Beyond Habitat

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9 Confronting the system

The process of realization of a building environment, really slugging it out, is the final test of any idea.

When I look at theoretical new town plans, housing proposals, I'm very conscious of what they have yet to go through before becoming physical reality. An abstract concept can ignore the existence of gravity, rely on miracle materials or be unrelated to the realities of economics. Yet I can think of no other profession where realized concepts and academic proposals are compared and discussed as if they were one and the same thing.

The building of environment depends on a great number of people physically participating in its realization: contractors, laborers, craftsmen. Therefore all technical solutions and detailing have to be in the context of what these people can or cannot do. You're dependent on the organizational structure of the business world, the industries that supply material, what they're prepared to do, what risk they're prepared to take. You're dependent on government because the city and sometimes the province and even the federal department have to approve the drawings. When they grant a building permit, they're accepting part of the liability for it, they're saying: "This is sound and safe." You're dealing with the whole legislative bureaucracy and tradition. You must either work in the context of the existing legislation or change it; you must build in the context of building codes and zoning laws.

Codes are established to set standards but their original intent is often forgotten. The code may say that a concrete wall, in order to withstand a severe fire, should be a minimum of eight inches thick. If you can show that a four-inch wall of new design could do the same, then you have satisfied the intent of the code. But too often that does not mean that you will be permitted to build the thinner wall.

In many cases, the code is really protecting a particular union practice. The code may refuse PVC plastic piping and insist on copper or cast iron. That may have a lot to do with the lobby of the plumbing union, or for that matter the copper manufacturers who would lose a substantial number of man-hours or material sales if PVC piping were introduced. New York building practice is notorious for such rulings. Every plumbing connection is described by the code. Often it has less to do with the performance of the plumbing than with the way plumbers like to work. *Performance codes* are much more meaningful than codes where the performance is translated to data and the data become the statements of the law. We are a long way from establishing uniform and versatile performance codes on this continent.

Zoning, on the other hand, attempts to establish certain environmental standards for such things as daylight or the separation of land uses. As it deals with environment, it is much more susceptible to value judgment and is less precise in definition. That a building should resist hundred-mile-an-hour winds is a very definite statement, and it can therefore be assessed. How much daylight a house should have is a less tangible thing. Zoning laws tend to be vague. Often, as our values change, such laws become an obstruction.

For example, for years it was impossible to put a shop in a housing project in Canada because in the early part of the century it was considered that a commercial function would be a nuisance to the tenants. When the Jeanne Mance public housing project in Montreal was being built in 1960 it was a major battle for CMHC to get one little shop on the ground floor of one of the buildings. In contrast, health regulations may require that each room have a set minimum of window area, but these requirements are so minimal that they are not an effective guarantee of environmental quality.

Habitat had to challenge the system at each of these levels. It had to challenge industry, the practice of labor, the by-laws, and the state of the building art of the time.

Habitat is a collection of statements of intent. Very often the intent was not fulfilled, but suggested. We had certain concepts of how the mechanical services of a dwelling should function, for example, and we developed systems that approached that concept, only to find that circumstances put it beyond realization.

The modules were a major challenge. The building is made up of boxlike modules of identical size. The modules are factory products, and we grouped them in an intricate three-dimensional structure.

Establishing the size of the module was a long process. If it was to be the size of an entire dwelling, it would be too heavy to lift. Another disadvantage was that there would be very little flexibility in design; a module a quarter or a third of a house could be combined in many permutations to achieve a variety of house types. Next we investigated small modules, a room size, sixteen by sixteen; the problem there was that then we would need a large number of connections, and connections are where the money is; it would also increase the number of crane lifts. So we reached the conclusion that the module should be a complete one-bedroom house or one-half, one-third, or one-quarter of a larger house. That meant a module of about six hundred square feet.

What shape should it be? A square did not lend itself to grouping. If it was oblong in plan, modules could be connected in a variety of shapes, including two-storey houses. The shape should also ensure that the point of connection be standard, to simplify the preparation of drawings and erection procedures on the site.

We concluded that the plumbing should be contained in vertical cylindrical shafts, located outside the modules. This suggested the modules should overlap one another rather than fit flush, to create a continuous space for the pipes. It also suggested the size of the overlap – three feet six inches to accommodate a three-foot shaft. After considerable trial and error we established a three-foot-six-inch grid as the dimensioning matrix for the entire system.

