front - freshly cast window wall panel. In the back - panels in curing.

Figure 6 - Example of steel form for casting of UCOPAN panels for roof/floor, used in Nepal.

Figure 7 - UCOPAN panels filled with water for 7 days of natural curing in open air in hot country condition.
(a) - wall panels
(b) - roof panels

Figure 8 - Scheme of use of UCOPAN system for single-storey housing construction (model).

Figure 9 - Scheme of use of UCOPAN system for multi-storey housing construction (model).

Figure 10 - View of roof panels placed in position and of joints with reinforcement for continuity, before filling in with concrete.

Figure 11 - View of two wall panels as they may appear in the building (both panels may also face the same direction). There is a gap between panels in the shape of a parallelogram which after filling from the top with fine concrete will serve as a lock. In case of multi-storey building vertical reinforcement will be dropped into the gap for vertical continuity.

Figure 12 - Example of reinforcement in joints between roof panel. Numbers in circles mean:
(1) - Longitudinal bar of 3/8" diameter for cantilever areas.
(2) - Standard continuous reinforcement of 3/8" diameter in all joints.

Figure 13 - Simple hoist designed for assembling of UCOPAN panels.
(a) - Hoist assembled on scooter wheels before placing of counter balance. This hoist is operated manually.
(b) - Hoist assembled on a jeep seen in the front of picture and scooter hoist-in the back of picture. (Sand bages used as counter balance).

Figure 14 - Ground floor plan of two segments of low cost single-storey row-type housing, developed in the Calcutta Metropolitan Planning Organisation (Architectural Consultant - Frederick C. Terzo, Structural - Z.A. Zielinski and R.N. Mukherjee)

Figure 15 - Section through single storey building as shown in Fig.14.

Figure 16 - Panel Wall Scheme

Figure 17 - Example of two room house designed in Siliguri Planning Organisation for flood victims in North Bengal.

Figure 18 - Different stages of assembling of houses for flood victims, build in 1969 according to design shown in Fig.17.

Figure 19 - Views of ready houses built for flood victims in North Bengal.

Figure 20 - Traditional Indian Alpona decorations demonstrated on panels inside of a house built for flood victims in North Bengal. (Interior Design Advisor - Czeslawa Zielinska).

Figure 21 - Design of a house for tea plantation workers in North Bengal.

Figure 22 - An example of split-level house made of UCOPAN panels.

Figure 23 - Illustrations of construction of series of low cost houses in Kathmandu, Nepal. Exposed, factory made, brick is used here for walls but roofs are made of UCOPAN panels. Slopping panels cover storage space. Stepping elevation and split level roof arrangement makes houses fit to mountainous environment - (Arch.Consultant - Carel Pruscha, Structural - Z.A. Zielinski)

Figure 24 - Example of UCOPAN panel made four-storey town house consisting of "Regular Two Room Apartments" (according to Indian Government Housing Standards)

Figure 25 - Illustrations of construction of two-storey apartment house made of standard UCOPAN panels, erected as a prototype in Calcutta.

Figure 26 - Design and model illustrations of the Center of Economic Development and Administration at Tribuvan University in Kathmandu. This building complex is designed using only exposed brick for walls and UCOPAN panels for roofs and floors. It consists of an auditorium, lecture rooms, offices and dormitories. Dormitories are located in four-storey, long building with sloping walls (Architectural Consultant - Carel Pruscha, Structural - Z.A. Zielinski and Umesh Malla).

Figure 27 - View of a model and of reflecting ceiling of the auditorium.

Figure 28 - Illustrations of construction of the Center of Economic Studies and Administration in Kathmandu. Scaffolding assembled for UCOPAN dome-type roof of auditorium (compare Fig.27).

Figure 29 - Structural model, elevation and selected design example of an apartment block for new city of Asswan in Egypt. Different type houses, urban units and the whole city were designed using the same standardised ribbed panels as seen in the model. This design was made in 1965/66 with the Ford Foundation assistance (Arch.Design and Planning - Jerzy Glowczeski and Kamal Abou Hamda, Structural Design - Z.A. Zielinski).

Figure 30 - Selected urban units and overall view of New City of Asswan.

Figure 31 - "LUCOPAN" - large scale panel system, designed for urban renewal of Detroit and Montreal. M-Module of 8 or 10 feet. Six modular panels produce the basic house unit, working as a box. Partition walls should be added.

Figure 32 - Examples of partition walls arrangement for LUCOPAN units as illustrated in Fig.31.

Figure 33 - Examples of composing of LUCOPAN houses (Architectural Designer - Bruno Leon, Structural - Z.A. Zielinski)

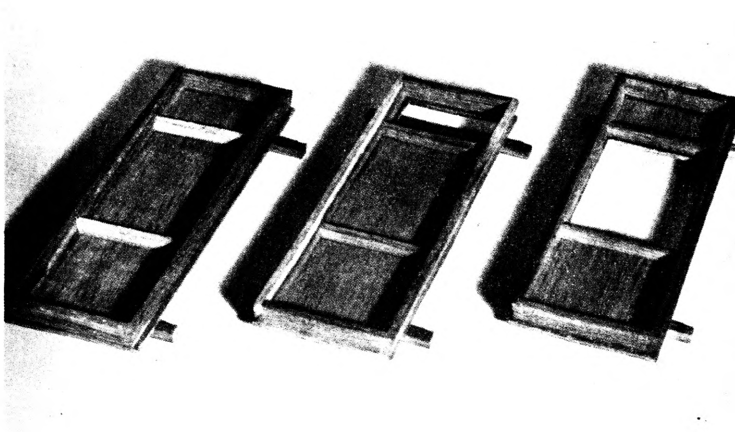


Fig. 1 UCOPAN - precast reinforced concrete wall panels: 9'x3' solid panel, ventilation panel and window panel.

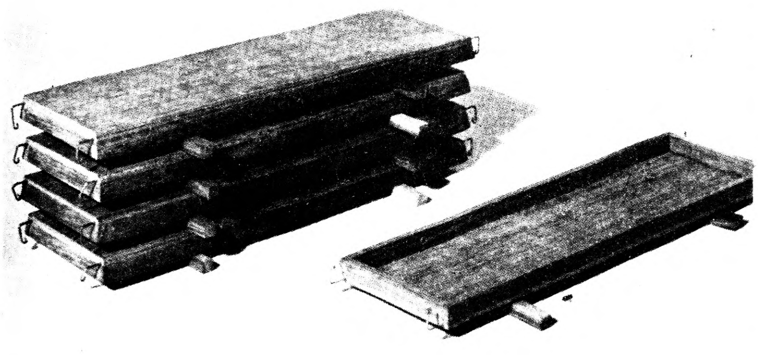


Fig. 2 UCOPAN - precast reinforced concrete floor and roof panels 10'x3'. Weight of Single panel 800 lbs.

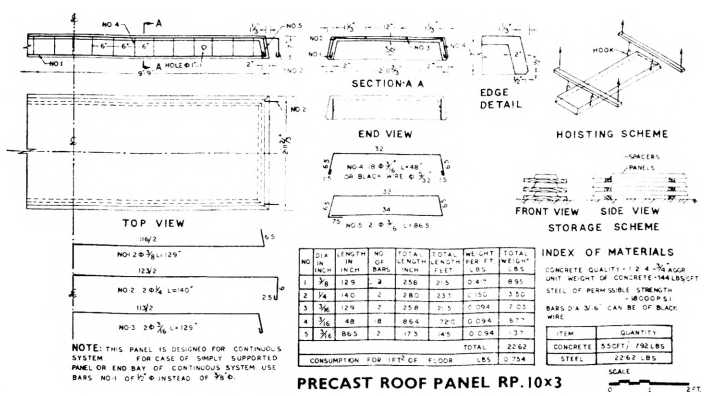


Fig. 3 Precast roof panel RP 10x3 - dimensions and reinforcement.

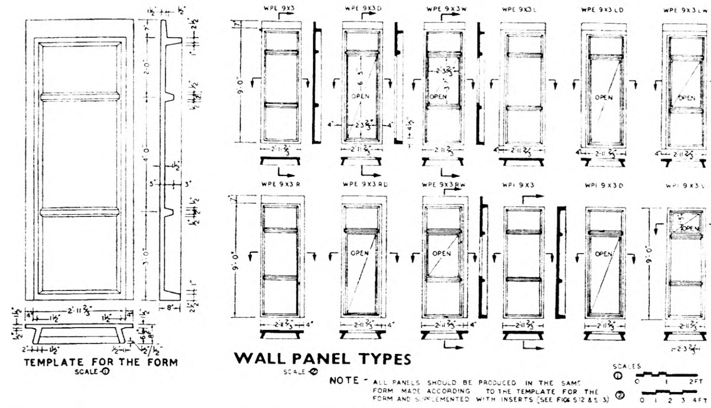


Fig. 4 Different wall panels which can be produced in the same universal form.

Fig. 5 Example of timberform for wall panels used in North Bengal. In front - freshly cast window wall panel. In the back - panels in curing.

Fig. 6 Example of steel form for casting of UCOPAN panels for roof/floor, used in Nepal.

a/ wall panels;

b/ roof panels

Fig. 7 UCOPAN panels filled with water for 7 days of natural curing in open air in hot country condition.

