Development and Construction of Durable Housing
--Kodan-Type Skeleton and Infill Housing (KSI Housing) Model Project--

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1. Background of the Development

At the present dawn of the 21st century, our surrounding natural environment and social structures are continuing to change. With this, our personal values and everyday consciousnesses are also changing.
In the housing sector, sustainable buildings that aim to save resources, to reduce waste, and to become a high quality stock of society are needed.
It is also necessary to note the change in tenants' consciousness. Because of the diversification of family structures and of lifestyle, new forms and functions of housing are required. Further, these needs are changing day by day. We can say that the required housings are those that properly respond to the diversified and changing needs of the tenants.
In addition, much of the housing complex stock which has been constructed already requires renewals in the functions in order to respond to the needs of the present day. The Urban Development Corporation (UDC), in addition to renewals through rebuilding, has been carrying out renewal projects in order to respond to the present needs since 1999. These improvements involve adjustments to the facilities, interiors, or, as the case may be, layout, mainly to housing stock constructed in the late 1960s and early 1970s. However, in the renewal of these housing stocks, drain pipes or ventilation pipes that pierce through the existing building, or complicated body skeletons, act as obstacles for renewal plans and construction. In the removal or new construction of the existing interiors, facilities or equipment, or wires and pipes, many problems remain to be solved for construction that is conducted in inhabited residential buildings. Such problems include noises and vibrations.
We are currently living in a time in which the needs of society demands the development and popularization of a new type of housing which is capable of responding to these issues.
One new housing type which responds to such needs is Skeleton and Infill (SI) housing. SI housing makes a clear distinction between the skeleton, which is required to give a house long-term durability, and the infill, which is required to be adaptable to allow modifications or renewal. Thus, SI housing is long-term durable housing in which both the skeleton and infill is improved in terms of durability and adaptability. As SI housing is expected to be very effective in solving the abovementioned problems of present housing complex, UDC has been promoting the technological development,

construction, and provision of Kodan-type SI housing (hereafter referred to as KSI housing; "Kodan" is a Japanese term for UDC that builds public housing).
This is a report on the technological development and the model project of KSI housing.

2. Outline of KSI Housing

2. 1. Concept of KSI Housing

In KSI housing, not only are the portions for common use and exclusive use distinguished by the skeleton and the infill, but also for each portion, such distinction is made in consideration of durability, adaptability, adjustability, and other such properties.
In KSI housing, the skeleton is the structural flame and the common facilities, while the infill is the interior and the exclusive facilities (exclusive infill) as well as non-structural walls such as outer walls and border walls (common infill), including sashes.
There are three concepts KSI housing technology development: open use, economic efficiency, and practical use.
This means that the technological requirements are determined on the precondition that the technology has open use that allows applicability for housing complex other than UDC housing, and also for the purpose of putting SI housing into practice sooner by an economical design which lowers the costs.
Further, in terms of the approach to adaptability of interiors or facilities inside the house, there are three levels of adaptability: adaptability of use (adaptability in which uses other than residential use are assumed), adaptability of floor area (adaptability in which removal or addition of the boundary walls for changing the floor area of the apartment is assumed), and adaptability of layout (adaptability in which changes of the partitions or interiors under the fixed apartment scale is assumed). Through such a system, it is possible to set the necessary adaptability that is suitable for individual projects, so as to give economic efficiency to design.

2.2.Significance of KSI Housing

UDC summarizes the significance of KSI housing from the following four perspectives:

1) Construction of long-term durable buildings which are suitable for sustainable and recycling-oriented society
   Contributes to reducing the burden to the natural environment by means of high adaptability for renewal or modification, furnished from a long-term durability body
2) Response to the changes of tenant lifestyles
   Creates residential space which can respond with flexibility to various needs such as changing lifestyles or family forms
3) New developments in the housing industry
   Anticipation of the development of a new housing provision system which is

suitable for the stock oriented society in which houses are resided in for the long-term with occasional changes to the plan of housing unit, and creation and the vitalization of an infill industry which supports such a system

4) Formation of a sustainable and high-quality streetscape
   Creates a lively streetscape through the combination of the skeleton, which maintains the familiar street frame, and the infill, which can flexibly respond to changing needs of the street

On the basis of such meanings, UDC is focusing on synthesizing technologies in its SI housing technologic development activities. At the same time, UDC is indicating future directions based on the needs of society in response to the development of elemental technologies by each of the private makers and general construction companies, and gathering such elemental technologies. Thus, UDC is actually promoting the construction and provision of SI housing.