It was essential that the box could be hoisted into place and left there safely in equilibrium even before being physically connected. So if one module was set crosswise on another, the center of gravity of the top one would be within the walls of the lower one. This meant that the length of the module had to be twice its width plus the overlaps.

In turn, the width had to be seventeen or eighteen feet in order to accommodate a stair running across the module from one floor to the other. Five of the three-foot-six grid units gave us a seventeen-foot-six module width. With an overlap of one grid unit we could have a length of eleven grid units, or thirty-eight feet, six inches. This gave an area of just over six hundred and seventy square feet, or about six hundred and forty square feet of floor area inside the walls. We considered this the minimum size for a one-bedroom house.

Those were the major considerations in setting up the grid, size, and proportions of the boxes. But the complexity of dealing with a building as a system is that one decision, such as the three-foot-six grid, affects every dimension in the building. It not only affects the size of mechanical shafts and the stability of the module during construction but also the size of rooms and the possible house plans; it affects the angle of inclination of the face of the structure, the placing of windows, the size of public spaces below, the size of gardens, everything.

I was aware even as we were fixing the grid and the module, that we were making some serious compromises. One was that since the dimensional system was for the outside of the boxes, the wall thicknesses had to be subtracted when we were dimensioning the inside of the house. That meant that the inside of the house was made up of a certain number of three-foot-six grids except at the outside walls, where it was three-foot-six minus the wall thickness. That threw everything off. We couldn't prefabricate the interior components to a fixed grid and still make them work everywhere. If partitions or floors were manufactured in three-foot-six panels they had to be chopped off at the edges of the box.

I was unable at the time to work out a dimensioning system that worked both inside and outside the house. Yet a comprehensive dimensional system is critical to the success of any building system. I think eventually one could find a system that works both inside and out, co-ordinating both structural and interior components.

Once we established the module there came the question of material. We thought about various plastics, fiberglass, and combinations of materials. But the plastics were too expensive, they were unpredictable technically, and above all, they melted at low temperatures. We considered steel too. Sheet metal had to be fire-proofed and, once fire-proofed, it became extremely costly and heavy. That led to concrete.

Concrete, unfortunately, is a very restricting material. It can take hardly any tension, it's relatively heavy and porous, and the most advanced methods had to be used in order to be able to construct a complex three-dimensional building at all.

Habitat's form, which was largely dictated by the relationship of houses and gardens, sunlight, and the desire to express the identity of the individual house within the group, was just possible in concrete, but it anticipates materials that are lighter, stronger in tension, have a watertight surface, and are easily moldable.

Working on Habitat I became increasingly aware of a basic shortcoming of the building industry. Its whole tradition is to build with what materials happen to be available. Every other industry defines its requirements and then develops the material best suited to the problem. They don't design an aircraft with steel just because they happen to have steel handy: if they come to the conclusion that they need a metal that's lighter, then they perfect the manufacturing of aluminum. When they discover that aluminum is going to melt at high supersonic speeds, they develop a material that has a greater heat resistance, like titanium. Dupont for example, came to the conclusion through market research that world resources of natural leather were very limited and that a synthetic material with the qualities of natural leather would be highly marketable. They poured in something like twenty-five million dollars over a period of several years to develop Corfam. Rocket nose-cones required a material that could resist very high temperatures and to that criterion Corning Glass developed Pyroceram.

I would say that as a rule industry, where it has the resources and organization, develops materials to meet a given specification. Fifty years ago, as Buckminster Fuller describes it in *Nine Chains to the Moon,* the tremendous demand for better weapons in World War I created the pressure to develop steel alloys that were harder and stronger than carbon steel. After the war they benefited the automobile and other industries. Where the pressure exists, an effort is made. But because of its organizational structure, its method of operating, and its fragmentation, the construction industry has neither the circumstances nor the resources to do the same and consequently has always used leftovers; it has used steel, aluminum, fiberglass after they were developed elsewhere. I don't think technologies are directly transferable from one industry to another. Each realm of manufacturing has its own specific needs. It can't just borrow–yet that's what the construction industry has been doing.

The material we needed for Habitat would have been about one fifth the weight of concrete, with a tensile strength double that of mild steel, so that you could hang twenty tons on a strip with an inch-square cross-section. It would have compressive strength and density where buckling is not a major design criterion, its relative lightness making its cross-section thick enough to give it that strength. Its lightness would also give it an insulation value equal, say, to foam plastic, and yet it would be completely moldable by simple processes. Its skin would be impermeable to water. I am not describing a "miracle" material. This material exists even today in the laboratory, in the hydrocarbon family of polymeric materials. All we have to do is find a way to manufacture it cheaply.