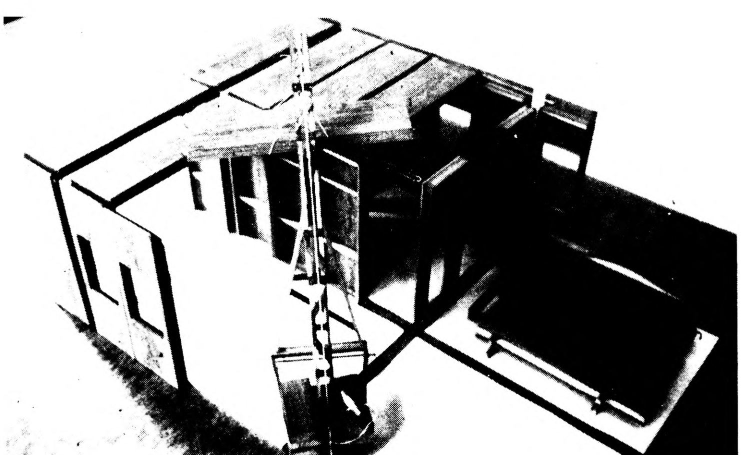


Fig. 8 Scheme of use of UCOPAN system for single-storey housing construction (model).

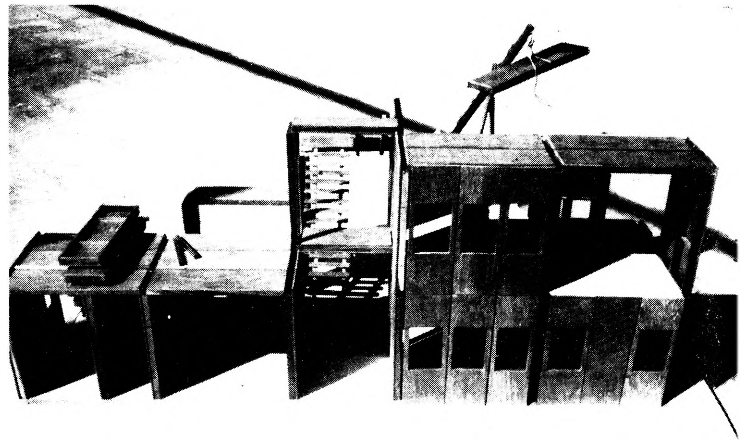


Fig. 9 Scheme of use of UCOPAN system for multi-storey housing construction (model

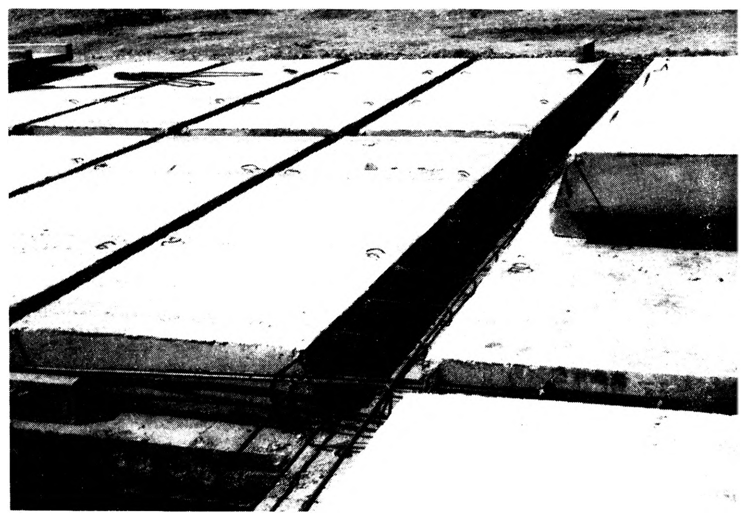


Fig. 10 View of roof panels placed in position and of joints with reinforcement for continuity, before filling in with concrete.

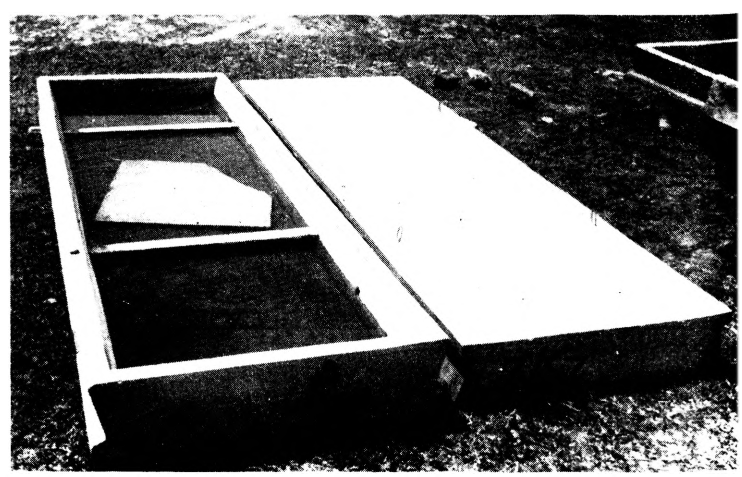


Fig. 11 View of two wall panels as they may appear in the building (both panels may al face the same direction). There is a gap between panels in the shape of a parallelogram which after filling from the top with fine concrete will serve as a lock. In case of multi-storey building vertical reinforcement will be dropped into the gap for vertical continuity.

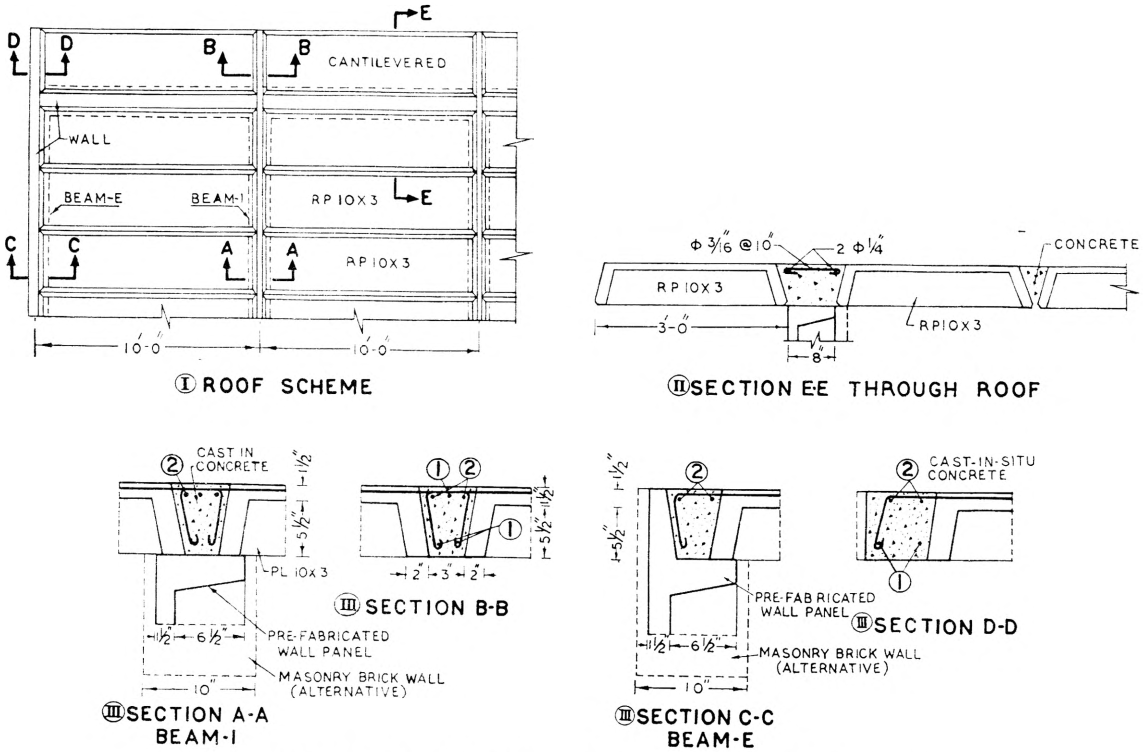
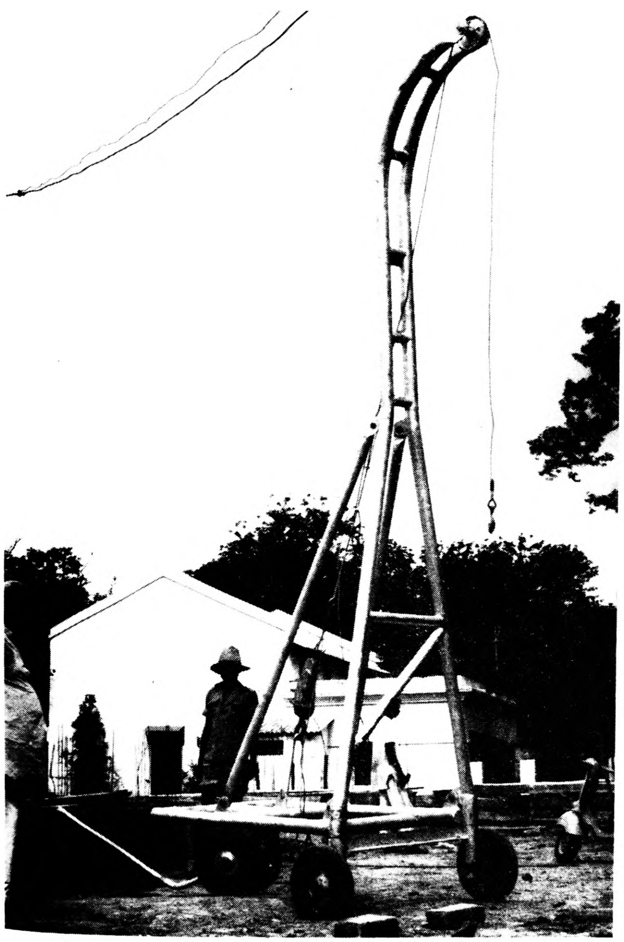


