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THE MAKING OF HABITAT 67
A Tense *Pas de Deux* between Moshe Safdie and August Komendant

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FIG. 1. HABITAT 67, MONTREAL, 2021. | BERNARD LEGAULT.

Habitat 67 is Montreal's, but also Canada's most iconic and internationally known work of postwar architecture (fig. 1).[1] From the moment the project's first images were published to the day of its inauguration, Habitat captured the architectural world's attention.[2] Designed by Moshe Safdie [b. 1938], an Israeli-born Canadian trained at McGill University's School of Architecture, Habitat is a high-density urban housing complex containing one hundred and fifty-eight apartments made up of three hundred and fifty-four prefabricated reinforced concrete modules stacked twelve storeys high in a stepped-up pattern. Straddling typological and technological innovation, the project engaged many of the most pressing issues then being discussed in debates about the future of architecture.

Built in the context of the 1967 International and Universal Exhibition, Habitat became one of the main attractions of the event. It also drew the attention of critics eager to assess its contribution to the future of housing. For the *New York Times* architecture critic Ada Louise Huxtable, Habitat 67 was an exciting prefabricated housing concept that was undermined by flaws in its execution.[3] A similar tension between enthusiasm and uneasiness permeated the review of Douglas Haskell, editor of *Architectural Forum*, who wrote: "Habitat 67 is spectacular, wonderful, and, in some ways, a failure."[4] After praising its form, its plan, its philosophy, and its implications for urban living, Haskell said: "its technology is, quite obviously, anachronistic." A few years later, the

British architecture critic Reyner Banham added, somewhat ungenerously, that Habitat illustrated "the unshakable belief that Technology . . . can make the most impractical dreams of the creative temperament come true."[5] As these reviews demonstrate, praise for Habitat's vision of modern living was often accompanied by a negative assessment of its construction method.

Fifty years later, the authors of *Canada: Modern Architectures in History* restated this ambivalent legacy: "Expo 67's most innovative structure was Moshe Safdie's Habitat. As a model for modernist public housing deploying industrial method, Habitat's legacy was alas more mythic than actual. In that respect it was both capstone and valedictory for Canadian Reconstruction and even idealistic modernism."[6] Yet despite the authors' evident misgivings, it is Habitat that appears on the book's cover, the complex's iconic image overcoming its "idealistic" shortcomings.

Over the decades, Habitat has been examined through various critical lenses, successively interpreted as a megastructure,[7] a Mediterranean-inspired project,[8] an embodiment of humanist architecture,[9] and an exemplar of the Brutalist style.[10] With the notable exception of Inderbir Singh Riar's major contribution—a thorough exploration of Habitat's theoretical origins and an enlightening analysis of its cultural, institutional, and technological underpinnings—Habitat has rarely been the subject of in-depth investigation.[11] Exploring the role of the engineer in the realization of this experimental complex, the present essay takes on the delicate issue of authorship, just one of many fascinating questions that emerge from close study of this ground-breaking work of postwar architecture.[12]

RECOUNTING THE STORY OF HABITAT 67

In his 1970 book *Beyond Habitat*, Safdie offers an extensive account of the project's development, narrating the many challenges he faced over the course of the three and a half years between the first scheme and the inauguration of the complex.[13] The book was—understandably—meant to provide a coherent, unified, and seamless narrative that helps substantiate the idea of Habitat as a new type of urban housing designed and realized by the architect as the commanding figure. And indeed, what one takes away from it is that the materialization of Habitat 67 was nothing less than a heroic achievement by the architect. This narrative has had a major impact on subsequent studies on Habitat, where Safdie generally appears as the sole author of the residential complex, as well as the main actor in the process of its construction. Rarely have the roles of other protagonists in Habitat's design as well as its construction been the subject of deeper historical investigations.

In this essay, I revisit the making of Habitat 67, from its first iteration in Safdie's 1961 student thesis to its realization as the pyramidal assemblage of concrete boxes inaugurated in April 1967. To do so, I use Safdie's recollections. But instead of focusing only on the architect's narrative, I also bring in the contributions and vision of another major actor: the Estonian-American engineer August Komendant [1906-1992].

In his book on the working relationship between architects and engineers, Andrew Saint examines the different facets of this collaboration over the last four hundred years, framing it as a "sibling rivalry."[14] While this "rivalry" may have taken different forms, it is usually assumed that it unfolds around a common goal. Yet it is my contention that Habitat may have been a rare case where, in the end, the architect and the engineer pursued different goals. In this essay, I argue that if Habitat was a project where engineering was without doubt at the service of the architect's architectural vision, the ambitious design endeavour also served the technological obsessions of the engineer. In other words, Habitat as it was built materialized two different agendas, two different visions.

SAFDIE'S STUDENT THESIS

To initiate this investigation, it is necessary to return to what is usually considered the beginning of the story: Safdie's final year thesis at McGill University's School of Architecture. It was prepared under the supervision of the architects John Bland [1911-2002] and Douglas Shadbolt [1925-2002], respectively director of and professor in the architecture school, and Sandy Van Ginkel [1920-2009], a former McGill lecturer who acted as external advisor. Submitted in May 1961, *A Case for City Living: A Study of Three Urban High Density Housing Systems for Community Development* was presented as an alternative to conventional suburban housing.[15] Each of the three different housing types entailed the exploration of a specific geometry and construction system.[16] System A was based on a structural frame supporting non-load-bearing, prefabricated modular units. System B followed a similar modular geometry erected with load-bearing concrete walls and slabs. System C allowed for either poured-in-place or precast elements to generate load-bearing modules arranged in a crisscross pattern. The thread linking these proposals was a "three-dimensional modular building system," that is, a system based on the combination

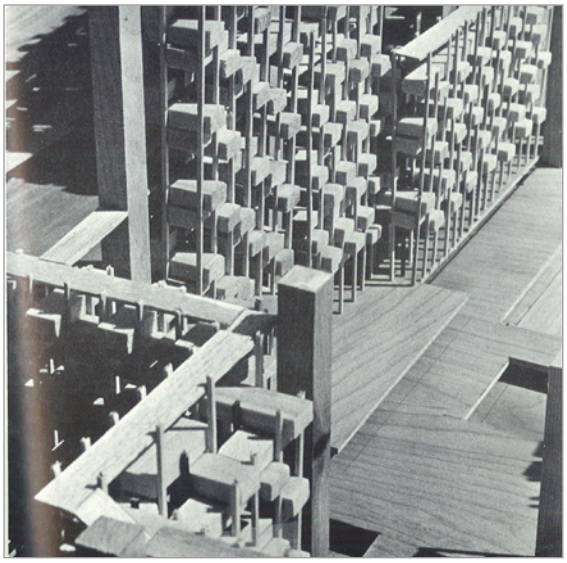

FIG. 2. MODEL FOR FORMULA A, *A THREE-DIMENSIONAL MODULAR BUILDING SYSTEM*, M.ARCH. THESIS, MCGILL SCHOOL OF ARCHITECTURE, MAY 1961. MOSHE SAFDIE, ARCHITECT AND PHOTOGRAPHER. | MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

FIG. 3. EXPO 67: MASTER PLAN FOR MCKAY PIER, DECEMBER 1963. *LES OBJECTIFS DU PLAN DIRECTEUR / MASTER PLAN DESIGN INTENT*, MONTREAL, CANADIAN CORPORATION FOR THE 1967 WORLD EXHIBITION, 1963. | AUTHOR'S COLLECTION.

of standardized elements that could be prefabricated. The best known of the three schemes is system A, where the modules are treated as plug-in units within a supporting structural frame (fig. 2). The reception of the student thesis was exceptional: it was published in Canadian journals—*Architecture Bâtiment Construction* in July 1961 and *Habitat* in December 1961—and also received coverage in Europe, appearing in the Dutch architecture journal *Forum* at the end of 1962.[17] In all of these publications, Safdie insisted on the possibilities offered by standardization and prefabrication as a means to achieve the goals of growth and flexibility.

SAFDIE'S FIRST HOUSING SCHEME FOR EXPO 67

In late 1963, two and a half years after completing his thesis, Safdie found himself at work on the design of an ambitious housing scheme for the international exhibition that was to take place in Montreal in 1967. Working under the direction of his mentor Van Ginkel, who was in charge of the exhibition master plan, Safdie was given the opportunity to further explore his concepts for a housing complex as a permanent Expo exhibit.[18] While this exploration was officially part of the exhibition's theme "Man in the City," Safdie soon turned it into a personal endeavour.[19] His memorandum of October 29, 1963, entitled "Habitat 67 / Permanent Housing Exhibit," which called for the design of "an *integrated three-dimensional whole* in which housing is in the external 'membrane' overlooking the river and the city," is proof of his growing autonomy.[20] Working by day on the Expo plan and by night on the housing scheme, Safdie spent the fall of 1963 advancing his ideas about planning and architecture. At the end of the year, his housing scheme was included in the official master plan that was presented to the Canadian Corporation for the 1967 World Exhibition (CCWE). When the master plan was approved by governmental authorities on December 20, 1963, Habitat, as a component of that plan, was also given the go-ahead for further exploration.

One of the few documents illustrating this early scheme is the first master plan of December 1963.[21] The plan shows a series of triangular configurations extending over McKay Pier, a strip of land that was to be integrated into the site (fig. 3). A photograph of a model offers a three-dimensional view of the proposed scheme (fig. 4).[22] It shows nine open-ended half pyramids varying in height from ten to twenty-two storeys, each made up of an agglomeration of seemingly identical housing modules.[23] All shared amenities were connected at the base of the pyramids, thus giving the impression of a continuous structure. Conceived as part of the overall Expo plan, the housing project was to be accessed by means of a complex network of three interrelated transportation systems planned for the exhibition site.

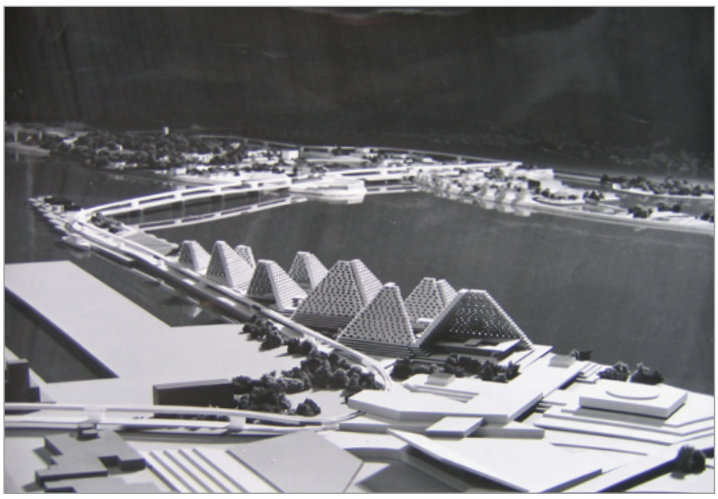

FIG. 4. MODEL OF THE FIRST PROPOSAL FOR HABITAT, DECEMBER 1963. | UNKNOWN PHOTOGRAPHER. SOURCE: AUGUST KOMENDANT COLLECTION, THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

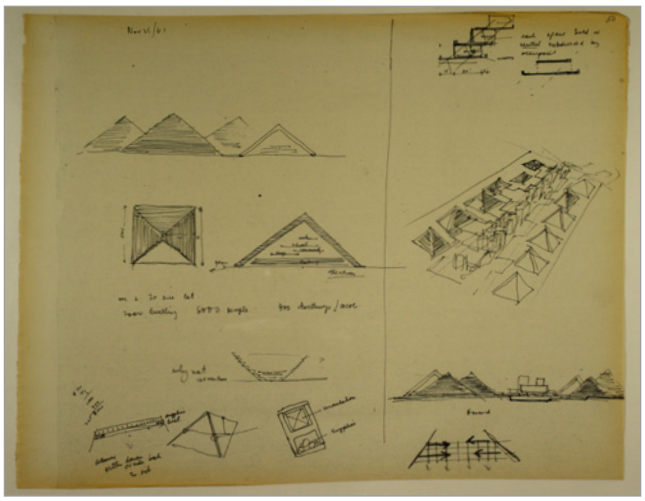

FIG. 5. SKETCHES SHOWING PYRAMIDAL BUILDINGS FOR THE MASTER PLAN OF THE NEW TOWN OF MEADOWVALE, ONTARIO, FALL 1961. MOSHE SAFDIE. | MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

This first scheme is obviously quite different from the student thesis. A comparison with system "A" reveals radical changes not only in form, but also in scale and complexity: the design moves from a rack-like structural frame to a pyramidal silhouette, from vertical distribution to sloping aggregation, and from housing to integrated urban environment. What is most striking is how the emphasis is placed on the geometric regularity of the pyramidal shapes rather than on the flexibility of the individual units. It seems to suggest that form rather than system is now taking the lead. How can we account for this substantial change from the thesis project to the first Habitat scheme?