But in 1964, the decision was that Habitat had to be concrete. It was a 1964 decision. Today I am building in Puerto Rico with walls half the thickness of the Habitat walls. Even with regular concrete there is considerable latitude to the state of the building art. This is only six years later–which gives some idea of the pace at which building practice can change.

The modular boxes had to be as light as possible. The fire code required reinforcing steel to be covered with at least two inches of concrete to give it a four-hour fire rating and that suggested a five-inch wall if it was to be all concrete. In the first discussions with Dr. Komendant and the other engineers, the precasters insisted that they couldn't pour ten-foot-high walls five inches thick with the kind of reinforcing we had in there. They feared the concrete wouldn't go to the bottom, that it would leave great pockets of honeycombing, but they eventually found that they were able to do it. Four years ago we were told we couldn't do five-inch walls; today we're being told we can't do two-inch walls. The fact that we've done both is all an expression of the immobility of the building industry.

The contractor naturally reacts by saying "No" because he's afraid to lose money. Usually he's on a lump sum fee. He looks at a drawing that calls for five-inch walls, and he usually has neither resources nor time to test it in the field. The trade unions resist change because they always think in terms of the number of hours of work for their particular trade. If you could connect plumbing parts with a magic joint it would cut the number of man-hours for plumbers by one-half or one-third, and so the unions resist. In contrast, I don't think there are many examples where the auto workers' unions have had a drag effect on how cars were to be made. Yet there are dozens of examples where construction procedures were dictated by the unions without regard for economy.

The modular boxes are tied to each other with steel rods, which being under tension, put the concrete under compression. Robert Shaw has a nice description for post-tensioned concrete. He compares it to the toy dolls that stand erect when you pull a cord and flop down when the cord is loose. The tension in the cord keeps the doll together and upright. This is basically how Habitat stands up; except that it is even more complex since each pair of boxes is post-tensioned to act that way rather than all the boxes being tied to each other by one continuous tension cord.

As all these major decisions were being made, the Habitat team was being further built up. I considered that the architects, the engineers, the technicians, those that industry assigned to the job, ought to be working in the same place. I felt you couldn't separate the process, and I succeeded in getting all of them to agree to work in my office. The mechanical and structural engineers, the representatives of the contractors, bathroom and partition manufacturers, actually came to the office and worked with us. There were close to a hundred people in one room. I doubt such a thing had ever been done before on a housing project.

But here too, in our relationship with industry, we were inhibited by accepted practice. The problem with calling public bids is that no one is prepared to risk doing work or research before he gets the job. The result is that when designing the products for which you're going to call bids you don't have the benefit of the know-how of the man who's going to make that product.

We circumvented this in two ways. On certain components I was able to get help from industry on a strictly voluntary basis. The precasters, for instance, sat in on our job meetings every Monday for several months before the job went out for public bids (luckily for them and us they were lowest bidder). This in itself was unprecedented and largely due to the circumstances of Expo. Secondly, we short-circuited things by modifying the bid procedures. Instead of drawing a product in great detail and then calling for bids, we described the product in terms of what it had to do and its general characteristics. We said a successful bidder should name the price for which he could both research and manufacture the product. The detailed design we would develop jointly after he had the contract.

From the outset I had hoped to have the bathroom, kitchen and partitioning system as pre-manufactured components. Fuller designed a prefabricated bathroom in the thirties for his Dymaxion house, and there had been attempts at prefabricated kitchens, but none had been commercially produced. The Habitat components, I felt, must conform with codes, or a revised code, and had to be within industry's capabilities.

The bathroom had to come as a complete room. We rejected metal because we realized the tooling cost would not be realistic for a hundred and sixty units. Eventually we concluded that gel-coat fiberglass was the best material. Expo suggested to Fiberglas Canada that they ought to contribute toward the research costs. Expo did not intend to pay more than the cost of a conventional bathroom and considered the difference should be covered by Fiberglas Canada because of the promotion the bathroom and their material would get. The president of Fiberglas Canada was very nervous about the whole affair. He was not convinced his material was good enough for bathrooms and several weeks elapsed before we could convince him that it was. We sent the material to the National Research Council of Canada and had them carry out extensive tests on the wear that would be expected over a twenty-year period. We determined that local damage by burning or breaking could be patched the way fiberglass boats and cars are fixed. And we were prepared to take a certain amount of risk.

