CIB W104 Open Building Implementation

11th meeting in Tokyo, September 30th, 2005

Session 1

Chairperson Prof. Dr. Kazunobu Minami, Shibaura Institute of Technology JAPAN

10:00 OMI Yasuo
CASE STUDIES ON ADAPTABLE BUILDINGS BY RENOVATING "TETSU-CHIN"APARTMENT HOUSES IN JAPAN

10:20 YOSHIDA Satoshi
DEMATERIALIZATION OF CONSTRUCTION RELATED INDUSTRY BY APPLICATION OF SERVICE LEVEL AGREEMENT CONTRACT

10:40 Gomes Mendes Martins Pereira Ana Rita
Innovating Built Heritage: Adapt the past for the future

11:00 OKAMURA Takuma, TSUNODA Makoto
PLANNING AND DESIGN METHODS FOR PARTIAL CONVERSION OF PUBLIC SCHOOL IN TOKYO 23WARDS

11:20 KADOWAKI Kozo
Factors in the Plumbed Installations Positioning of Multi-unit Residential Buildings

11:40-13:00 Lunch / Business Meeting of CIB W104

Session 2

Chairperson
Prof. Dr. Jia Beisi, Hong Kong University HONG KONG

13:00 FUJII Shunji
Improvement of building stocks by connecting adjacent tall-narrow buildings

13:25 MORITA Yoshiro
ANALYSIS ON THE CHARACTERISTICS OF HOUSING STOCKS IN BEIJING OLD CITY -CASE STUDY: 'EIGHT STREETS IN JINGSHAN' AREA-

13:50 ADACHI Yoshikazu

A New Attempt of an Open Building to Realize Sound Use of Condominium Stock

14:15 SATO Koichi, MATSUMURA Shuichi

An Open Building Approach to Revitalizing Building Stock Converting Offices into Dwellings

14:40 YAMAZAKI Yusuke

Development of new building systems using innovative structural materials

Part1: An approach and strategy to develop sustainable building systems to promote urban revitalization

15:05-15:30 Tea Break

Session 3

Chairperson

Prof. Dr. Stephen Kendall, Ball State University U.S.A.

15:30 KOESTER Robert

Open Building and Community Harvest: New Definitions of What Can Comprise a Base Building?

15:55 PARK Jin-Ho

Demountable and Interchangeable Construction System: R. M.Schindler's Panel Post Construction

16:20 SCHEUBLIN Frits

The drivers for adaptable buildings in the 21st century

16:45 KENDALL Stephen

OPEN BUILDING: IMPLICATIONS FOR ARCHITECTURAL EDUCATION

CONCLUSIONS

17:15 KENDALL Stephen

CASE STUDIES ON ADAPTABLE BUILDINGS BY RENOVATING “TETSU-CHIN” APARTMENT HOUSES IN JAPAN

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Keywords: adaptable building, renovation, apartment house, steel structure, prefabricated house

Summary

From the viewpoint of environmental conservation, no-demolishing buildings and reusing those spaces is a better solution than demolishing and recycling those by-products. For the purpose, existing buildings have to be renovated to accommodate social and technical change.

Picking up two-stories and steel-framed apartment houses (so called “Tetsu-chin apartment house” in Japanese) built by prefabricated house providers, we studied methods of renovation by combining narrow dwelling units vertically and making maisonette apartment houses. By enlarging dwellings and splitting them vertically, it is possible to make multi-purpose spaces and give new values to them (e.g. SOHO in style). It is also possible to solve the floor impact noise problems between households of upper and lower level.

We estimated the rates of reused steel in modifying structures and showed that over 85% of steel can be reused in all cases. Accordingly we concluded that the method is much effective in environmental conservation and this is one of the best ways to adapt existing old narrow dwelling stocks like “Tetsu-chin” apartment houses to new ones that suit to social change.

1. Introduction

In Japan, over 1 million dwelling units are newly provided every year and about one third of those are in apartment houses for rent. 40% of such units are less than 40 m^2 and 20% are less than 30m^2. Lots of those apartment houses are built by steel-framed structure and two-stories, so called “Tetsu-chin”.

In Tokyo, there are over 2 millions of households of bachelors (including old widows and widowers) and those came to be the most part of all types of household, because of the trend of late marriage and aging society. Lots of them live in narrow and close (27 m^2 in average) dwelling units for rent like “Tetsu-chin”.

In addition, the average life span of steel-framed apartment houses is only about 30 years in Japan (it is shorter especially in case of “Tetsu-chin”). Comparing with buildings of other kinds of structures or uses, it is the shortest next to steel-framed office buildings although life span of buildings are generally short in Japan. They are not rebuilt due to their physical durability, but due to their social durability to suit to the change of life style. Most of existing “Tetsu-chin” apartment houses do not seem to be good housing stocks for the future.

Narrow steel-framed apartment houses would be taken place by wider ones. But it is not desirable to rebuild them by short life span from the viewpoint of environmental impact. Enlarging such narrow dwelling units will make them easy to suit to the change of life style and last their life span.

In this paper, we studied a couple of method of renovation by combining narrow dwelling units in “Tetsu-chin” apartment houses vertically and making maisonette apartment houses.

2. Case Studies

2.1 Case 1

2.1.1 Outline of the case

This building, 2 stories steel-framed apartment house, exists in a residential area in Edogawa-ward of Tokyo. It was built by a major prefabricated provider in 1991 and has 20 dwelling units (10 units in each story). Each unit is the same plan that has 1 bedroom and 21.2 m^2 in area. It is anticipated that vacant room rate would increase because of aging and narrowness.

2.1.2 Policy of the renovation

The policy of the renovation from flat to maisonette in this case is as follows,

- Combining 2 dwelling units of upper and lower level vertically.
- Modifying balconies (of each floor) and exterior corridor (of 2nd floor) to interior space.
- Arranging bedroom and dining/kitchen at upper level and multi-space that can be used as SOHO at lower level.

2.1.3 Planning of the renovation

According to the policy, the plan of the dwelling unit is modified as follows,

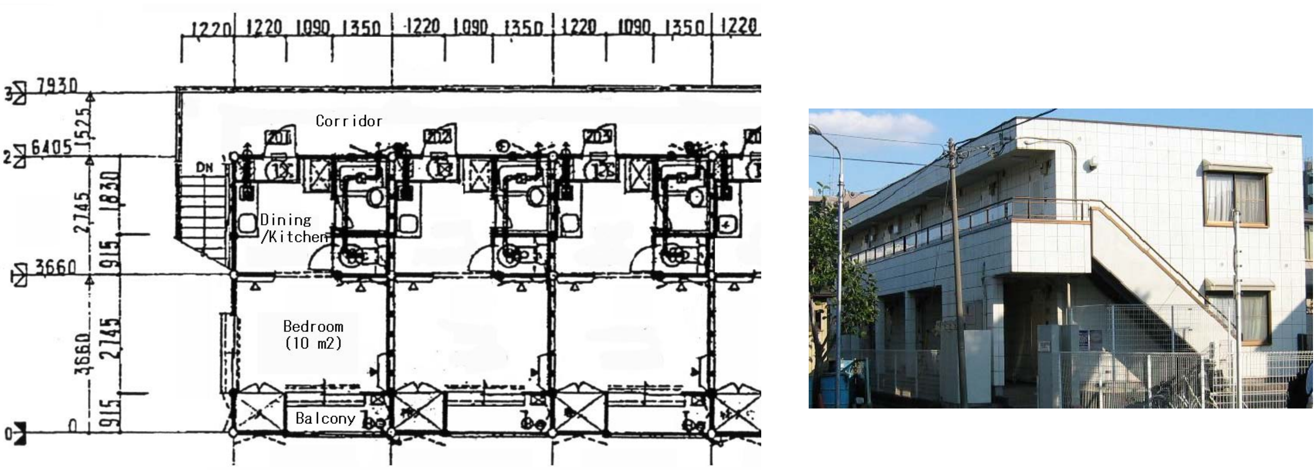

Figure 1 Existing plan of 2nd floor (partial) and exterior

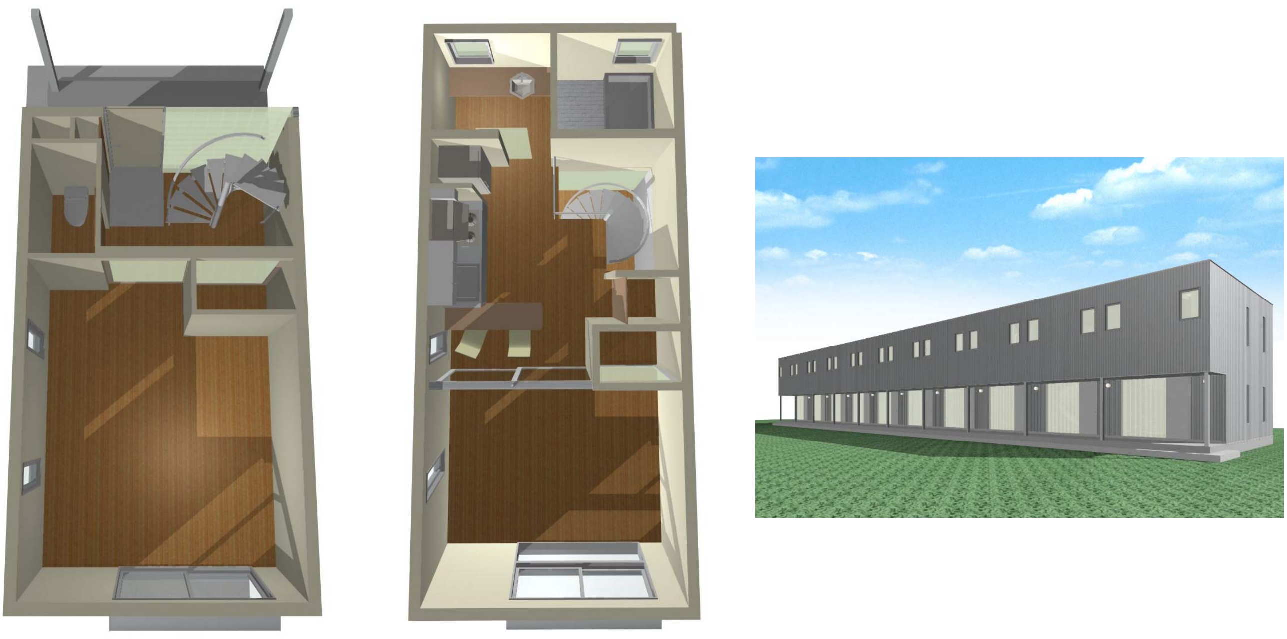

Figure 2 Renovation plan for the dwelling unit (52.5m^2 in area) and exterior

2.1.4 Modification of the structure

To realize the renovation plan, the modification of the structure is necessary as follows,

- Moving/adding beams and changing horizontal braces to set up the spiral staircase and top light.
- Adding columns and changing beams to modifying exterior corridor to interior space.

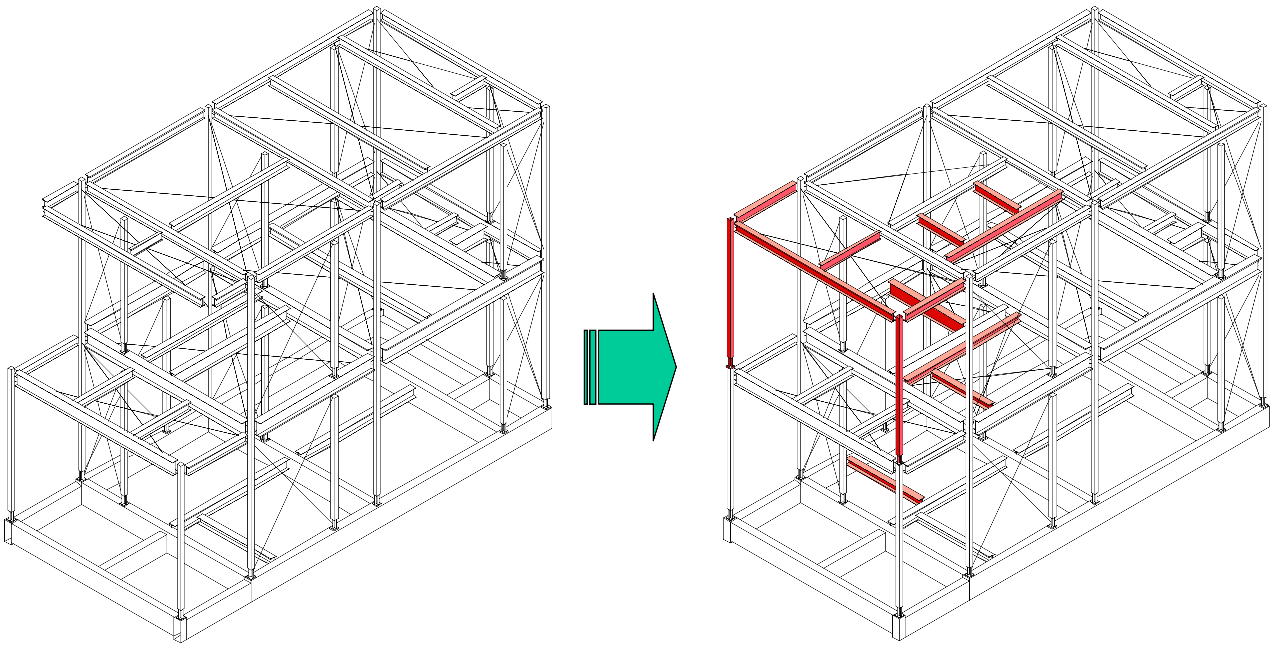

Figure 3 Modification of structure of the dwelling unit
(the applicable elements are painted out)

Below is the alteration of the weight of steel structure. 97.1% of steel would be carried on and only 9.1% steel would be necessary for the renovation.

Table 1 Weight of steel structure (whole building)

	Weight of steel structure (t)
Before the renovation	24.59 (100%)
Elimination	0.71 (2.9%)
Addition	2.33 (9.1%)
After the renovation	26.11 (106.2%)
Rate of reused steel	97.1%

2.2 Case 2

2.2.1 Outline of the case

This type of building, also 2 stories steel-framed apartment house, consists of a standard plan of a major prefabricated house provider (different from case 1) and therefore exists in many areas in Japan. Each unit is the same plan that has 2 tatami-rooms and 30 m^2 in area. It is anticipated that it would be avoided because of their outdated style and narrowness.

2.2.2 Policy of the renovation

The policy of the renovation from flat to maisonette in this case is as follows,

- Combining 2 dwelling units of upper and lower level vertically.
- Modifying partial interior space of 2^{nd} floor to exterior space (terrace).
- Arranging private space (bedroom and terrace) at upper level, while dining/kitchen and multi-space that can be used as SOHO at lower level.