THE MISSING LINKS

The first missing link can be found in an unrealized master plan for the new town of Meadowvale, Ontario, undertaken by the consulting firm of Sandy and Blanche Van Ginkel in 1961.[24] Employed as an assistant by his former advisor, Safdie worked on the project from August to December 1961. He also developed his own version of the urban plan. His sketches describe massive pyramidal "clusters" of civic buildings, industrial sectors, and housing complexes attached to transport spines (fig. 5). While the precise source of the pyramidal form is unknown, its function was clear: to provide a monumental form for the future urban development. When Safdie published fragments of his Meadowvale exploration in an article in the Canadian journal *Habitat*, the pyramidal forms were presented as part of an urban master plan that focused on the ideas of "growth, change and repetition."[25] As such, both the Meadowvale project and the article continued the main themes of his student thesis: those of growth and flexibility.

The second missing link can be found in Safdie's time in Louis Kahn's office that began in the fall of 1962.[26] His experience in Philadelphia proved critical for the future development of the Habitat project.[27] Safdie discussed and tested his ideas on growth and flexibility with Kahn's associate Anne Tyng, who was carrying out advanced studies on basic geometric elements and their structural arrangement.[28] It was also in Kahn's office that he gave form to the most direct precedent to the first Expo housing scheme of December 1963: a theoretical proposal for a high-density city for the resettlement of two hundred and fifty thousand Palestinian refugees.[29] The site Safdie chose for this project was the city of Giza just outside Cairo, situated near the pyramid complex.[30] The proposed development was conceived as a three-dimensional housing scheme that would include commercial and institutional facilities interconnected by a series of public transportation systems. Housing was provided in inclined thirty to forty-storey high "membranes" with public amenities filling the space below (fig. 6).[31] The most striking feature of this scheme is the degree to which pyramidal shapes were adopted.[32]

While it is tempting to read the housing form of the Giza plan as a purely contextual gesture, the Meadowvale project demonstrates that it was not the first time Safdie explored pyramidal shapes. However, it is the Giza project that gave him the opportunity to appropriate and further develop this configuration, and

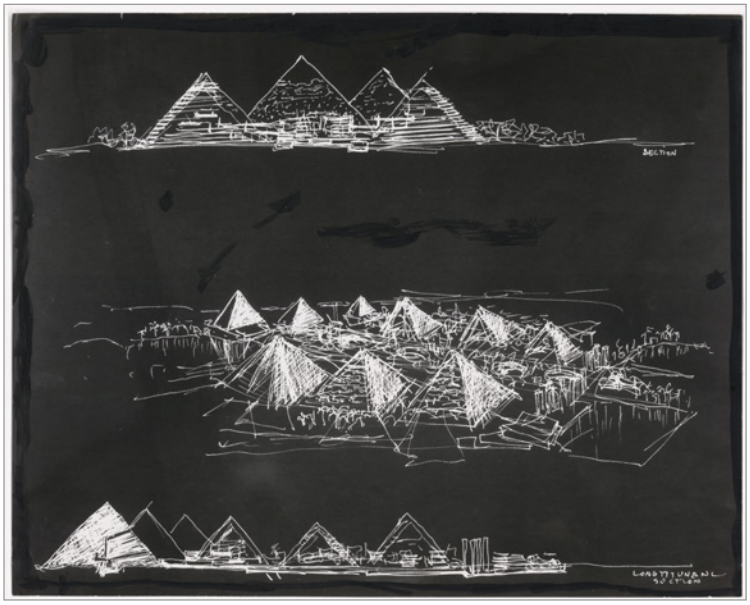

FIG. 6. SKETCHES SHOWING PYRAMIDAL BUILDINGS FOR A HOUSING SCHEME FOR GIZA, EGYPT, *C.* FALL 1962. MOSHE SAFDIE. | MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

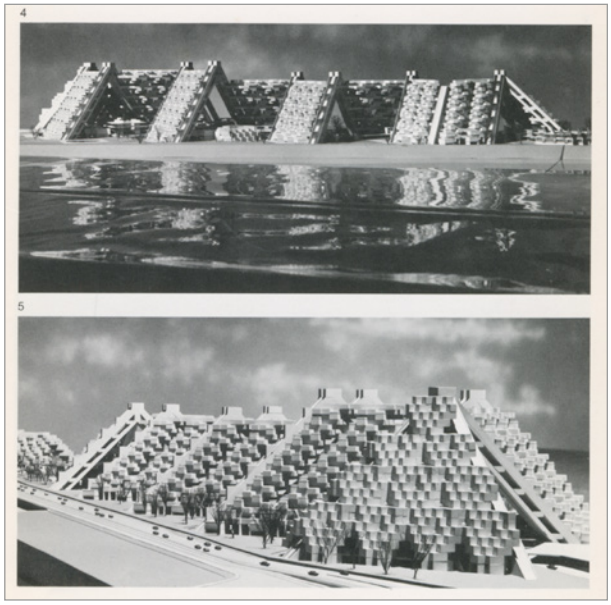

FIG. 7. MODEL FOR THE FIRST HABITAT PROJECT, FEBRUARY 1964. | SAFDIE ARCHITECTS. SOURCE: MOSHE SAFDIE, *BEYOND HABITAT,* EDITED BY JOHN KETTLE, MONTREAL, TUNDRA BOOKS, 1970, P. 17. COURTESY: SAFDIE ARCHITECTS.

to adopt it as a major component of his formal language. In *Beyond Habitat*, Safdie openly acknowledges the significance of the Meadowvale and Giza plans on the conception of the Expo master plan prepared in the fall of 1963.[33] But he refrains from stating the obvious: that the pyramidal forms of the first Habitat scheme derived directly from these two unrealized exercises.

AUGUST KOMENDANT ENTERS THE SCENE

Safdie's preliminary scheme was officially integrated into the Expo plan at the end of December 1963. He was then given eight weeks to come up with a complete proposal that would be approved or rejected by the Expo 67 review panel. In the fall of 1963, Safdie had already begun to work with a small team of collaborators who supported the project: the Montreal architect Jean-Louis Lalonde, who represented the cement companies of Canada; Stewart M. Andrews and Eric Bell, from the Toronto office of the real estate development firm Webb & Knapp; and the Philadelphia architect Dave Rinehart, whom Safdie had met in Kahn's office.[34] Lalonde had succeeded in getting the feasibility study funded by the Committee of Canadian Cement Companies. Although this support would seem to suggest that the project's materiality was set from almost the start, it was agreed that the project did not have to be tied to the exclusive use of concrete.

The project Safdie and his team presented on February 21, 1964, to Colonel Edward Churchill, Expo's director of installations, was for a community complex comprising between one thousand and one thousand five hundred apartment units (fig. 7).[35] The dwellings, each with its own garden, were to be prefabricated based on a repetitive modular system. Again, this proposal was significantly different from the one presented two months earlier. In this new scheme, the half pyramids are gone, replaced by sloping membranes now called "rhomboidal planes." Moreover, these planes are framed by visually prominent A-shaped structural members connected at their apex, emphasizing the continuity of the structural system and connecting pedestrian girders at different levels. Finally, and most importantly, all the housing units are load bearing, and made of precast reinforced concrete. How can such a significant change from the December proposal to the February project be explained?

After receiving the go-ahead in December 1963, the next, but essential step was to assess the project's feasibility. Safdie immediately turned to Louis Kahn's structural engineer, August Komendant, whom he had met during his internship. As he recounted in *Beyond Habitat*, Safdie felt Komendant was the only engineer capable of tackling such a project.[36] In early January, Safdie and his collaborators went to Montclair, New Jersey, to present the project to

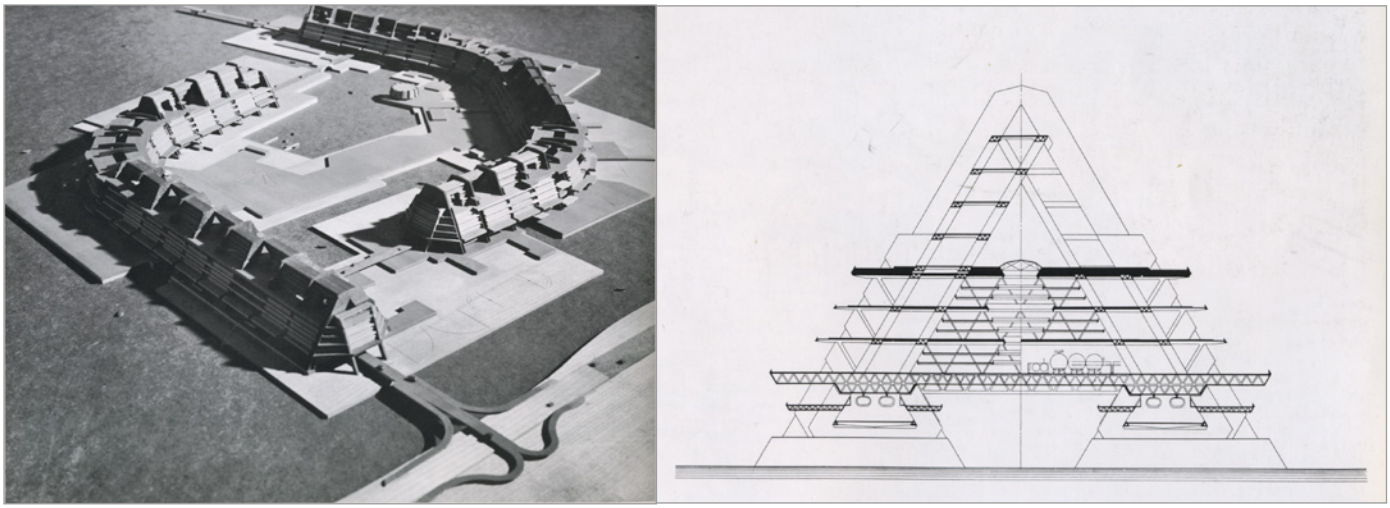

FIG. 8. MODEL AND SECTION FOR THE BOSTON HARBOR PROJECT, 1959-1960. KENZO TANGE, ARCHITECT, WITH MIT STUDENTS. | AKIO KAWASUMI; © AKIO KAWASUMI. COURTESY: TANGE ASSOCIATES / KAWASUMI•KOBAYASHI KENJI PHOTOGRAPH OFFICE.

the engineer.[37] As he later wrote: "We spread the sketches and drawings on the floor; Komendant took out his pipe and started sucking on it. Three hours later, in his Old Prussian style, he said, 'Yes, it can be done.'"[38] Thanks to the engineer, the project was given a new impetus. "At that point," Safdie wrote, "we made a very important decision: the housing modules would be load-bearing as well as space-enclosing."[39] It is important to keep in mind that up until that point, Safdie's housing explorations had always been theoretical, their technical features mentioned but never really validated. He subsequently admitted that he did not have the technical knowledge to make any decision on this question. His meeting with Komendant put an end to this phase of uncertainty: from then on, Safdie's Habitat project was given a very clear structural orientation.[40]

As will become clearer later, the decision to treat the modules as load-bearing elements would have major consequences for the configuration of the project. Yet this expeditious recommendation had more immediate consequences. Until then, Safdie, like many contemporary architects, believed that new urban developments could be based on the combination of load-bearing structural systems and non-load-bearing, movable spatial units, as shown in projects like Yona Friedman's Spatial Cities (1958), Eckard Schulze-Fielitz's Raumstadt (1959), and Kenzo Tange's Boston Harbor project (1959).[41] Combining monumental A-shaped frames with concrete floor slabs, Tange created an especially compelling image of this building strategy (fig. 8). And indeed, as Safdie recounted, "It's the obvious, simple solution: put up a frame and plug things into it."[42] But the efficiency-driven suggestion by Komendant encouraged Safdie to abandon this idea without further reflection, which had the effect of tipping the balance toward the structural integration of support and housing modules.