2.3. History of the Development of KSI Housing

Figure 1 shows the technological development flow of KSI Housing. UDC has been carrying out in full scale the technological development of KSI housing since 1997. It constructed an experimental KSI housing building in 1998, which is at present around Stage 3 or Stage 4 of development.

In the model projects of Stage 3, more practical examination is carried out through applying the elemental technologies of KSI housing for actual projects. This includes designing with the cost balance, detail development, actual measurement of sound insulation or other functions, and cost analysis, as well as examination of the ordering system and provision system.

In Stage 4, the standardization by degree of KSI housing in UDC housing construction will be promoted, based of the achievement of the model projects.

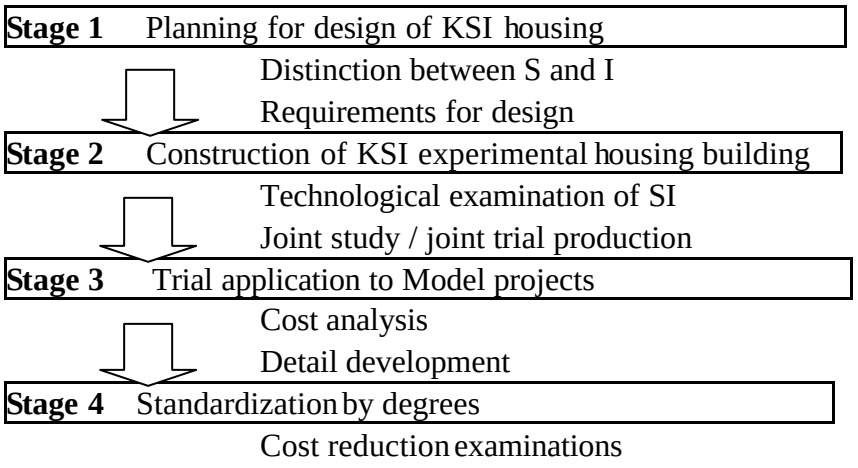

Figure 1 The Program of KSI housing project

2.4. Design criteria for KSI Housing

UDC has determined the following criteria be satisfied in designing KSI housing in high-rise or middle-rise buildings. These criteria are determined from the aforementioned concepts of open use, economic efficiency, and practical use. The current criteria are shown as follows:

1) Structure life of 100 years.
2) One large floor slab without unevenness and sub-beams.
3) Vertical drain pipes for common use is installed outside the housing units.
4) Electrical wiring should be separated from the structure.

It should be noted that the way to design the infill is not particularly determined in these requirements. This is because there should be fewer limitations for the infill design to allow greater freedom. Needless to say, it is desirable that the infill is freely designed on the basis of the tenants' needs and that such freedom will be secured in the future.
However, the houses for lease supplied by UDC are managed by UDC over the long-term. In such a situation, the infill design or construction should not be entirely under the needs of the tenant, and thus there must be certain restrictions.
Regarding the interior design of KSI housing model projects, the interior is basically prepared by UDC for provision. However, there are some projects that, in the stage of design planning, adopt movable partitions and other such fixtures so that the tenants can carry out layout changes or repair work as easily as possible.

2. 5. Construction of the Experimental KSI Housing Building

UDC constructed the experimental KSI housing building at the Technology center in Hachioji City, Tokyo, in 1998. There, the elemental technologies for SI housing are developed and examined, and joint development and research is carried out with private businesses which have related technologies
This experimental building is a 2-story, pure rigid frame reinforced concrete structure. Structural calculations allow for up to 11 stories. The building is 3-span, and composed of 6 rooms. One KSI infill model apartment, planned by UDC (Figure 5), as well as three private infill models constructed on the basis of the joint study and trial production with private businesses, have been completed. There, various experiments on construction and flexibility are carried out.