2.2.3 Planning of the renovation

The plan of the dwelling unit is modified as follows,

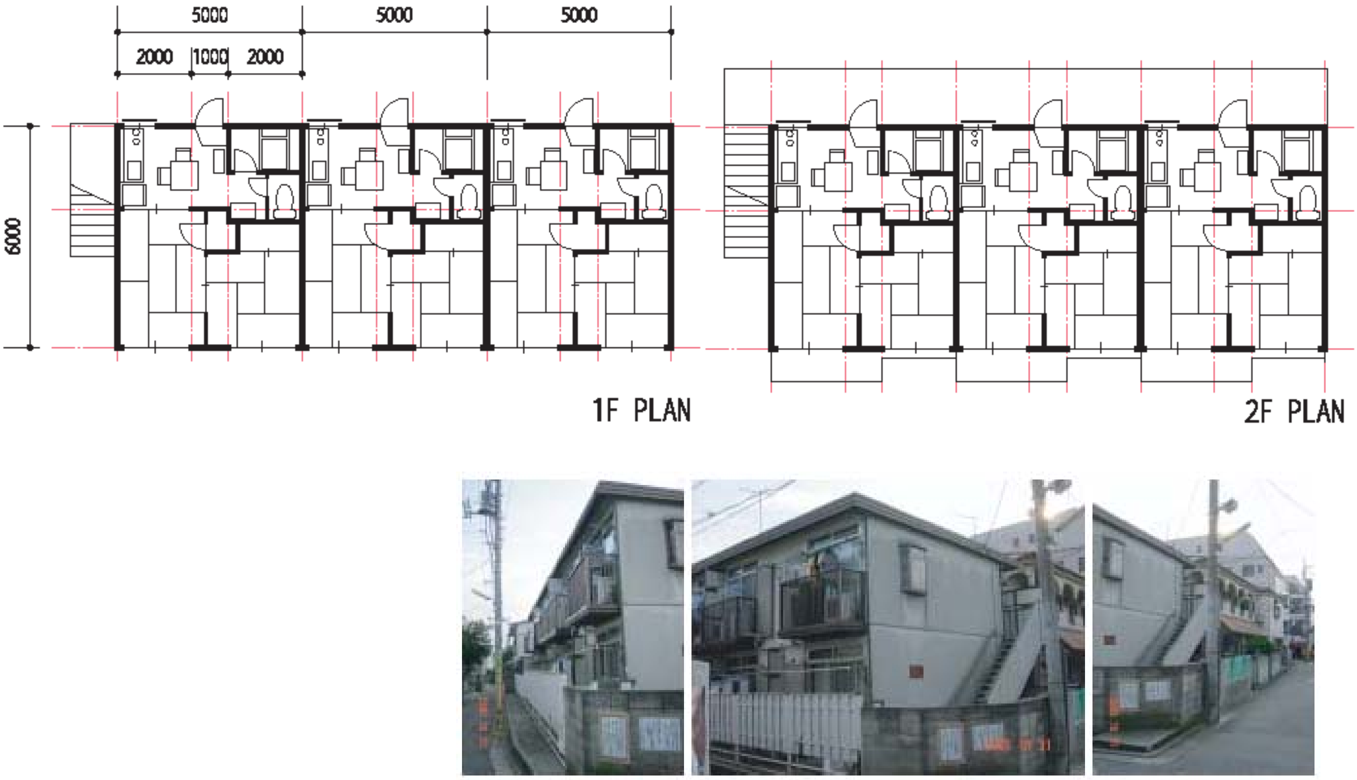

Figure 4 Existing plan and exterior

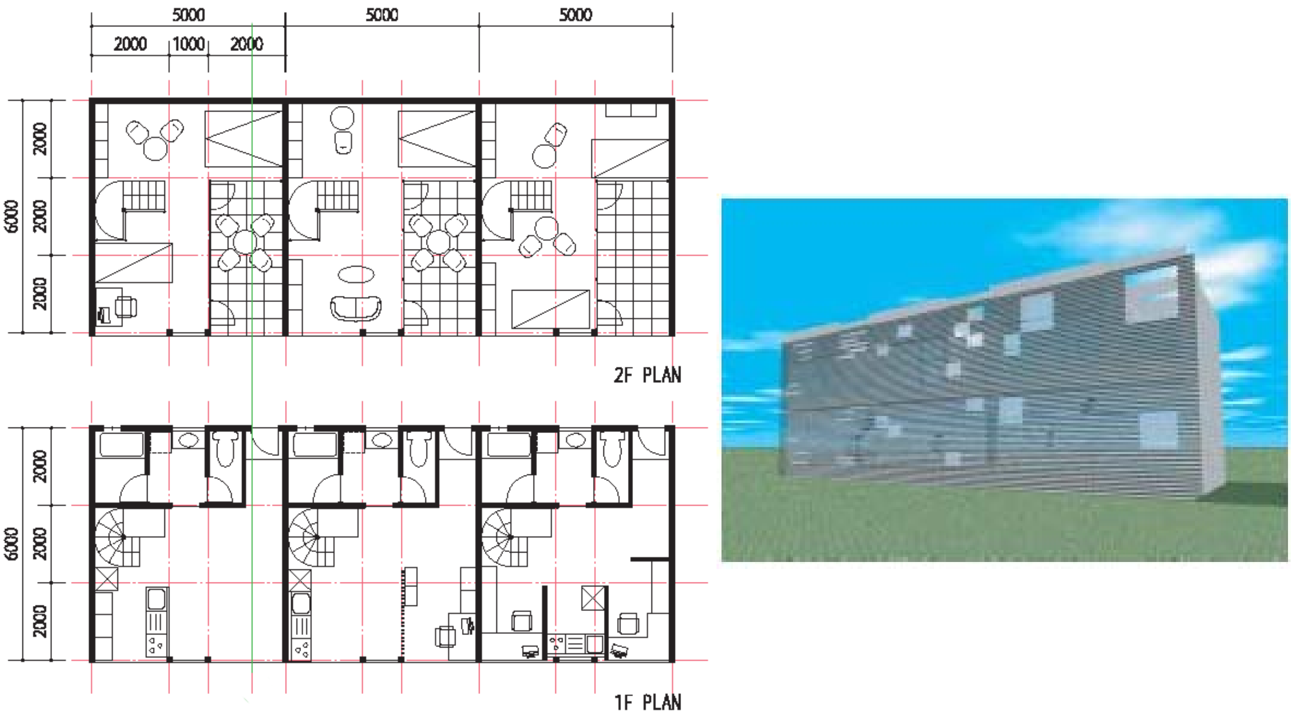

Figure 5 Renovation plan and exterior

2.2.4 Modification of the structure

To realize the renovation plan, the modification of the structure is necessary as follows,

- Changing floor beams and removing horizontal braces to make void.
- Adding wall frames and floor panels (Autoclaved Lightweight Concrete) to modifying interior to terrace.

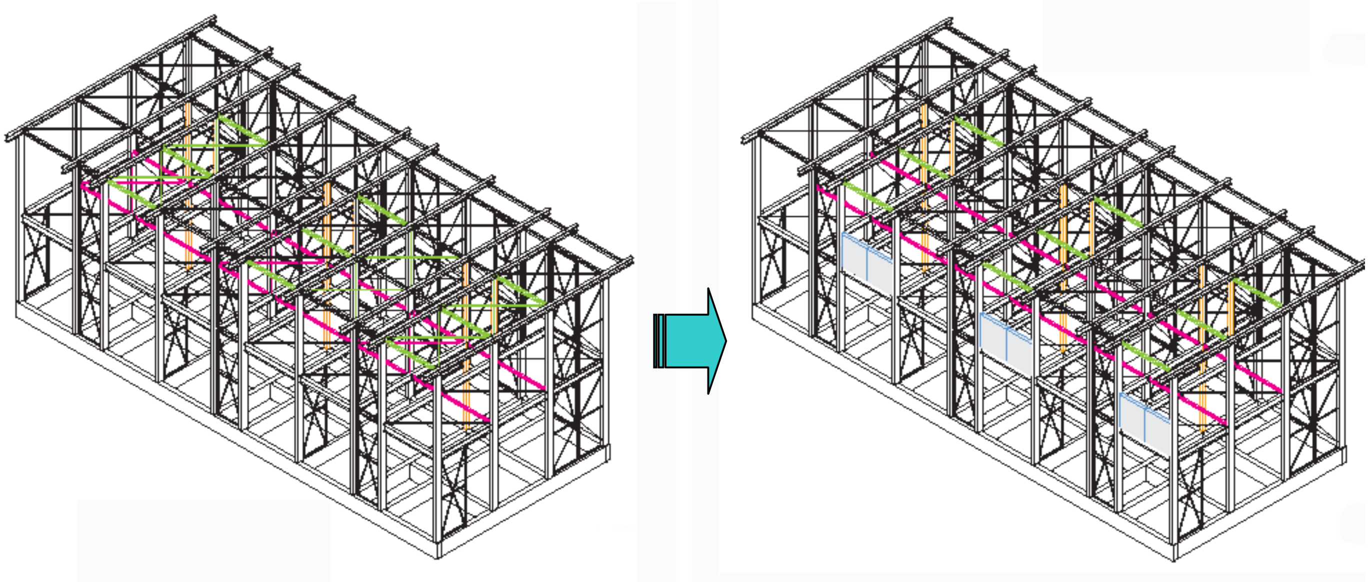

Figure 6 Modification of structure
(the applicable elements are painted out)

Below is the alteration of the weight of steel structure. 94.8% of steel would be carried on and 24.8% steel would be necessary for the renovation.

Table 2 Weight of steel structure (whole building)

	Weight of steel structure (t)
Before the renovation	11.63 (100%)
Elimination	0.61 (5.2%)
Addition	3.49 (30.0%)
After the renovation	14.51 (124.8%)
Rate of reused steel	94.8%

2.3 Case 3

2.3.1 Outline of the case

This type of building is a similar condition to case 2 that has 1 tatami-rooms and 27 m^2 in area. It is also anticipated that it would be avoided because of their outdated style and narrowness.

2.3.2 Policy of the renovation

The policy of the renovation from flat to maisonette in this case is as follows,

- Combining 2 dwelling units of upper and lower level vertically.
- Fixing all position of existing doors and windows to minimize modification of the structure.
- Fixing existing columns and beams, if possible, to minimize modification of the structure.
- Removing exterior corridor of 2nd floor.
- Arranging private space (bedroom and bathroom) at upper level, while dining/kitchen and multi-space that can be used as SOHO at lower level.

2.3.3 Planning of the renovation

The plan of the dwelling unit is modified as follows,

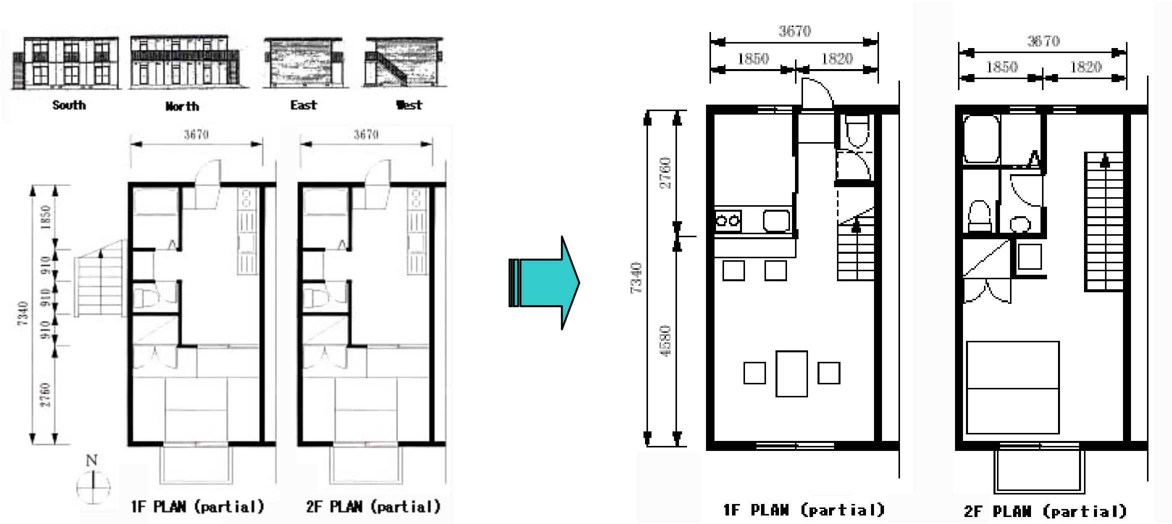

Figure 7   Modification of plan

2.2.4 Modification of the structure

The modification of the structure is as follows,

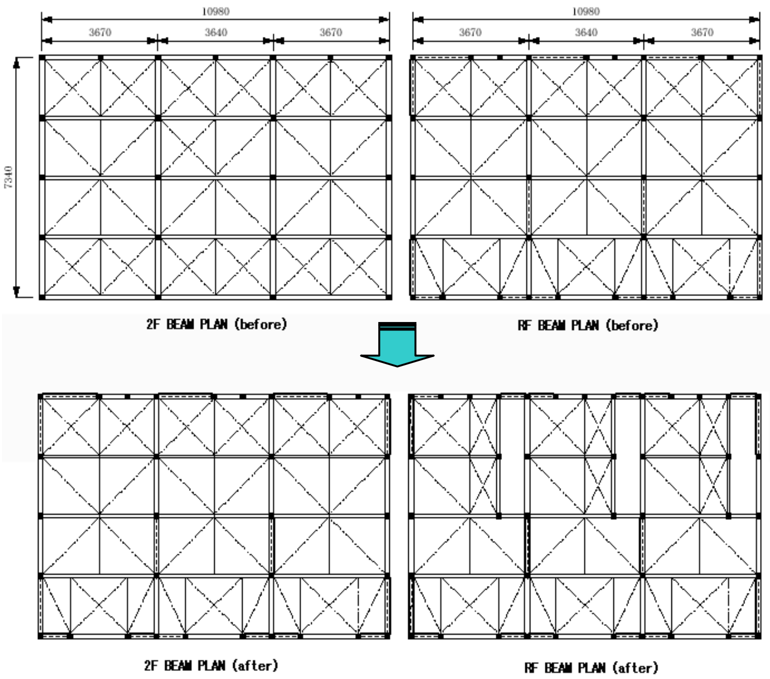

Figure 8   Modification of beam plan

Table 3   Weight of steel structure (whole building)

	Weight of steel structure (t)
Before the renovation	16.20 (100%)
Elimination	2.07 (12.8%)
Addition	0.99 (6.1%)
After the renovation	15.12 (93.3%)
Rate of reused steel	87.2%

3. Conclusion

In every case, the rate of reused steel in modifying structure is over 85%. It is expected that other building elements would be carried on by the renovations. It is also expected to make new values to the dwellings like SOHO and solve the floor impact noise problem between households of upper and lower level. Accordingly we concluded that this method is much effective from the viewpoint of environmental conservation and this is one of the best ways to adapt existing old narrow dwelling stocks like “Tetsu-chin” apartment houses to new ones that suit to social change.