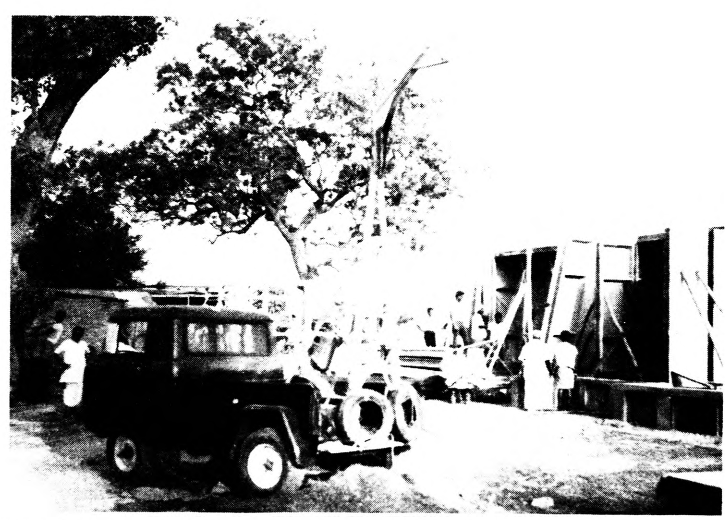
Fig. 12 Example of reinforcement in joints between roof panel. Numbers in circles mean:

(1) - Longitudinal bar of 3/8'' diameter for cantilever areas.

(2) - Standard continuous reinforcement of 3/8'' diameter in all joints.



(a) - Hoist assembled in scooter wheels before placing on counter balance. This hoist is operated manually.



(b) - Hoist assembled on a jeep seen in the front of picture and scooter hoist-in the back of picture. (Sand bags used as counter balance).

Fig. 13 Simple hoist designed for assembling of UCOPAN panels.

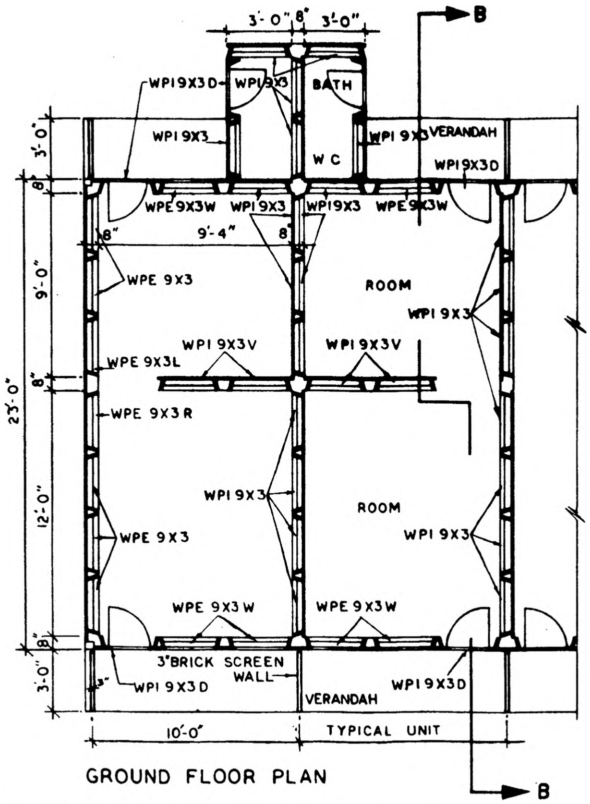


Fig. 14 Ground floor plan of two segments of low cost single storey row type housing, developed in the Calcutta Metropolitan Planning Organization (Architectural Consultant - Frederick C. Terzo, Structural - Z.A. Zielinski and R.N. Mukherjee).

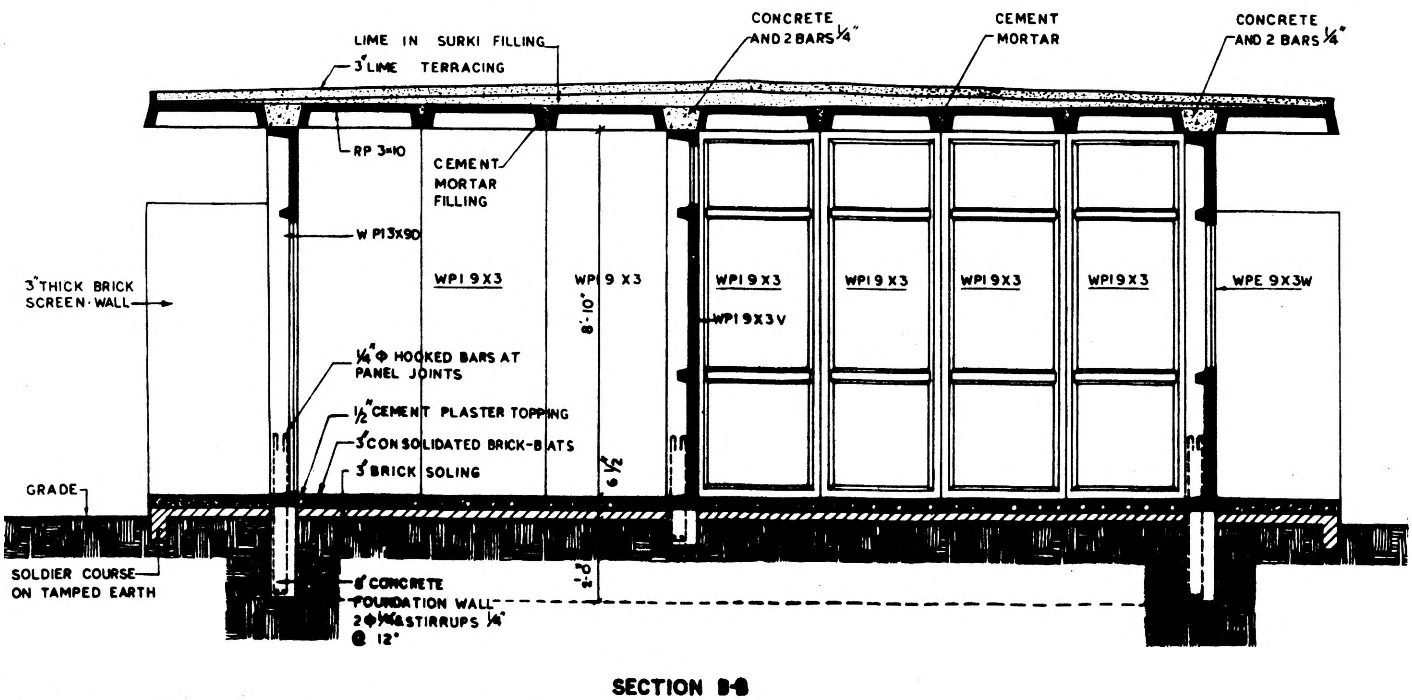
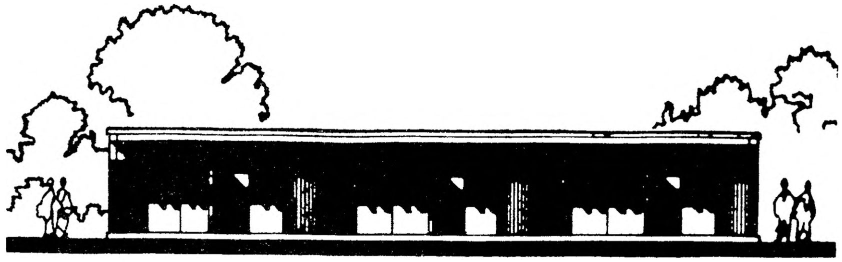
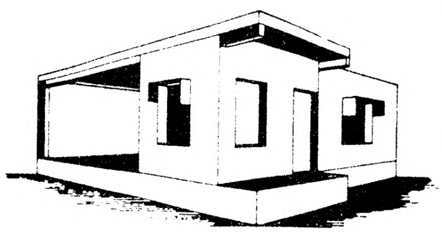


