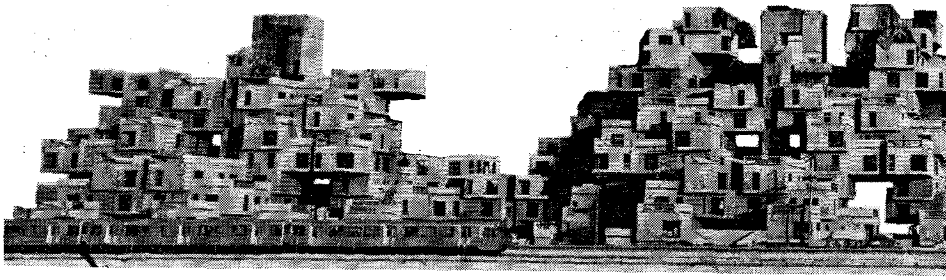


Habitat '67—Towards the Development of a Building System

by Moshe Safdie*

A SOLUTION FOR ENVIRONMENT

Rather than talk at great length about the technical aspects of precasting Habitat '67, a task which could be better undertaken by the precasting contractor and the structural consultant for this project, I prefer to deal with the concept of Habitat in a broader sense as a building system.

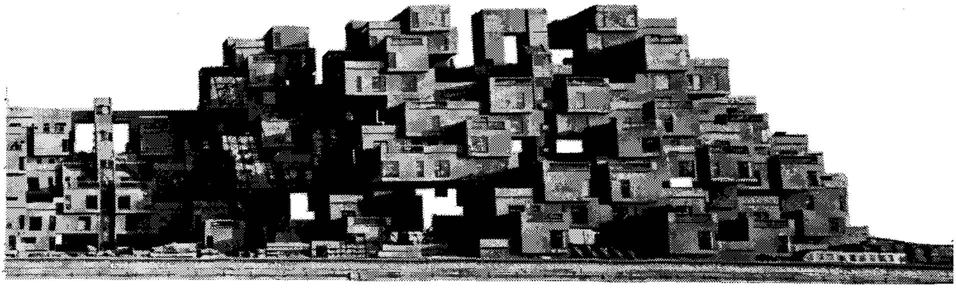
Habitat '67 is a three-dimensional building system, capable of a variety of applications to different sites. In its undertaking, Habitat attempts to indicate the shortcomings of the present pattern of the construction industry and to suggest the direction towards which it should develop.

Habitat '67 is a prototype, "hand-made" product of a potential, fully mass-produced system. It therefore deals with specific implications to housing and construction using assembly-line methods. Any assembly line requires the use of repetitive elements making up the final product. The greater the quantities, the greater the number of repetitive units possible. Automobiles produced by the millions are assembled of thousands of repetitive units. A toaster on the other hand may be assembled of 20 or 30 repetitive units.

In the construction of an environment, the problem presented by mass production is how to achieve a variety of spaces required in the make-up of the city; how to achieve a variety of house types; how to achieve a variety in the patterns and groupings of the elements of the city to avoid monotony, without sacrificing the prerequisites of repetitive use of similar elements.

Habitat deals with two of these problems. A single standardized three-dimensional precast component is used as the repetitive modular construction element. This unit is then combined as one, two or three elements to form 15 different house types. The modular unit is a structural element; it supports itself and the units above it; it encloses the space for the dwelling; and it forms

*Architect
Montreal, Quebec, Canada



the exterior surface of the house. Its size permits for the pre-finishing of all auxiliary elements within an assembly line on the ground, eliminating the traditional construction "in place" for the mechanical, electrical and other sub-trades.

The elements can be grouped to form clusters of various sizes and rising from two to 25 stories in the air, depending on site conditions, density required and the economics of the particular program.

The modular unit is equipped with other components, also standardized and mass produced in plants elsewhere. The various components, such as bathrooms, kitchens, storage units, mechanical distribution systems, and heating and cooling equipment, arrive at the assembly line and are installed in a sequence just as the various components that make up a car are manufactured in different plants to be finally assembled in the car plant.

Habitat '67 is at once a research project, a mock-up prototype—and an exciting structure of the future that is certain to be a significant architectural milestone. The concept is bold—but not for boldness' sake. It is one man's answer to the ever louder cry of anguish from our cities. And the answer has warmth and feeling, for it is offered with people and families in mind.

Habitat '67 is part of Expo '67 and, largely because of this, was made possible. At least made possible more easily, since the atmosphere surrounding a World's Fair reaches out to the new, and daring, and imaginative. To avoid the frustrations, delays and tediums that many planners face, is all to the good. But at once the pressure of time seriously limited desired preliminary study, research and development, and even change as the project unfolds. Its technology is the best that the engineers, architects, fabricators, and constructors directly involved *can offer—and this is considerable. But it could not hope to achieve the optimum in all technologies.*

As a research project it will offer most in what to seek in the future. As a prototype it will exhibit function within its present frame of reference. And the big test still remains—will it do for people, for families, for the city, that which is envisioned.