DEMATERIALIZATION OF CONSTRUCTION RELATED INDUSTRY BY APPLICATION OF SERVICE LEVEL AGREEMENT CONTRACT

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Keywords: dematerialization, service provider, lease, infill components, service level agreement(SLA)

Summary

For promotion of construction ecology, it is essential to create a method of dematerialization of construction industry. The authors have proposed the concept of "service provider" as key principle of dematerialization of construction industry. While "product provider" gets the revenue by providing building as a product, "service provider" gets the revenue by providing service generated by building as a device. By creating and by evolution of new business model of "service provider", resource productivity of building is expected to be fundamentally improved, because industrial sectors do not need to use enormous quantity of resources to generate value by new building.

Based on the idea, the authors have tried to develop new business model where infills (= fit outs) of buildings are leased or rented as a device to provide services. The new business model developed by the authors demonstrated to general public through mock-up infill system model rooms. The demonstration raised the concern of sectors in building industry and several sectors created various business models. The paper introduced some examples of new service providing business model in Japan.

In order to prevent probable conflict that could be serious constrains for evolution of service providing business, through the collaboration with legal experts, the authors tried to design the standard contract format for infill leasing business as a prototype contract for service providing business. The designed standard contract format is based on the service level agreement (SLA) contract The paper presents the structure of the standard contract format for infill leasing based on SLA, and it Illustrates the method to define the scope and level of service generated by infill leasing in contractual document.

1. Introduction

Industrial ecology evolution in building related economic activities is a key issue for fundamental improvement of resource productivity in construction. This paper illustrates an experimental project of infill base phased refurbishment. The methodology developed by the experimental projects is based on the idea to define infill as movable property. The methodology is composed of those for demountable and movable infill system as well as those for attracting investment to refurbishment by which the investment is independent from financial difficulty of building owners. The paper also presents presents insights and lessons from an ongoing R&D project based on the service provider concept that is based on potential policy design to facilitate refurbishment using the developed methodology.

2. The idea of the service provider for better resource productivity

Product providers, which currently constitute most of the building sector, generate their revenues by providing ‘products’ to customers. A larger quantity of resource input brings larger revenue to product providers. Thus, the nature of the product providers’ business gives weak incentives to dematerialization. On the other hand, service providers get their revenue by providing services to customers. For service providers, building is a device for supplying services, and the quality of service does not depend on the quantity of resource. Thus, the business model of the service provider has the potential to promote dematerialization.

Definition of infill as movable property can be alternative solution; If infill could be treated as movable property, infill can be the interdependent device to generate exclusive cash flow by getting revenue for providing ‘services’ embodied with the infill space. ‘Services’ here means convenience, comfort, security and various benefits embodied with function and performance of buildings. Eventually, the provider of services of infill can be termed as service provider as it is shown in Figure 1.

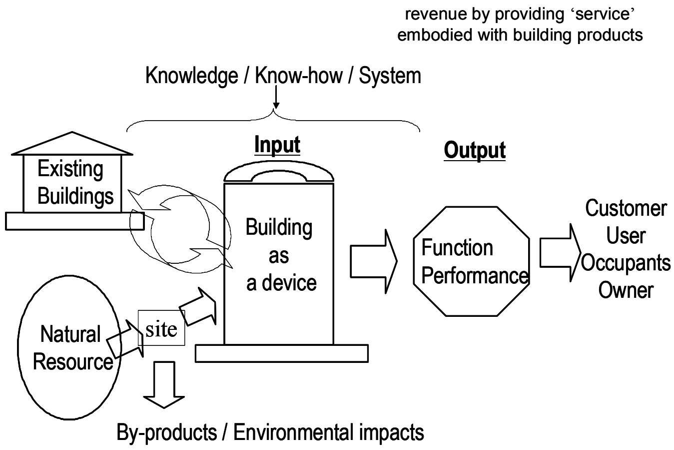

Figure 1 Idea of service provider

By defining infill as movable property used for generating services, cash flow generated can be understood as the output of independent project to provide customers services of infill. Thus, the diagram in Figure 1 indicates new business model; the model is expected to attract investment through project based finance scheme where magnitude of expectancy and risk of generating cash flow by providing service of infill is main concern by various investors.

3. Demonstration Projects of Service Provider; Leasing of prefabricated Infill Components

3.1 Infill Components as Movable Property

The idea to define and treat infill of building as movable property, as it is illustrated by the diagram shown in Figure 2, can be the key idea for the integrated methodology. In the diagram, a building is separated into two parts; skeleton and infill. Skeleton can be termed as base building and includes structure, fabric and building services for common use such as lift, stair case, vertical pipe and wires, equipments for energy and water supply to whole buildings etc. Infill can be termed as fit-out and includes all installation and finishing to each spatial department of interior.

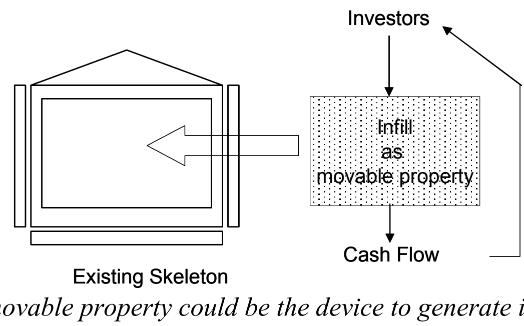

Figure 2 Infill as movable property could be the device to generate independent cash flow that is nothing to do with stakeholders to existing skeleton

There are two points for the integrated methodology with this viewpoint. First, attachable and detachable nature of infill as movable property has potential advantage to create the innovative method to enable quick installation and removable of infill like furniture. The method could be the seed for solution against probable inefficiency and inconsistency by spatially and temporally fragmented refurbishment works.

Second, more importantly, if skeleton and infill can be completely separated by refurbishment, probable complicated financial and legal relationship with various stakeholders around building’s owner can be enclosed within the scope skeleton. In another word, the separation of skeleton and infill could make infill free from entangled relationship around building’s owner.

3.2 Context and motivation

In the current business environment off-site infill component fabricators are typical product providers. The revenue of component fabricators depends on how many products are sold. In most cases, their task is completed when they sell their product.

However, because of the below mentioned context of the Japanese case, the authors identified the leasing business of infill components to generate sufficient feasibility and that it could be an effective demonstrator of the service provider business model.

・The infill component industry is powerful in terms of market share and innovation ability in Japan.

・Fabricators of off-site made infill components are seriously seeking new business areas, especially in refurbishment.

・Current social and economic circumstances accelerate the transition of requirement by building occupants and residents.

・Without reuse and/or recycling, frequent replacement of installed infill components has the risk to increase waste production.

3.3 Potential benefits

In the product provider's business model, products are handled in a one-way flow from production to usage to disposal. By contrast, in the leasing business model, products are returned to the supplier from the previous customer and re-manufactured for the succeeding customer. Thus, the repetitive use of 'devices' reduces the cost for transaction procedures of the business. Eventually, the leasing business is expected to give incentives to 'device' suppliers to create re-usability methods for infill components.

By enhancing the leasing business to a package of long term maintenance and upgrading service, occupants and residents can enjoy assured quality of services embodied with functions and performance of components for the duration of the contract. Though there is a risk for the suppliers' side on future expenses for maintenance and repair, it also could be beneficial for suppliers because of the potential to increase business opportunities reflecting the accelerated change of requirements.

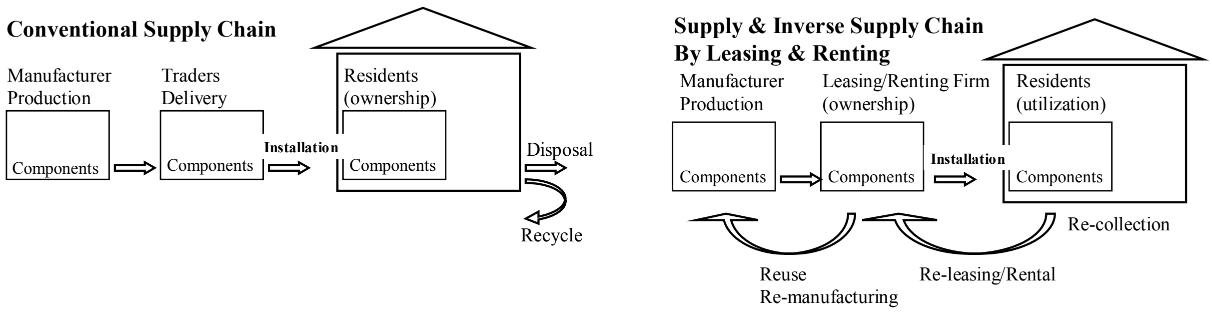

Figure 3 Sustainable system with leasing model

3.4 Requirements to define infill as movable property

Definition of infill as a movable property could be the key idea to establish integrated methodologies to enhance refurbishment in Japanese contexts by breaking through physical and financial constrains. Then the following question is emerged; Is it legally and technically feasible to define infill as movable property?

Fortunately the author got the government research fund from FY2001 to FY2003 to implement feasibility of the definition and the new business model. The title of subsidized project is 'Morphological technology development toward redefinition of improved urban amenity'. The project is required to be, and is actually to be, implemented by academics - industry joined consortium. Key items to being investigated are;

Identification of legal requirements to treat infill as movable property

Demountable and adaptable infill system as movable independent property

The first and second item above give answers to the question on feasibility of the definition of infill as movable property.

The author collaborated with barrister to analyze legal case precedents on legal debates and conflicts relating to the independence of infill from skeleton. Though the final conclusion is varied in those cases, criteria of judgment are consistent among those cases. The courts give judgment based on the following criteria.

Demountability of elements of infill

Degree of socio-economic disadvantage by removal of infill

If elements of an infill are demountable without any damage to skeleton and if removal of infill does not generate serious socio-economic disadvantage by assuring re-usability of removed second-hand elements in other sites, the court judged that the infill is independent property from skeleton. In case removal of infill generate serious socio-economic disadvantage such as serious inconvenience of base building or such as quite a few waste production etc., the court judged that the infill is attached object to skeleton.

Though the judgment precedents do not have strong legal status, the consistency in the criteria of judgment could be the basis for legal requirement to define infill as movable property. Therefore, the author understood that the following is the legal requirements to treat infill as movable property.

Elements of infill are visibly or apparently demountable from skeleton within considerably short period of time and cost acceptable for end user or customer

Removed elements of infill are re-usable in other sites, and removal of infill does not cause unacceptable nuisance, inconvenience and damage to the stakeholders of the building

3.5 Demonstration Project

In order to verify the feasibility of developed methodology for refurbishment based on the idea of infill as movable property, the developed infill system was installed to actually vacant building located in Tokyo.

The plan is composed of three module ‘boxes’ standing on the raised floor. Three boxes include those for kitchen, for bathroom and for toilet. The boxes are easily demountable and movable, thus the plan has been re-fitted from first phase to second phase. The re-fitting took only four days with two operatives. This fact suggests that the developed infill system has feasible adaptability to ever-changing various requirements by easily movable ‘boxes’, In addition, the fact also indicates that infill systems are demountable and reusable in the other buildings.

More than 500 people visited the site of demonstration project that includes those from local residents, local authority, community-based organizations, banking and financial facilities and building related industry. The author got positive offers from demand side sectors like financial institutions, local authorities and buildings’ owners, and from supply side sectors which learned the significance of supply chain management and customization to individual customers. The project gave considerable impacts on both on demand side and supply side sectors.

In downtown area in Tokyo, Osaka and other mega-cities in Japan, small and medium size buildings for offices for rent are now losing tenancy because of reduction of demand and increase of new supply by recently completed large size urban renewal projects. Though those areas have historically significance with mix used compact neihbourhood, small and medium size buildings for offices are getting vacant. In some area, rent for flat is considerably higher than the rent for office, thus, many groups standing on suppliers’ side believe and expect conversion from office to flat has economic feasibility like the examples in European cities where whole buildings are dramatically refurbished. Certainly, several successful examples of ‘from offices to rent’ are emerging in Japan.

4 Impact by demonstration project ; Emerging Service Provider

This demonstration showed the practical method of infill lease model, and several companies related to construction have strong interesting in this project. Some of the companies and institutes have already started to develop new practical business model based on the concept. There are several examples of new service providing business model in Japan including leasing of elevators and building service equipments, clean air providing contract business as an alternative of providing air-cleaning equipment, office function providing services and etc. These business models focus on the utilization fee based on continuous maintenance instead of construction fee. The idea has same viewpoint as cell phone business and communication network business, which focuses on the profit of lasting service contract in place of temporary trade.

Shin Nippon Air Technologies, one of the Japanese mechanical companies, created a business model with leasing mechanical equipments including air conditioning units. Their idea is to provide financial merit to customers. The customers need not own the equipments, so they can reduce the initial cost that put a strain on customers’ finances. The total customers’ cost for air conditioning including maintenance is almost same as the case to purchase these equipments at the standing point of long-term cash flow.

In the other case, Mitsubishi Electric Building Techno-Service, one of the elevator maintenance companies, provides the total building mechanical and electronical equipments leasing system, including elevators, air conditioning equipments, plumbing equipments, electronic transformer equipments, automatic doors etc.. Customers reduce the large initial cost and the special staff to take care maintenance of these equipments.

The list of the examples of impact by demonstration project is as follow. In every case, customer need not buy physical objects, and the supplier provide service as follow.

Table1 Service Business Models based on Service Provide in Japan

	lease service
Shin Nippon Air Technologies Co. Ltd.	air condition system with maintenance
Mitsubishi Electric Building Techno-Service Co. Ltd.	electric light bulb, fluorescent light tube
Matsushita Electric Industrial Co., Ltd.	mechanical & electronical equipment
CW Facillity Solution Inc.	finishing, furniture, security

(Source; 2004-7-26 Nikkei Architecuture, 2004, pp073-pp077)

5. Service Level Agreement (SLA) for contractual agreement

5.1 Concept of SLA

In order to evolve and disseminate these new business models in market place, it is essential to establish contractual method between customers and service providers, because 'service' generated by building is invisible. Without clear contractual agreement of the scope and definition of service, conflict could be generated between supplier and customer.

In order to prevent probable conflict that could be serious constrains for evolution of service providing business, through the collaboration with lawyers, the authors tried to design the standard contract format for infill leasing business as a prototype contract for service providing business. The designed standard contract format is based on the service level agreement (SLA) contract which is generally used in software industry. In this case, the provider, that offers various services, warrants the quality of continuous service.

