Life Cycle Assessment of Support/Infill Housing in House Japan Project

Shuichi Matsumura, Prof., Dr.Eng.

Dept. of Architecture, School of Engineering, the University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo, 113-8656 Japan
TEL81-3-5841-6152  FAX81-3-5841-8518
smatsu@buildcon.t.u-tokyo.ac.jp
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ABSTRACT:
House Japan Project was a seven years (April 1994 - March 2001) research and development project conducted by former Ministry of International Trade and Industry (MITI) in Japan. In this project, in which about forty companies had participated, one of its four major purposes was to improve life cycle performances of Japanese house-buildings. To realize that the open building concept was applied and about ten companies developed their own new infill systems. In this paper those infill systems are introduced at first. In the last year (from April 2000 to March 2001) two kinds of integrated design of single-family dwellings and multi-family dwellings using those infill systems were the major tasks of the members of House Japan Project. In this paper life cycle assessment of those integrated design is shown secondly. Lastly based on the results of House Japan Project, the effectiveness of the application of the open building concept is discussed.
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Introduction
House Japan Project, former MITI’s (Ministry of International Trade and Industry) seven years technology development project for house-building in Japan, finished at the end of March in 2001. In this project, which 38 companies participated in, about seventy themes had been tackled. Those can be classified into four groups shown as below.
(a) establishment of performance evaluation and indication system using IT
(b) realization of long-life residential building using support / infill concept
(c) improvement of indoor comfort
(d) improvement of energy saving in residential buildings
As for the theme(b), ten companies, which included six component and material manufacturers, three general contractors and one detached house manufacturer and supplier, developed each infill system or infill component and four companies were engaged in development works to improve the capacity of support systems.
In seven years each of them built one unit or one room at the least to find out what to improve. In the sixth year some of them participated in an experimental building project of multi-family dwellings, which was named Flexsus 21. In the final year of the project, they designed one detached house and one condominium using every infill system or component developed in order to examine the superiority of life cycle cost saving.
In this paper the result of the final examination is shown after classifying those infill system and component development in House Japan Project.

Infill Systems and Components Developed in House Japan Project
Infill systems and components developed in House Japan Project can be classified into three groups as shown below.
(a) Interior components which can be easily installed and changed by residents
(b) Integrated infill systems for effective construction and alteration
(c) Changeable sanitary equipments

Interior Components for DIY installation
1. A Partition Wall System for Detached Houses by Juken Sangyo Co.,Ltd.
The purpose of the development by Juken Sangyo is to realize a partition wall system which is easy for residents to install and move. The final system is composed of LVL (Laminated Veneer Lumber) attachment parts and 600mm wide panels made of LVL frames, paper honeycomb and MDF (Medium Density Fiberboard) boards. In this system wiring is easily placed between one attachment part and another.
Their experimental installation by two persons made clear that this system reduced the installation time by 40% and the remove time by 60%. And they estimated that alteration works cost using this system could be less than a third of that using conventional methods although the initial installation cost for this system could be 1.3 times as high as conventional construction.

2. A Partition System for Detached Houses by Sumitomo Forestry Co., Ltd
The purpose of the development by Sumitomo Forestry is similar to that by Juken Sangyo. The system is composed of partition walls, partition furniture and DIY assembling doors. Based on the fact that more than 80% of Japanese residents have only small screwdrivers, cutters and a hammer concerning DIY tools, this system is designed to be installed only with those three kinds of tools. And in this system almost components are not panels nor boxes but boards in order to make handling works easy for residents.

3. Floor Finish Components by Dantani Corporation
Those who want to change floor finish from carpets or tatami mats to wooden floorings for better indoor air quality have recently increased in Japan. Dantani focuses on this kind of demands. In stead of conventional wooden flooring components fixed by nail attachment and adhesion, they developed thin finish boards to be easily cut and fixing system with adsorption tapes.
Their products were developed on the basis of fact-finding studies about Japanese residents’ skill. After several experimental installation they realized floor finish components which can be fixed for about 7 square meter room in two and a half hours by residents themselves. Although their material cost is about 1.4 times as high as that of general wooden flooring components, their total cost can be reduced by 30% because of 100% reduction of labor cost.