Moshe Safdie, architect, presented the "why" of Habitat '67 at PCI's Houston Convention and Engineer Jan Komocki reports on its intricacies of structural design in the following articles.

—Editor

The economies which have affected industry through mass production go beyond the simple question of labor saving through the ability to tool up and mechanize processes which otherwise would require extensive hand labor. The assembly line permits the analysis of every step of production and its improvement towards greater economies through the careful planning of every step in manufacturing.

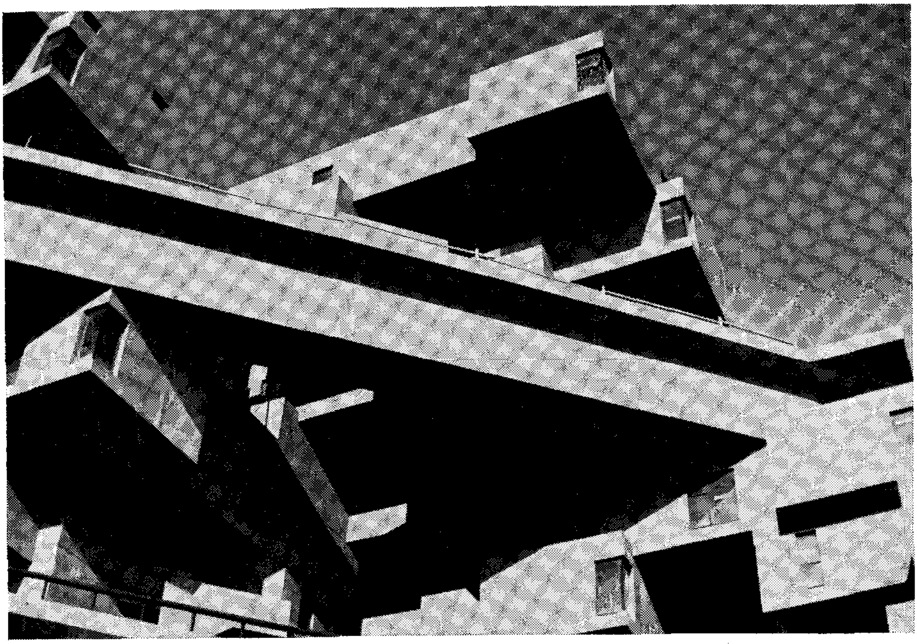
The construction industry is perhaps the only one today where methodical planning is impossible. Just compare the typical construction site to a typical factory of a manufactured product. Along the assembly line of a refrigerator factory, each worker installs a component which has been prefitted to given conditions. Each step is considered in relationship to other steps. Never does one see idleness in a factory of this kind. Never does one see work being torn out because it has not provided for other components, or because it has not fitted the given tolerances. In contrast, the typical construction site is swarmed with idle men: riggers waiting for a piece to be installed; workers carrying equipment and material for installation through the multi-storey structure; workers ripping out work to provide for other trades; plumbers interfering with carpenters or concrete men; components being modified because they do not fit within the structure; and hand labors used for a multitude of construction operations, from building of form work for concrete, to the fitting and bending of ducts and pipes. All this indicates waste and inefficiency.

Habitat '67 attempts to demonstrate that there is no reason why the construction industry should not adopt all the methods used by other industries.

URBAN IMPLICATIONS

As a building system, Habitat '67 attempts to provide for the present growth of existing and new urban developments. It is an alternative to both suburbia and to the rising towers of public housing and urban renewal projects sprouting in our cities. It attempts to provide for families within a multi-storey high density structure, i.e., to give the amenities which the family wants, such as privacy, a garden and open space, and identity which they now seek in the suburbs. Further it gives both the privacy of the house and urbanity of the public meeting place which the suburb does not give.

The land-use concept of Habitat is that it is more efficient within a single development to integrate all the land uses—residential, commercial, institutional, open space—rather than to have these serve each other in adjacent developments as is the present pattern within the two-dimensional city. Instead of having residential developments, with shopping centres, parks, hospitals, schools and the like adjacent to each other, they are grouped vertically in three-dimensional pattern. The houses, forming the outside membrane, are exposed to sunlight and view and within are grouped a continuous network of commercial and institutional facilities. The road and service networks are independent of the pedestrian network within the complex. Presently, developments have been built with densities of 300 people per acre, but they required an equal area adjacent to them to serve this population. In Habitat '67 the residential density could be 150 or 200 people per acre, but within that same area all the



commercial and recreational functions are provided for, doubling the effective density, and increasing amenities.