Fig. 15 Section through single storey building as shown in Fig. 14

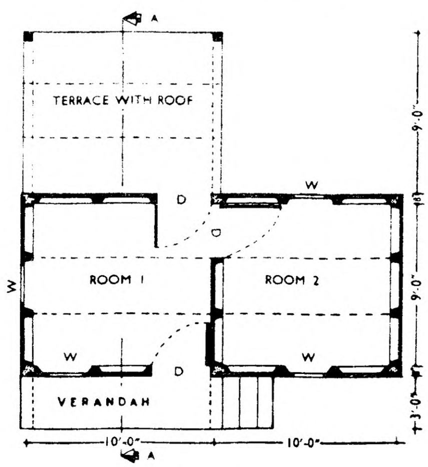


PANEL WALL SCHEME

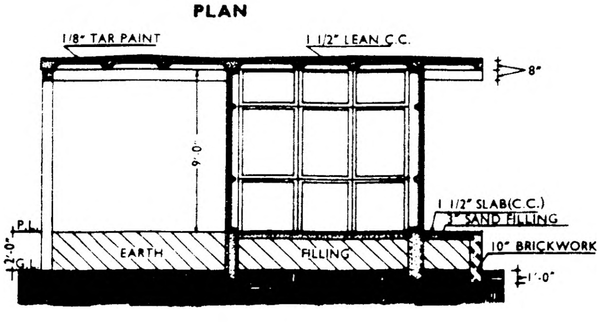
Fig. 16



CONSTRUCTION MATERIAL PRECAST R. C. C. PANELS	
TOTAL PLINTH AREA	344 sq. ft.
TOTAL FLOOR AREA	280 sq. ft.
ROOM 1	84 sq. ft.
ROOM 2	84 sq. ft.
TERRACE AREA WITH ROOF	84 sq. ft.
VERANDAH AREA WITH ROOF	28 sq. ft.
COST	RS. 2,700



PLAN



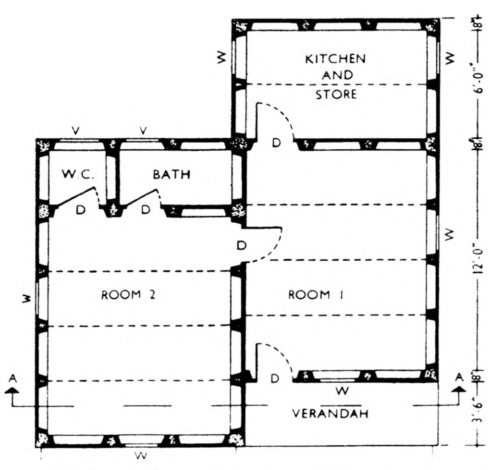
SECTION ON A-A

Fig. 17 Example of two room house designed in Siliguri Planning Organization for flood victims in North Bengal.

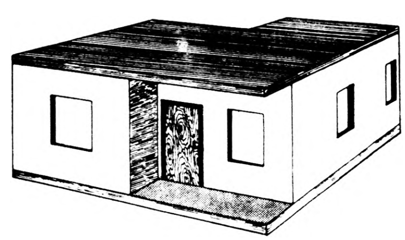
Fig. 18 Different stages of assembling of houses for flood victims, build in 1969 according to design shown in Fig. 17.

Fig. 19 Views of ready houses built for flood victims in North Bengal.

Fig. 20 Traditional Indian alpona decorations demonstrated on panels inside of a house built for flood victims in North Bengal. (Interior Design Advisor - Czeslawa Zielinska)



PLAN

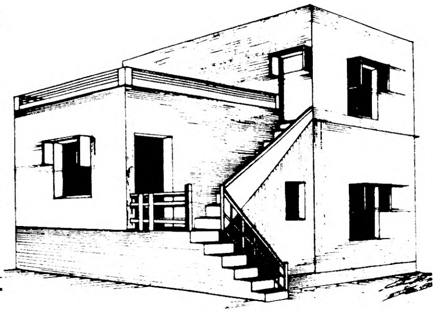


PERSPECTIVE VIEW

CONSTRUCTION MATERIAL PRECAST R. C. C. PANELS	
TOTAL PLINTH AREA	415 sq. ft
TOTAL FLOOR AREA	338 sq. ft
ROOM 1	112 sq. ft.
ROOM 2	112 sq. ft
KITCHEN AND STORE	56 sq. ft.
BATH	18 sq. ft.
W.C	10 sq. ft.
VERANDAH	30 sq. ft.
COST	RS. 4,000

Fig. 21 Design of a house for tea plantation workers in North Bengal.

CONSTRUCTION MATERIAL PRECAST R. C. C. PANELS	
TOTAL PLINTH AREA	296 sq. ft.
TOTAL FLOOR AREA	323 sq. ft.
ROOM 1	103 sq. ft.
ROOM 2	90 sq. ft.
ROOM 3	103 sq. ft.
BATH AND W.C.	18 sq. ft.
STAIRCASE	36 sq. ft.
OPEN TERRACE	90 sq. ft.
COST	RS. 4,400



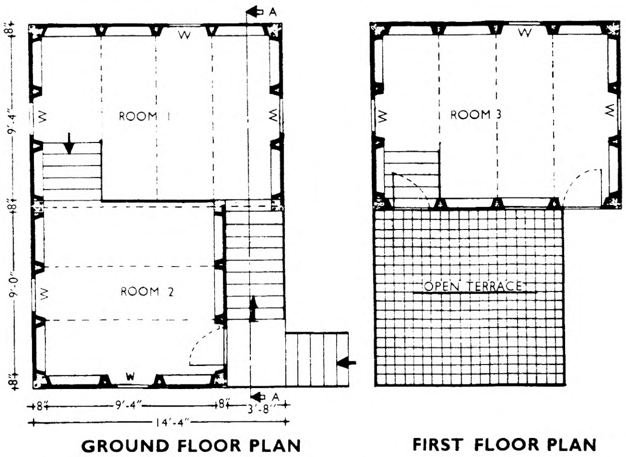
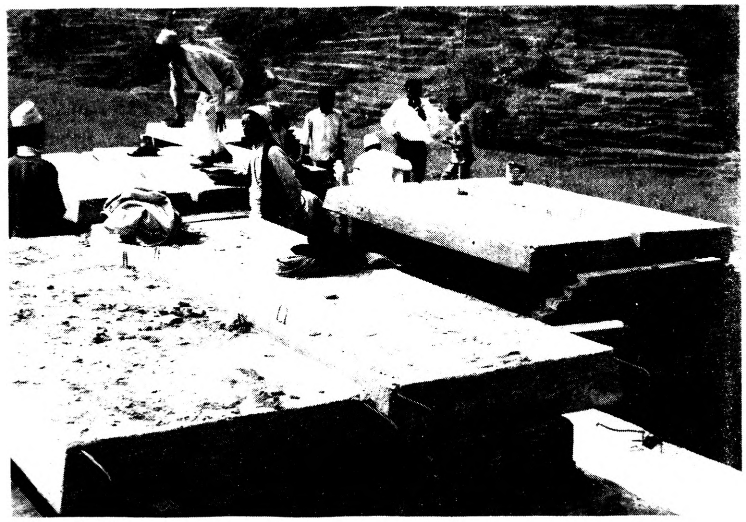
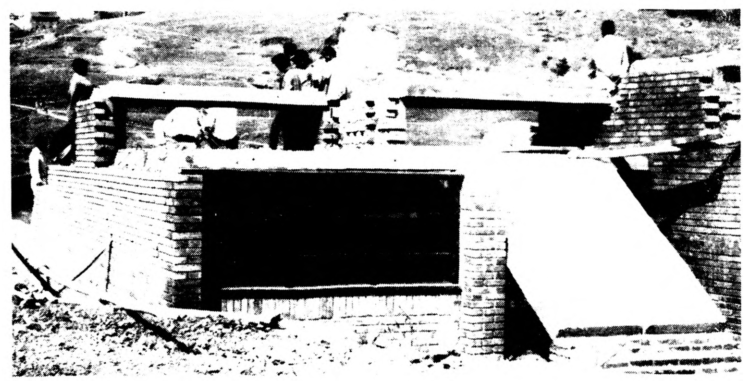


Fig. 22 An example of split-level house made of UCOPAN panels.