5.2 The structure of the standard contract for infill leasing based on SLA

It is necessary to define the "service" to make a clear contractual agreement between supplier and customer. Without clear contractual agreement of the scope and definition of service, conflict could be generated.

Firstly, it is important to understand the basic functions of requirement. Each "object" has its own requirement that is composed with three items, "structure", "initial specification" and "maintenance specification." For example, toilet seat has a "structure" with Body, Tank, Piping and Toilet Paper Holder. Each item need to be decided its "initial specification" with a clear standard. "Maintenance specification" of toilet seat is several items such as cleanliness of seat, non-condensation of tank and pipe, noise reduction, wash power, strength of seat or trap function.

Secondly, it is necessary to get the information of customer's requirement, and the point is how to understand each customer's requirement. Table 2 is a part of check-list customer's check list that is the tool to understand the customer's requirement, and this list includes the physical measurement and commissioning.

It is necessary to make clear Initial Specification and Maintenance Specification including physical service for supplier and customer, because subjective judgment must be removed from the contract. Check-list is the tool by which suppliers and customers periodically could have common understanding on the content and benchmarking of services, so this proposal planes other check-list on each step. Especially, quality and specification check-list for maintenance indicates the necessity of customer's requirement and common maintenance

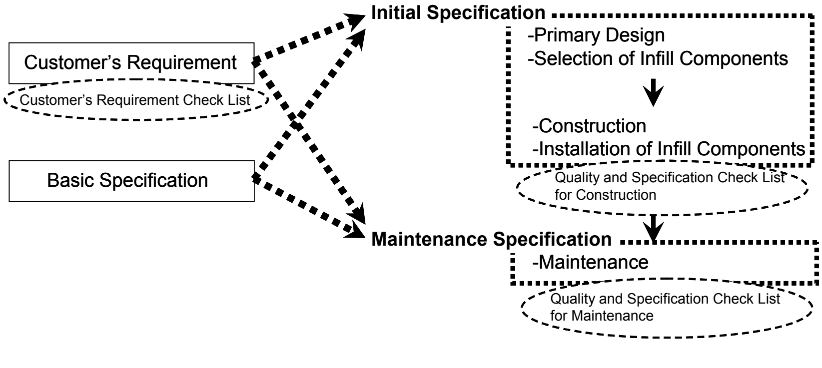

Figure 6 Framework of Initial Specification and Maintenance Specification

Table 2 A part of Customer's Requirement Check-List

Toilet Box	quantity		☐0 ☐1 ☐2 ☐( )	Parts	toilet seat		☐yes
	size	width	☐1200 ☐1800 ☐( )	in Toilet Box			*manufacturer( ) product no.( )
		depth	☐1200 ☐1800 ☐( )		washbowl		☐yes
		height	☐2100 ☐2300 ☐2400 ☐( )				*manufacturer( ) product no.( )
	exterior	wall material	☐aluminum ☐board ☐membrane ☐( )		shower toilet		☐yes
		finish	*manufacturer( ) product no.( )				*manufacturer( ) product no.( )
	interior	wall material	☐aluminum ☐board ☐membrane ☐( )		washing pomp		*manufacturer( ) product no.( )
		finish	*manufacturer( ) product no.( )		socket	quantity	☐0 ☐1 ☐2 ☐( )
	floor	finish	☐wooden ☐plastic tile ☐carpet tile ☐( )			requirement	( )
			*manufacturer( ) product no.( )		switch	quantity	☐0 ☐1 ☐2 ☐( )
		hearting system	☐yes			requirement	( )
			*manufacturer( ) product no.( )		lighting		*manufacturer( ) product no.( )
	ceiling	material	☐aluminum ☐board ☐membrane ☐( )		handrail		☐yes
		finish	*manufacturer( ) product no.( )				*manufacturer( ) product no.( )

The contract is based on the information of these check-lists. It is necessary to make clear the right and duty for customer, supplier and property owner. Following table is the standard contract outline for infill leasing business as a prototype contract for service providing business. Through the collaboration with legal experts, we tried to make clear the points that prevent probable conflict that could be serious constrains for evolution of service providing business.

- Provisions (purpose of contract, outline of service, contract schedule)
- Infill Design Service (basic design, basic design revise, construction document, construction document revise)
- Infill Installation Service (procurement of infill, infill installation, customer's inspection of infill)
- Service with Infill
- Infill Maintenance Service (supplier's maintenance, customer's maintenance, insurance of infill, damage of infill)
- Infill Removal Service
- Revise of Infill Component
- Payment for Service
- Responsibility of Infill Accident
- Contract Period

6. Concluding Comments

This brief discussion paper illustrates the integrated methodology to facilitate phased refurbishment by re-fitting infill based on service level agreement (SLA). The value of infill base phased refurbishment is dependent on the degree of cooperation with agreed visions of the district by stakeholders and the degree of customization to each user and customer. So the methodology to get the agreement without misunderstanding between customer and supplier is essential to establish new contract model

The new business model for infill base phased refurbishment illustrated in this paper still has the legal incompleteness in terms of judgment on independence of infill from skeleton. To exclude the legal incompleteness, special law termed as Infill Act need to be drafted at the Parliament. However, for generating the initiatives and appeal for new Act, there is a need to demonstrate real examples by which general public understand the potential benefit by separation of infill from skeleton.

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INNOVATING BUILT HERITAGE: ADAPT THE PAST TO THE FUTURE

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Keywords: built heritage, cultural values, interventions, lifespan rehabilitations, reuse, recycle, sustainability

Summary

The contemporary worldwide targets towards sustainability, especially when regarding the building sector, have been guiding many researchers and technicians through the development of new challenges in the building industry. Many outlines came throughout, but mostly considering new buildings, where new technologies as well as new materials did not have to deal with a pre-existent environment.

With a large scale of urbanized areas, from past and present generations, we face an entire stock of resources that has been underestimated, by society and consequently by their social actors. This same stock of resources embodies different buildings, technologies and materials, mostly designed without any predetermined lifespan and built without giving much importance for the service life of their spaces, structures, and materials.

Re-Architecture: Lifespan rehabilitation of built heritage is a PhD research surveying a conscious way of intervening in the existing stock, taking into account all the necessary aspects of the building process, from pre-design, design, construction, use, further interventions and demolition, considering in advance the reuse or recycle of all included materials. Born as a concept in 2002, such research is now under development in the BTO Department, Eindhoven University of Technology, orientated by Prof. Ir. Jouke Post and Dr. Ir. Peter Erkelens.

1. Introduction

Old buildings face many problems of inadequacy regarding their natural aged or functionality, mostly aggravated by the lack of maintenance or inappropriate use. Either for abandon, technical ignorance or lack of capital to intervene, involuntary or not, the fact is that these promising new development areas, just in the city centre, make their stockholders dream economically higher, not measuring resources for building a total new building, fulfilled with modern infrastructures adequate to the contemporary living, even if that means to totally destroy a building that partially, if not totally could see its components been reused or recycled.

Such interventions and their waste of resources are many times sheltered by the urbanity scale of rehabilitation, believing in a true contribution for the built heritage preservation. There is even a current tendency of, when not totally demolishing the old structure, to hide this new innovative building behind the envelope of the old building. As if it wasn't enough sometimes even the new building sees its façade being constructed exactly as the one demolished before, but with the use of modern technologies, losing character and lifespan.

We could understand, even if debatable, part of this intervention philosophy emerging after natural and humankind calamities (earthquake, war, etc.) because then a huge urban area is totally destroyed within several monuments and built heritage, but not for exclusively economical aims.

What happen to the so debated authenticity? Shouldn't we build according to our contemporaneity? Shouldn't we embrace the fact that all obsolete buildings should and can be reused, but respecting the existence and their heritage character? We believe that something can be done in order to fulfil this gap: Interventions can reuse or recycle the maximum of the existent resources and integrate all modern infrastructures regarding the XXI century needs.

2. The lifespan of built heritage

By built heritage, we consider all the existing buildings that passed down through one or more generations, just like an object of inheritance that a precedent generation left for the following ones. Even if not interesting by any particular reason, they always represent the daily environment of humanity and provide a sense of local continuity anchored in the past toward the uncertain future. Associated to their inhabitants or actions, they represent past traditions of architectural design, craftsmanship, and ways of living and building in their own contemporaneity.

Built heritage can always contribute for the development of future incoming generations, even if not in its totality, as an existing resource of structures, elements, and materials. Existing buildings should not be simply demolished without considering its resources management. It is our believe that after these principles had been stimulated among governments and policies, many stockholders, constructers and technicians will have necessarily to start thinking about their actions and choices regarding built heritage interventions.

But what to do with all these old buildings? Wouldn't it be much easier, as commonly defended, to simply demolish it and build a totally new and updated building, much profitable, flexible, and functional? In fact, old buildings face several pathologies that depending of its gravity of scale can represent a considerable application of economic resources in specialized technicians that need specific conditions, material and time to work. This fact is not well received by common stockholders that think "no need for specialties", because they know what to do, and in the end, they treat old buildings, using exactly the same technologies they are acquainted for building new buildings, independent of the building original composition.

We will not deny that economical values are important, but we have reached a time where also other factors should to be taken into consideration. Our planet is facing serious ecological problems that everyone has to become conscious. It is undeniable that built heritage gets obsolete, degraded, outdated, and old-fashioned; however, not every building components have the same characteristics, behavior, present the same pathologies, neither have the same lifespan. A building is considered as a combination of "several layers of longevity of building components." (Duffy, F. 1990), but the analysis of the building components and their lifespan cannot be restricted to the substance of the building, forms, components neither materials. Francis Duffy distinguished four layers in a building: *shell* for the structure, *services* for all the technical installations, *scenery* for the internal partitions and *set* for the furniture.

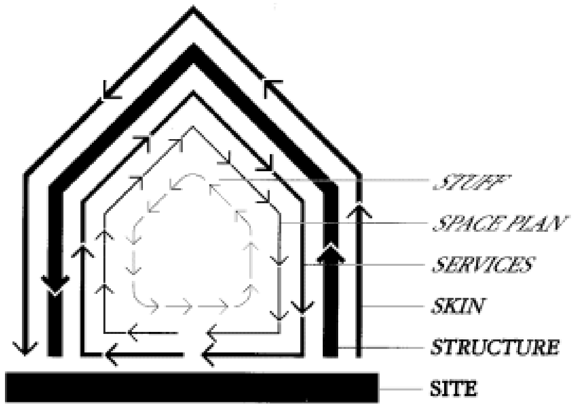

Figure 1 Shearing layers of Change (Brand, S. 1994)

Those "four S's" have been later expanded for "six S's" by Steward Brand, subdividing the anterior terminology *shell* as ***skin*** for the external surfaces and ***structure*** for foundations and load-bearing elements; altering the previous *scenery* to ***space plan*** and *set* to ***stuff***, maintaining from Duffy's theories the term ***services***. He also referred two more "S's", but as you can perceive in figure 1 only ***site*** takes part of the "shearing layers of change" within the intention of adding concepts such as geographical setting, urban locations and legal lots into the building components layering. Human ***souls*** come only mentioned as a possible seventh and last "S" from the layering hierarchy.

In figure 2, Brand's "shearing layers of change", most oriented towards commercial buildings, were re-structured focusing our target of survey: built heritage, which has to be regarded particularly due to its vast range of forms, elements and materials. For example, in some heritage buildings *skin* and *space plan* are synonym of *structure* and do not follow the lifetime expectancy of thirty years, but much more than 300 years, varying according to the building environment, inherent cultural values and individual features.

Environment is considered as all the circumstances and conditions that surround, affect, and influence the development and survival of every existing building or the group of buildings, combining the former *site* and *soul* in only one term. S*ite* is here replaced by geographical and physical environment, embracing not only the building setting (altimetry, morphology, biology, resources), but also the climate to which the building is exposed to. S*ouls* became the anthropological environment, embracing not only the users, “servants to our stuff” (Brand, S. 1994), but the entire group of social actors that interact with built heritage as leaders (stockholders, politicians), experts (historians, archaeologists, architects, engineers) or simply as constituents (owners, users).

Every human being has their own principles and intentions towards reality and in this particular case to what built heritage values, but in some cases their approaches and reactions appear quite stereotyped, following their social groups. The **cultural values** are then no more than invisible filters created by society to overlook reality, changing from generation to generation, from social group to social group, from human being to human being. As target of a hierarchical overview of significances, an existing building can be appreciated by its historical, aesthetical, scientific, age, ecological, social, economic or political value. Even if these are the most subjective of all the layers presented, cultural values are the ones that most influence and model decisions of intervention, often independent of the building features and grade of conservation.

A building is not subjective but a living product of its own contemporary society, with substance, function, production complexity, performance and costs. These **features** are not static but change constantly with time. Without an intervention, the substance of the building gets more and more degraded, the function more outdated, the production complexity more simple and the performance less efficient. Only the building costs increase, parallel to its historic, aesthetical, social, economic and political value considered by its anthropologic environment.

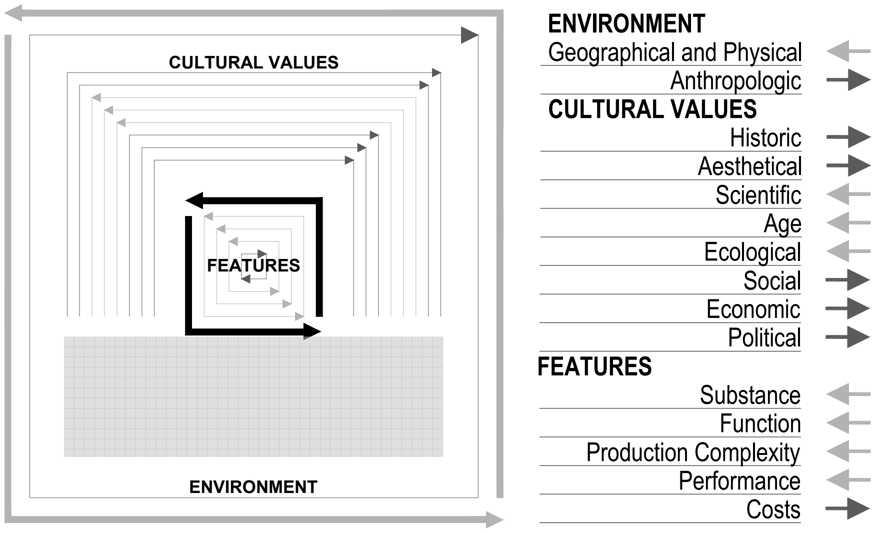

Figure 2 Built heritage “shearing layers of change”

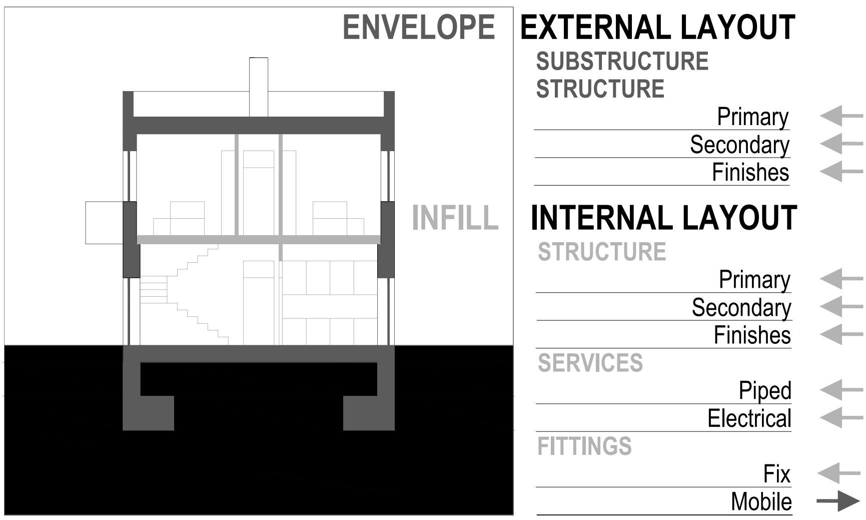

Figure 3 Built Heritage substance

Substance is subsequently the big aggregate of all the 5 remaining Steward Brand “S’s”. Totally objective and precise, it encloses all building time layers in three possibilities of materiality: either as forms, regarding the spatial planning and necessary areas for the specific function in question; as components, regarding the building composition and elements (external and internal layout); or merely as materials regarding the availability of resources (stone, bricks, concrete, wood, glass, etc.).