Since the design for the experiment building is that of the experimental facilities, the level and scale of adaptability is set rather high. The elemental technologies are adopted accordingly.

3. Model Projects

3.1. Outline of Model Projects

A model project refers to a project in which the KSI housing model is applied to the actual construction or provision carried out by UDC. For "hardware" aspects, high feasibility examinations are carried out on details, cost, and construction by applying the elemental technologies which have been examined before constructing the experimental KSI housing for actual design. For "software" aspects such as business methods and provision methods, a method utilizing the new hardware aspect of SI is sought and tested. For this purpose, UDC has begun pilot construction of KSI housing in the volume several projects per year, with considerations to the locations and the nature of the projects. The order was placed for the construction of the first project at the end of FY1998, and so far four model projects are under construction. There were also orders placed for KSI projects in FY2000 and 2001. In this report, the designing details and product planning of three projects that are being constructed in the Tokyo area are introduced among these three projects mentioned above. The outline of the projects is shown in Table 1.

	Sangenjaya project	Meguro project	Shiodome project
Location	Setagaya-ku, Tokyo	Shinagawa-ku, Tokyo	Minato-ku, Tokyo
Year of order	FY1999	FY1998	FY1999
Number of stories	6F	9F / 12F / 6F / 13F	56F (2 basement floors)
Number of rooms	47 rooms	484 rooms	About 770 rooms (683 UDC rooms planned)
Total floor area	About 3,900 sq. meters	About 38,400 sq. meters (total area of buildings No. 1 to No. 4)	About 88,000 sq. meters (skyscraper building)
Structure	RC quake-resistant wall rigid framework	RC quake-resistant wall rigid framework	RC pure rigid framework
Slab Form	One large floor slab without unevenness and sub-beams	One large floor slab without unevenness and sub-beams (buildings No. 1, 3)	One large floor slab with unevenness
Concrete	water –cement ratio: 55% or less Fc 24N / mm 2 or more	water –cement ratio: 55% or less Fc 27N / mm 2 or more	water –cement ratio : 55% or less Fc 27N / mm 2 or more
Main floor height	3000 mm	2875 – 2950 mm	3250 mm (floor of a private business's leased residence) 3050 – 3150 mm (floor of a UDC's leased residence)
Vertical pipe for drainage	Set in the common use portion (within the plane of structure)	Set in the common use portion (outside the plane structure in the buildings No. 1, 3)	Set in the common use portion (within the plane structure)

Drainage inclination angle	Drainage header system, inclined at an angle of 1 /100	Drainage header system, inclined at an angle of 1 /100 (buildings No. 1, 3)	Drainage header system, inclined at an angle of 1 /100
Wiring for electricity	Separated from the structural body in the exclusive use portion	Separated from the structural body in the exclusive use portion	Separated from the structural body in the exclusive use portion
Ceiling lighting system	Inside the double ceiling	Inside the double ceiling	Inside the double ceiling

Table 1 Outline of KSI housing model projects in the Tokyo area

3.2. Sangenjaya prpject

Sangenjaya project, which is located within walking distance from the Tokyu Sangenjaya Station in Setagaya-ku, Tokyo, was previously the site of Meiji Pharmaceutical University and is now developed jointly by UDC and a private business. Existing trees still remain on the site, which is about 3 ha in area. Construction is planned for 8 high-rise UDC residential buildings for a total of 523 rooms for lease, and 3 high-rise private condominiums for a total of 109 rooms for sale, as well as facilities for life support such as a convenience store. Thus, this is a project to provide a convenient urban residence.

In the planning of the housing, because sub-beams or vertical drainage pipes do not appear inside the house. As a result, the flexible housing plan enables the tenants to choose their own layout as by moving the partition fittings furnished by UDC or furniture that can be used for a partition.

