BUILDING HOUSING ABROAD: COMBINING IMPORTED SERVICE CORES AND LOCAL TECHNOLOGY

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Abstract

Properly applied, industrialisation can deliver affordable, high quality housing to the vast majority of people all around the world, as well as solve the ever widening gap between the formation of slums and the capacity to replace them. The ultimate goal is to bring to the site 3D modules, completely finished at the factory, but these are usually too expensive when building abroad as an important part of the transportation cost goes to carrying "air", and because of probable conflicts within the local context.

An optimal solution is offered by a hybrid approach; concentrating the "Serving areas" (kitchen, bathroom, toilets, laundry room, stairs, mechanical block, etc.) in compact factory-made 3D modules called Service Cores. On site, the Cores are positioned perpendicularly to the façade, while locally built floors and exterior walls span longitudinally between them to generate the "Served areas" (living room, dining room and bedrooms).

The Service Core is to housing what the engine is to the body of an automobile, or to the fuselage of an airplane.

In Japan, the Sekisui-Heim's and Misawa Ceramics' compact steel-framed 3D modules can readily be used as Load-Bearing Service Cores for single-family housing; they are produced on fully integrated assembly lines identical to those of the automobile industry. In Canada, a precast concrete Load-Bearing Service Core is being developed to serve a variety of urban housing types.

Keywords: Load-Bearing Service Cores; Serving/Served Areas; Factory-Made 3D Modules; Local Resources; Adaptability.

Introduction

The demand for affordable quality housing is present in most countries of the world. In some countries, people are looking for better housing whereas in others, the quest to replace slums is ever increasing. "*Slums, especially in the developing world, are forming at a rate five to ten times faster than the rate targeted by the international community to upgrade them*" (Tibaijuka, 2003). "*Today, there are approximately 998 million slum dwellers in the world. UN-HABITAT estimates that, if current trends continue, the slum population will reach 1.4 billion by 2020*" (UN-Habitat, 2006).

Innovative methods are necessary. An obvious one is the application of industrialised strategies and technologies. If industrialisation is able to deliver complex goods like automobiles and electronic devices to the vast majority of people, there is no reason not to do it for quality housing.

Yes, some have made mistakes in trying to do it but that is not a reason to abandon the approach altogether.

Industrialised Building Systems

Industrialisation is, first and foremost. a mathematical equation; a large market ("quantity") will amortise (divide into marginal fractions) the initial investment in a technology capable of simplifying the production of a finished product. The result is an affordable product offered to the vast majority of people**.**

In the case of construction, the finished product should not be a standard building, as the user needs and sites are quite different each time. The finished product is preferably a "building system"; the same set of coordinated components or tools is generating a large quantity of buildings of different shapes, sizes, functions, and locations. In a building system situation, the details are identical but the buildings could all be different.

Building Housing Abroad

Many areas of the world depend on others to have access to highly industrialised building systems. Already important, the market will increase as international agencies, hopefully, devote more funds to solve the problem of sprawling slums. The bigger the market the better for industrialised building systems, as their feasibility is directly tied to "quantity".

Research methods

Research Hypothesis

The key criteria for selecting an industrialised system to "Build Housing Abroad" have to do with:

- Adaptability to different users;
- Distribution of the work between factory and site; and
- Response to the local context.

Which System?

Although there is no such a thing as the universal "best" system applicable anywhere, a set of specific "performance" criteria would be the most objective way to select an optimal type of system for "Building Housing Abroad".

Performance Criteria

"The concept of performance specifications relates to what products must do rather than what they must be…The concept of specifying by performance provides for new ways to meet a given set of criteria, and opens new opportunities for ingenuity and innovation in the development of new methods and technology, and potentially for new ways to meet the basic user requirements" (Ehrenkrantz, 1989).

Of course, many performance criteria could be outlined but, considering the specifics of aiming at different users in different geographical environments, the key ones have to do with (a) adaptability of the dwelling unit to a diversity of layouts, (b) distribution of the work between factory and site, and (c) response to the local context.