Thus, by zooming in the substance layer in the components option (figure 3) we find two main groups, the external layout **envelope** – substructure and structure (primary, secondary and finishes); and the internal layout **infill** – structure (primary, secondary and finishes), services (piped, electrical) and fittings (fix and mobile furniture). Both envelope and infill have three sub categories of layers regarding their lifetime expectancy and flexibility: long, mid and short term. Without any intervention, again the shearing layers of change do not progress, except for the mobile fittings (furniture, decorations, electrical equipment, etc.), that with a shorter lifespan are more sensible to society’s changing fashions and technological developments.

3. The Lifespan rehabilitation of built heritage

Interventions are becoming more and more common in what concerns reusing or giving new uses to existing buildings, but our question is how are they being done? Do they consider all cultural values in harmony with each other or do they simply ignore all values except for the political, economic and social ones? Sheltered by the urban scale of rehabilitation, interventions can often be quite destructive and represent a huge amount of resources waste.

The following figures 4 and 5 represent two rehabilitation interventions, one in Portugal and other in the Netherlands, where both buildings have been demolished, but in the Portuguese case, the specter of what once was the main façade was left for inheritance. Portugal is not yet as developed as the Netherlands on sustainable matters, so there was no waste management and all materials have been sent to the Landfill without any previous ecological consideration, neither material division.

An inevitable question rises: If the intervention program is to end up with an old building in appearance, why to totally or “partially” demolish and rebuild it exactly the same in form and style? Was the building in such a conservation state that nothing at all could be recovered and reused? It is difficult to believe how the new technological structures can compete in quality and lifespan with the old structures that survived throughout all kind of adversities during centuries, but evidentially historical aesthetical and scientific values didn’t take much priority in these cases.

Figure 4 Rehabilitation of an old villa in Cascais, Portugal

Figure 5 Rehabilitation of an old quarter in Eindhoven, The Netherlands

Authenticity is so proclaimed in international charters and declarations, but still in old urban areas we find abundantly this type of interventions. If it is highly recommended that every intervention is done with the available tools and technologies in your contemporaneity, why to pretend that the building apparent exactly the same as tree hundred years ago, even if in fact is a XXI century building? Can’t we do something to subvert this economical exploitation tendency? Table 1 presents the scale of intervention for each building feature that can among time demonstrate or be responsible for building pathologies. Such pathologies will eventually stimulate interventions, and choice possibilities are valuated by a one to five scale [I to V], according to their sustainable weight and use of natural resources.

With this scale it is not our purpose to declare that for every feature and building case, only scale V intervention is the best and should be the option to choose, because by the fact that you are considering to reuse an existing building and its urban infrastructure is already more sustainable than just let it there abandoned and go built in some other place else without any infrastructures. However, in what regards the intervention sustainable weight there exists an ideal standard - wasting the least human, energetic and natural resources possible, which does not happen in scale **I** where disregard, demolition and waste are the mainly rules.

Table 1 Scale of intervention

					Scale
Features	**V**	**IV**	**III**	**II**	**I**
function	use	reuse (upgrade)	readapt (compatible)	readapt (incompatible)	not use
substance forms	use	reuse (upgrade)	partial additions or subtractions	partial additions and subtractions	global mutation
substance components	arrest decay, repair, consolidate or reinforce (compatible)	partial substitution (compatible)	total substitution (compatible)	partial substitution (incompatible)	total substitution (incompatible)
substance materials	use	demount and reuse in a different situation	demount, recycle and use	demount and recycle	demolition and waste
production complexity	very easy	easy	reasonable	difficult	very difficult
physical and technical performance	improve	maintain	recover	decrease	replace
costs	profit immediate	profit short term	profit mid term	profit long term	no profit

An intervention does not need to reach the standard ideal in every feature, because also, the building and the design program cannot allow that expectation, but the goal is to pursue sustainability always, even if dependent from the circumstances of every building feature. For example, if you have an intervention in hands, where the design program purpose is to change the function of the existent building into an incompatible one (scale **II**), you will necessarily have to make more spatial additions and subtractions to the existent form of the building (scale **II**) than if it was a reuse or even a compatible function. This situation is and was very common in every historical center of the world, especially regarding the last century considerable percentage of housing sector that has been converted into services (commerce, services, etc.) and the deactivated functions such as industries, religious and educational buildings that have also been target of rehabilitation, especially if located in the CBD (central business district).

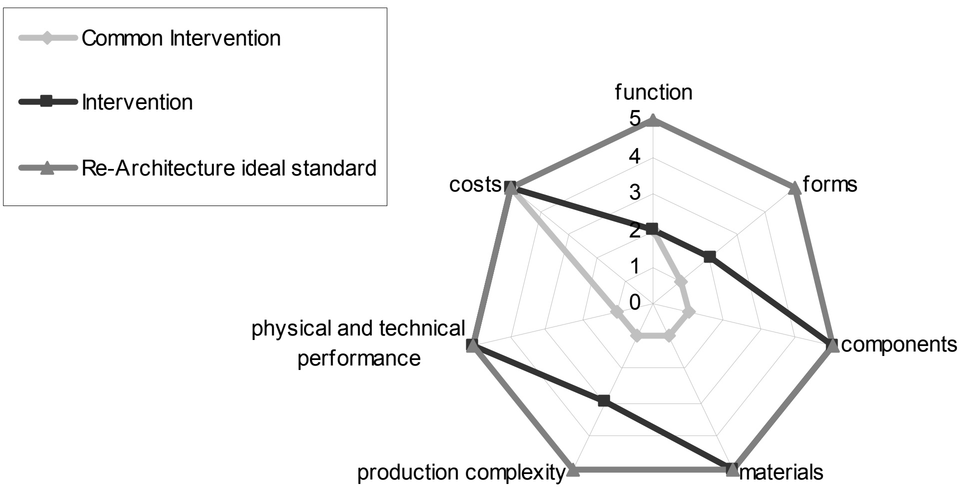

Figure 6 Scale of intervention

Nevertheless, the intervention scale regarding functional and formal spatiality, the status of conservation and cultural value of the building substance has to be observed consciously. Then you can start by choosing to think sustainable through;

- maximizing the use of building components that are still presenting good performance and state of conservation (scale V);
- reuse for some spatial additions the components or materials subtracted earlier (scale IV and III), by arresting decay, repairing, consolidating and reinforcing whenever necessary;
- send to recycle the exceeding components (scale II), contributing for the growth of recycling materials in the construction industry;
- and only as last hypotheses, send the materials that cannot be recycled (hazardous, obsolete, etc.), to the landfill as waste (scale I).

With this philosophy of intervention (rehabilitation), you will improve the performance of the building instead of totally replacing it (demolition), especially if you also consider some regeneration measures (passive and active) in its technical and physical behavior facing the geographical and physical environment.

Additionally, not only rehabilitation has an easier production complexity if you compared it to the entire process of demolition and building a total new building, but also the costs/profits of such intervention do not rise, because proportionally the percentage of resources reused will decrease the use of new resources. Figure 6 presents a summary of the building features explained in the previous paragraphs and the sustainable area disparity when confronting a common intervention and a conscious intervention.

4. Conclusion

The existing building stock has to change, allowing, and facilitating changes. Always appropriate in several uses, buildings cannot be synonym of dilemma anymore, but synonym of answer. Even if a building and their designers cannot challenge the uncertainties that the future might bring, something has to be done in order to subvert social tendency that accept the fact that every building can be demolished and new can be built instead. The Land filled wastes in industrialized countries show that already 20 to 30% of the global waste goes to Construction and Demolition waste.

An intervention cannot be seen anymore as an isolated action. It has to consider the existing building and its interrelations, before and after intervention (pre-design, design, construction), providing all necessary information for a better use, maintenance and further interventions that will certainly take place in the future.

If it is always expected in built heritage interventions an improvement regarding the inhabitance conditions in quality, comfort, safety and salubrity, a step forward should be taken in order to make ecology a rule and not the exceptional consideration. As presented sustainability is easily achieved in every building feature, even in what regards ventilation, lighting, thermal isolation, acoustic insulation, domestic water systems and the energy needed to provide an update till the contemporary standards.

We believe that something can be done in order to fulfill this gap: Interventions can reuse or recycle the maximum of the existent resources and still integrate all modern infrastructures regarding the XXI century needs.

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PLANNING AND DESIGN METHODS FOR PARTIAL CONVERSION OF PUBLIC SCHOOL IN TOKYO 23WARDS

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Keywords: conversion, school building, public facilities, design method, floor planning, stock management

Summary

In Japan, demolition and new construction based on declining in the durability and increased availability of buildings continues to be practiced. This practice is unfavorable from the viewpoint of utilization of the existing building stock. The conversion of existing public buildings can be quickly and flexibly support of demand of local residents. Therefore, conversion is an extremely effective technique leading preservation and improvement of the public property. In this study, the actual conditions of conversion from an elementary school to other functions were clarified and the content of design process and the problem were found out.

Main conclusions are the followings:

1. The partial conversion of the public elementary and junior high schools in Japan restricts various conditions such as the area of the existing floor space to be converted and arrangement of earthquake-resistant elements.

2. The total floor space following conversion, together with the type and number of rooms required for the new facility application are closely related to its planning.

3. The location of entrance and corridors which provide a circulation following conversion also affected a great part in the planning and design.

1. Introduction

Effective utilization of existing public facilities is a requisite theme for the development of buildings in a sustainable society, for the maintenance of public property and protection of resources. In urban areas of Japan these days, the number of closed schools and idle classrooms is increasing due to fewer children, and many attempts have been made to utilize them effectively by converting their original use. With an anticipated increase in the number of such surplus facilities due to the further declining birth rate, their effective utilization is an essential task for school facilities in the future.

This study aimed to clarify concrete design methods and draw on useful information for the planning and design of the partial conversion of school buildings, through a brief understanding of the partial conversions carried out on public elementary and junior high schools in the 23 Wards comprising central Tokyo, as well as organizing and understanding just how the school spaces were changed as a result of such conversions.

2. Research Subject and Method

The 23 Wards of Tokyo show both a significant advancement in their aging population and a declining birthrate. As a result, the numbers of idle classrooms in school are increase and shortages of social welfare facilities are insufficient. Therefore, there are many cases of elementary and junior high schools in this area being partially converted to function as other public facilities. In this study, the entire 34 cases of schools which implemented such conversions in the 23 Wards were selected, and a questionnaire survey was carried out amongst the education boards of each school district concerned. In addition, the collection of drawings, field surveys and an interview survey of the architects concerning their designs were conducted, in order to clarify the design methods specific to the partial conversion of school buildings.

3. Research Results and Discussion

3.1 The area of Conversion

Following conversions, it was learned that many of them are used for facilities which are in short supply in the central Tokyo, such as social educational facilities (e.g. community centers), facilities for social welfare for the aged (e.g. day-care facilities for the elderly) and nursery schools.(Fig. 1) The average total floor space of these facilities was approximately 300 square meters, which more or less represents the area of three standard classrooms before conversion.(Fig. 2)

The area ratio between classrooms and the total floor space converted is shown in Fig. 3, by dividing the school into the standard classroom space (standard and special classrooms etc.) and non-classroom space (corridors, lavatories, staircases, entrances etc.). In all cases, 50 percent or more of the converted area consisted of the classroom space. It also shows the tendency that, the larger the converted floor space, the larger the ratio of the non-classroom area.

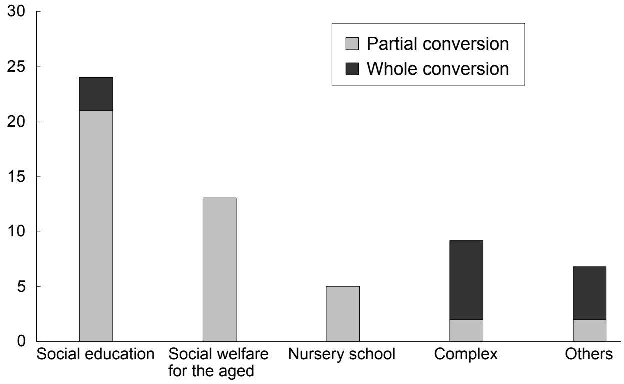


Figure 1 Number of building facilities after conversions of public school buildings in the 23 wards of Tokyo

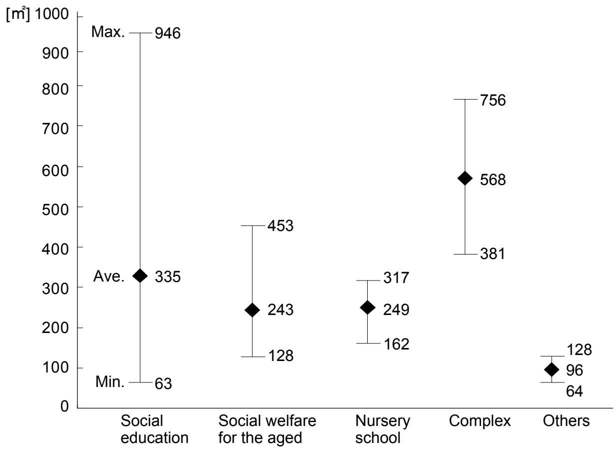


Figure 2 Area of floors after conversion

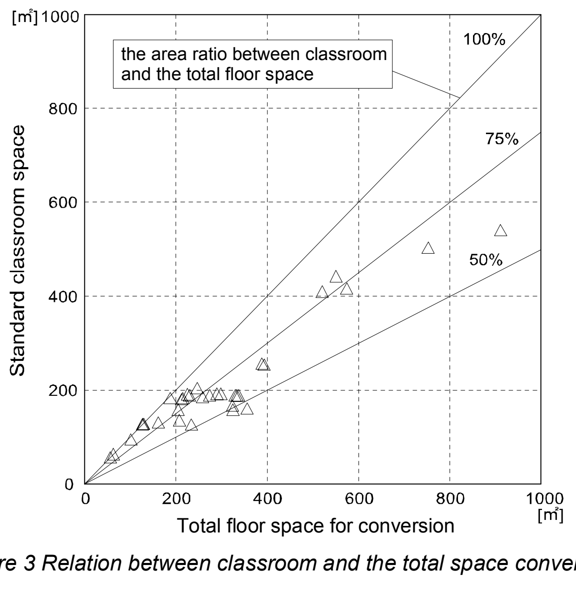


Figure 3 Relation between classroom and the total space converted

3.2 The Use of Rooms Before and After Conversion

The use of rooms before and after conversion is shown in Fig. 4. When a large floor space was required for a new facility, such as multipurpose room in community center, rehabilitation room in day-care facility and nursery room, the conversion was mostly made from standard classrooms as they are relatively large in size. When it was not required (e.g. for an office), the conversion was made from various areas regardless of their former use, except that in the case of water sections such as lavatories and kitchens, the conversion tended to reuse a special classroom in order to make use of its existing piping etc.