Back in Montreal after their momentous visit to Montclair, Safdie and his team embarked on a hurried race to develop the project. A week later, Safdie wrote to Komendant: "In developing the scheme, we have departed from the isolated pyramids which have restrictions of orientations, etc. The system we are considering is one of inclined 'planes' supporting each other . . . The planes of houses now meet at the 'ends' in a triangulated way."[43] The purpose of the letter was not only to inform Komendant about their progress; Safdie also needed a structural assessment and asked the engineer: "We wonder if this step has validity from a structural point of view. Have we introduced a new problem?" From January 1964 onward, the American engineer would be involved in every step of Habitat 67's design.

Exchanges between the architect and the engineer continued until the official presentation of the project to the Expo board at the end of February 1964.[44] The document submitted by Safdie—a description of the goals, the program, and the details of the project—was for a housing complex comprising between one thousand and one thousand five hundred housing units.[45] An accompanying report by Komendant titled "The Structural System" offered a detailed description of the proposed structural strategy and construction method. Komendant paid special attention to the overall structure of the complex, explaining that "the

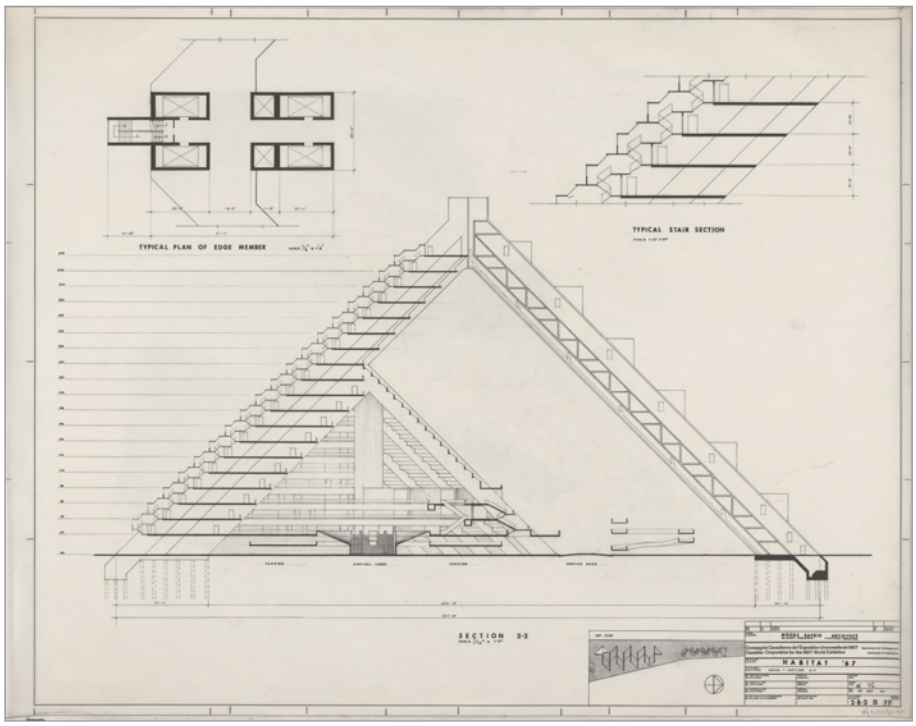

FIG. 9. RHOMBOIDAL PLANES AND STRUCTURAL MEMBERS FOR THE FIRST HABITAT PROJECT, AS DEPICTED IN DRAWINGS DATED JULY 20, 1964. | MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

structure is made of rhomboidal planes inclined at 60 degrees to the horizontal," that "each plane . . . is a structural unit in itself," and that "external stability of the planes is obtained by marginal members along the external inclined edges of the rhomboid and a series of bridging members" (fig. 9).

The description of the structure is followed by a specification of materials. Both the marginal members—which came to be called A-frames—and the bridge members could be either "poured-in-place and post-tensioned concrete or a combination of steel-rigid-truss structure embedded in concrete and post-tensioned." Finally, the report specifies that "due to the economy (maintenance), nature and structural characteristics of the design, the individual housing units are [to be] manufactured as precast concrete mass products."

THE PROMISES OF PRESTRESSED CONCRETE

Given Komendant's background, it is not surprising that he proposed an advanced concrete construction system. By the early 1960s, he was acknowledged as the preeminent North American expert on precast, prestressed, and post-tensioned concrete. Born in Estonia, Komendant studied engineering in Dresden where he learned advanced German concrete construction techniques. After the Second World War, he worked for the U.S. Army rebuilding bridges in Europe before immigrating to the United States in 1950. Published in 1952, his book *Prestressed Concrete Structures* was one of the first North American studies on the topic.[46] In 1956, he had designed and built a precasting-prestressing concrete plant in Lakewood, New Jersey, and was working for the company as an engineering consultant.[47] He had also recently completed a series of projects that highlighted the promises of this construction technology. They include the celebrated Richards Medical Research Building at the University of Pennsylvania—an accomplishment in precast, prestressed, and post-tensioned concrete—designed by Louis Kahn (fig. 10). Begun in 1957, the first phase of the medical complex was completed in 1961, when it was celebrated as the subject of an exhibition at the Museum of Modern Art in New York.[48]

Komendant also worked on the Philadelphia Police Administration Building by the firm of Geddes Brecher Qualls and Cunningham. Designed in 1959, the building, which is famous for its three-storey load-bearing precast concrete panels, was inaugurated in 1962. And finally, at the time Safdie was working in Kahn's office, Komendant was at work on the design of the post-tensioned concrete structure of Kahn's Salk Institute (1959-1965) in San Diego.[49] A 1960 article in *Progressive Architecture* placed him in full view within the architectural community. In it, Komendant expressed his conviction that the use of cast-in-place concrete was soon to be replaced by precast and prestressed concrete—what he called the "new reinforced concrete."[50]

THE CHOICE OF CONCRETE

While the use of precast and prestressed concrete was without a doubt the cornerstone of Komendant's February 1964 proposal, he implied that there was still some room for alternative solutions. As the report stated, a "combination of steel-rigid-truss structure embedded in concrete and post-tensioned" could also be considered. Komendant was well aware that although the feasibility study had been paid by the cement industry, the Expo authorities were unwilling to

FIG. 10. RICHARDS MEDICAL RESEARCH BUILDING, PHILADELPHIA, LOUIS KAHN, ARCHITECT; AUGUST KOMENDANT, STRUCTURAL ENGINEER, *C.* 1960. | UNKNOWN PHOTOGRAPHER. SOURCE: AUGUST KOMENDANT COLLECTION, THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

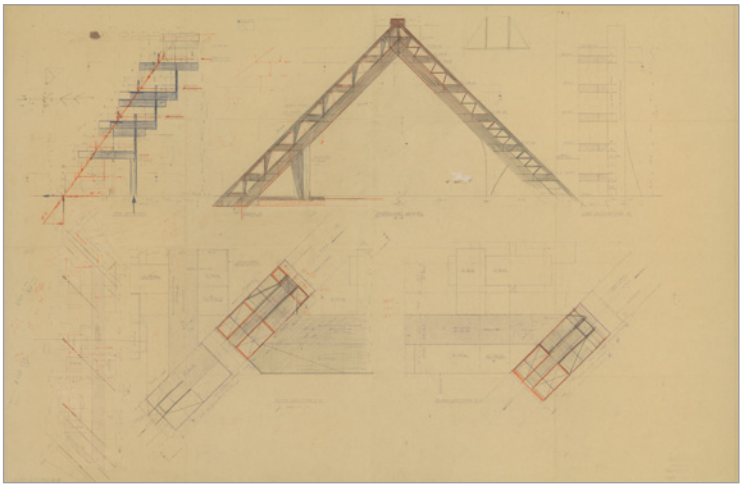

FIG. 11. STUDY DRAWING FOR STRUCTURAL A-FRAMES FOR FIRST HABITAT PROJECT, AUGUST KOMENDANT, SPRING 1964. | AUGUST KOMENDANT COLLECTION, THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

exclude the possible contribution of the steel industry. This was the very first issue raised after the February submission. Writing to Komendant, Safdie requested a letter from him "which would outline on a comparative basis the advantages and disadvantages of the various possible structural materials for Habitat 67."[51] The letter needed to explain why concrete was selected and what other structural materials could have been considered for this specific design. Komendant responded that after a thorough study of the use of concrete as well as steel and aluminum, he had come to the conclusion that "as the house units have to resist torsional, compressive and tensile stresses . . . , the only material which can be used economically is concrete," adding that it possessed all the qualities for precasting and mass production.[52] Komendant's conviction that the project would be entirely based on advanced concrete construction was confirmed a month later. In a letter to the Stressteel Corporation, a company that produced rods for prestressed and post-tensioned concrete, the engineer enthusiastically stated that regarding Habitat 67, a project he admitted was still in its preliminary design stage, "there will be a tremendous amount of post-tensioning."[53]

With Komendant at the helm of Habitat's engineering, the project now had a very clear direction. From then on, the building could only be conceived and realized—both structurally and spatially—as an inflexible entity, where all elements were compressed together by means of invisible cables. Given Komendant's expertise, the Habitat housing project would become nothing less than a showcase for the possibilities of prefabricated, prestressed and post-tensioned concrete construction.

THE CHALLENGES

With the official approval of the Expo organizers secured in the early spring of 1964, the designers of Habitat had overcome a major hurdle. The next six months were devoted to the development of the entire project, including studies for the site, the structure, the housing units, and the circulation. This phase of work was done in collaboration with the Montreal architectural firm of David, Barott and Boulva. Drawings in Komendant's archive show various options for the structural A-frames required to support the inclined planes. One of them explores the potential of a triangulated concrete truss with asymmetrical struts of varying thickness (fig. 11).[54] A finished model highlighting the material integration of the structural framework and the aggregation of housing units is further proof of the engineer's crucial involvement in this phase of the project (fig. 12).

Presented to representatives of the Expo Board, the Canada Mortgage and Housing Corporation, and the Treasury Board of Canada in September 1964, the scheme now comprised two sections: the first contained nine hundred and fifty units assembled on twenty-two-storey structures; the second, much smaller, contained one hundred and fifty units aggregated in a ten-storey building. This proposal was unequivocally rejected by the authorities, the main reason being cost. Despite Safdie's considerable efforts to find outside sponsorship, Habitat still lacked a major financial

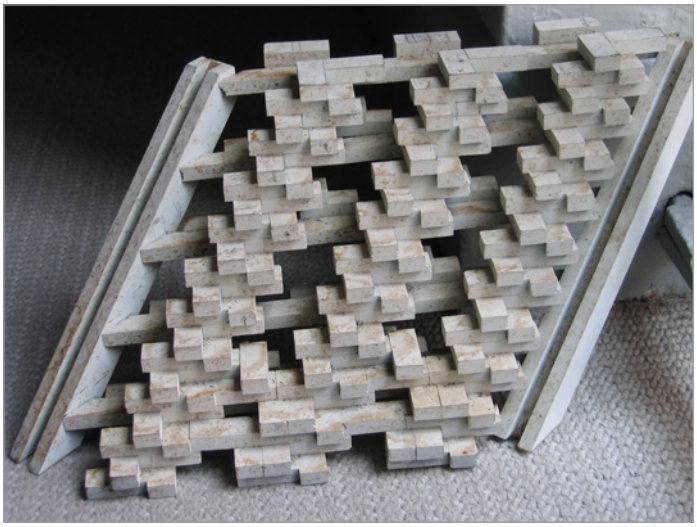

FIG. 12. MODEL OF STRUCTURAL A-FRAMES AND HOUSING UNITS FOR FIRST HABITAT PROJECT, AUGUST KOMENDANT, SPRING 1964. | RÉJEAN LEGAULT. COURTESY: AUGUST KOMENDANT COLLECTION, THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

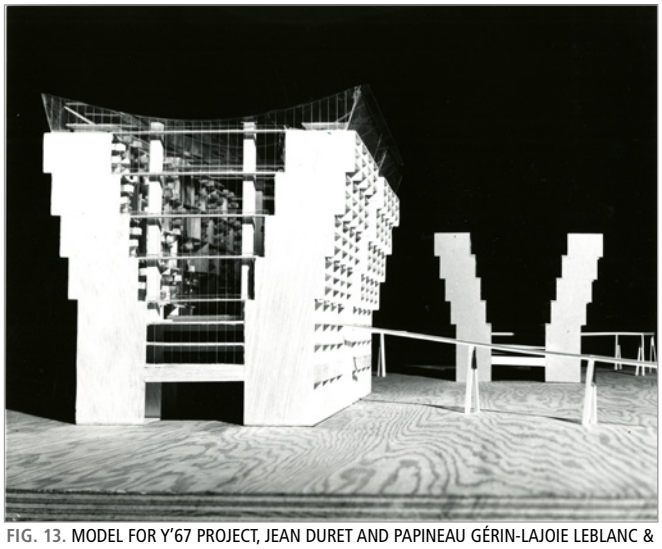

FIG. 13. MODEL FOR Y'67 PROJECT, JEAN DURET AND PAPINEAU GÉRIN-LAJOIE LEBLANC & LUC DURAND, ARCHITECTS, FALL 1964. | DENIS DINIACOPOULOS. SOURCE: DENIS DINIACOPOULOS FONDS, CONCORDIA UNIVERSITY RECORDS MANAGEMENT AND ARCHIVES.

backer. Cost estimates for the realization of this ambitious project far exceeded any budget Canadian authorities could assume alone.