DESCRIPTION OF PROJECT

Construction System

The construction system consists of large precast concrete, three-dimensional modular units. These box-like elements measure 17 ft. 6 in. x 38 ft. 6 in. x 10 ft. high. They are precast in steel molds, using 5000-psi concrete, and steam cured. Following the casting, these modular units are taken to a finishing area where all components, fixtures and finishes are installed in an assembly-line method. Kitchens, bathrooms, window frames, insulation, etc. are all installed into the box unit, which is then ready for erection. The finished unit is brought to the crane site at which time it is lifted into position. The weight of the boxes varies from 70 to 90 tons at the time of lifting. Precasting and plant conditions provide for a good surface finish for exterior exposure. The interior of the units is lined with insulation and wall finish. The majority of the components (bathrooms, kitchens, etc.) are pre-made and installed as complete units into the box before the roof is connected. The modular units are incorporated into the structure in such a way that adjacent walls, floors, and ceilings of neighboring houses are separated, thus high levels of sound and vibration insulation are achieved.

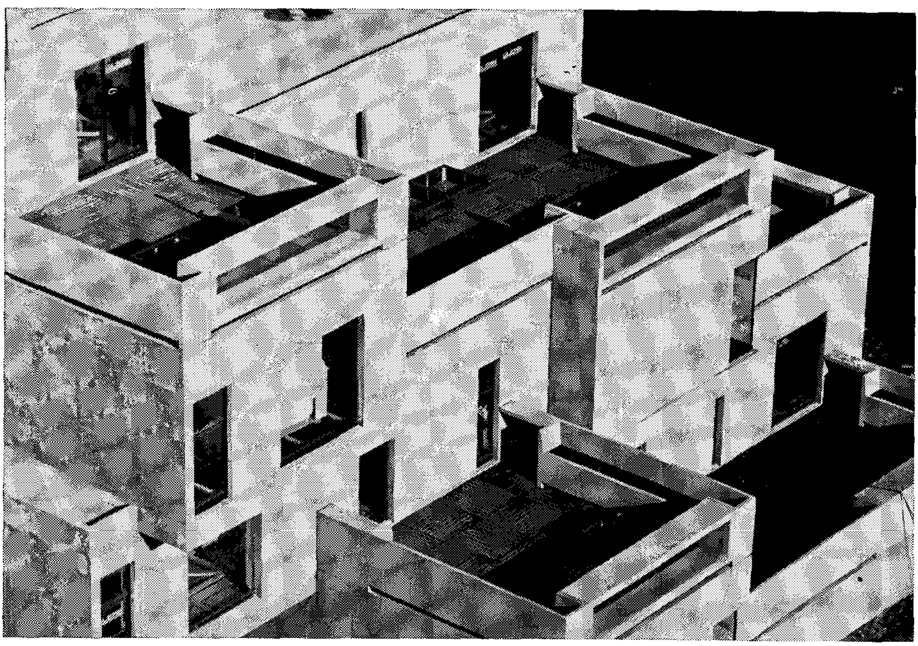
In grouping the units, gardens are formed on the roofs of the units below, with the large ones measuring 17 x 36 ft. All houses have at least one garden, and the larger houses have two gardens.