Adaptability of the dwelling unit

Wherever the location and whatever the cultural patterns, two types of spaces are present in any building: the "Served", and the "Serving" areas. These spaces are predominant features in the design of any building type.

The Served areas are completely open spaces, accommodating the main activities of the building and occupying most of the floor areas (± 70 to 80%); in housing they usually include the living room, dining room, family room, and bedrooms.

The Serving areas are support facilities of generic nature occupying a limited but strategic part of the floor areas (± 20 to 30%); in housing they normally include the kitchen, bathroom(s), powder room, laundry room, staircases, elevator shaft, mechanical shaft (water heater, electrical panel, HVAC machinery, etc.) and they integrate most of the electrical-mechanical conduits.

As each individual and each household is different from itsneighbour and different from himself/herself/themselves through time, the building system should provide flexible Served areas whereas the Serving areas, catering to more basic human needs, can display similar features from one dwelling unit to another.

Distribution of the Work between the Factory and the Site

Factory production offers climatic protection, justifies sophisticated production tools and handling equipment that can simplify the process, permits a rationalised distribution of the work along an assembly line thereby allowing for the use of semi-skilled labour, assures the conditions for a better quality control, provides a single delivery point for bulk purchasing, and eliminates all the usual wastes found on traditional construction sites.

The ultimate goal is to bring to the site 3D modules completely finished at the factory, but these are too expensive when building abroad, because a major part of the transportation cost goes to carrying "air" and because of probable conflicts within the local context.

An optimal industrialised building system would then maximize factory production, while minimizing transportation, especially when building abroad, and simplifying the work to do on site.

Local Context

Local resources and architectural heritage should be priorities in any given project, whether built by local or foreign contractors. Local resources make sense economically, at least for some parts of the process, and people are usually proud of their architectural heritage up to the point where a foreign design can be rejected.

Research Objectives

- The Served areas are completely open spaces accommodating the main activities of a dwelling unit whereas the Serving areas are support facilities of generic nature. As each individual/household is different from its neighbour and different from himself/herself/themselves through time, the building system should provide flexible Served areas whereas the Serving areas can similar features from one dwelling unit to another.
- Ideally, an optimal industrialised building system would maximize factory production, minimize transportation, especially when building abroad, and simplify the work to do on site.

Selecting an optimal building system for "Building Housing Abroad"

Which type of industrialised building system would better meet the three criteria?

As buildings are site-related and as technology is mostly factory-related, three basic building systems strategies are identified and should be considered: the Site-Assembled Kit-of-Parts, the Factory-Made Module and the Hybrid (Richard, 2007).

- The Site-Assembled Kit-of-Parts ("Meccano") strategy regroups the Post & Beam, the Slab & Column, the Panels, and the Integrated Joint. All the sub-systems, including the structure, are usually produced in large quantity at the component level in various specialised plants and transported separately to the site where an intensive series of jointing operations takes place. However, there is a major deterrent when building abroad; most of these jointing operations normally require skilled labour which, very often, has to come from the exporting country and at a very high cost due to transportation, premiums, and many other fees.

- In the Factory-Made 3D Module strategy, all spaces and all components of the building are entirely assembled and finished at the plant as 3D modules. "*The ultimate goal of prefabrication technology is to transport a finished product to the site*" (Utida, 2002). Once on site, they are rapidly attached to the foundations and connected to the main service entries, as well as between themselves. However, there is a major deterrent when building abroad; factory-made 3D modules are normally too expensive because a major part of the transportation cost goes to carrying "air", as most of the volume is occupied by the served areas (±70 to 80%), and because of probable conflict within the local context.

- The Hybrid strategy reaches for the best of both worlds, manufacturing at the plant the complex parts of the building and leaving the simple and/or heavy operations to the site. Three different approaches are proposed: the Load-Bearing Service Core, the Mega-structure, and Site Mechanisation. Load-Bearing Service Cores are factory-made 3D modules concentrating the Serving areas of the building and, once on site, acting as the sole vertical support of the Served areas.