With no other option available to him, Safdie reluctantly reduced the scope and size of the project. Taking up the small section of the scheme, he retained the modular housing units but replaced the system of inclined planes with a grouping based on cluster geometry. The new proposal was for a twelve-storey building composed of one hundred and fifty-eight housing units. Presented at the end of October 1964 to the same authorities that had rejected it the previous month, the revised scheme was finally accepted, with the proviso that the total cost could not exceed eleven and a half million dollars.[55]

While securing financing had been a major hurdle, another challenge to Habitat's realization according to Safdie's plan came from an unexpected quarter: the prefabrication industry itself. While the project was being developed in the summer, Safdie had contacted several manufacturers and industries, including precasting contractors. Among those that showed interest was the Camus Company, the preeminent specialist in prefabrication and industrialized concrete construction in France.[56] As Safdie recalls, Camus offered to examine the project to see if they could work as the precast contractor and provide technical help.[57] The company, however, went beyond exploring a possible contribution, going so far as to try to take over the project by engaging the Swiss architect Jean Duret and the Montreal architectural firm of Papineau Gérin-Lajoie Leblanc with Luc Durand to design a counter-proposal. The project, known as Y'67, was based on a set of apartment towers cantilevering outward in a "Y" shape (fig. 13).[58] Though this proposal was presented to Canadian authorities, who quickly rejected it in early November 1964, the episode confirms that precast concrete had by then been fully accepted as the preferred method for the construction of Expo 67's experimental housing project.

HABITAT, PHASE 1

The revised scheme, which came to be called Habitat–Phase 1, was based on the geometrical arrangement of three hundred and fifty-four prefabricated concrete modules (fig. 14). The changes brought by this new version were many: scale, composition, urban amenities. They also affected the appearance of the overall system, with the supporting elements drawn back to give more prominence to the aggregation of housing modules.

The design development of this phase of the project took another six months, from November 1964 to April 1965. The overall structural system devised by Komendant consisted of three basic components: box clusters, street girders, and supporting elements, which included columns, elevator towers, and stair towers. Each precast box measured thirty-eight and a half feet long, seventeen and a half feet wide, and ten feet high (fig. 15). The combinations of one, two, or three pre-cast boxes generated fifteen different house types, resulting

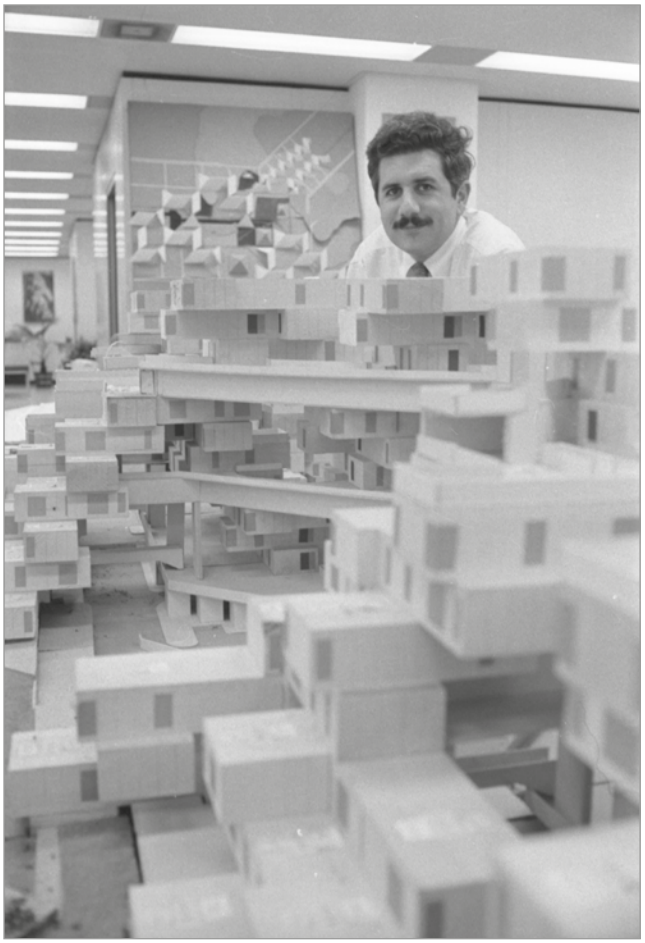

FIG. 14. MOSHE SAFDIE WITH STUDY MODEL FOR HABITAT PHASE 1 (GIZA PROJECT MOUNTED ON BACK WALL), EARLY 1965. | ANTOINE DESILETS. SOURCE: BIBLIOTHÈQUE ET ARCHIVES NATIONALES DU QUÉBEC. CREATIVE COMMONS.

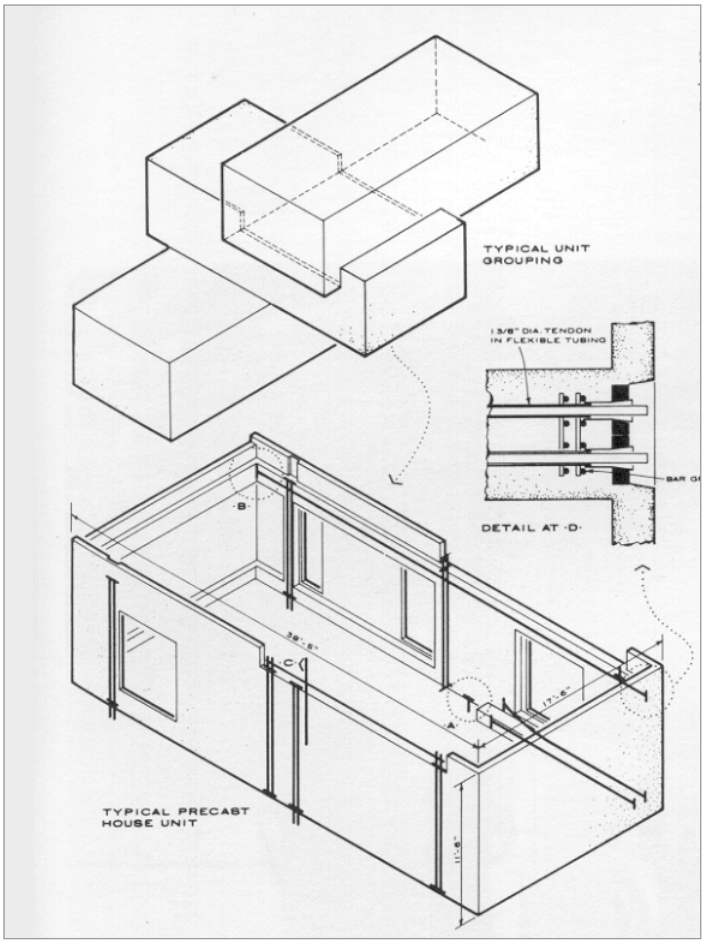

FIG. 15. AXONOMETRIC DRAWINGS AND DETAIL FOR PRECAST CONCRETE MODULES, *C.* 1965. SAFDIE ARCHITECTS. | MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

in dwellings of either one or two levels and ranging in size from six hundred to one thousand and seven hundred square feet. Most intriguing from a structural point of view were the clusters of prefabricated boxes (or modules). Each cluster consisted of eight boxes, two per level, arranged in an L-shaped pattern. These four-storey box clusters were tied together with post-tensioning cables, creating a single structural entity (fig. 16).[59] The clusters were also fastened to the horizontal street girders located at levels five and nine, which were themselves supported by the vertical towers and columns (fig. 17). The clusters as well as street girders were inclined about sixty degrees in respect to each other. The new Habitat project was therefore based on the stacking of three clusters of boxes tied vertically to each other and horizontally to the street girders, all of which rested on a poured-in-place structure at plaza level.

Construction also faced bureaucratic challenges. Like all Expo pavilions, this complex structure had to be granted a building permit. Obtaining this formal validation proved harder than expected. Assuming that the engineers of the City of Montreal would be unable to assess such a structure, Safdie suggested to convene a committee of distinguished Canadian engineers to review the proposal. According to their expert opinion, released in spring 1965, "the building as designed would collapse."[60] Among their criticisms was the lack of expansion joints and a proper earthquake risk analysis. Although the committee had had the opportunity to meet with Komendant, the report recommended that "'competent' engineers be hired to handle the job."[61]

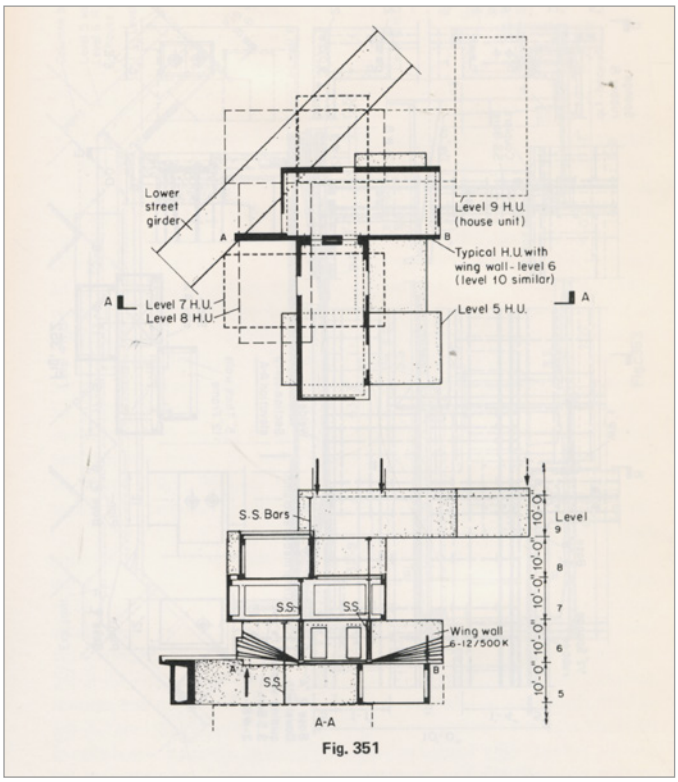

FIG. 16. PLAN AND SECTION FOR FOUR-STOREY BOX CLUSTERS, AUGUST KOMENDANT, 1965. | AUGUST KOMENDANT, *CONTEMPORARY CONCRETE STRUCTURES*, HUNTINGTON, NY, R.E. KRIEGER, 1977, P. 539. COURTESY: THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