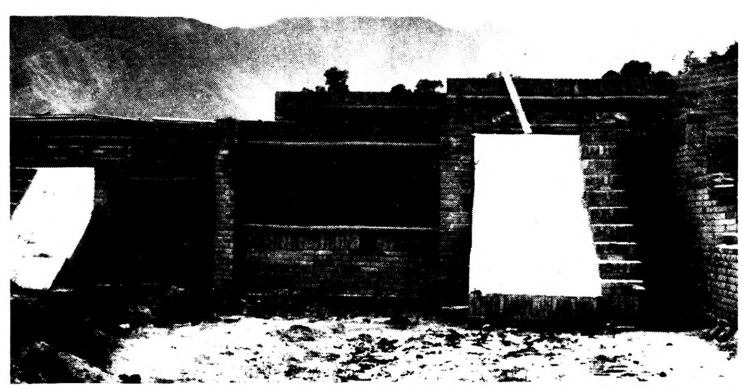
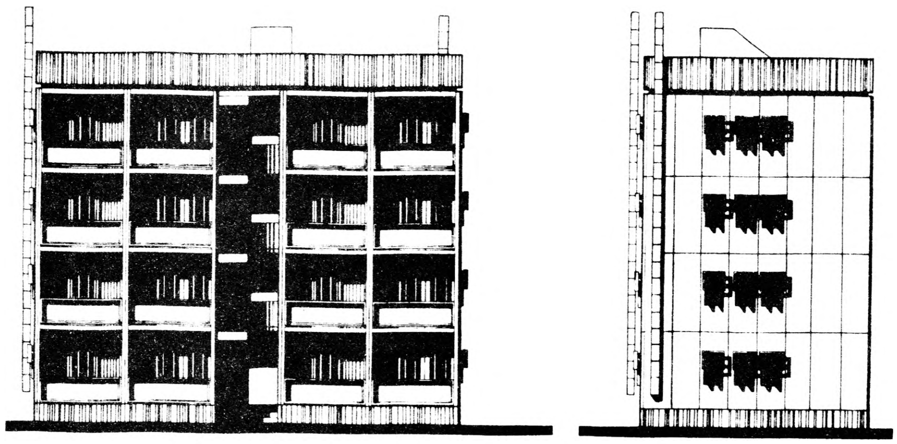
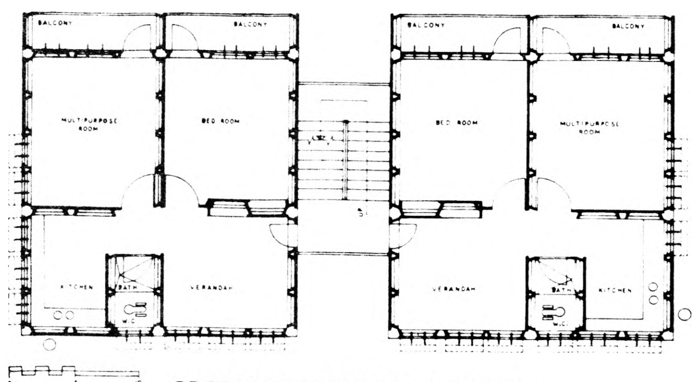


Fig. 23 Illustrations of construction of series of low cost houses in Kathmandu, Nepal. Exposed, factory made, brick is used here for walls but roofs are made of UCOPAN panels. Slopping panels cover storage space. Stepping elevation and split level roof arrangement makes houses fit to mountainous environment - (Arch.Con.-Carel Pruscha, Structural - Z.A. Zielinski)

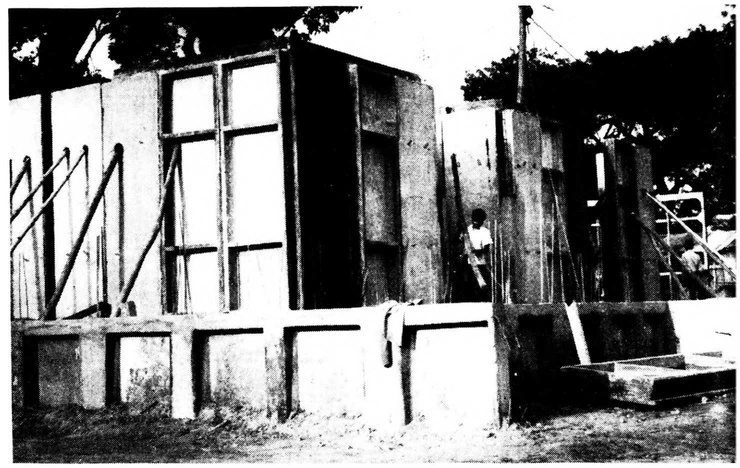


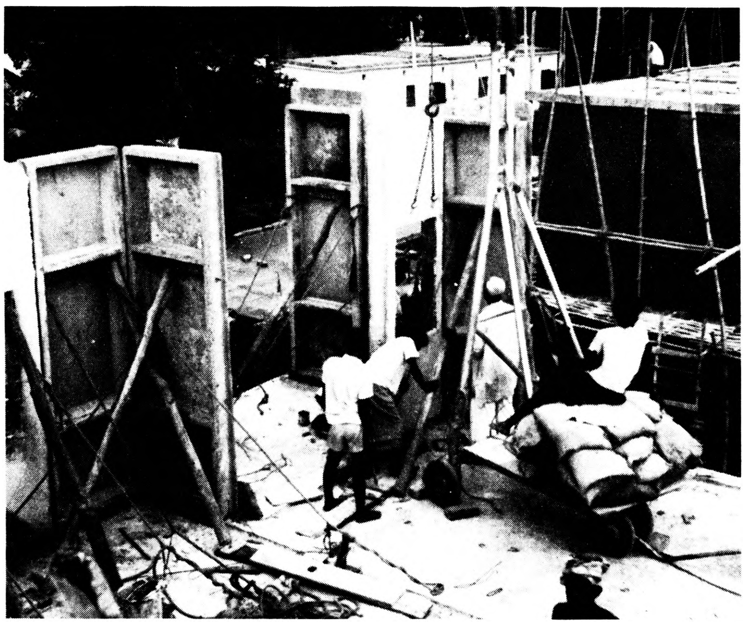
Proposed Regular Two-Room Apartment Blocks
Made of UCOPAN Elements

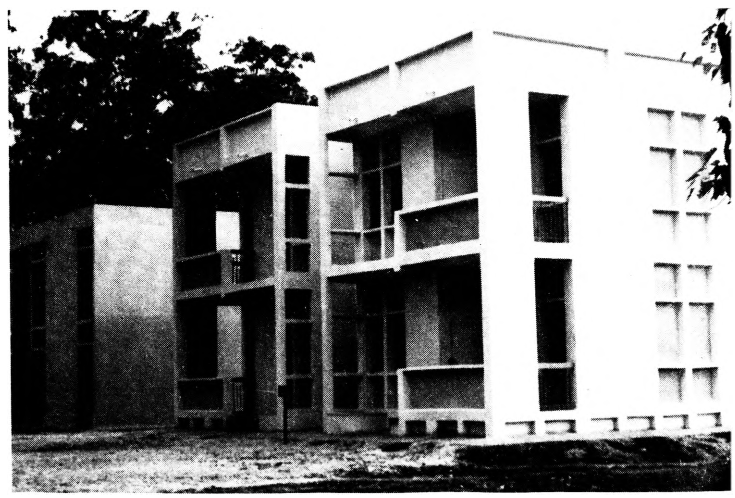


PROPOSED REGULAR TWO-UNIT

Fig. 24 Examples of UCOPAN panel made four-storey town house consisting of "Regular Two Room Apartments" (according to Indian Government Housing Standards)