Further, in this area, the condominium constructed by the private business also adopts the private business SI housing system.

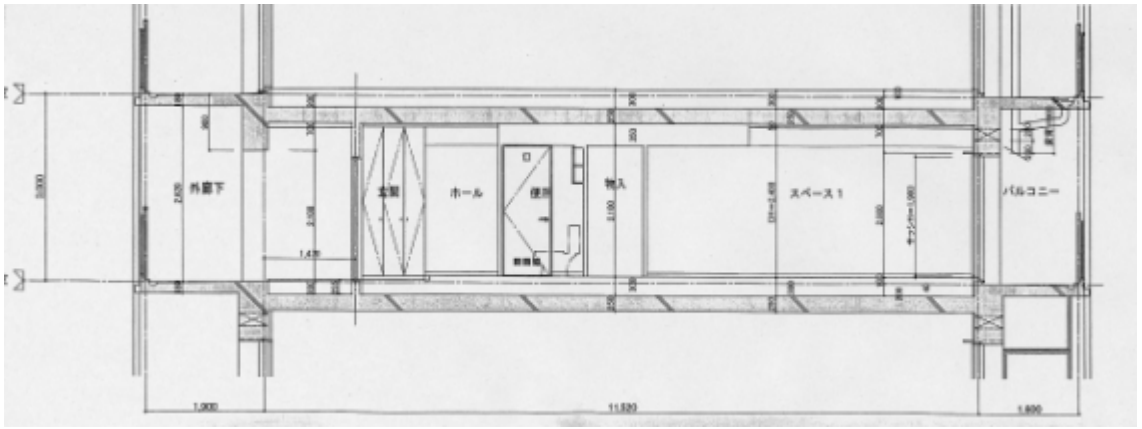

Figure 2 Section of the apartment

3.3. Meguro Project

Meguro Project is located in Shinagawa-ku, Tokyo, and is a 2 minutes' walk from JR Yamanote Line. As it is located in a place which is particularly convenient for

transportation in the center of Tokyo, this is UDC's representative project for metropolitan housing.
As the buildings of inside corridor type have four planes of structure, the sanitary facilities are only placed in the corridor side. The residential building facing north adopts a structure in which the reverse beams are set only the balcony side.
In the product planning, on the other hand, public contribution is invited for a new infill design which, utilizing the advantages of KSI housing, responds to metropolitan residential style, while proposals are made for a new residential style which responds to metropolitan housing lifestyles. Figures 3 show examples of interior design proposed by public contribution. In the same skeleton, different styles of housing responding to different lifestyles of different individuals are proposed.

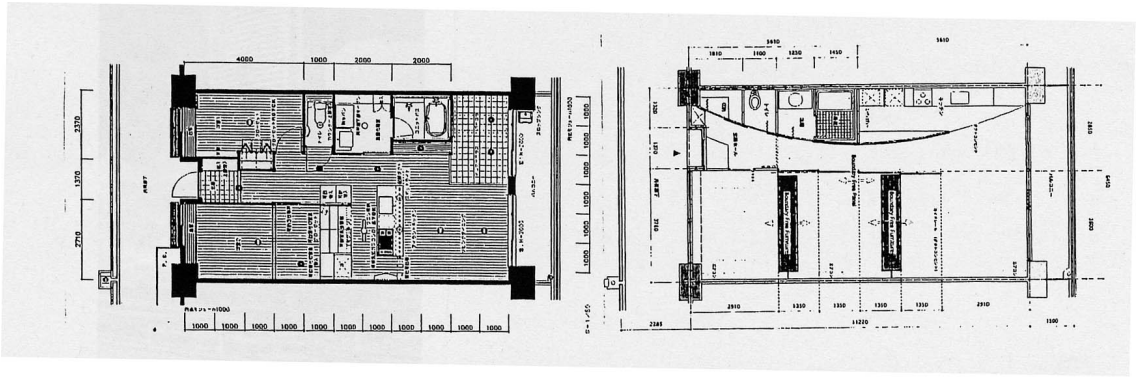

Figure 3 Meguro project, examples of proposed interior designs
Both of the right and the left examples are proposed to the same skeleton