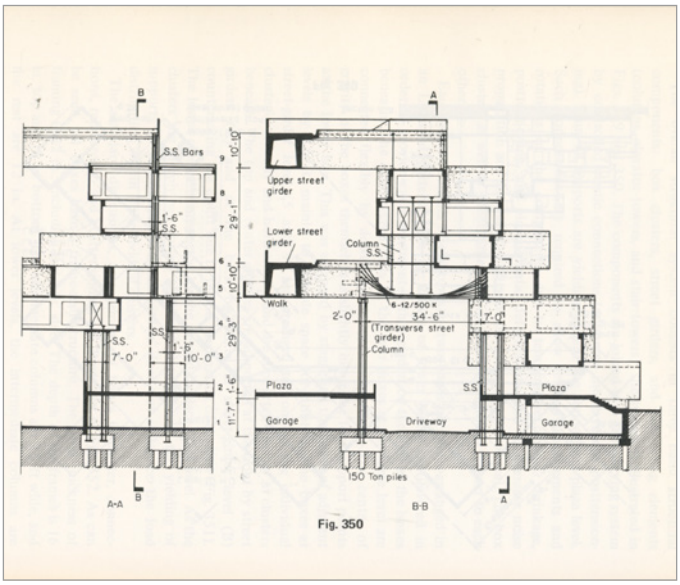

FIG. 17. SECTIONS FOR BOX CLUSTERS, STREET GIRDERS, AND COLUMNS, AUGUST KOMENDANT, 1965. | AUGUST KOMENDANT, *CONTEMPORARY CONCRETE STRUCTURES*, HUNTINGTON, NY, R.E. KRIEGER, 1977, P. 538. COURTESY: THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

Given the complexity of the structure—a continuous, integrated, three-dimensional structure where loads are transmitted in complex patterns—very few engineers were able to comprehend, and thus assess, its constructability. Though a local engineering firm—Monti, Lavoie, Nadon—had been mandated to work in collaboration with the consulting engineer, the Expo authorities' decision rested primarily on Komendant's reputation. After much deliberation, including a phone call to San Diego to the builders of Kahn's Salk Institute to validate the engineer's earthquake design, Churchill, director of installations, sided with Komendant against the engineering committee's recommendation.[62]

Many refinements were made to the project during the six months needed to produce a complete set of drawings to be submitted for tenders in April 1965. Given that the entire housing complex was now conceived as one continuous, integrated, three-dimensional entity, each iteration in the design involved changes, both small and large, to the structure.[63] And each time, Komendant was called upon to provide a solution.

THE CONSTRUCTION SAGA

Komendant's part in the project took on another dimension after ground was broken in July 1965. In addition to his role as structural consultant for the conception of the project, he was now entrusted with the supervision of the entire fabrication process, a change that was duly recorded in the contract he signed with Safdie and his associates in August 1965. As the contract specified, Komendant was to provide "structural engineering services and structural engineering supervision for the completion of the overall design and for the erection of Phase 1."[64] It was also understood from the outset that "in technical structural engineering matters and decisions, Komendant shall have both final responsibility and authority."

If the validation of the project had been a trying experience, the almost two-year construction period—from July 1965 to April 1967—was even more demanding. First among the many technical challenges was the production of the precast concrete boxes.[65] After the construction of a precasting plant on site, the fabrication of the boxes entailed many phases, beginning with the fabrication of the steel armatures for each module and their custom arrangement in the large steel precasting mould (fig. 18). Even though the external dimensions of the three hundred and fifty-four boxes were identical, there were one hundred and thirty-six different configurations of the basic module, the rest being either mirror or repeats of these.[66] Among the modifications brought to the basic module

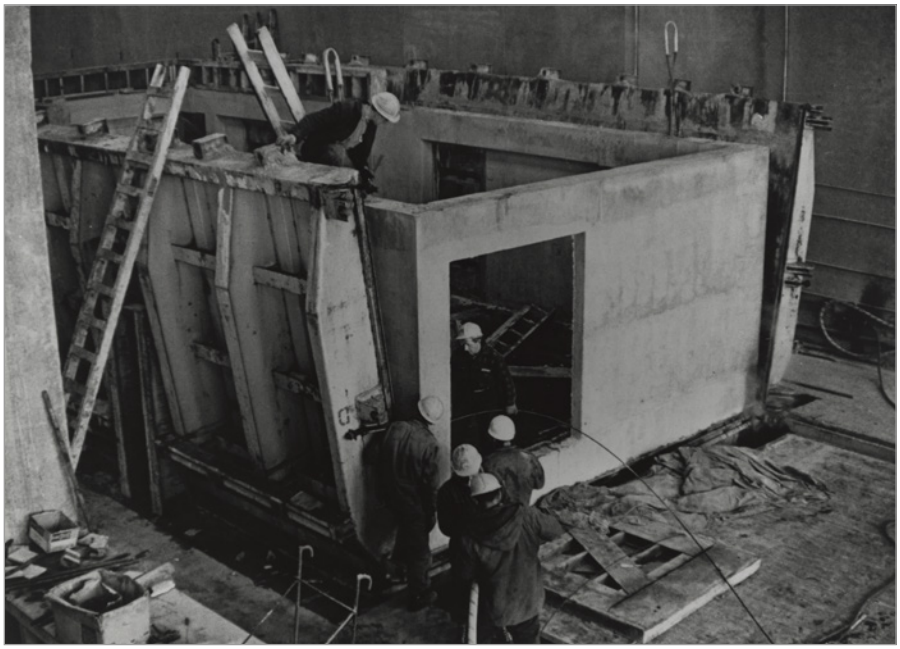

FIG. 18. CASTING OF HOUSING MODULE, 1966. | SAFDIE ARCHITECTS. SOURCE: MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

FIG. 19. GANTRY CRANE LIFTING MODULE INTO PLACE, 1966-1967. | SAFDIE ARCHITECTS. SOURCE: MOSHE SAFDIE FONDS, CANADIAN ARCHITECTURE COLLECTION, MCGILL UNIVERSITY LIBRARY, MONTREAL. COURTESY: SAFDIE ARCHITECTS.

was the wall thickness, which, though generally five inches thick, increased to as much as twelve inches depending on the box's location within the structure. Therefore, close to forty percent of the three hundred and fifty-four precast modules of Habitat were unique, with each requiring the production of three sets of drawings: the architecture drawings, the engineering drawings, and the shop drawings. Responsible for the engineering drawings, Komendant did all the stress calculations by hand.

The casting operation required careful attention. The moulding of the concrete boxes was completed in two phases: first the floor, then the walls. To alleviate the weight of the boxes, their tops had to be cast separately. After the concrete was poured, it was first vibrated and then steam cured. The units were then moved to the finishing area adjacent to the site. On the outside, the finishing of the modules required sand blasting and the installation of post-tensioning cables. Inside, it entailed the installation of insulation, glazing, partitions, plumbing, kitchen cabinetry, and the prefabricated fiberglass bathroom pods.

Another major technical challenge lay in the assembly of the boxes and their supporting structures. Weighing between seventy and ninety tons, the boxes had to be lifted with a gantry crane that moved along the site on rails (fig. 19).[67] After fixing and post-tensioning with bolts and cables, each box was capped with a roof slab. In the same manner, four-storey clusters, circulation girders, elevators, stairs, and other structural elements were tied together by post-tensioning cables. The structural integrity of the entire complex rested on the precise coordination needed to tie up the various elements of the experimental building system.

KOMENDANT'S AUTHORITY

It should be clear by now that the making of Habitat involved many protagonists: the architect and his team, the engineering consultant, the local engineering firm, the building firm (Anglin-Norcross), as well as the firm in charge of prefabrication (Francon). A complex web of relationships and dealings between diverse agents and stakeholders characterized the construction process. Not surprisingly, it became a hotbed of friction and conflict. Komendant was in the centre of it all.

In spring 1966, during the early months of the precasting work, Francon, the contractor, complained about communications with the consulting engineer, citing difficulties in producing the shop drawings from the engineering drawings.[68] Komendant's response was swift, extensive, and forceful, addressing

each grievance with a detailed and precise answer. He did not hide his irritation at being told that he was not performing services that he had not been hired to carry out, especially after being told that these services were "considered unnecessary" when he had offered them.[69]

By the middle of the summer, however, most of the complaints were going in the other direction. In July 1966, Komendant told Safdie about all the problems he encountered on the building site. The letter reads like a construction horror story. Komendant took great care all the while to underline that his criticism was only made to avoid inefficiencies and lack of quality, which, as he stressed, are extremely important when trying to demonstrate the feasibility of an advanced research project like Habitat.[70] Although he expressed great disappointment about time and cost overruns, his tone remained conciliatory. By August, however, his attitude had changed. He complained to Safdie that "regardless of made promises to take corrective action, the almost reckless performance went on without a slightest change," which led him to express serious concerns about the safety of the structure.[71]

Komendant continued to raise concerns over the next three months. In October, he brought up his original stipulation that during construction the inspection of the elements during manufacturing and erection had to be made against structural drawings: "I have repeated this request and emphasized the importance of it several times but regardless of this it has not been carried out."[72] At the end of October, he felt the need to clarify his obligations, responsibilities, and rights, reiterating that "in technical structural engineering matters and decisions, Komendant shall have both final responsibilities and authority."[73] For the engineer, assuming all these responsibilities was essential because "Habitat 67 is a revolutionary research project whose design is based upon advanced knowledge, research results, ultimate strength of materials and structural system." In short, it was a *sine qua non* because, in his mind, Habitat was first and foremost an engineering challenge.

It was during this tense period around the building site that Komendant found an opportunity to publicly air his views about the project. In October 1966, *Progressive Architecture* (*P/A*) devoted an entire issue to the future of concrete, which included an interview with Komendant as a leading expert in the field. His description of the project under construction reveals the engineer's vision: "The system now being used for the revised, smaller Habitat is a crystal-like structure. It is very functional and expressive. It comprises a variety of cantilevers made stable and efficient by a combination of beam, suspension, and arch actions."[74] While the notion of "crystal-like structure" recalls the preoccupations of Safdie's Philadelphia colleague, Anne Tyng, it also encapsulates the idea that the whole complex existed as a single, unified structural entity. The article also offered Komendant the occasion to state that there was no friction between architect and engineer: "I respect his views and I help him as much as possible, and of course this is mutual."

THE RESPONSIBILITY CRISIS

This moment of détente was not to last long. A new crisis was triggered by another article in the same issue of *Progressive Architecture*. Unbeknownst to Komendant, Jan Rowan, the journal's editor, also included interviews with a wide swathe of actors involved in and observers of the Habitat project. Komendant was not among them. Outraged by the content of a long passage on "The Contractor's Habitat," which put all of the responsibilities for the project's shortcomings on his shoulders, Komendant prepared a detailed response.[75] In a draft letter to Rowan, Komendant gave a point-by-point rebuttal of a series of quoted statements by the construction contractor, stating that they were "entirely wrong."[76] He expressed indignation at being called "ignorant and inexperienced" by the contractors, while at the same time being expected to be constantly available to assist in every phase of construction.

Komendant was not the only one irritated by *P/A*'s presentation of the project. In his own draft letter to Rowan, Safdie, together with the contractor and the precaster, complained about the article's inaccurate characterization of the rapport between the project's various protagonists, taking particular issue with its description of the relationship "between the Contractor's forces and the Consultant's forces [as] one of constant disagreement."[77] The reality, he added, was much to the contrary: "the spirit which prevails is one of healthy controversy rather than disagreement—an atmosphere which is essential if new methods, new techniques, and new structural concepts are to be achieved."

Jumping into the fray, Robert Shaw, the deputy commissioner of the Expo, advised against responding to the criticism: "Dr. Komendant is most unwise in attempting to 'set the record straight' when the result speaks for itself."[78] Shaw underlined that as an exhibit, Habitat 67 was undertaken "to stir up controversy on a new concept in architecture, engineering, urban development and construction procedures." Stressing that there was no need for the protagonists to take part in this controversy, Shaw forbade anyone to send comments to the editor.

In his private response to Safdie, Komendant argued that, on the contrary, it was the engineer's professional obligation to set the record straight, especially when charged with all the ills of the construction process.[79] According to him, it was "the general contractor who failed to cooperate from the very beginning of the project." But Komendant's outrage did not stop there. Invoking the clauses of his contract, which stated that all publications concerning structural matters had to be approved by him, and that "in all other releases and publications proper credits and acknowledgements shall be given Komendant," he claimed that this agreement had been almost entirely violated. It was obvious to him that all publications on Habitat always focused on the achievements of the architect, "entirely ignoring the engineers whose skills and knowledge" had made it possible. While the letter confirms that Komendant was an extremely sensitive, if not to say prickly, character, it also reveals that the contributions of the engineer had become a major point of contention.