Whereas the Site-Assembled Kit-of-Parts and the Factory-Made 3D Module strategies are confronted with major deterrents when building abroad, the "Load-Bearing Service Core" approach proposed within the Hybrid strategy is quite close to the performance criteria set above.

Research results

The Load-Bearing Service Core

The “Service Core” concept governs the architecture of many buildings. In a typical office building for instance, the Serving areas are usually clustered into a volume identified as the “Service Core”, mainly because of its key role in the building and because of its location at the very center, in order to leave the window frontage to the Served areas.

> “*Service cores are an increasingly important aspect of building design, architecturally, structurally, and from the building scientist’s point of view. This importance is attributed to many factors, not least of which is the increased level of mechanical and electrical (M&E) engineering systems within modern buildings… Some designers even regard the core as the most important part of the building*” (Yeang, 2000).

In the “Load-Bearing Service Core” approach applied to housing, the Service Cores are compact factory-made 3D modules containing all the Serving areas: kitchen, bathroom(s), toilet(s), laundry room, stairs, utility block, etc. The Cores are similar in size but their interior layouts can accommodate different equipments of different configurations and dimensions.

The transportation of those 3D modules, even for long distances, is justified by its high value-added content, by the fact that such content would have to be transported to the site anyway and by a geometry within the standards for road transportation.

On site, the Cores are positioned perpendicularly to the front of the building and spaced to generate the Served areas between them. The Service Core approach fully meets the sustainability agenda when mechanical (“dry”) joints are used in order to permit reconfigurations without any demolition.

The Service Cores become “thick party walls” acting as the single vertical “Load-Bearing” elements of the building, supporting the Slabs and Exterior Wall Panels sub-systems that constitute the Served areas. These sub-systems can be supplied locally: either prefabricated in regional plants or built right on site.

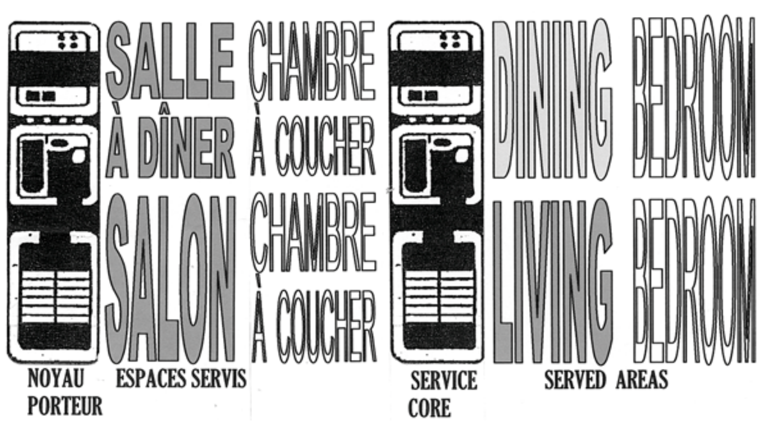

Fig. 1. Schematic distribution of Serving and Served areas in the Load-Bearing Service Core approach

Therefore, the Load-Bearing Service Core meets the three "Building Housing Abroad" performance criteria outlined above:

- The Served areas generated between the Cores are functionally adaptable, open to a diversity of scenarios and accommodating either "loft" or partitioned arrangements.
- The generic nature of the Cores provides the quantity required to benefit from a sophisticated mass-production line and its compact high value-added content justifies long distance transportation.
- The construction of the Served areas, and its adaptability to suit changing needs, is a simple activity which deserves to be done locally, both for economical and cultural reasons. The exterior wall panels are curtain walls connected to the Cores; they constitute an open sub-system in terms of materials and forms, and they can play a determinant role in responding to the local culture.

Service Cores are much more generic than the buildings they serve. Indeed, the Load-Bearing Service Core is to housing what the engine is to the body of an automobile, or to the fuselage of an airplane: a small but highly complex element essential to a series of variations.