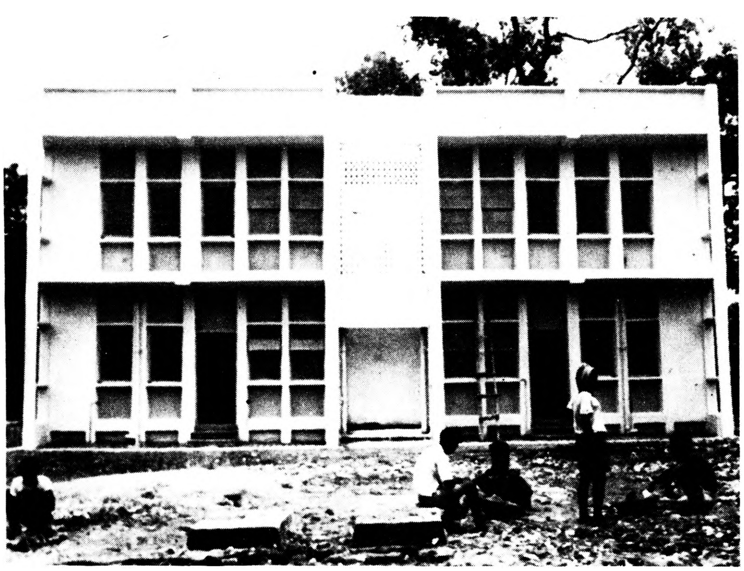
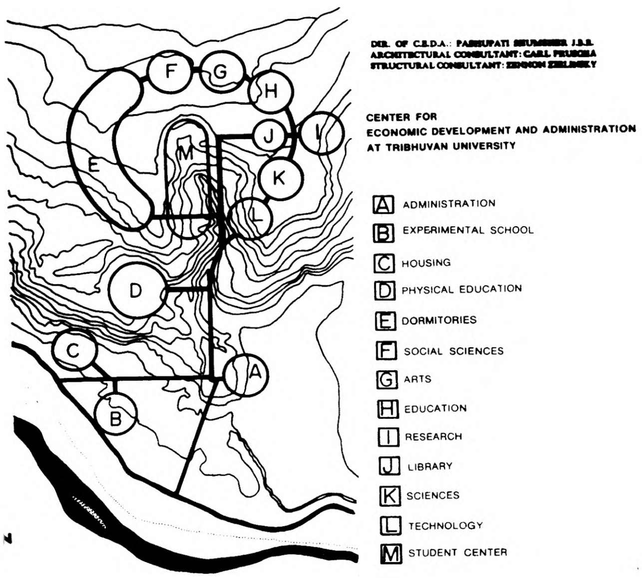
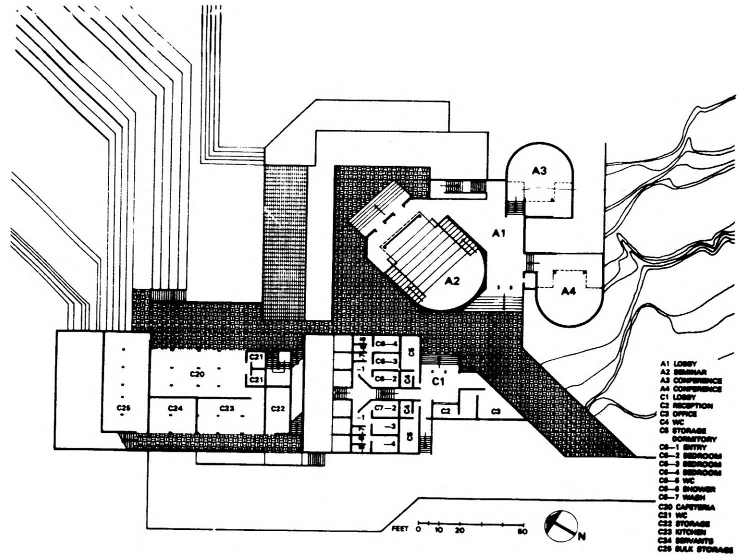
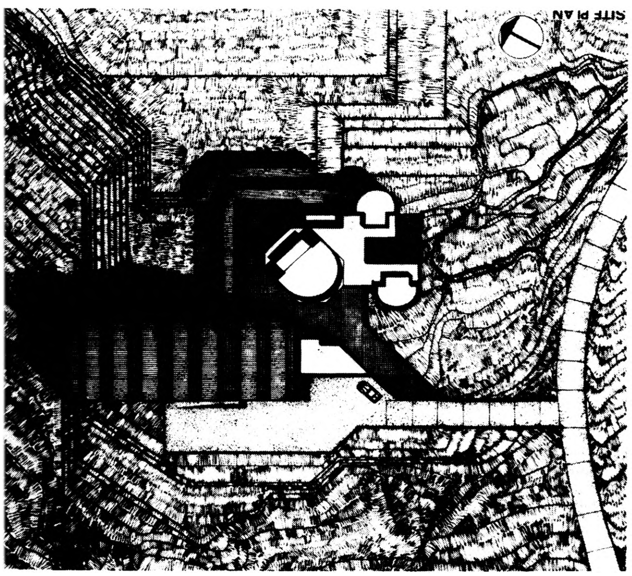
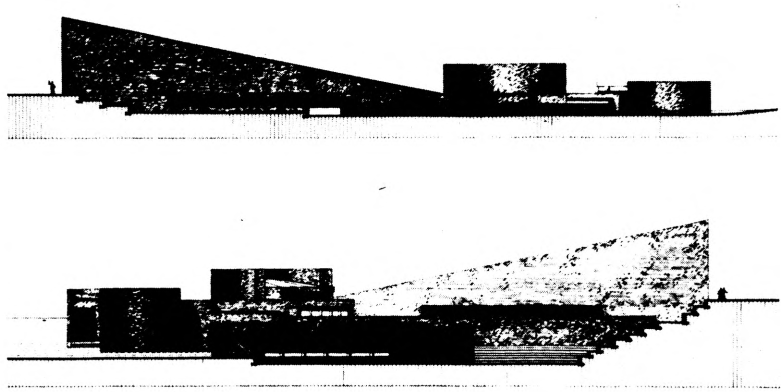


Fig. 25 Illustrations of construction of two-storey apartment house made of standard UCOPAN panels, erected as a prototype in Calcutta.









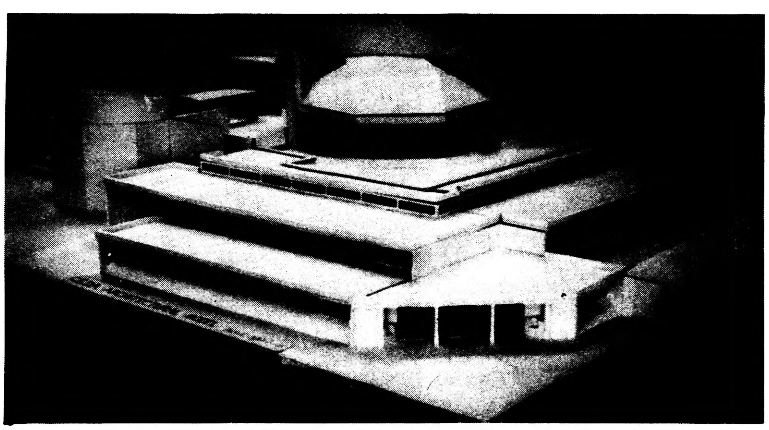


Fig. 26 Design and model illustrations of the Center of Economic Development and Administration at Tribuvan University in Kathmandu. This building complex is designed using only exposed brick for walls and UCOPAN panels for roofs and floors. It consists of an auditorium, lecture rooms, offices and dormitories. Dormitories are located in four-storey, long building with sloping walls (Architectural Consultant - Carel Pruscha, Structural - Z.A. Zielinski and Umesh Malla)

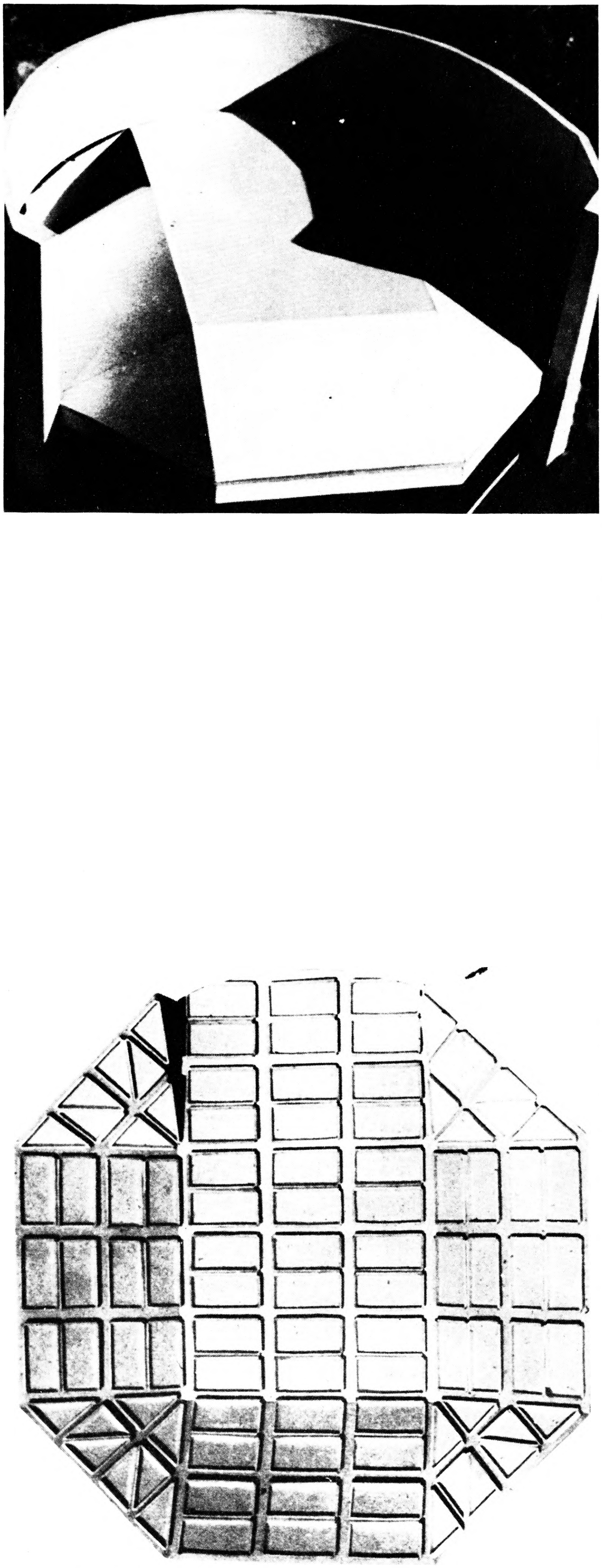


Fig. 27 View of a model and of reflecting ceiling of the auditorium.