THE AUTHORSHIP CONUNDRUM

The delicate question of credit did not vanish with the completion of the building. The inauguration of Habitat 67 instead seemed only to encourage Komendant to complain more about the experience. In a letter to a fellow structural engineer with whom he had worked on the Salk Institute, Komendant could not help himself from ranting (and making a regrettable comparison): "Montreal is finished, it came out well—no major mishaps. But it was rough, I established myself a new profession—'call girl,' holding hands and lecturing almost continuously for 2½ years."[80]

The grievances he outlined in an interview with a Philadelphia journalist were more comprehensive and much more unambiguous. To Ruth Molloy's question about the most difficult problem with Habitat, Komendant replied: "It was to fight with and force acceptance of my completely new structural approach for realization of this concept."[81] To another question from the same journalist about the relationship between the architect and the structural engineer, he responded:

> Architects usually consider engineers as unavoidable nuisance, stress analyst or plain draftsman who spoil their architectural success by their engineering or so-called structural reasons. Due to this attitude they never give any credit to engineers. . . In reality, what *made* these unusual buildings? The engineer's imagination, understanding, knowledge, and experience.[82]

In subsequent correspondence with Molloy, Komendant was even more candid about his feelings. After stating that "there were no plans when I was first contacted but only a very abstract concept," he mused: "the finished Habitat is my very old acquaintance—where I have walked and worried days and nights, developed new theories, manufacturing and erection methods. Besides, being the always present babysitter and call-girl, holding hands with everybody concerned, guardian for its behavior, safety and good health . . . "[83] This exchange proved so convincing that in her published article, Molloy concluded about the project's authorship: "I will never say *Safdie's Habitat* again. But, as the Montrealers do, sometimes putting French first, sometimes English first, I will say *Safdie-Komendant* or *Komendant-Safdie* Habitat 67."[84]

POST-MORTEM

For his part, six months after Habitat opened, Safdie published his reflections on the entire experience in the *Journal of the Royal Institute of British Architects*. He was clear about the commanding role of the architect, writing: "I personally think that of the members of the team, only the architect has a sufficiently overall view to be able to integrate all the many aspects into a building system, drawing on the others for technical and conceptual help."[85]

Not surprisingly, Safdie's characterization triggered a strong response from Komendant. In November 1967, the engineer contacted the editor of *Progressive Architecture* with an offer "to make the real story of Habitat 67 available."[86] The letter included an unpublished manuscript titled "The Story and Critical Analysis of Habitat 67." After editing and revisions, it was published in the journal in March 1968 under the title "Post-mortem on Habitat."[87] From the outset, Komendant reaffirmed his belief that in a complex design like Habitat 67, "architecture and engineering are inseparable." Somewhat unexpectedly for an engineer, Komendant then ventured into an aesthetic evaluation of the complex through a series of comments about the relationship between the conceptual image and the realized structure.[88] It was followed by a thorough presentation of all the technical aspects of the project, and a detailed accounting of all its flaws. Despite them, Komendant concluded that the project was an important step forward. But he did not miss the opportunity to reaffirm the central role played—or that should have been played—by the consulting engineer: "Habitat could have been built in its own right within reasonable time and economical limits if there had been a single executive authority completely in charge of all phases of the project. This authority would need up-to-date technical knowledge and be well experienced in construction and mass-production

FIG. 20. AUGUST KOMENDANT (RIGHT) WITH AN UNKNOWN COLLEAGUE AT HABITAT, *C.* 1967. | UNKNOWN PHOTOGRAPHER. SOURCE: AUGUST KOMENDANT COLLECTION, THE ARCHITECTURAL ARCHIVES, UNIVERSITY OF PENNSYLVANIA.

methods."[89] He clearly wasn't referring to Safdie. These skills all pointed in the direction of the consulting engineer rather than the architect.

A QUESTION OF CHARACTER?

What are we to make of all Komendant's claims and complaints? They are not so different from the ones that appeared in 1975 in his book *18 Years with Louis Kahn*, in which he complains about Kahn's lack of recognition of his contribution to the projects on which they worked together, and takes every opportunity to point to instances of the architect's lack of understanding about structures and constructional matters.[90] According to the architectural historian Mark Donchin, many of Kahn's collaborators have questioned the truthfulness of and motivations behind Komendant's diatribe.[91] In a close examination of this thorny issue, Donchin argues that the engineer's attitude was motivated by a "perceived lack of status" as well as a desire "to expand his sphere of influence."[92] The key question that emerges from this debate is that of the creative contribution of Komendant. Did he truly participate in the design process or was he merely the technical enabler of Kahn's projects? In the eyes of Jack McAllister, who worked for Kahn for over a decade and served as project architect on the Salk Institute, "Komendant was a follower and not a leader. He never in my experience provided answers except in making what Lou sketched work."[93] According to Nikolas Gianopoulos, a Philadelphia engineer who provided calculations for many of Kahn's buildings, "Komendant never looked upon architects as being the prime designers," explaining that in Germany and Estonia, he had always been the leader of the project.[94] Gianopoulos also unequivocally put limits on Komendant's contributions: "We have often said among ourselves, if Komendant had never come along, Lou would have found some other source of engineering; and his building may have had a different character, but they still would have been Lou's buildings."[95]

But the young and inexperienced Moshe Safdie was not Louis Kahn, a confidant, world famous architect who had some thirty years of experience before meeting Komendant. With the Habitat project spearheaded by an architectural novice, Komendant had the opportunity to not only play a critical role in the construction process but also in the design phase, beginning with the conception of the structural system and ending with the supervision of all the minute details of the execution. It is from this central position that Komendant was able to see the Habitat project as highly original, and partly his own (fig. 20).[96]

AFTER HABITAT

Even before the inauguration of Expo 67, Safdie had begun promoting the "Habitat" concept of industrialized building. In June 1967, he was contacted by the newly created United States Department of Housing and Urban Development (HUD) to discuss a "Proposed Experimental Project for Washington, D.C." In quick succession, several other projects followed, including Habitat New York I (1967-1968), Habitat New York II (1968-1969), Habitat Puerto Rico (1968-1970), Habitat Israel (1969-1970), and Habitat Rochester (1971).[97] None of them were ever completed.

It may come as a surprise that despite his rancor about the way Habitat 67 had evolved, Komendant was also keen to continue the Habitat building concept, albeit with other architects and developers. As early as June 1967, he was solicited by the Yeskel Development Company of Newark to consider a collaboration

FIG. 21. VIVIENDA 70, SAN JUAN, PUERTO RICO, AUGUST KOMENDANT, CONSULTANT FOR SHELLEY SYSTEM, *C.* 1970. | UNKNOWN PHOTOGRAPHER. SOURCE: UNKNOWN.

"in building such [Habitat] units" in New Jersey.[98] In the same period, he was invited to consult on Vivienda 70, a low-cost housing complex of two thousand prefabricated units to be built in San Juan, Puerto Rico, with the Shelley System (fig. 21).[99] His views on prefabrication were clearly expressed in his response to a June 1969 article by Ada Louise Huxtable on the prefabrication of standardized housing units.[100] Disputing Huxtable's claim that there was "as yet, no standardization of any of these building units," Komendant brought up his own experience with the Vivienda 70 complex under construction, stressing that it is "not Safdie's Habitat Puerto Rico—said to be dead or close to the natural dead end."[101] While he readily acknowledged the experience gained on the Habitat 67 project—"as you may know, I was most closely connected with its design, manufacturing and erection"—Komendant asserted that the Vivienda project would not yield to the same "triumph and disaster" scenario of its predecessor.

Yet it is Komendant's concluding comments that best capture his final judgment of Habitat. "In Vivienda 70," he writes, "we started not from an architectural dream but from reality. . . This result could be obtained only by close teamwork—architect, engineer and contractor, which was not the case with Habitat '67," adding disparagingly, "Dreams—freedom by ignorance—never face realities."[102]

EPILOGUE

By focusing on Komendant's narrative of Habitat, the goal of this essay is certainly not to question Safdie's architectural achievement. Habitat was, and still is, an exceptional realization that would not have seen the light of day without the talent and determination of its architect. Rather, my intention is to reveal how Habitat was a project that inspired the pursuit of not one, but two interrelated, yet very distinct "dreams."

Safdie's dream was first and foremost architectural. It envisioned a new type of urban housing based on a series of elements and principles—standardized modules, clusters, individual gardens, communal spaces—designed and realized by the architect as the conductor. By contrast, Komendant's dream was one of pure engineering. It envisioned the triumph of precast, prestressed, and post-tensioned concrete conceived and executed under the supervision of the engineer as the commanding figure.

In *Beyond Habitat*, published three years after the completion of the building, Safdie openly declared that "without Komendant, Habitat would not have been there."[103] But he did not stop there, reflecting on the tension seemingly built into the collaboration between building professionals:

> The relationship between architect and engineer is a complex one. There is that dependency on each other, resented by both and yet accepted. There is that natural tension of any relationship which is rooted in inter-dependency. This was even more so in Habitat. The conception of environment, the conception of structure, and the conception of construction were one and inseparable, and it took some pretty intense exchanges to bring about the resolution of all the factors that had to be contended with.[104]

If the relationship between the two was extremely productive, it could also be strained, turning into a tense *pas de deux* between architect and engineer. This allusion to dance and dance partners is inspired by reflections made by Komendant himself. In a 1991 interview, he recalled that after a technical discussion with Louis Kahn, the engineer Abba Tor proposed the suggestive image of the engineer as a "male dancer in a classical ballet who, feet firmly planted on the ground, catches the daring ballerina in midair and helps her complete her movements gracefully rather than fall on her face."[105] In his protracted duet with Safdie, Komendant—like Tor—clearly viewed himself as the male partner.[106]

With Habitat, the engineer was no doubt working in service to the architectural

TECHNICAL BULLETIN

STRESSTEEL CORPORATION

AUGUST, 1967 BULLETIN No. 27

Imaginative Engineering Ties Habitat's Many Elements into Unified Structure

Award Winner 1967 Award Program

PRESTRESSED CONCRETE INSTITUTE PCI

Essential to the success of the bold idea expressed in Habitat '67, Montreal, are the means which tie together the huge structure. It involved stacking 354 precast boxes, each 38½-ft. long by 17½-ft. wide by 10-ft. high, weighing 80 to 95-tons, into a composite structure of 158 housing units, 12 stories high. Since many of these rectangular boxes sit on the cantilevered halves of lower boxes in order to provide each house with a garden on the roof of the house beneath it, the structural engineering was complex.

Moshe Safdie, Habitat's architect, views the structure as a technical building system in which framing is eliminated and the module units are made load bearing. The walls, roof and floor of the box act structurally to transmit loads downward from one box to another. Also broad elevated concreate "streets" on the fourth and ninth floor levels, anchored to precast, post-tensioned vertical elevator and stair cores, provide additional support. Casting the units as complete five-sided boxes did away with the difficulty of connecting panels at corners and reduced on-site assembly cost.

The combination of these factors, however, made the prestressing of the units, and providing moment connections to tie them together, matters of critical consideration. Habitat is bound together by miles of post-tensioned tendons. Horizontal tendons, placed along the longitudinal walls of the cantilevered units, make them act as structural deep girders which carry loads from above. These tendons con-

FIG. 22. COVER OF THE *TECHNICAL BULLETIN OF STRESSTEEL CORPORATION*, AUGUST 1967. | UNKNOWN PHOTOGRAPHER. SOURCE: AUTHOR'S COLLECTION.

dream. But the architect also ended up serving the ambitions, even the obsessions, of the engineer. Contemporary observers seem to have been cognizant of this possibility. For Douglas Haskell, Habitat could have been built with "metal-and-plastic boxes, weighing a mere fraction of the weight of the 90-ton concrete crates that make up the prototype in Montreal."[107] In other words, he felt there would have been workable alternatives to the Komendant-style Habitat that was put up in Montreal.[108] But in this project, Komendant's goal was also to construct a building that defied conventional structural logic. One might even argue that with Komendant's intervention, Habitat's form was maintained at all costs by means of the magic of technology.[109] It is this subterfuge that apparently irritated Louis Kahn, who stressed that the shape designed by Safdie did not really make visible the trajectory of the forces that made the building possible.[110] Seen this way, Habitat may be viewed as nothing less than a monumental *trompe l'oeil*.