4. A Ceiling and Partition Wall System for Multi-family Dwellings by Obayashi Corporation
Obayashi Corporation developed their own ceiling and partition wall system for multi-family dwellings. As they introduced the details of integrated ceiling and removable partition wall system for high-rise office buildings to such residential buildings, they could reduce the labor cost for changing the floor layout as well as the initial construction and made residents’ work possible while the material cost increased. At the final phase they redesigned the details to have two kinds of systems. One is called “general type” which uses cheaper materials to reduce the material cost. And the other is called “SOHO type” which uses rather expensive metal details to make changing works simpler, for SOHO (Small Office Home Office) seems to need more frequent changes of floor layouts.

Integrated Infill Systems for Effective Construction and Alteration
1. An Infill System for Multi-family Dwellings as well as Detached Houses by Matsushita Electric Works, Ltd.
Matsushita Electric Works’ infill system is composed of raised floor components, suspended ceiling components and partition wall components. The partition wall, which has
been the focus of their development, is composed of general-purpose wall materials and highly accurate and durable aluminum stud columns. They can be disassembled by removing the screws and nails and reassembled to be used in other areas. Wiring devices and wires are installed within the stud columns’ area so that they can be easily changed even after the wall is finished.

2. An Infill System to Realize Special Use Room by Nippon Sheet Glass Co., Ltd.
Nippon Sheet Glass tried to respond to the change of residents’ life stage with value-added infill systems. They gave attention to remodeling works from general rooms to care-rooms for elderly people or sound-proof rooms for those who wanted to enjoy their specific audio visual devices and playing instruments. Their system is mainly composed of panels. Their experimental construction showed the necessary man-power could be reduced by 78% and removing cost by 14% in case of the care-room type. Also they made sure of the noize-reduction performance of the sound-proof room type.

3. An Infill System for Multi-family Dwellings by Takenaka Corporation
Takenaka’s system is composed of six kinds of components. The first ones are movable storage partition components which enables woman’s DIY works without the sacrifice of their sound-proof performance. The second ones are sliding walls which ease the short-term change of the floor layout with not so much sacrifice of their physical performance as partition walls. The third ones are light weight partition wall components using steel which enable residents’ installation and alteration. The forth ones are wiring components at the bottom of the partition walls and around the doors which can be changed independently from partition walls and floors. The fifth ones are simple raised floor components. The sixth ones compose the HVAC system which can follow various changes of the floor layout using the space under the floor and above the ceiling as chambers for HVAC system. Their experimental construction confirms 23% reduction of the alteration cost and 56% reduction of the alteration time compared with conventional methods, while they know 23% increase of the initial construction cost because of components manufactured outside of the general production line.

4. An Infill System for Multi-family Dwellings by Kajima Corporation
Kajima developed not only their own infill system but also the design technique utilizing the infill system. Their infill system is composed of partition wall components and new wiring devices. As to partition walls three types of movable partition wall components are developed so that designers can select appropriate partition wall components to meet the required specification for uses, locations and so on. In the development of the new wiring devices, centralized control functions of electric lines are realized with loop series wiring using optical fiber in order to make the change of wiring easier. The design technique developed is called “Free Choice System”, which allows expected residents to do computer-aided design of the suitable floor plan by combining the selected layout variations in each of three zones- the family zone, the sanitary zone and the private
zone. They can utilize this CD-ROM based system in case of remodeling as well as newly building.

**Changeable Sanitary Equipments**

1. **A Flexible Sanitary Plumbing System by INAX Corporation**

   In order to clearly separate infill from support in case of multi-family dwellings, it is important to locate the common piping space outside of each housing unit. But as drainage pipes need appropriate slope the freedom of floor layout of each housing unit is often limited by the location of common vertical pipes. To overcome such difficulties and improve the freedom of the layout of the infill, INAX developed a new plumbing system using a pressure pump. Concerning the pressure pump, two types- 200V type and 100V type are developed to minimize the noise and vibration problem and to make maintenance simple. As for the piping system, compact integrated piping space under the floor or on the wall is designed to save related construction works in case of piping works and to secure maintenance accessibility for piping. As the result of that, construction time for changing the layout of the sanitary space can be reduced by more than 50%.