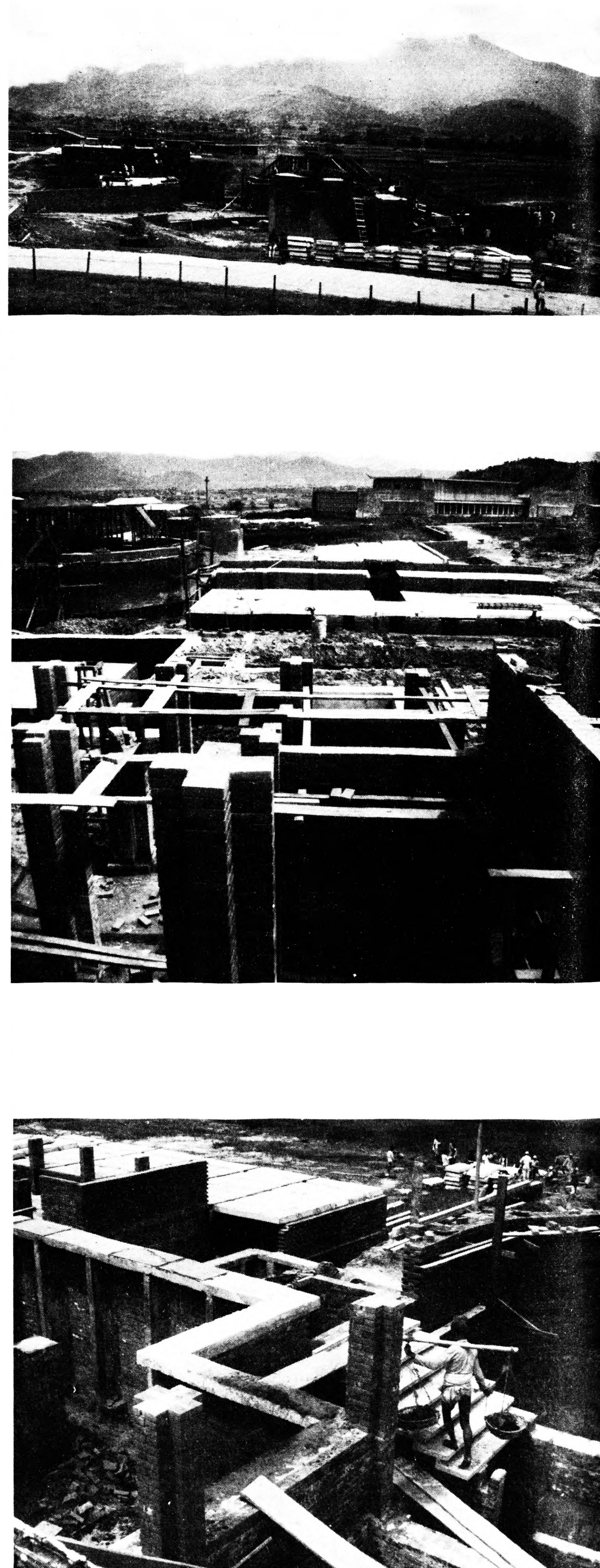


Fig. 28 Illustrations of construction of the Center of Economic Studies & Administratic in Kathmandu. Scaffolding assembled for UCOPAN dometype roof of auditoriu (compare Fig. 27)

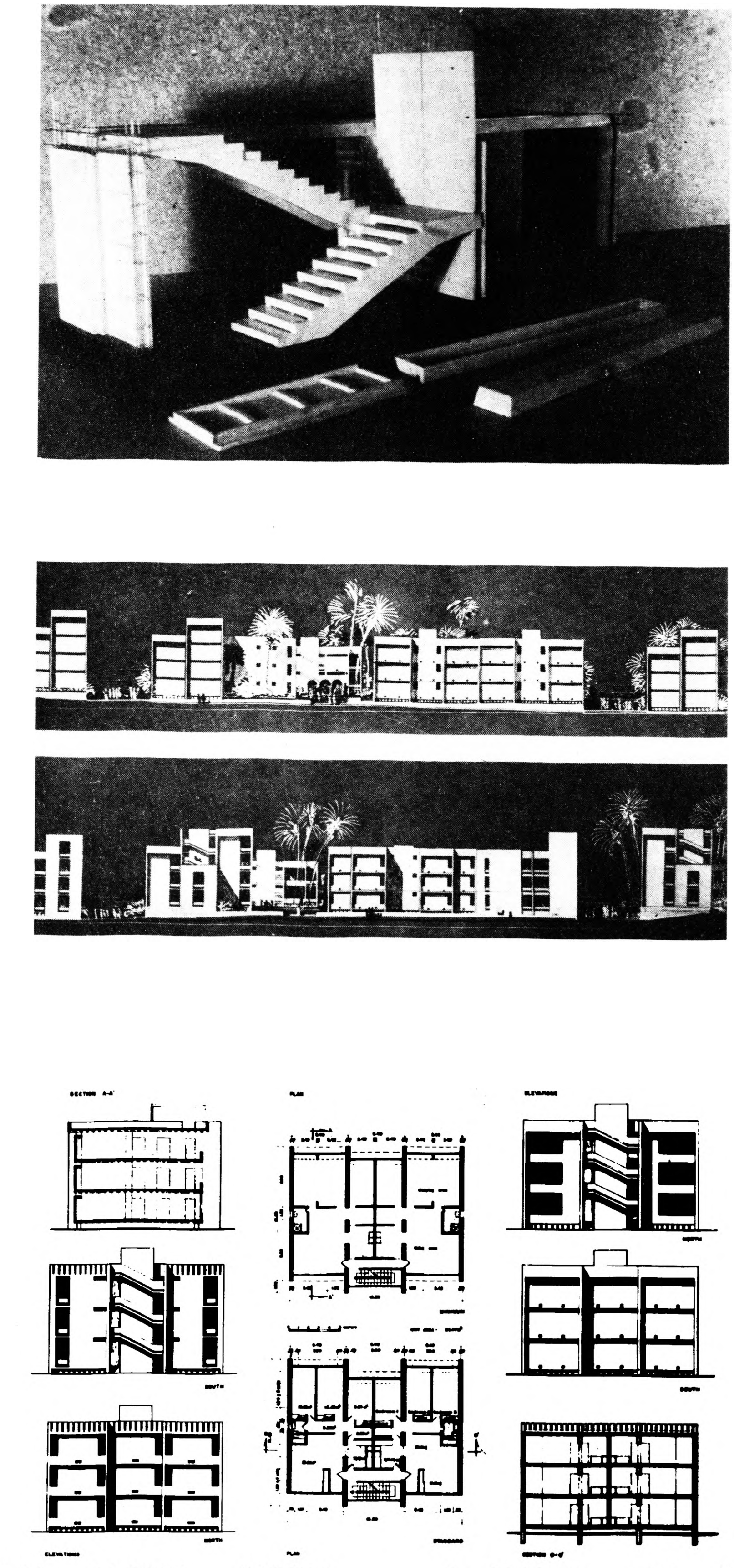
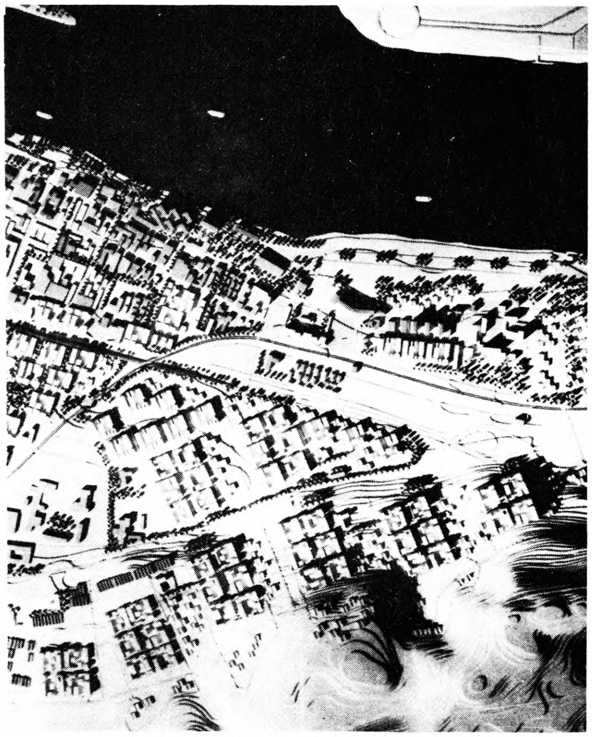
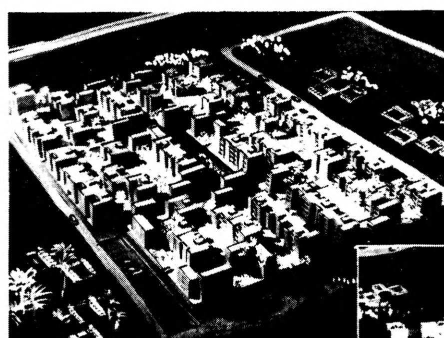


Fig. 29 Structural model, elevation and selected design example of an apartment block for new City of Asswan in Egypt. Different type houses, urban units and the whole city were designed using the same standardised rubbed panels as seen in the model. This design was made in 1965/66 with the Ford Foundation assistance (Arch. Design & Planning - Jerzy Glowczeski & Kamal Abou Hamda, Struct. Design - Z.A. Zielinski)



CENTRAL PORTION OF THE CITY

OVERALL VIEW OF THE CITY



View from East Side

View from West Side

URBAN UNIT TYPE B
SHORT AXIS EXTENDED NORTH-SOUTH

Fig. 30 Selected urban units and overall view of New City of Asswan.