In a sophisticated assessment of Habitat published thirty years after its inauguration, the architecture critic Michael Sorkin unexpectedly confirmed the crucial role played by the structural system. While critical of the first project, where "the form of the cliff dwelling-faces was very much subordinated to the heroic tectonics of the apparatus of support," he praised the solution adopted for the reduced scheme, where "the means of support has been incorporated into the pods themselves, yielding a far richer and more eccentric statical condition."[111] It is here, he argued, where one of Habitat's beauties lies, that is, "the complexities of its loading and the fiendish negotiated transfer of the forces that stabilize the structure." While praising Safdie's vision, Sorkin could not have made a more convincing statement about the determinant role played by Komendant.

We have seen that Safdie's original concept was based on the idea of growth and flexibility. Yet with its custom-made modules fixed within a post-tensioned structure, Habitat had become the antithesis of the flexible, expandable environment.[112] If the final version of Habitat was only possible because of Komendant's post-tensioning magic, it was also limited by the constraints inherent in the technique. In fact, the necessary solidarity between all the components of the system can also be read as a sign of dependency, where the failure of a single member could threaten the

stability of the entire structure. Rather than representing the ideals of growth and flexibility, Habitat became a monument to fixity and stasis (fig. 22).[113] Yet paradoxically, it is most probably because Habitat was made of these heavy prefabricated concrete boxes tied together with post-tensioning cables that it is still there today, endowing a building born out of an architectural dream with the qualities of a true monument.[114]

NOTES

1. Research for this paper was initially carried out in the Moshe Safdie Archive at McGill University in 2003 and 2007. The first outcome was a heritage study commissioned by the Ville de Montréal completed in 2007. Additional research was done in the August Komendant Collection at the University of Pennsylvania in 2007 and 2009. Material for this paper remained dormant until UQAM's Centre de design was solicited to organize the exhibition *Habitat 67 vers l'avenir / The Shape of Things to Come*, presented in June 2017 as one of the events organized for the fiftieth anniversary of Expo 67. It is in this context that I organized the Study Day *Habitat 67: sources et répercussions / Sources and Reverberations* and presented a short version of this paper. For their comments and suggestions, I thank Carlo Carbone and Cammie McAtee for reviewing an early draft of this paper, and the SSAC's anonymous reviewer.

2. See Béringer, Hubert, 2014, *Habitat 67 dans la presse architecturale*, doctoral dissertation in art history, Université Paris 1. The preliminary results of this investigation were published in Béringer, Hubert, 2002, "Habitat 67 : architectures d'images, images d'architectures," *JSSAC*, vol. 27, nos. 1-2, p. 3-20. See also: Béringer, Hubert, 2002, "Dit, non-dit, contredit et discrédit de l'iconographie du chantier d'Habitat 67," *Globe*, no. 51, p. 35-52.

3. Huxtable, Ada Louise, 1967, "Habitat: Exciting Concept, Flawed Execution," *The New York Times*, April 30.

4. Haskell, Douglas, 1967, "Habitat and After," *Architectural Forum*, May, p. 34.

5. Banham, Reyner, 1971, review of *Beyond Habitat* by Moshe Safdie, *Architectural Forum*, vol. 135, July/August, p. 10. In his 1976 book *Megastructures. Urban Futures of the Recent Past* (London, Thames & Hudson), Banham offers a very perceptive analysis of the building, touching on a number of aspects: the student thesis, the influence of Anne Tyng, the contrast between the original and the built project, the Mediterranean imagery betrayed by the Beaux-Arts composition, the fallacy of "factory-built" housing, and Safdie's interest in systematic geometries.

6. Liscombe, Rhodri Windsor and Michelangelo Sabatino, 2016, *Canada. Modern Architectures in History*, London, Reaktion Books, p. 226.

7. Banham, *Megastructures. Urban Futures of the Recent Past*, *op. cit.*

8. See Sorkin, Michael, 1996, "Habitat and After," in Wendy Kohn (ed.), *Moshe Safdie*, London, Academy Editions, p. 15-17; see also Gopnick, Blake and Michael Sorkin (eds.), 1998, *Moshe Safdie: Habitat '67, Montreal*, Torino, Testo & imagine.

9. Albrecht, Donald and Sarah Williams Goldhagen (eds.), 2010, *Global Citizen: The Architecture of Moshe Safdie*, London, Scala Publishers.

10. Elser, Oliver, Philip Kurz, and Cachola Schmal (eds.), 2018, *SOS Brutalism: A Global Survey*, Zurich, Park Books.

11. Riar, Inderbir Singh, 2014, *Expo 67 or the Architecture of Late Modernity*, Ph.D. in Architectural History, Columbia University.

12. This was the goal of the session "Habitat 67 and Postwar Architecture" I organized for the annual meeting of the Society of Architectural Historians held online, April 16, 2021.

13. Safdie, Moshe (John Kettle, ed.), 1970, *Beyond Habitat*, Montreal, Tundra Books. While this book is essential to understand the development of the project, it is also often imprecise regarding the exact dating of events, compelling the researcher to confront Safdie's narrative with the archival sources.

14. See Saint, Andrew, 2007, *Architect and Engineer. A Study in Sibling Rivalry*, New Haven and London, Yale University Press. See especially chap. 5, entitled "Reconciliation," which focuses on the twentieth century. Saint writes that "the relationship between architecture and engineering is seldom simple: that compromise and partnership are the rule, not the exception; and that the balance between the two professions shifts from project to project" (p. 7). See also Herbert, Gilbert, "Interactions Between Architect and Engineer," in Gilbert Herbert and Mark Donchin (eds.), 2013, *The Collaborators: Interactions in the Architectural Design Process*, London, Ashgate, p. 9-15.

15. Safdie, Moshe, 1961, *A Case for City Living. A Study of Three Urban High Density Housing Systems for Community Development*, final thesis, McGill University, Montreal.

16. See Zantovska Murray, Irena (ed.), 1996, *Moshe Safdie. Buildings and Projects 1967-1992*, Montreal, McGill-Queen's University Press, 1996, p. 45.

17. Safdie, Moshe, 1961, "Un nouvel aspect d'habitat urbain," *Architecture Bâtiment Construction*, vol. 16, no. 183, p. 32-37; Safdie, Moshe, 1961, "A Case for City Living," *Habitat*, vol. 4, no. 6, p. 2-10; Safdie, Moshe, 1962, "Fallacies, Nostalgia and Reality / A Case for City Living," *Forum*, vol. 16, no. 5, p. 170-183. For a discussion on the theoretical sources of the project, see Riar, *Expo 67 or the Architecture of Late Modernity*, *op. cit.*

18. Safdie had returned to Montreal in August 1963 at the invitation of Van Ginkel. This opportunity was one of the conditions negotiated by Safdie for his acceptance to work alongside Van Ginkel on the planning of the exhibition. Safdie, *Beyond Habitat*, *op. cit.*, p. 63.

19. On the Expo themes "Man in the City" and "Housing – Man in the City," see Riar, *Expo 67 or the Architecture of Late Modernity*, *op. cit.*, p. 309 *et seq.*

20. On the October 29, 1963, memorandum by Safdie, see Riar, *id.*, p. 304 *et seq.*

21. *Les objectifs du plan directeur / Master Plan Design Intent*, 1963, Montreal, Canadian Corporation for the 1967 World Exhibition.

22. This photograph of the model of the first scheme was found in the August Komendant Collection, The Architectural Archives, University of Pennsylvania [hereafter AK Collection]. To the best of my knowledge, this view of the model has never been published and does not seem to be in the Moshe Safdie Archive.

23. In *Beyond Habitat* (p. 75), Safdie offers a very brief description of the first scheme: "At that time, Habitat was to be an inclined structure, not quite regular pyramids, but open-ended half pyramids leaning on each other. All the community facilities were below. Since I had not then decided whether the units would be load-bearing or inserted into a frame, in the sketches we showed the alternatives: one, a steel frame with units plugged in; the other with load-bearing units."

24. The first scholar to examine the connection between the Meadowvale plan and the first Habitat scheme is Riar. While noting the formal aspect of the "large pyramid," Riar focuses on the urbanistic goals of the plan. He writes: "Working closely with Van Ginkel for four months, Safdie attempted to discover how a 'core' could 'grow.' He borrowed heavily from Kenzo Tange's 'civic axis' for the Tokyo Bay Plan of 1960, with its 'radial structure' of traffic feeding into a 'linear structure.'" Riar, *Expo 67 or the Architecture of Late Modernity*, *op. cit.*, p. 308. While acknowledging the importance of this contribution, my reading of this connection focuses instead on the import of the pyramidal form on the Habitat scheme.
25. Safdie, Moshe, 1962, "The Master Plan: Growth, Change and Repetition," *Habitat*, vol. 5, no. 3, p. 2-7.
26. On his internship, see Safdie, letters to Kahn, January 24 and February 19, 1962, Louis I. Kahn Collection, The Architectural Archives, University of Pennsylvania.
27. Safdie's year in Kahn's office was examined by William Whitaker in his talk at the *Habitat 67: sources et répercussions / Sources and Reverberations* study day held at UQAM in June 2017. Whitaker paid special attention to Safdie's connection with the architect Dave Rinehart, who went on to play a key role in the development of the Habitat project.
28. Anne Tyng, who worked as an architect in Kahn's office for 19 years, had a major influence on Kahn's geometric designs during those years, including the City Tower project for Philadelphia (1952-1953). Safdie recalls that Tyng approached "the environment from the atoms, molecules and crystals that make it up and the system that structures them." Safdie, *Beyond Habitat*, *op. cit.*, p. 59. On her thinking and work, see Alicia Imperiale, Jenny E. Sabin, Ingrid Schaffner, Srdjan Jovanovic Weiss, and William Whitaker, 2012, *Anne Tyng: Inhabiting Geometry*, Institute of Contemporary Art, University of Pennsylvania.
29. In the Safdie archive, the project titled "City for Palestinian Refugees (Giza)" is dated 1962, though the drawings and notes pertaining to the project are undated. The file also contains documents dated 1966, confirming Safdie's long-term interest in the project. Moshe Safdie Archive, Canadian Architecture Collection, McGill University [hereafter MS Archive].
30. Safdie, *Beyond Habitat*, *op. cit.*, p. 61.
31. Zantovska Murray, *Moshe Safdie. Buildings and Projects*, *op. cit.*, p. 47.
32. As Safdie recalls, "the first proposal consisted of a series of inclined sloping transparent membranes, thirty to forty story in the air. The membranes were made up of houses, each an entity in itself, with gardens and public parks penetrating them." Safdie, *Beyond Habitat*, *op. cit.*, p. 62.
33. *Id.*, p. 65.
34. *Id.*, p. 75.
35. Safdie, Moshe and Stuart M. Andrews, *Report on the Proposed Permanent Housing Exhibit Habitat 67*, n.d. [February 21, 1964], AK Collection.
36. Safdie recalls: "We needed a good engineer and I suggested Dr. August Komendant, an engineer who did much of the structural engineering for Louis Kahn's work and whom I had met in Kahn's office. I felt that he, more than any other man I knew, would be capable of dealing with a structure that might or might not turn out to be concrete but was, in any case, going to be highly complex." Safdie, *Beyond Habitat*, *op. cit.*, p. 77.
37. The meeting took place on Wednesday, January 15, 1964.
38. Safdie, *Beyond Habitat*, p. 77.
39. *Id.*, p. 78.
40. Safdie recalls: "The redundancy of two such heavy systems seemed wrong, and Komendant then made the judgement—which I agreed with—that, given the use of concrete, it would be a superior system if the units not only enclosed space but were load-bearing as well." Safdie, *Beyond Habitat*, p. 79.
41. While other scholars have often mentioned Peter Cook's *Plug-in City* (1964) as one of Safdie's precedents, I believe that its first publication in autumn 1964 in *Archigram 5*—a little-known architecture pamphlet printed in England—years after his student thesis, undermine this argument.
42. Safdie recalls: "It was the first thing I thought of doing in my thesis. It's also the obvious solution to mass producing, because the plug-in units are all identical." Safdie, *Beyond Habitat*, p. 78.
43. Safdie, letter to Komendant, January 23, 1964, AK Collection.
44. "I am enclosing prints of a section and elevation of one housing plane as well as plan at the edge member." Safdie, letter to Komendant, February 7, 1964, AK Collection. A week later, Komendant was able to provide a report on "the structural description and recommended use of materials as well as construction methods of the Project Habitat." Komendant, letter to Safdie, February 13, 1964, AK Collection.
45. Safdie and Andrews, *Report on the Proposed Permanent Housing Exhibit*, *op. cit.*
46. Komendant, August, 1952, *Prestressed Concrete Structures*, New York, McGraw-Hill. The American engineer Kurt Billig, who had already published on the topic, also came out with a book in 1952: *Concrete Structures*, published by Van Nostrand, NY.
47. Komendant, August, 1975, *18 Years with Louis I. Kahn*, Englewood, Aloray Publisher, p. 4.
48. The exhibition on the Richards Medical Research Building was presented at the Museum of Modern Art (MoMA) in New York from June 6 to July 16, 1961.
49. See Leslie, Thomas, 2005, *Louis I. Kahn. Building Art, Building Science*, New York, Georges Braziller, p. 148.
50. Komendant, August, 1960, "Precasting Makes New Strides," in Concrete Technology, thematic issue of *Progressive Architecture*, October, p. 176-191. Introducing the topic, the editor wrote: "Precasting of concrete, coupled with stressing techniques, offers a formidable threat to other architectural construction methods" (p. 176).
51. Safdie, letter to Komendant, March 6, 1964, AK Collection.
52. Komendant, letter to Safdie, April 11, 1964, AK Collection.
53. Komendant, letter to E. Schechter, Stressteel Corporation, May 11, 1964, AK Collection.
54. Among the study drawings for the A-frame, one is dated April 1964, AK Collection.
55. In *Beyond Habitat* (p. 93), Safdie dates the approval of the revised scheme to October 28, 1964. However, two letters sent by Safdie to Komendant in mid-November 1964 seem to confirm that the engineer was also involved in the conception of the revised project. Safdie, letters to Komendant, November 6 and 19, 1964, MS Archive. These documents tend to confirm that the "official" date of approval is only one of the many steps entailed in the design of the revised scheme.
56. On the Camus Company, see Delemontey, Yvan, 2013, "Camus et l'avènement de la préfabrication lourde en France : vers un nouveau paradigme structurel," *Centraliens. La revue des Arts et Manufactures*, no. 625, p. 57-62.