2. **A Partly Changeable Kitchen System by TOTO Ltd**

   TOTO’s fact finding study clarified that kitchens needed to be remodeled once every 15 years in average and the construction cost was almost equivalent to that of new kitchen cabinets and built-in appliances themselves in Japan. In order to reduce the construction cost, a kitchen system is developed using a framework to which cabinets and built-in appliances can be attached and that minimizes the necessary work for integration of the kitchen cabinets and built-in appliances into a house’s structure. With this system kitchen remodeling can be a DIY project, since residents only need a screwdriver to replace components. They estimate that this system yields an overall savings of 30% if a kitchen is remodeled twice, while the price of the kitchen furnishings is higher by 80% than conventional ones.

**The Life Cycle Effect of Utilizing the Infill Systems and Components**

In the last year of the project, integrated design and life cycle cost estimation groups were organized. There are two groups. One is the detached houses group including Juken Sangyo, Sumitomo Forestry, Dantani, Nippon Sheet Glass, Matsushita Electric Works, INAX, TOTO and Mitsui Home which has developed technologies for support. And the other is the multi-family dwellings group including Obayashi, Matsushita Electric Works, Takenaka, Kajima, INAX and three other companies which have been engaged in other themes than infill system development.

Conditions for the life cycle cost estimation in case of detached houses group are defined as shown below. Those in case of multi-family dwellings group are similar.

1. to omit energy cost for living because the purpose of estimation is to compare their design to an ordinary house design and no difference of thermal performance is between them
2. to suppose that the cost for remove and demolishing will increase by 10% every 15 years
3. to neglect the increase of prices, interest and rent
4. to suppose that, only in case of their design, it will be unnecessary for residents to move out to another house when floor plan alteration will be executed
5. to include even repairs and changes of small parts
6. to use up-to-date prices

A scenario was prepared for estimating life cycle costs. The outline of the scenario for a detached house is:
a. large alteration of floor plan will occur in the fifteenth year
b. In the thirtieth year a two story conventional house will be demolished and a new three story house will be built, in which the third story will be added with the technologies developed in House Japan Project according to each company
c. A special care-room will be needed in the forty-fifth year and be removed in the fifty-second year
d. In the sixtieth year both will be demolished.

The outline of the scenario for a multi-family dwellings’ case is:
e. large alteration of floor plan of all the fifty-three housing units in a nine story building will occur in the fifteenth, the thirty-fifth, the fiftieth, the sixty-fifth and the eighty-fifth year
f. large renovation works for common facilities and common space will be executed in every twenty-five years
g. a conventional building will be demolished and rebuilt in the fiftieth year, while the building following their design will last for a hundred year because of the upgrading of support and the application of support / infill concept.

Consequently, while the initial cost of the integrated design in House Japan Project is higher than that of conventional design by 10% in case of detached houses and by 7% in case of multi-family dwellings, the life cycle cost of the integrated design is lower than that of conventional design by 27% in case of detached houses during sixty years and by 23.5% in case of multi-family dwellings during one hundred years.
In the detail of multi-family dwellings’ case, the reduction rate of life cycle cost of each infill system or components compared with its conventional counterpart is: (fig.1)
Simple raised floor components (Takenaka) : 54.12%
Movable storage partition components (Takenaka) : 28.66%
Wiring components (Takenaka) : 20.93%
Movable partition components (Kajima) : 20.93%
Changeable doors (Kajima) : 20.69%
Partition walls (Matsushita Electric Works) : 20.93%
Ceiling components "general type" (Obayashi) : 31.65%
Flexible sanitary plumbing system (INAX) : 17.12%

Conclusion
Thus the application of those infill systems and components are examined to be effective especially from the viewpoint of life cycle cost, owing to their continuous improvement through experimental construction. But it should be understood that life cycle cost estimation much depends on supposed conditions and a scenario. It is why some detailed explanation is done in this paper. The conditions can change following the design and the scenario can differ in each country.

In Japan the results shown here may have persuasive power in the real industry. The rest of difficulties against the diffusion of those new technologies is to organize housing process using those. For that, every participant in housing should understand the fact that housing means long lasting continuous process in stead of the former story that housing means building a new house.
References