Discussion and conclusions

Planning Discipline

The presence of transversal Cores at regular intervals (depending on the span of the floor structure – usually between 4.5 and 7.0 meters) does impose a strict planning discipline but it is a useful one, as those "thick party walls" help both with soundproofing and fireproofing. A discipline is not a constraint. A discipline can become an incentive for creativity; the discipline of the piano notes is the starting point for a great concert by the artist who masters them. To an imaginative designer, the transversal Cores are the elements of an architectural language offering variations at four levels: in planning the interior layouts, in planning the open space between the Cores, in treating the facades, and in combining the Cores to generate various geometries.

Frontage Constraint

In a standard dwelling unit, the "Serving areas" are usually parallel to the façade and located in the middle of the unit. As the Cores are perpendicular to the façade and as the "Served areas" still need comfortable dimensions, the total frontage will consequently be wider. That is a constraint (or a limit) of the system and, most likely, a factor increasing the linear distribution of infrastructures. However, there is a compensating reward; the transversal space offers visual transparency, natural cross-ventilation (comfort without air-conditioning), 360° vistas and, continuous day-lighting (including solar radiation gain if desired).

Two Options

Two options of the Load-Bearing Service Core approach are presently or prospectively available:

- Steel-framed lightweight Service Cores suitable for single-family housing, detached or attached, readily available from Sekisui-Heim and Misawa Home in Japan;
- Precast concrete Service Cores suitable for single-family attached or multifamily housing, being developed in Canada.

Steel-Framed Service Cores from Japan

In Japan, Sekisui-Heim and Misawa Ceramics are producing 3D modules on fully integrated assembly lines, identical to those of the automobile industry, and capable of generating a different house each time. No single house is like another. Sekisui-Heim and Misawa Ceramics achieve diversity notably by combining different standard components within a modular multipurpose framework, thereby fully applying the concept of “mass-customization” (Richard and Noguchi, 2006).

Fig. 2. Typical Sekisui-Heim assembly line

A regular single family house would require 12 to 16 modules, which makes them too expensive for exportation to most foreign markets, since an important part of the cost would go to carrying “air” and because there would be too many jointing operations on site. However, shipping only 2 to 4 “Core Units” containing all the services and equipments (the most expensive parts) is something else.

A Research Fellowship from the Japan Society for the Promotion of Science (JSPS) was granted to the author in the Fall of 2007, in order to do research at the University of Tokyo on the implementation of Japanese 3D “units” as Load-Bearing Service Cores. The research was undertaken with the support of Dr Shuichi Matsumura, Professor at the Department of Architecture and Head of the Matsumura-Fujita Lab.

The conclusion is a recommendation to consider the Sekisui-Heim and Misawa Ceramics modules as ready to be used as Load-Bearing Service Cores for single family detached or attached hosing all over the world. The conclusion is based on the fact that these modules are structurally rigid, autonomous, of extremely high quality, and close to the size of a container; they are framed at the edges, thereby leaving each horizontal or vertical plane completely adaptable.

The great advantage of the Sekisui-Heim and Misawa Ceramics modules lies with the fact that they are produced on sophisticated assembly lines which have been operational for more than a quarter of a century. Obviously, the investment is quite amortised by now. The fact that these assembly lines are presently not running at their full capacity does increase their availability for a Load-Bearing Service Core version.

A Load-Bearing Service Core version would be processed exactly like a regular 3D module. The operations would be initiated by a regular purchase order and no modification of the production line would be necessary. Produced in Japan, the Cores can then be easily shipped anywhere in the world and combined with local technology.