57. This episode on the Camus affair is entirely based on Safdie's own narrative, which does not provide precise dates. Safdie, *Beyond Habitat*, *op. cit.* p. 92-93.

58. The project by Jean Duret, Luc Durand, and PGL Architects is documented in an album entitled *Y'67*, Montréal, conserved in the Fonds Luc Durand (AP121), Canadian Centre for Architecture.

59. The best description of the cluster system is to be found in August Komendant's 1972 book, *Contemporary Concrete Structure*, New York, McGraw-Hill, p. 535-543.

60. Two of the three committee members were Professor John O. McCutcheon, chairman of the Civil Engineering and Applied Mechanics Department at McGill University, and Professor Gaspar K. Kani, a respected structural engineer from the University of Toronto. Safdie, *Beyond Habitat*, *op. cit.*, p. 94.

61. *Ibid.*

62. *Id.*, p. 95. It is at that time that the local engineering firm Monti, Lavoie, Nadon was brought in to collaborate on the project with Komendant.

63. "We have now been definitely instructed by the CCWE to proceed with Alternative "B," making both ends of the structure symmetrical as presently at the north end of the project." Safdie, letter to Komendant, June 22, 1965, AK Collection.

64. "Memorandum of agreement of lease and hire of services by and between Moshe Safdie & David, Barott, Boulva and Dr. August Komendant," August 26, 1965, p. 3, AK Collection.

65. A meeting of all the parties involved regarding the details of the mould and the casting operation highlights the central role played by Komendant. Anglin-Norcross Quebec Limited, Habitat 67 # 30015. Meeting RE: Forms, October 19, 1965, AK Collection.

66. Komocki, Jan, 1967, "Structural Design of Habitat '67," *Journal of the Prestressed Concrete Institute*, vol. 12, no. 1, p. 67. Komocki was an engineer working for the engineering firm Monti, Lavoie, Nadon.

67. The constraints of this operation were such that every lift had to be rehearsed with a scale model available on the building site.

68. J.M.R. Thompson, letter to G. Lancaster, April 15, 1966, AK Collection. The first concrete box was cast February 18, 1966.

69. Komendant, letter to Safdie, April 23, 1966, (AK Collection.

70. Komendant, letter to Safdie, July 25, 1966, AK Collection.

71. Komendant, letter to Safdie, August 8, 1966, AK Collection.

72. Komendant, letter to Safdie, October 7, 1966, AK Collection.

73. Komendant, letter to Safdie, October 31, 1966, AK Collection. In November, Komendant wrote to Safdie that despite his many requests to take corrective actions, his "orders" had been ignored, and given that these addressed the safety of the structure, it was nothing less than "criminal." Komendant, letter to Safdie, November 7, 1966, AK Collection.

74. Komendant, August, 1966, "Komendant on Concrete," in Concrete: Where Do We Go From Here?, thematic issue of *Progressive Architecture*, October, p. 211.

75. "The Contractor's Habitat" is a sub-heading in "Building a City with King Kong Blocks," *Progressive Architecture*, October, p. 234-236.

76. Komendant, draft letter to the editor of *Progressive Architecture*, undated, AK Collection.

77. Safdie, Moshe, Robert Hughes, and David J. Fitzgerald, draft letter to the editor of *Progressive Architecture*, November 26, 1966, AK Collection.

78. Shaw, Robert, letter to Safdie, Komendant, T. Monti, and R. Hughes, November 30, 1966, AK Collection.

79. He adds: "All technical publications or releases concerning the construction in structural matters shall be subject to the sole and exclusive approval of Komendant." Komendant, letter to Safdie, December 9, 1966, AK Collection.

80. Komendant, letter to Robert C. Dorland, April 4, 1967, AK Collection.

81. Molloy, Ruth, 1967, "Retrospect," *Philadelphia Magazine*," undated clipping in AK Collection. The article was based on written exchanges between Molloy and Komendant dated March 24 and March 29, 1967, AK Collection.

82. [Original emphasis] Molloy, *id.*

83. Komendant, letter to Molloy, March 29, 1967, AK Collection.

84. *Id.*

85. Safdie, Moshe, 1967, "Habitat: A Post-mortem," *RIBA Journal*, November, p. 493.

86. Komendant, letter to Jan Rowan, November 4, 1967, AK Collection.

87. Komendant, August, 1968, "Post-mortem on Habitat," *Progressive Architecture*, March, p. 138-147.

88. Among his many comments, Komendant writes: "The river side cluster arrangement is random, accidental and leaning too much against the opposite side clusters, creating unnecessary dense interlocking of the H.U.'s at the top." Komendant, *id.*, p. 8.

89. *Id.*, p. 147.

90. Komendant, *18 Years with Louis I. Kahn*, *op. cit.*

91. Donchin, Mark, 2013, "Kahn, Komendant and the Kimbell Art Museum: Cooperation, Competition, and Conflict," in Herbert and Donchin (eds.), *The Collaborators*, *op. cit.*, p. 205-236.

92. *Id.*, p. 230.

93. Jack McAllister, cited in Donchin, *id.*, p. 226.

94. Nikolas Gianopoulos, cited in Donchin, *id.*, p. 227.

95. *Id.*, p. 230.

96. In his book on concrete structures published a few years later, Komendant discusses the various phases of the design process in architecture, revealing a true concern for the aesthetic quality of a work. Komendant, *Contemporary Concrete Structure*, *op. cit.*

97. For a brief description of these projects see Zantovska Murray, *Moshe Safdie. Buildings and Projects*, *op. cit.*

98. Emanuel Yeskel, Development Company (Newark, New Jersey), letter to Komendant, June 20, 1967, AK Collection. Komendant responded: "As for my availability for your project, it depends mainly upon who will be your architect, because the architecture and engineering of this type of project are inseparable and furthermore upon what are the other conditions." Komendant, letter to Yeskel, June 26, 1967, AK Collection.

99. The project, commissioned by HUD, utilized the Shelley System. On the system, see Mora, Luis E., 1970, "Shelley-Modular Housing System," *International Symposia on Low Cost Housing Problems*, no. 18, p. 95-97. On Vivienda 70, see [Jensen, Robert], 1971, "Vivienda 70 in Puerto Rico: Shelley System's first project is next to complete," *Architectural Record*, April, p. 116-119. An undated document describing the Vivienda "70" construction system is preserved in the AK Collection. Komendant's involvement in the project led him to apply for a patent, granted in 1980 (Modular, multi-floor building, US4195453A filed 1977).

100. Huxtable, Ada Louise, 1969, "Tinker Toy City Hall in Israel is 'Space Packed,'" *The New York Times*, June 5.

101. Komendant, letter to Huxtable, June 5, 1969, AK Collection.

102. *Ibid.*

103. Safdie, *Beyond Habitat*, *op. cit.*, p. 78.

104. *Ibid.*

105. Komendant added: "When Olivetti and Kimbell projects came along, our association was re-established. In this period we were really perfect 'dance partners.' Both projects are novelties—advanced design—and the 'male dancer' had to take care of the balancing and performance." Komendant, August, 1991, "Architect-Engineer Relationship," in Alessandra Latour (ed.), *Louis Kahn: Writings, Lectures, Interviews*, New York, Rizzoli, p. 319.

106. Despite these frictions, Safdie and Komendant worked together again on a Habitat-inspired project and an art centre for Teheran in 1976-1978, on the Robina New Town project in Queensland, Australia in 1981-1982, and on the National Gallery of Canada in 1983-1988.

107. Haskell, Douglas, 1967, "Habitat and After," *Architectural Forum*, May, p. 34.

108. The point of this issue of *Architectural Forum* was to bring up alternatives to the Safdie-Komendant approach. Haskell, *id.*, p. 34-51.

109. For the critic of *Canadian Architect*, Habitat had always been compromised by *Formverlangen*, that is, "the desire for form, a form which could create an image," arguing that Safdie had made "frantic technological efforts" to cling to that image. Elte, Hans, 1967, "Habitat 67: The Critical Eye 2," *Canadian Architect*, October, p. 37. See also Riar, *Expo 67 or the Architecture of Late Modernity*, *op. cit.*, p. 382.

110. See Molley, letter to Komendant, March 24, 1967, AK Collection. In his book on Kahn, Komendant recalls that the architect disliked Habitat, calling it Safdie's "bad dream." He added that it was success in the structural sense, "but not architecturally." Komendant, *18 Years with Louis I. Kahn*, *op. cit.*, p. 107.

111. Sorkin, "Habitat and After," *op. cit.*, p. 17.

112. This fixity and lack of flexibility did not go unnoticed. In his contemporary review of Habitat, the critic Scott Kelly argued that one of the major shortcomings of most cluster plans is their inflexible form: "The manner in which cluster dwellings are fitted together makes it virtually impossible to expand or reduce the size of apartments in later years." Kelly, Scott, 1967, "Expo's Promising Pile of Boxes," *Industrial Design*, vol. 14, July, p. 57. After Habitat became a private property in 1987 and individual owners started to merge housing units, Komendant had to calculate and approve all the changes made to the openings in the boxes.

113. When government authorities suggested to cut the north cluster to reduce costs, Komendant produced a report demonstrating that it had to be built in order to maintain the stability of the structure. Safdie, *Beyond Habitat*, *op. cit.*, p. 131.

114. Considering Habitat in 1995, the authors of *Architecture in North America since 1960* wrote: "If a monument in our time, in the sense that the tower of Eiffel is a monument, is a structure that succeeds in incorporating in a memorable image the said fundamental needs, aspirations, and perceived potentials of a people at a given place and moment, then the three-dimensional space structure of Habitat deserves that title." Tzonis, Alexander, Liane Lefaivre, and Richard Diamond (eds.), 1996, *Architecture in North America since 1960*, Boston–New York–Toronto–London, Bulfinch Press Book, p. 116.