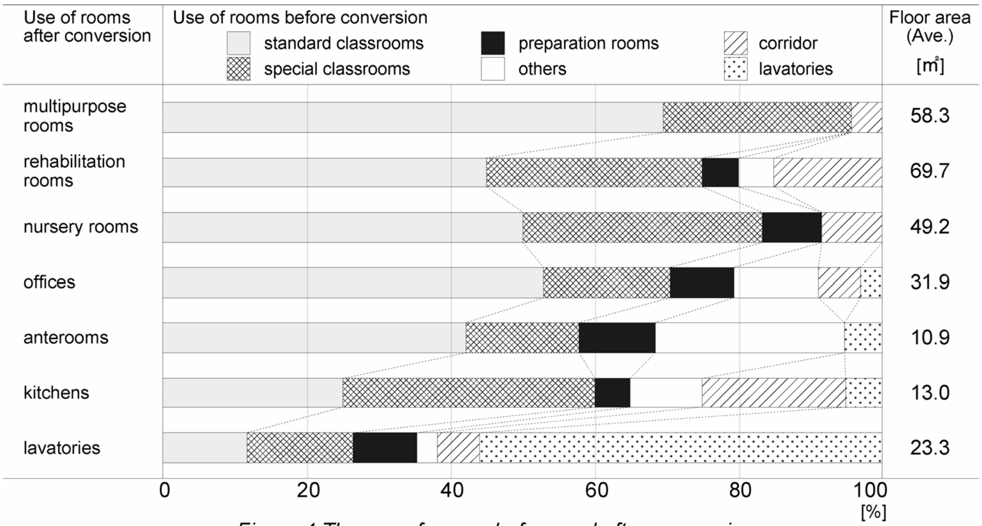
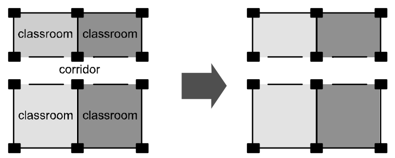
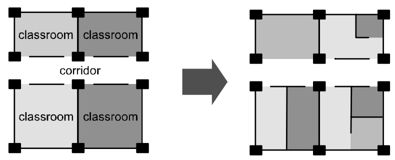
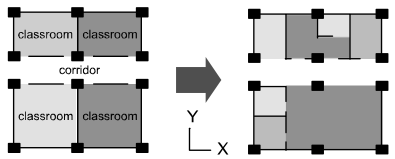
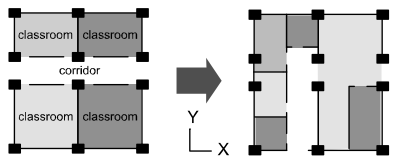
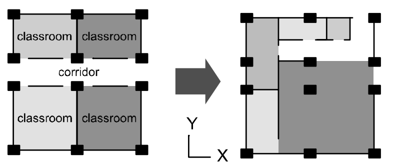


Figure 4 The use of rooms before and after conversion

3.3 Changes of the Floor Planning Before and After Conversion

Noting to what extent the existing floor planning has influenced the design of its conversion, the design methods were patternized as shown in Table 1. As a result, Series A(subdivided Type R and Type S), which retained the existing floor plans, represented over 60 percent of all cases, while Series B(subdivided Type X, Type Y and Type XY), which were disregarded the existing floor plan, represented slightly less than 40 percent.

Table 1 Floor planning patterns in conversions

			Number of cases
Series A	Type R		5
	Type S		17
Series B	Type X		4
	Type Y		4
	Type XY		4

With regard to the total floor space for each pattern (Table 2), those of Series B were smaller compared with Series A. This shows that in the case of Series B have to provide rooms with a single open space within a relatively small given area, as a consequence their floor planning are obliged to disregard the existing plan.

With respect to the number of cases per facility use (Fig. 5), most of the social educational facilities fall under Series A using the existing plan, while about half of the facilities for social welfare for the aged, nursery schools and complex facilities fall under Series B, free from the existing plan.

Table 2 Total floor area for each pattern

		Ave.(m²)		Min.(m²)	Max.(m²)
Series A	Type R	140.6	323.4	56.0	189.0
	Type S	380.6		101.7	911.0
Series B	Type X	286.3	262.0	187.1	520.2
	Type Y	270.5		161.6	322.8
	Type XY	229.7		214.3	388.0

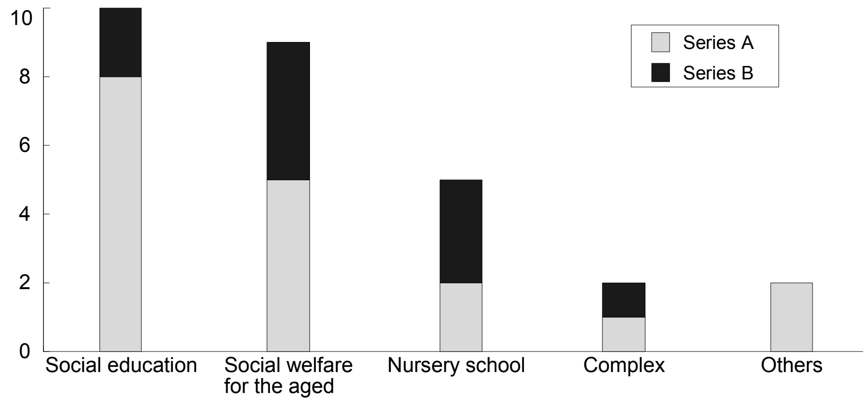


Figure 5 Number of cases in floor planning pattern per facility use

3.4 Changes of Corridors Before and After Conversion

Typical floor plans of Japanese elementary and junior high schools consist of the side corridor plan which places classrooms on one side of a corridor and the center corridor plan which places classrooms on both sides of a corridor. Resulting from this fact, a significant difference was seen between Series A and B regarding how the area of the existing corridor was changed. In Type S, the existing corridors in most cases were retained without changing their use. On the other hand in Type X, there are some cases which converted parts of the existing classroom to a corridor, thereby expanding the circulation. In Type Y, in all its four cases, part of the existing corridor was combined with an adjacent existing classroom to create a room which met the new planning, of which three were schools with the center corridor plan.

3.5 Changes of the Ceiling Height Before and After Conversion

In 70 percent of all cases, the ceiling height was made lower as shown in Table 3. This was mainly due in many cases to the installment of new plumbing and wiring under the roof and/or floor when converted. Another reason may lie in the design implementing an appropriate space proportion to a new room, as the high story height typical of Japanese school buildings may be too high for its new application.

Table 3 Changing ceiling height in each pattern of floor planning

Ceiling height		Expansion	Sameness	Reduction
Series A	Type R	0	4	1
	Type S	0	4	13
Series B	Type X	0	0	4
	Type Y	0	0	4
	Type XY	0	1	3

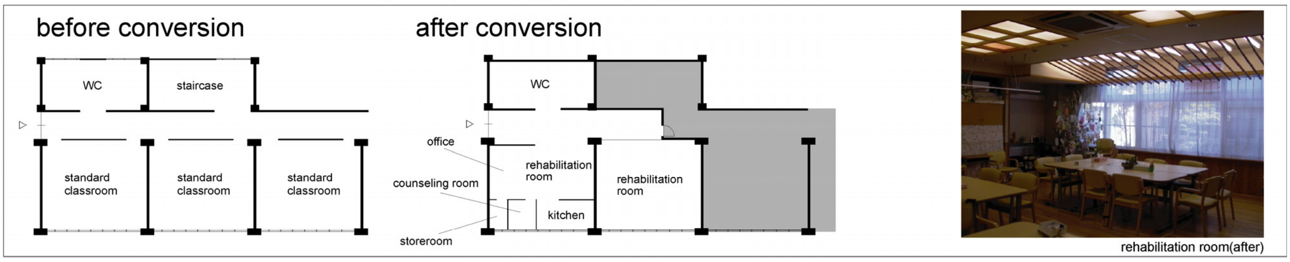
3.6 Example of the Partial Conversion Design

An interview survey was carried out with the architects regarding one case each of Series A and B respectively (Fig. 6). Both cases were subject to the condition that no structural changes should be made to the building frame, while the use, number and size of rooms required after the conversion were given.

In Case I, the design was made while placing top priority on securing appropriate floor areas according to the use of each room following conversion. Being restricted by the fact that location of the entrance of the new facility had been decided, and that no alteration to the corridor, as a circulation, was allowed, the design resulted in one respecting the existing room plan. In Case II, as it was required to locate the entrance and the office space next to each other, while securing a traffic line leading to the kitchen for carrying in and out, the design was made to link the inside to the outside of the building, by allocating the office space and kitchen in the former corridor area.

Some architects stated in their answer that one of the specific issues of school building conversion is the fact that they cannot remove walls between classrooms because of their earthquake-resistant function, and that this represents a great constraint on their floor planning.

Case Ⅰ: Social welfare for the aged planning pattern:Type S



Case Ⅱ: Nursery school planning pattern:Type Y

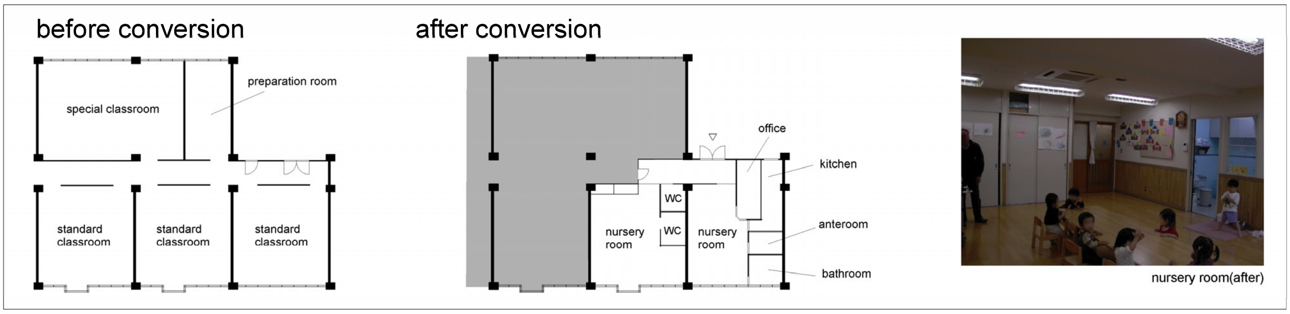


Figure 6 Specific example of the floor planning in each series

4. Conclusions

The study revealed that although the partial conversion of the public elementary and junior high schools in Japan restricts various conditions such as the area of the existing floor space to be converted and arrangement of earthquake-resistant elements, a broad range of design methods exists. Further, with respect to floor planning, it became clear that the total floor space following conversion, together with the type and number of rooms required for the new facility application are closely related to its planning. The location of entrance and corridors which provide a circulation following conversion also affected a great part in the planning and design. There were no examples in this study of cases which included extension of a building during conversion. It is however necessary to consider partial extension in order to sufficiently meet the function of new facilities. Regarding the issue arising from the restriction of not being able to make changes to a building's structural frame, this can be solved through the establishment of a conversion design method linked with seismic retrofitting.

Acknowledgment

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FACTORS IN THE PLUMBED INSTALLATIONS POSITIONING OF MULTI-UNIT RESIDENTIAL BUILDINGS

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Summary

There are have been remarkable achievements in terms of technological development for adaptable residential buildings in Japan. One of the principal subjects in recent research and development programs concerning adaptable residential buildings has involved developing technologies to allow the user to decide the positioning of baths, washbasins, sinks, washing machine pans and other plumbed installations: technologies allowing free layout of such plumbed installations within each dwelling unit and plumbed installations laid out such as to facilitate replacement. However, the numerous factors applicable to plumbed installations positioning mean that free layouts of installations are likely to require more than simply technological solutions alone. This paper aims to analyze the factors concerning the positioning of plumbed installations within multi-unit residential buildings. Firstly, we found that there were various relevant factors concerning the positioning of installations when taking an overview of the history of Japanese residential buildings' construction. Secondly, we showed the influence of building characteristics on the installations positioning quantitatively, through a statistical analysis of existing residential buildings and a theoretical analysis. Through these analyses, the need for a comprehensive approach in designing adaptable buildings to ensure success became clear.

1. Introduction

There are have been remarkable achievements in terms of technological development for adaptable residential buildings in Japan. Following the initial research and development program concerning adaptable residential buildings led by public sectors and commencing from the early 1970s, numerous programs followed on a continual basis in order to resolve diverse problems faced by adaptable residential buildings.

One of the principal subjects in recent programs has involved developing technologies to allow the user to decide the positioning of baths, washbasins, sinks, washing machine pans and other plumbed installations: technologies allowing free layout of such plumbed installations within each dwelling unit and plumbed installations laid out such as to facilitate replacement. These efforts brought new methods and technologies for the base building and fit-out design, and have also being generally adopted for the construction of multi-unit residential buildings since about 1999.

However, the numerous factors applicable to plumbed installations positioning mean that free layouts of installations are likely to require more than simply technological solutions alone. This paper aims to analyze the factors concerning the positioning of plumbed installations within multi-unit residential buildings. Through this analysis, the need for a comprehensive approach in designing adaptable buildings to ensure success will become clear.