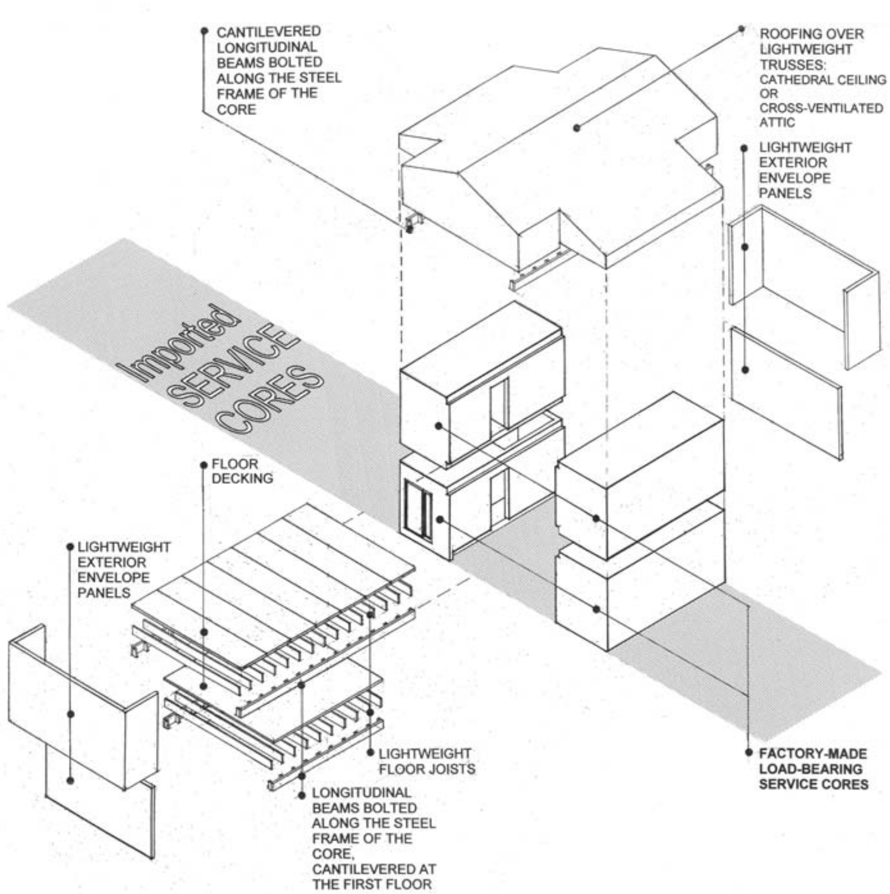

Fig. 3. Typical combination of Japanese factory-made Service Cores with local technology

On site, longitudinal beams bolted along the steel frame of the Cores will support the components of the Served areas between them:

- Lightweight Floor Joist options (wood or open-web steel, pre-engineered wood “I”, or “PSL” or LVL”) or Slab options (stressed-skin wood, lightweight-steel concrete composite, steel decking, etc.).
- Lightweight Exterior Envelope Panels options (stressed-skin, wood or steel lintels, metal curtain walls, fibreglass reinforced polyester sandwich, lightweight concrete, bamboo lattices, steel framed, mashrabiya screens, etc.).
- Variable roofing options.

Sekisui-Heim would use a proprietary adaptor to reach the exact dimensions and geometry of an ISO container, removing and bringing the adaptor back at the plant once the Core reach its final destination.