3.4. Shiodome project

Shiodome project is one of the development projects by Minato-ku, Tokyo, for the site which was previously the location of JR Shiodome. It is a zone near Hamamatsucho Station of the JR Yamanote Line. The Shiodome site development has planned residential buildings as well as business and commercial establishments, such as headquarters buildings for some of Japan's biggest businesses and hotels. In such a context, UDC is carrying out the construction of a skyscraper residential building of 56 stories for lease.
In principle, UDC's policy is that skyscraper residential buildings should be constructed as KSI housing. This is due to the facts that common design specifications for skyscraper residential buildings are similar to the designing policy for KSI housing, and that many parts are different from those of the high-rise residential buildings of one side corridor type which are most popular type of buildings for resident in Japan.
Principal features of UDC's design specifications for standard skyscraping residential buildings are as follows.

1) High strength reinforced concrete is used. So concrete have enough durability.
2) For structural reasons, many of them have a pure rigid frame, they don't have shear

walls. So we can set plan without restriction of shear walls..

3) As it is necessary to install a sprinkler, a double ceiling must be used. We can separate electrical wire from structural body easily.

Therefore, if facilities such as drainage vertical pipes for common use are set outside the apartment in addition to the conventional design specifications for skyscrapers, it is comparatively easy to satisfy the designing requirements for KSI housing.

The floor heights of the skyscraper residential building in Shiodome project are set in three types: 3050 mm, 3150 mm, and 3250 mm.

Further, in Shiodome project, UDC has adopted a new project system of skeleton house leasing for the first time. Under this system, the floors from the 45th to 56th floor are to be leased for private businesses in the skeleton condition, and these floors will be open for tenant applications as private residential housing for lease after the private businesses set the infill. This means that both UDC housing for lease and private housing for lease will be placed in the same skyscraper residential building.

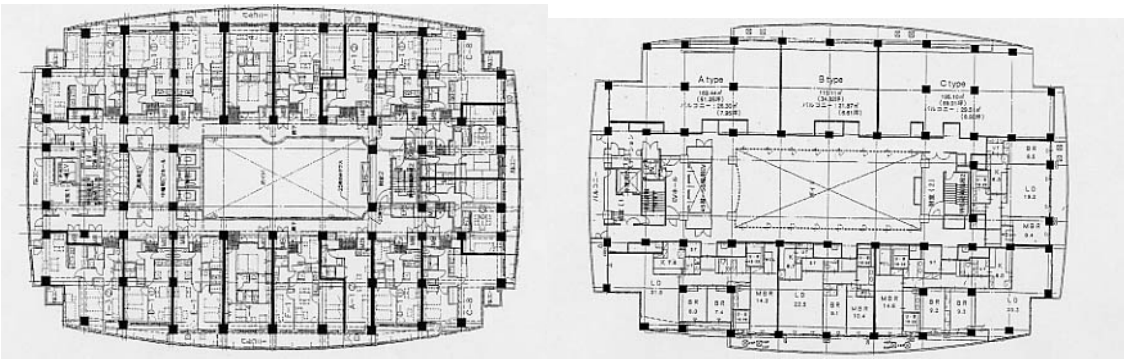

Figure 4

Left: plan of an ordinary floor for the UDC leasing portion

Right: plan of an ordinary floor for the residential part of private businesses

4. Conclusion

UDC's development of KSI housing has advanced from a stage of model project construction to that of standardization by degree, after examinations of the experimental KSI housing experiment building at the Technology center.

Through such advancement, new tasks have been found. Tasks to be solved in the future are as follows.

The biggest and most important task is to reduce the cost of KSI housing. In addition, further considerations are needed on the cost effect from a lifecycle viewpoint. Other tasks to be considered include the ordering system for skeleton and infill construction that is suitable for SI housing, and application of SI technologies for renewal technologies.

UDC intends to make every effort to develop KSI Housing.

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