2. Building Construction and Layout of Installations

2.1 The Initial and Developmental Stages

We will start by providing a context to the construction of residential buildings and plumbed installations layouts in Japan in chronological order.

Multistoried residential buildings appeared around 1925 and became widespread after WWII in Japan. Since reinforced concrete construction had already been introduced into Japan in 1925, the building frames have been made from reinforced concrete right from the start. Following generalization, multistoried residential buildings in Japan are characterized by the inclusion of a fully waterproofed bathroom within each dwelling unit (Fukao 1992). Concerning mechanical systems, the absence of the central water heating system in Japan saw each new dwelling unit equipped with a water heating system, and the mechanical systems involved were the object of considerable and rapid development.

The problem arising when heating water in each dwelling unit was the means of allowing noxious fumes from burning fuel to escape and how to ensure a supply of fresh air. Although the advent of balanced flue boilers in the 1960s enabled safe fuel burning indoors, the bathroom had to look onto an outside wall, to allow the boilers to exhaust polluted air and supply fresh air. An additional reason for the bathroom layout looking onto the outside was the natural ventilation via an exterior wall, required due to the humidity of the Japanese climate. Consequently, dwelling units of this time were designed with wide frontages to ensure rooms were well-lit and well-ventilated.

To ensure residents' privacy as well as natural lighting and ventilation, stairway access type buildings, where twin dwelling units on the same floor were connected with a single stairway, were designed. Since including an elevator in individual stairways of such buildings would be inefficient, residential buildings of the time were generally limited to four or five story constructions.

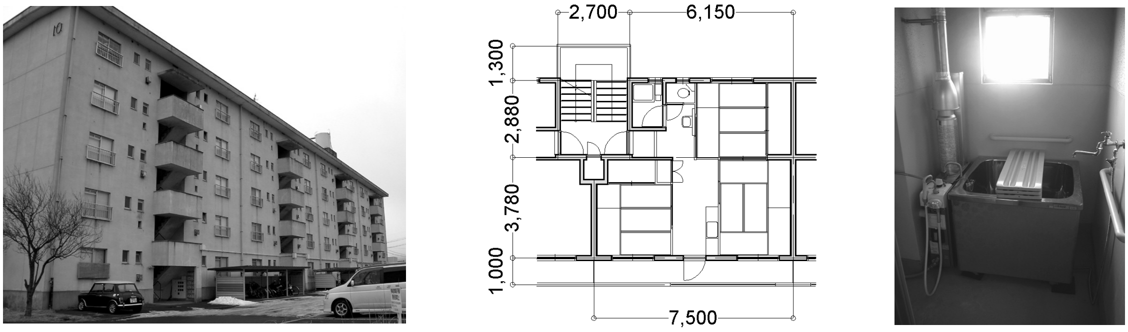

Figure 1 A Residential Building, a Dwelling Unit Plan, and a Bathroom Constructed in the Early 1970s

2.2 The Establishing Stage

From then onwards, technologies for bathrooms and other plumbed installations made remarkable progress in the pre-1980 period: with the appearance of bath units developed from bathrooms using pan panels, compact electronically-controlled boilers which could be installed outside, and mechanical ventilation systems using ducts. Bath units also enabled fully waterproofed bathrooms without the need for problematic asphalt waterproofing. Compact boilers and mechanical ventilation systems, meanwhile, enabled bathrooms without requiring windows looking onto the outside. These technologies succeeded in achieving new freedom for freely plumbed installation layouts.

During this period, there was one additional dramatic change in the height of general residential buildings; namely from mid- to high-rise buildings. Since climbing the stairs in such high-rise buildings would be tiring, elevators had to be installed. Although Japanese elevators boast the strictest global safety standards, maintenance costs are high. In terms of running costs, it is said that those for a single elevator should be divided by more than 60 families. Accordingly, this ensures effective passageway access to dwelling units within high-rise residential buildings. In most high-rise residential buildings in Japan, the access axis was arranged outside rather than within a building, in order to maximize natural lighting.

Subsequently, the next change involved a revised standardization of bathroom positioning. Since Japanese people favor south-facing dwellings, it became necessary to narrow the width of dwelling units to pack the maximum possible number of south-facing units into the building, as we shall see later in chapter 4. The narrow unit means the bathroom positioning is restricted to the center of unit and without natural light.

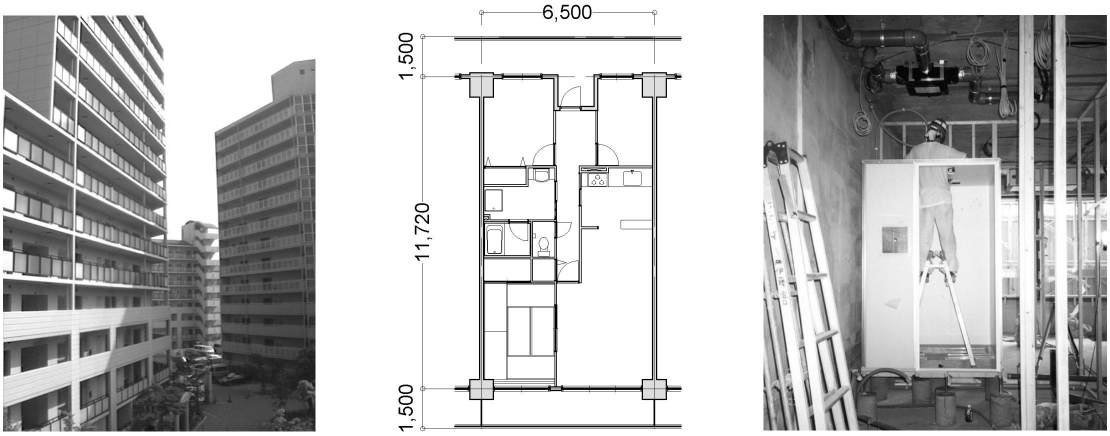

Figure 2 Residential Buildings, a Dwelling Unit Plan, and a Bath Unit Constructed in the Post-1980 Period

2.3 The Present Situation

As an opposition to standardized bathrooms, certain architects have recently argued that bathrooms should be designed to look on to the outside. With this in mind, the supply of so-called non-standardized dwelling units in central Tokyo, targeting young rich families, is beginning to grow. In addition, there is a slight tendency for rooms, which do not legally require natural lighting, for example laundry rooms, to look onto the outside (Waku et al. 2003). Based on these remarks, you may say that the positioning of plumbed installations in Japan can be said to demonstrate diversity.

Turning now to adaptable buildings in Japan, the development of technologies for free plumbed layouts, in renovation as well as new constructions, began in late 1980s and have now become established as general technologies. Their advent has signaled dramatic changes in the base building design. In particular, it has become seemingly important to secure a large and deep underfloor space in order to accommodate long horizontal pipes, and to design a flat slab without a beam to avoid ducting obstructions. Figure 4 shows a cross-section of a typical latest base building structural design, namely an "Inverted Slab / Beam Structure" designed to enable free layouts of plumbed installations.

Figure 3 A Bathroom Designed to Look on to the Outside Constructed in 2003

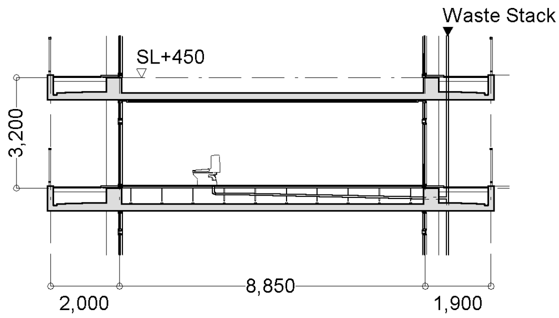

Figure 4 Cross-section of a Dwelling Unit with the Inverted Slab / Beam Structure

3. Statistical Analysis

3.1 Procedure for Analysis

In the former chapter, we found that there were various relevant factors concerning the positioning of plumbed installations when taking an overview of the history of Japanese residential buildings' construction. In this chapter, we will show the influence of such building characteristics on the plumbed installations positioning quantitatively, through a statistical analysis of existing residential buildings.

Table 1 The Definitions and Statistics of the Variables Used in Chapter 3

Variable	Definition	Unit	Statistics	
			Min. Max.	Ave. Sta. Dev.
Story Height	The floor-to-floor height of the base building.	mm	2650.0 3600.0	2833.6 169.6
Available Depth of Underfloor Space for Piping	The maximum depth of a raised floor for piping.	mm	30.0 730.0	233.1 98.6
Slab Level Difference	The level difference of slab surfaces where applicable. For Inverted Slab / Beam Structure, the length between the beam top surface and slab top surface.	mm	0.0 600.0	105.4 124.3
Maximum Distance between Plumbed Installations and Drainage Stacks	The maximum horizontal distance between plumbed installations and waste stacks connected to the equipment by underfloor piping.	m	0.000 13.299	3.049 1.658
Minimum distance between Plumbed Installations and Peripheral Walls	The minimum distance between plumbed installations excepting the kitchen unit and the peripheral walls of the dwelling unit.	m	0.000 4.700	1.315 1.571
Length of Wall Surface Capable of Natural Lighting per Unit Area	The total horizontal cross-sectional length of walls in which openings can be designed divided by the area of the dwelling unit.	m / m^2	0.065 0.478	0.228 0.093
Dwelling Unit Area	The total area of the dwelling unit.	m^2	31.540 167.296	80.196 19.746
Number of Private Rooms per Unit Area	The number of private rooms per dwelling unit area.	$1 / m^2$	0.015 0.056	0.037 0.008
Average Area of Private Rooms	The average area of private rooms.	m^2	9.119 20.223	12.300 1.933

This analysis deals with reinforced and steel-framed reinforced concrete (including concrete-filled steel tube structures) medium- to high-rise post-1980 multi-storied residential buildings built in Japan, whose blueprints (plans, cross-sections and elevations of the buildings and dwelling units) were collected. One hundred and sixty dwelling units were selected by extracting a single unit from each building for analysis. However, dwelling units on the top or bottom floors and duplex units were excluded, since they seemed to be designed differently from the flat units on the middle floors. In addition, the survey was limited to buildings constructed post-1980 since they would be likely to contain utilities and structural framing methods affecting the plumbed installations layouts similar to those currently used for general residential buildings, due to the standardization of bath units, compact boilers, and mechanical ventilation systems.

In addition to the basic information concerning the 160 cases including the owner and year of construction, the value of variables characterizing the design of each dwelling unit was then measured based on documentations such as the drawings. To obtain numerical data, we calculated the correlation coefficient of each combination, and analyzed the scatter diagram to investigate the influence of the building characteristics on the positioning of the plumbed installations. The definitions and statistics used in this chapter are listed in Table 1.

3.2 Influence of the Building Characteristics on the Installations Layouts

To design plumbed installations layouts freely or to alter their positioning, a large and deep underfloor space is required in order to accommodate the long waste branches connected with the stacks. The relationship between the available depth of underfloor space and the maximum distance between the plumbed installation and waste stacks reveals that the deeper the underfloor space, the further plumbed installations can be located from the stack (Figure 5). However, conversely, there is a strong correlation apparent and increased scatter, as the maximum distance between the plumbed installation and waste stack and the

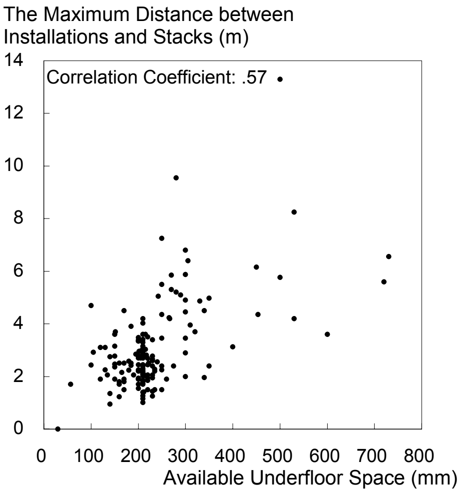

Figure 5 The Available Underfloor Space and the Maximum Distance between the Installations and Stacks

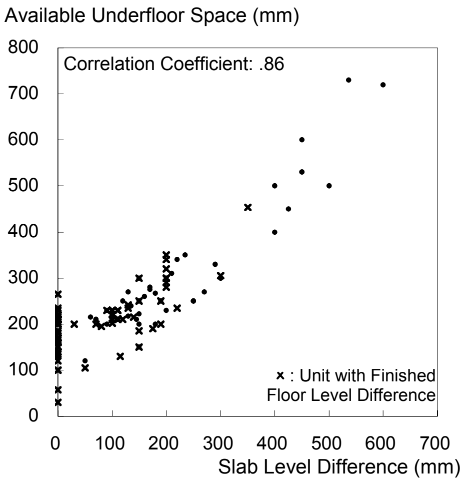

Figure 6 The Slab Level Difference and the Available Underfloor Space

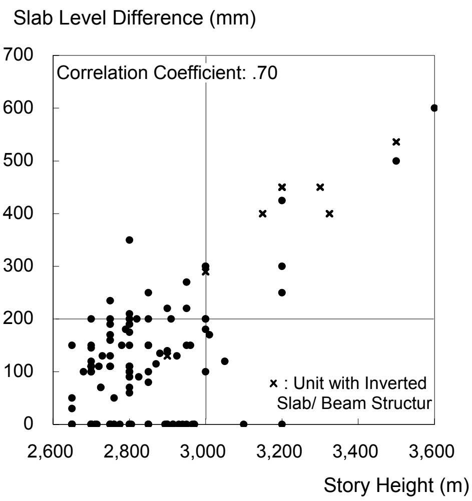

Figure 7 The Story Height (Floor-to-floor Height) and the Slab Level Difference

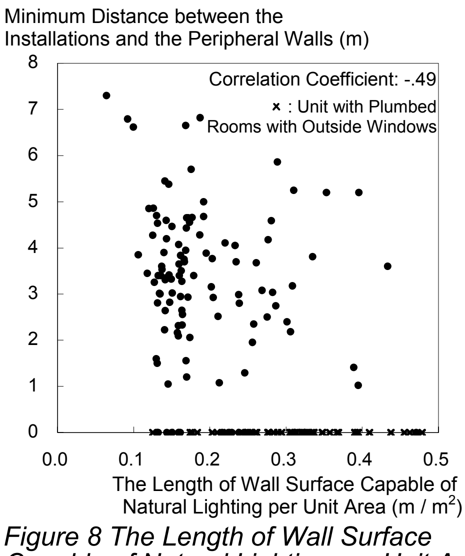

Figure 8 The Length of Wall Surface Capable of Natural Lighting per Unit Area and the Minimum Distance between the Installations and the Peripheral Walls

maximum depth of the underfloor space rise in tandem. This may be due to the fact that once ample underfloor space is secured, the depth of such space is determined not only by the requirement of the present plan designs but also consideration of the future variability of the plumbed areas.