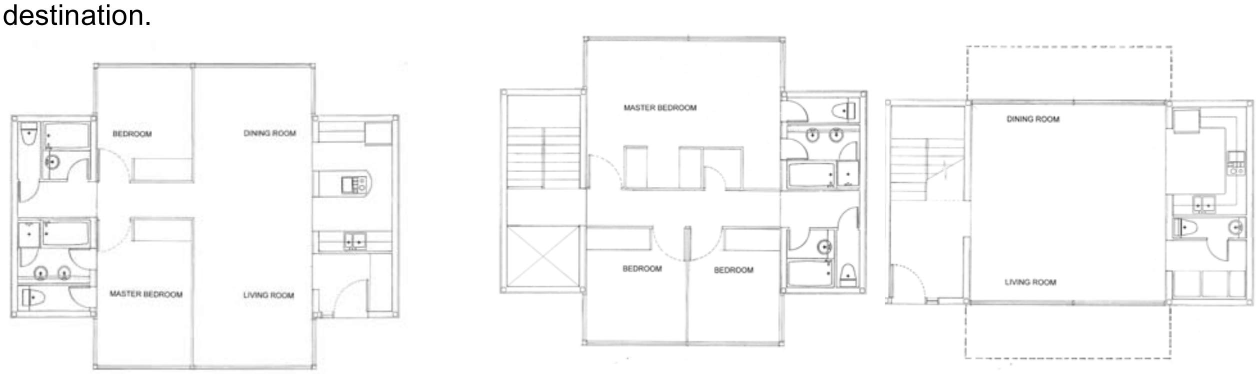

Fig. 4. Typical floor plans of single level and of “maisonette” single-family detached houses using Sekisui-Heim 3D “units” as Load-Bearing Service Cores

Misawa Ceramics is already producing the equivalent of the Load-Bearing Service Core with its “Hybrid-M” series. Initially, the objective was to avoid transporting “empty” 3D modules to the site i.e. to avoid carrying “air”.