We got only one bid for bathrooms, from Reff Plastics and Tielemans in joint venture. Reff Plastics were working on their own fiberglass bathroom at the time, by a happy coincidence. Tielemans had made various large fiberglass elements but not bathrooms. Before bids were called, Fiberglas Canada had finally said they would contribute a hundred thousand dollars to the project. Once the bid was in however, they went back on the informal agreement. It looked as if they were about to kill "Operation Bathroom," a project that we thought might revolutionize the market for their product. In the end they made a compromise offer to Expo of thirty thousand dollars. The bathroom was about to be abandoned when I went to Churchill and told him what was happening. The bathroom demonstrated the possibility of pre-manufacturing large interior components into a modular system, I said, and if we resorted to conventional bits and pieces – tubs and sinks and tile and cabinets – we would kill the demonstration of an industrialized building process. Churchill and Shaw met and the next day the budget was increased to fill the gap left by Fiberglas' reversal.

Once the bathroom contract was awarded, Reff Plastics proceeded with the technical drawings from which the molds were to be made. This was for me one of the most rewarding experiences of Habitat. We spent hours together going over the drawing. I was absorbing the background and experience of manufacturing with fiberglass. The mold – the negative form of the bathroom – was made by hand out of wood, plastic laminate and fiberglass. The gel-coat and fiberglass were sprayed on and then the bathroom popped off. I went down to Toronto once a week as the master mold was being made. Robert Zoebelein of Reff Plastics and I would get into the tub, sit in it to see if it was comfortable, make the soap dish, change our minds, remold it, fill it up, carve it out, try the towels. It was a trial-and-error process finally resulting in a room that appeared to be the kind of bathroom we wanted. After Expo, Zoebelein modified the bathroom to overcome the difficulty of shipping it. He changed it from two, to three sections that fit into one another so that it could be shipped in a small package. He put it on the market for something like five hundred and sixty dollars – one of the first success stories from Habitat! As the ministers and other officials came down from Ottawa criticizing the money wasted at Expo, we could retort that we had put a new Canadian product on the market. A year later the Crane Company bought out Reff Plastics and put the fiberglass bathroom on its international marketing network.

Following the same procedures, we described the kind of kitchen we wanted and how it should function. Again we set a maximum: the kitchens could not exceed one thousand dollars each. We knew that this couldn't be done and that only an industry that was prepared to contribute some of its own funds could bid. One corporation was prepared to do it: Frigidaire, a subsidiary of General Motors. They produced a very sophisticated kitchen, through relatively conventional in its manufacturing. I was told they put two hundred thousand dollars of their own funds into the program. Bud Andrews and I set the strategy for this project: to convince Frigidaire that the Habitat kitchen could be the means of going from the appliance business into the kitchen business. We met with the president of Frigidaire Canada and his chief engineer. As a result of a number of meetings with the technical staff, there was enthusiastic response, leading to Frigidaire's bid and our successful collaboration with them. It will be interesting to see now whether Frigidaire follows up and starts manufacturing whole kitchens for general consumption.

The importance of Frigidaire's decision to sponsor the kitchen cannot be underestimated. As a result of their public support, Habitat acquired a certain respectability with people in and outside of Expo who, until then, were very skeptical. If General Motors was prepared to put a quarter of a million dollars into this project as their participation in Expo, the project was obviously respectable.

When the time came to design the mechanical service shafts, my first sketches were for a metal shaft. Since the bids we received were over the budget, we decided to try out fiberglass. Now I was able to go to Reff Plastics, who already had the bathroom contract. We spent several evenings discussing the problem. They developed a system at a third the cost of the metal bids. We then called for bids, and of course they got the job.

What I learned in these ventures was the wealth of experience, the whole world of possibilities, that arises when you work with the people who make the product. Designing that shaft or the bathroom with the people who understood all the subtleties of making it was a completely different process from sitting in my office with a piece of paper and thinking what a bathroom should be, ignoring the potential of industry. It was a unique relationship and it produced a different kind of design. Habitat at its best was produced from such relationships. It convinced me that the set-up in which the architect is independent of the manufacturing process is totally obsolete.