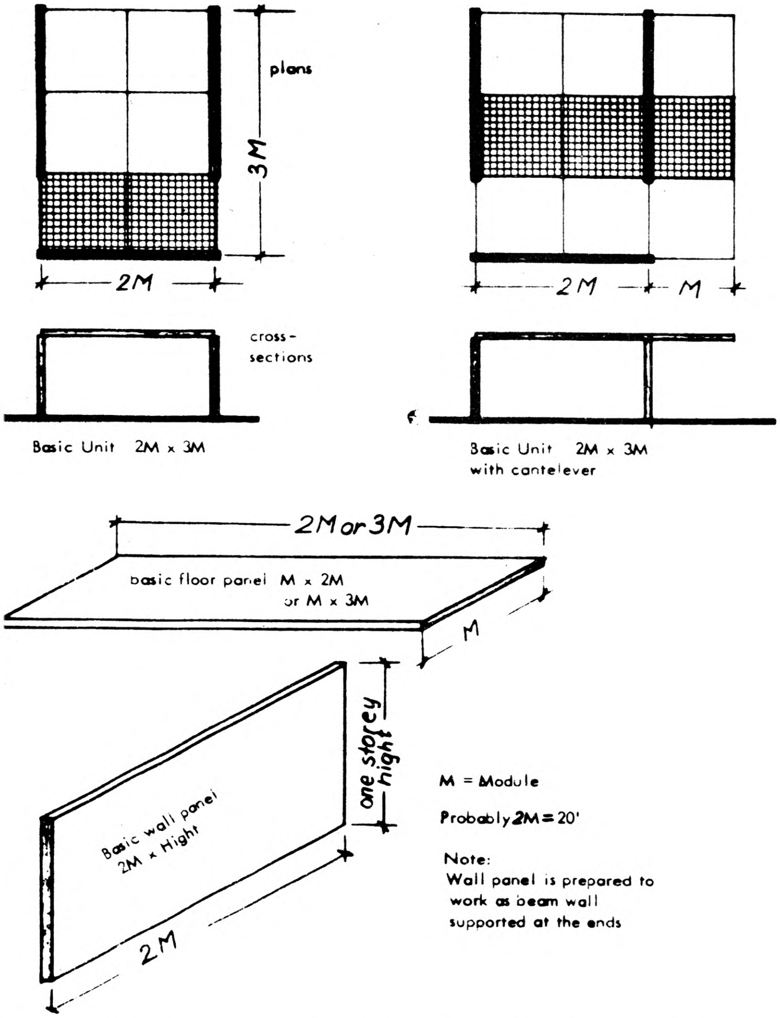


Fig. 31 "LUCOPAN" - large scale panel system, designed for urban renewal of Detroit and Montreal. M-Module of 8 or 10 feet. Six modular panels produce the basic house unit, working as a box. Partition walls should be added.

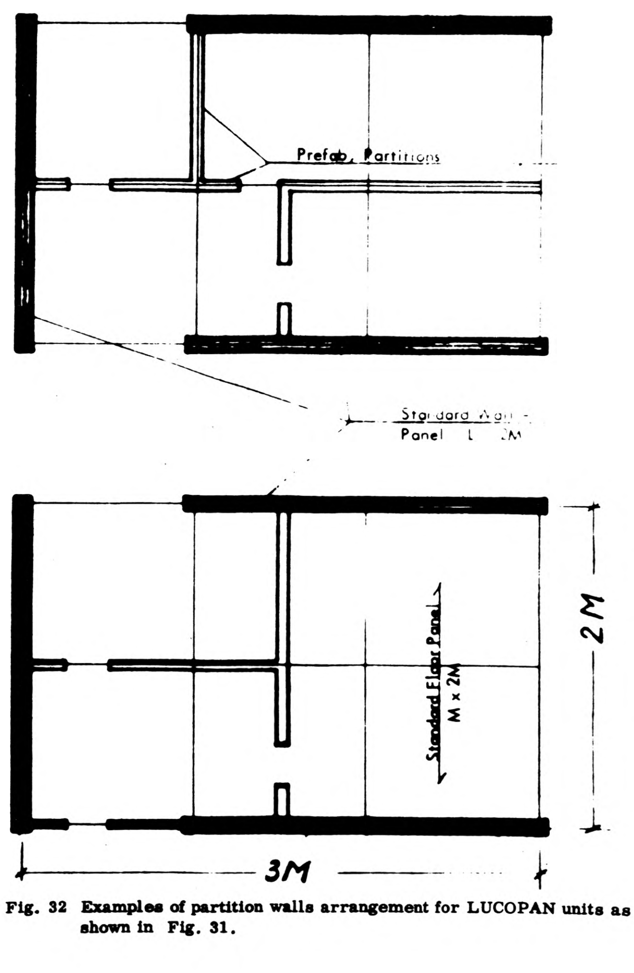
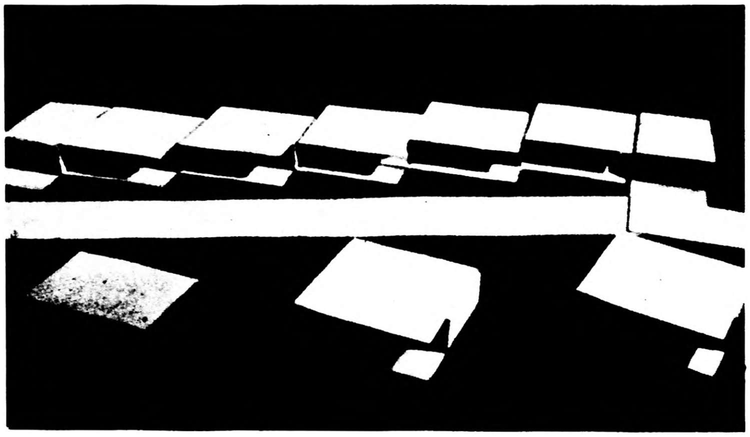
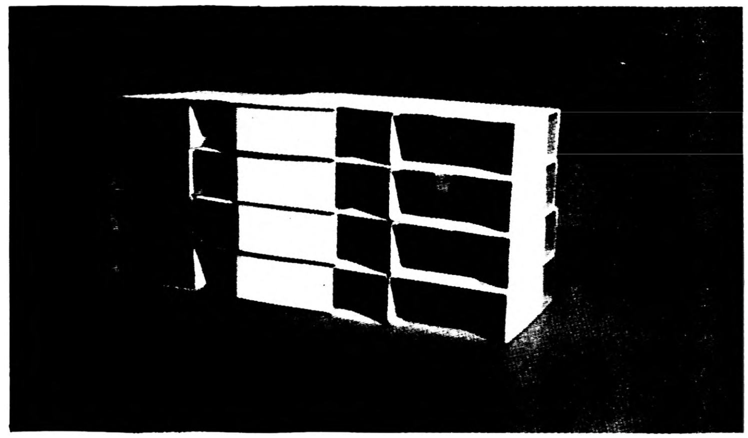


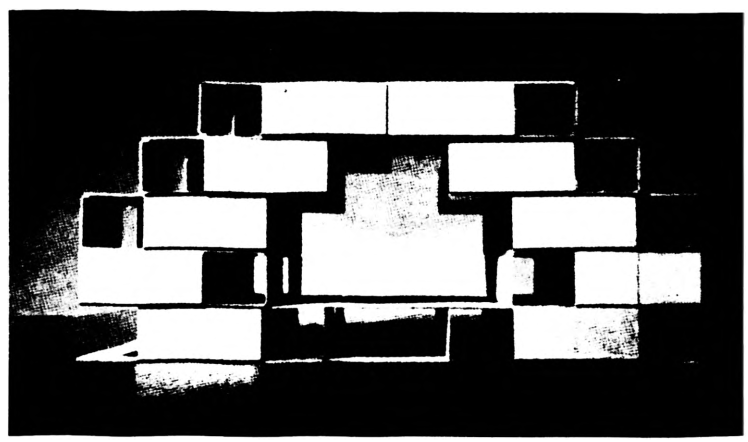
Fig. 32 **Examples of partition walls arrangement for LUCOPAN units as shown in Fig. 31.**



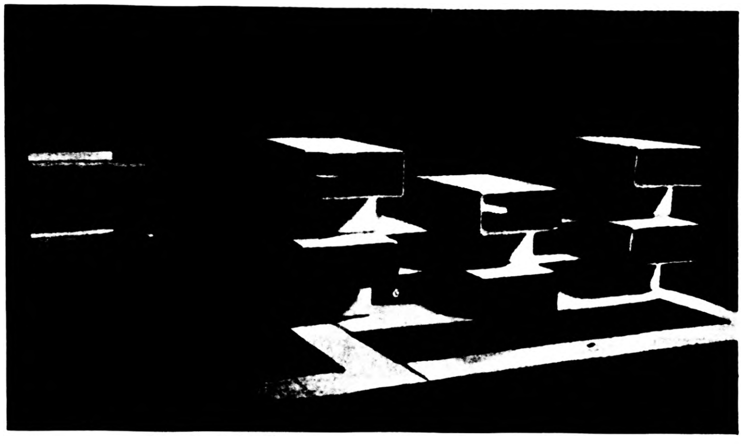
LUCOPAN--large-scale universal precast reinforced concrete panel, used for single-storey housing as developed by the author for Detroit, U.S.A. Size of single panel 10' x 20' or 10' x 30'. Size of housing unit about 600 sq. ft.



LUCOPAN used for terrace and overhanging apartment blocks. Membrane like behaviour of panel permits cantilevering, without increasing cost of construction.



LUCOPAN used for modern terrace housing and covered shopping blocks ("Habitat").



LUCOPAN used for multi-storey town housing.

Fig. 33 Examples of composing of LUCOPAN houses (Architectural Designer - Bruno Leon, Structural - Z.A. Zielinski)