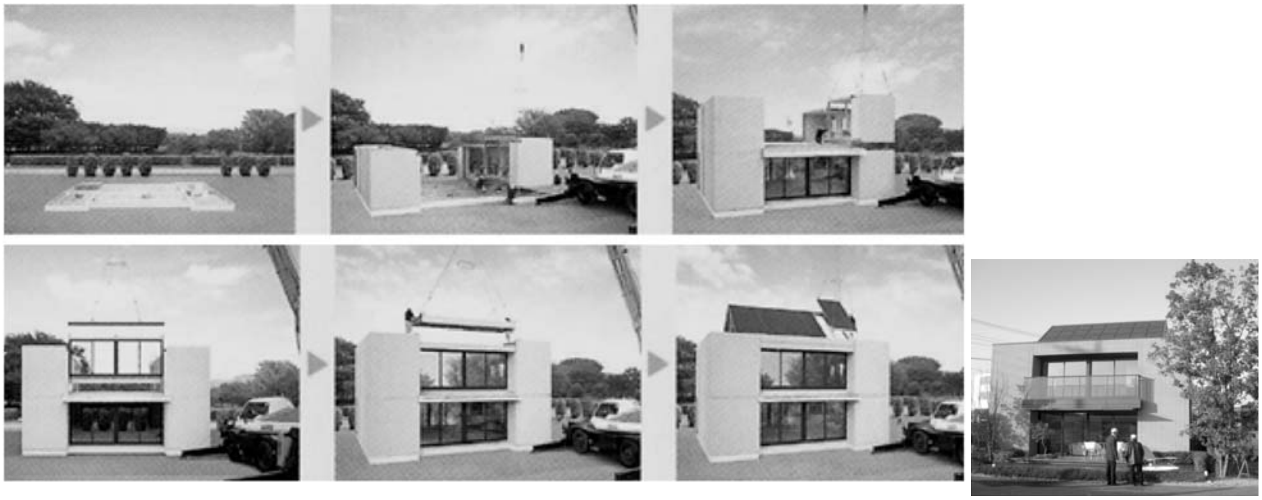

Fig. 5. Assembly of a typical Hybrid “M” house produced by Misawa Home

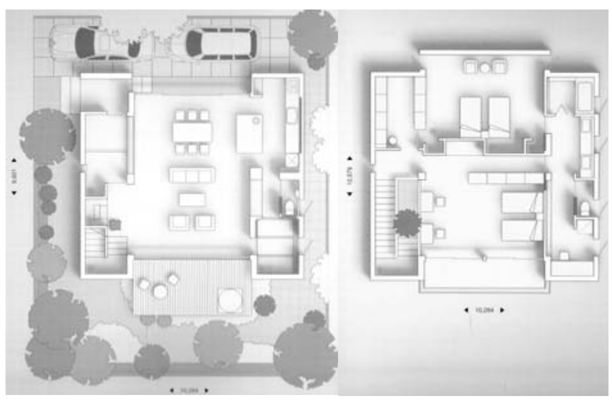

Fig. 6. Floor plans of a typical Misawa Hybrid “M” model

Precast concrete Service Cores from Canada

When urban housing is required, precast concrete cores are most appropriate, notably to meet both the fireproofing and soundproofing criteria (Richard, 2005). The *Richardesign* precast concrete Load-Bearing Service Core system is presently being developed in Quebec, Canada. The Core is exactly the size of an ISO container. Its production will be shared between a precast concrete plant for the shell and a modular housing factory for the installation of the services & equipment, together with the finishing. The shell can be produced in two moulding operation: casting the walls and ceiling shell through collapsible formworks, and the floor panels on a regular horizontal casting table.

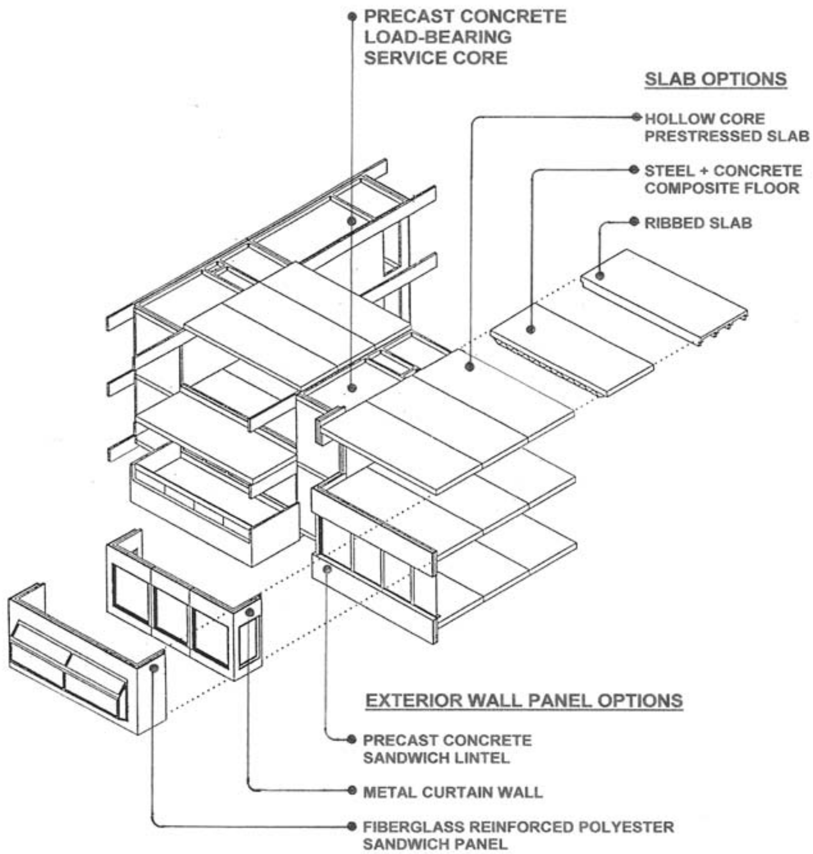

Fig. 7. Combination of *Richardesign* precast concrete Load-Bearing Service Cores with Slab and Exterior Wall Panel sub-systems

Produced in Canada, the Cores could then be easily shipped anywhere in the world and combined with local technology; the total weight is still under the weight-volume ratio conditioning for maritime transportation. On site, longitudinal beams bolted along the Core will support the components of the “Served” areas between them:

- Slab options (hollow core pre-stressed, steel-concrete composite, ribbed, etc.)
- Exterior Wall Panel options (precast concrete sandwich lintel, metal curtain wall, fibreglass reinforced polyester sandwich, metal sandwich, lightweight concrete, etc.).
- Variable roofing options.

Most housing types and groupings are available: straight line (with a rectangular slab) or curved (with a trapeze-shaped Slab); single level, two-storey “maisonette”, or split level (when the cores are staggered vertically); plurality of sizes (from the small 1½-Core low cost R+4 apartment to the large 5-Cores condominium or townhouse).