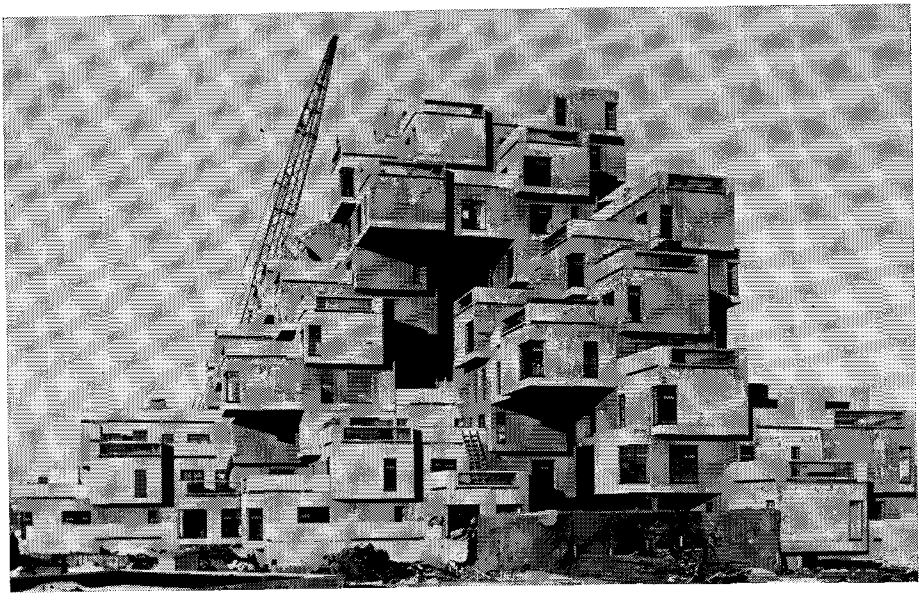
Structural System

The modular units are load bearing. They are erected one on top of the other, carrying the major part of the load through walls and piers. Further structural support is given by the horizontal streets. These streets are 10 ft. high and contain mechanical services within them and pedestrian circulation on top of them. A portion of the loads is transmitted from the boxes to these streets, then horizontally to the vertical elevators and stair cores which transmit them to the ground. In addition, overall stability for wind and seismic conditions is provided by the interaction of house units and streets. The house units are connected to each other by post-tensioned tendons and bolting, and the street units themselves are constructed of sections which are post-tensioned to form one unit.

CHOICE OF MATERIAL IN THE DEVELOPMENT OF THE PROJECT

Extensive study was given to the choice of the primary structural material. Studies were undertaken by the Steel Institute of Canada and the Committee of Cement Companies to determine the relative merit of different materials. Concrete was used for the modular unit because it could act as a structure to enclose space, furnish exterior surface, and it is fireproof. Steel structures would require fireproofing. The alternative of constructing a large frame and inserting non-structural modular units was rejected on the grounds that it resulted in a redundant structure. The frame must have enough strength to support the units, but the units nevertheless are heavy since they, too, had to be fireproof and could not be constructed from materials as light as sheet metal or plastics.





The minimum size for the modular unit permitting prefinishing is in the range of 600 sq. ft. which, using concrete, resulted in components weighing approximately 80 tons. This is a rather heavy load which in future applications will have to be reduced to achieve greater economies. Habitat '67 uses concrete as the most economical material for the building system within existing technology. While using the material to its limits, it also indicates its shortcomings when applied to three-dimensional building systems. Just as an airplane designer first establishes the problem and then sets to find a material to do the job, so in construction we must search for materials which would best solve our problems. The ideal material, which is relatively light, has a high structural capacity in both tension and compression, and has surfaces which are not porous to moisture, is yet to be developed. I think it is important to bear in mind that these properties in building materials are essential; this presents the need for basic research in the construction industry.

In other industries, the large corporations are able to undertake extensive basic research at a cost of millions of dollars which they then recover through the merchandizing of a particular product over a number of years. Furthermore, these industries are able to develop prototypes, tool up for them, and then recover these costs through extensive marketing. For example, recognizing the need for artificial leather, Dupont spent millions finding a synthetic material. In another example, Britain and France are spending one billion dollars for the design and construction of the first prototype of a supersonic passenger airliner. In each case, the proportion of cost of research and design development to the final product cost is much greater than in the construction industry.

The construction industry is fragmented from the manufacturer of basic raw materials and components, to the contractor and sub-contractors and to the architects and the engineers, with each group working in a vacuum. While it is inconceivable to imagine that each person would have a car custom designed for himself, because it is economically unrealistic, yet most people expect a custom-designed house, and one which is a well-functioning product, and this for 5% of the product cost.

The construction industry must be put in a position which enables it to develop its own basic materials as it requires them and to undertake the design development of complete systems. Perhaps through the introduction of large corporations to the manufacture of building systems; perhaps through the partnership of these corporations with governments dealing with housing problems; or perhaps by the extension of manufacturers of basic products into the field of manufacturing building systems, will this be possible. The relationship of the architectural, structural, and mechanical designer to the contractor, as we know it today, will change, and I believe this change to be a constructive one resulting in a better environment.

Presented at the Twelfth Annual Convention of the Prestressed Concrete Institute, Houston, Texas, September 1966.

Discussion of this paper is invited. Please forward your discussion to PCI Headquarters before May 1 to permit publication in the August 1967 issue of the PCI JOURNAL.

HABITAT '67—STATISTICAL DATA

Number of house units	354
Number of street girders	18
Number of cantilever girders	6
Number of stair shafts	7
Number of elevator shafts	6
Number of precast columns	24
Number of walkway bridges	4
Number of expanded base piles	1120
Total weight of reinforcing steel	4,000 tons
Total volume of concrete	26,000 cu. yd.
Total length of prestressing steel (bars and cables)	145,600 lin. ft.
Average concrete strength	6,400 psi
Dry-packed concrete, 7-day strength	9,800 psi

Associated Architects: Moshe Safdie and David, Barott, Boulva
Structural Engineers: Dr. August E. Komendant and Monti, Lavoie, Nadon
Mechanical Engineer: Huza & Thibault
Electrical Engineer: Nicholas Fodor & Associates
General Contractor: Anglin-Norcross Quebec, Ltd.
Precast Concrete: Francon (1966) Ltd.