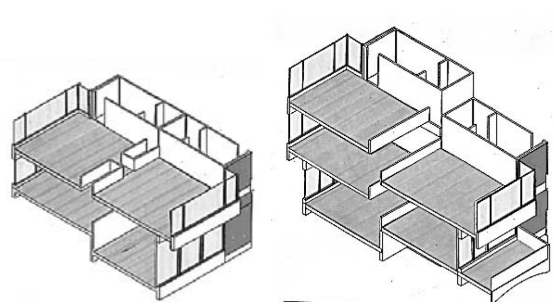

Fig. 8. Typical *Richardesign* Load-Bearing Service Core townhouses

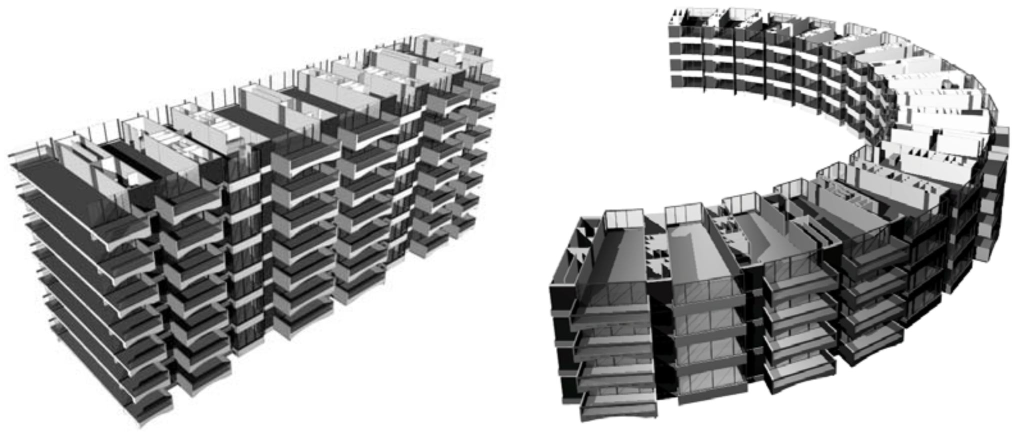

Fig. 9. Typical *Richardesign* Load-Bearing Service Core multifamily housing

Procurement

The Core should be considered as a sub-system and its manufacturer as a subcontractor. The mass-customization potential of the Core is available to any project that follows the modular coordination and the interfacing details. Purchase orders will govern the production and the manufacturer will normally transport, as well as install the Cores on the site. The general contractor or its equivalent will schedule the interactive installation, prepare the foundations and coordinate the Core-Slabs installation sequence, whereas the installation of the Exterior Envelope Panels and Roofing can be completed independently later. The responsibilities are easy to distribute as the boundaries between the Core and the rest of the building are clearly defined.

Key Lessons Learned:

- Load-Bearing Service Cores are factory-made 3D modules concentrating all the Serving areas of the dwelling unit. Their compact high value-added content justifies long distance transportation and, positioned perpendicularly to the façade once on site, they act as the sole vertical support of locally built Served areas, open to a diversity of scenarios.
- The Load-Bearing Service Core approach is introducing a planning discipline of its own; a wider façade is imposed but that constraint is balanced by a Served transversal space offering visual transparency, cross ventilation, and continuity with the path of the sun.
- The compact lightweight steel-framed 3D modules presently produced in Japan by Sekisui-Heim and Misawa Ceramics are ready to serve as Load-Bearing Service Cores for single-family housing. The precast concrete Load-Bearing Service Core presently developed in Canada is specifically designed to serve a variety of attached single-family and multifamily types.
- The Service Core is to housing what the engine is to the body of an automobile, or the fuselage of an airplane. Full of value-added elements and compatible with the geometry of a container, the Load-Bearing Service Core can easily be transported anywhere in our globalised world, to developed or developing countries alike, and/or be the object of a technology transfer.

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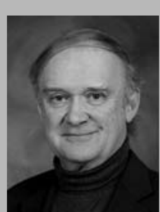

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