To secure a deep underfloor space, the floor slab level is sometimes lowered below the beam's top level, for example, in the aforementioned Inverted Slab / Beam Structure. The slab level difference is found to be directly proportional to the depth of underfloor space (Figure 6), with a very strong correlation between the two. To accommodate the branch pipes, the end floor level of the rooms in the plumbed section, for example the washroom, is sometimes raised higher than that of the habitable rooms, although this is considered undesirable when considering the needs of elderly residents. When stratifying the relationship in terms of the presence / absence of differences in the finished floor level, findings showed that a difference of 200mm in slab level was required to secure a free plumbed installations layout while maintaining the finished floor level entirely flat.

The slab level difference and the story (floor-to-floor) height of the dwelling unit also show a strong positive correlation (Figure 7), indicating that the higher the story, the greater the depth at which secure slab level difference is possible, and the greater the scope for a deeper underfloor space to be designed. Thus we see that it is important to design a high story unit in order to improve the degree of freedom concerning the layout of plumbed installations.

To secure a slab level difference exceeding 200mm in order to flatten the finished floor level, the dwelling unit should be more than 3m in story height. In addition, Inverted Slab / Beam Structures are often adopted for cases where the slab level difference exceeds 400mm.

A relatively strong negative correlation is observed between the length of wall surface capable of natural lighting per unit area, which represents the index of unit lighting conditions, and the minimum distance between plumbed installations and the peripheral walls (Figure 8). This indicates that plumbed installations tend to be designed in the center of a unit in the case of insufficient natural lighting. In order to improve the degree of freedom concerning the layout of plumbed installations, it is important not only to secure a large story height and ample underfloor space, but also to design a unit with a wide frontage to allow sufficient natural lighting.

3.3 Comparative Analysis in Building Characteristics

Now, let's compare the building characteristics of two groups: Group I where the rooms in the plumbed section, for example the bathroom, are designed to be outward-looking while Group II features plumbed rooms without outside windows. Group I includes 48 dwelling units, while Group II includes 112. We examined the presence of any significant differences between Groups I and II in terms of the dwelling unit area, the number of private rooms per unit area, the average area of private rooms, and the length of wall surface capable of natural lighting per unit area (table 2).

Table 2 Statistical Comparisons between Group I and Group II

Statistics \ Variables		Dwelling Unit Area	Number of Private Rooms per Unit Area	Average Area of Private Rooms	Length of Wall Surface Capable of Natural Lighting per Unit Area
Average: x	Group I	86.5541	0.0378	12.7724	0.3068
	Group II	77.4708	0.0371	12.0974	0.1941
Standard Deviation: s	Group I	19.6981	0.0081	2.3554	0.0806
	Group II	19.2161	0.0081	1.6934	0.0753
Difference of Sample Means: X_1-X_2		9.0833	0.0007	0.6750	0.1126
Standard Error: SE(X_1-X_2)		3.3735	0.0014	0.3757	0.0136
Test Statistic: Z_{OBS}		2.6925	0.4940	1.7964	8.2614
P-Value		0.0035	0.3106	0.0362	0.0000
.05 Level of Significance		**Significant**	Insignificant	**Significant**	**Significant**
.01 Level of Significance		**Significant**	Insignificant	Insignificant	**Significant**

The results were as follows:

- The dwelling units in Group I tended to be larger in terms of dwelling unit area than those in Group II at an .01 level of significance.
- There was no significant difference in the number of private rooms per unit area.
- The average area of private rooms tended to be larger in Group I than in Group II at an .05 level of significance.
- The length of wall surface capable of natural lighting per unit area tended to be longer in Grope I than in Group II at an .01 level of significance.

It is therefore reasonable to conclude that it is also important to design a spacious dwelling unit in order to improve the degree of freedom concerning the layout of the rooms in the plumbed section.

4. Lighting Condition and Density of Dwelling Units

In the former chapter, we obtained the following result: in order to design plumbed installations layouts in freedom, it is important not only to secure a large story height but also to design well-lit dwelling units. Well, as was suggested in chapter 2, the density of dwelling units has an impact on the lighting conditions of the same, rendering this subject worthy of further attention.

Let us now consider a residential building constructed in Japan, as shown in Figure 9. The building lot is W in length from east to west, D from north to south, and with an area S. The building is m-storied, and there are n dwelling units, of the same proportions, on each building floor.

Because Japanese people prefer south-facing dwellings, all dwelling units in this building face due south to avoid any decline in the real estate value of the building. External passageway access is adopted in this building, and each dwelling unit has natural lighting from the windows in the north and south unit-wide exterior walls. To maximize the number of dwelling units, the building width is almost equal to that of the building lot itself.

This building is of a standard height for this city, with another building of the same height on the neighboring lot to the south. In Japan, one of the standards generally regarded as important, in terms of lighting for the home, is to ensure more than four hours sunlight is available in the principal rooms daily during the winter solstice. To ensure this, it is necessary to maintain an angle between the horizontal plane and oblique line directed due south from the far south end of the residential building to far north end of the next building below θ.

In addition, each dwelling unit includes the dimensions w in width, d in depth and s in area.

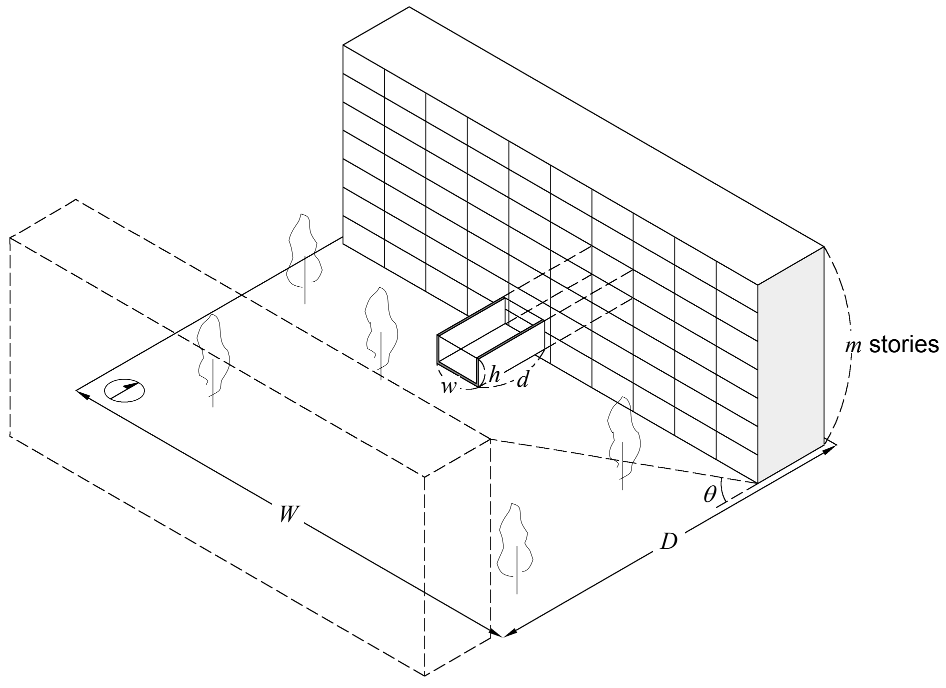

Figure 9 A Model of a Residential Building for a Theoretical Analysis

Consider now the density of dwelling units within this building lot.

If N expresses the number of dwelling units in this building, N / S expresses the number of dwelling units per lot area, in other words, the density of dwelling units for the building lot. There are n dwelling units in each building floor. Besides, the relation among n, W and w is $n = W / w$. Accordingly, N can be revealed using the following equation:

$$N = mn = mW / w \qquad (1)$$

Well, $S = WD$, and D is a factor of the height of the neighbouring building to the south, meaning angle θ will satisfy the lighting condition standard. The relationship can be shown using the following equation:

$$D - d \geq \frac{H}{\tan\theta} \tag{2}$$

Hence it follows that the minimum value of D is $H / \tan\theta + d$. Accordingly, S can be revealed by the following equation:

$$S = WD = W\left(\frac{H}{\tan\theta} + d\right) \tag{3}$$

Therefore, the density of dwelling units N / S can be calculated using the following equation:

$$N / S = \frac{mW / w}{W\left(\frac{H}{\tan\theta} + d\right)} = \frac{m}{w\left(\frac{H}{\tan\theta} + d\right)} \tag{4}$$

The following equation is then obtained on referring to $H = mh$ and $d = s / w$:

$$N / S = \frac{m}{w\left(\frac{mh}{\tan\theta} + \frac{s}{w}\right)} = \frac{m}{\frac{mhw}{\tan\theta} + s} \tag{5}$$

The relation among the density of dwelling units, the width of dwelling units w, and the number of building stories m can be represented as Figure 10, assuming the area of each dwelling unit s as 70m^2, the story height h as 3 meters, and a $\tan\theta$ of below 0.6 in this city.

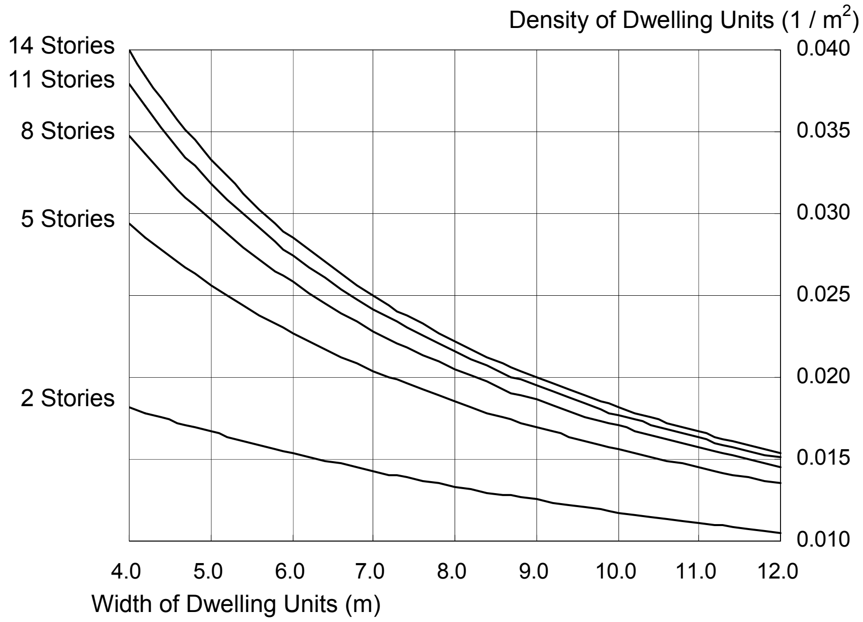

Figure 10 The Relation among the Density of Units, the Width of Units, and the Number of Building Stories

As Figure 10 shows, as the dwelling units narrow, their density increases. As the number of building stories m increases, meanwhile, the slope of the density curve gets steeper. This indicates an intensification of the narrowing effect causing the dwelling units' density to climb in the high-rise city areas. These results can be said to effectively represent the characteristics of post-1980 dwelling unit design in Japan.

5. Conclusion

The results of this research are as follows:

1) The most significant factor affecting the positioning of plumbed installations in multi-unit residential buildings was the volume of underfloor space available for piping. It indicated that adaptable base buildings should have large floor-to-floor height.
2) Well-lit dwelling units, for example those having a wide frontage, were also strongly affected in terms of the positioning of plumbed installations. Plumbed installations in narrow units tended to lie on sunless centers.
3) Accordingly, a narrow unit with a large floor-to-floor height would not always allow free installations layouts. It might be just considered an overinvestment.
4) The rooms in the plumbed sections, for example bathrooms, tended to be restricted into central areas in the units with limited unit areas. It indicated that adaptable residential building should have spacious dwelling units. Besides, the tendency for installations to look onto the outside in recent years was interpreted as a manifestation of improved living conditions in Japan.
5) They also tended to be centrally located in high dense buildings. It in important to consider building site plans and so on in order to conserve urban residential buildings of high density as valuable property in future.

Acknowledgement

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IMPROVEMENT OF BUILDING STOCKS BY CONNECTIONG ADJACENT TALL-NARROW BUILDINGS

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Keywords: building, stock, renovation, seismic retrofit, fire evacuation, conversion

Summary

We find many tall-narrow buildings in the center of large cities such as Tokyo and Osaka, yet these buildings have problems such as inefficiencies in floor planning, limited fire evacuation, insufficient seismic safety, and inefficiencies in mechanical facilities. The authors have been studying the improvement of such tall-narrow buildings by connecting existing buildings located side by side. The study focuses on the architectural and engineering point of views, as well as the social and economical point of views. This paper presents the effect of connecting buildings on the improvement of floor planning, seismic performance, and fire evacuation. Case studies of connecting such buildings and the improvements of each building are introduced. Also the improvement of a city block composed of such building stocks by applying this connection method is presented.

1. Introduction

We find many tall-narrow buildings in the center of large cities such as Tokyo and Osaka, yet these buildings have problems such as inefficiencies in floor planning, limited fire evacuation, insufficient seismic safety, and inefficiencies in mechanical facilities. We think that by connecting such tall-narrow building standing side by side, solution of these problems can be achieved in an easier way than we figure out the solution for independent buildings. In the sense of architectural planning, the combination of two buildings can offer more commercial spaces by reducing utility spaces and a combined larger floor area allows better use of the buildings. For the seismic performance, the connection of two buildings offer double stance to increase stiffness and stability. By applying a structural control between the buildings a seismic retrofit of old buildings can be achieved more effectively than the retrofit work for each building separately. Connecting buildings supplies multiple evacuation ways horizontally as well as vertically, enhances the safety of occupants in the event of fire. For mechanical facilities shared use of equipments by two adjacent buildings offers more efficient capability than separate use, and the connection to the infrastructure can be reduced from two to one, resulting in the reduced operational cost.

Typical buildings treated in this study are presented in Fig. 1. The width of the target buildings is 5 to 7 m composed of one span of columns, and the depth is about 15 to 20 m, composing the floor area of 100 to 150 m^2. The height of the buildings is 5 to 10 storey, making these building tall and narrow. The connection of two buildings standing side by side such as buildings indicated by ▼ and ■ are the major objective. Also we find 2-3 story small buildings in between tall buildings. When these small buildings will be removed and re-constructed to taller buildings, a planning of the new building in consideration of connecting to the adjacent building, rather than an independent planning, will be also beneficial. By extending such connection of two buildings to a town scale, an improvement of comfort and safety of the area could be achieved. If buildings owned by different owners will be combined, the freedom of the owner will be limited. Also the current law assumes that each building is self contained. To enable such connection of different buildings, such social aspects need to be studied and incentives and legal possibilities have to be cleared and economical incentive has to be made clear. These social and economical works have been also conducted and presented in the reference.

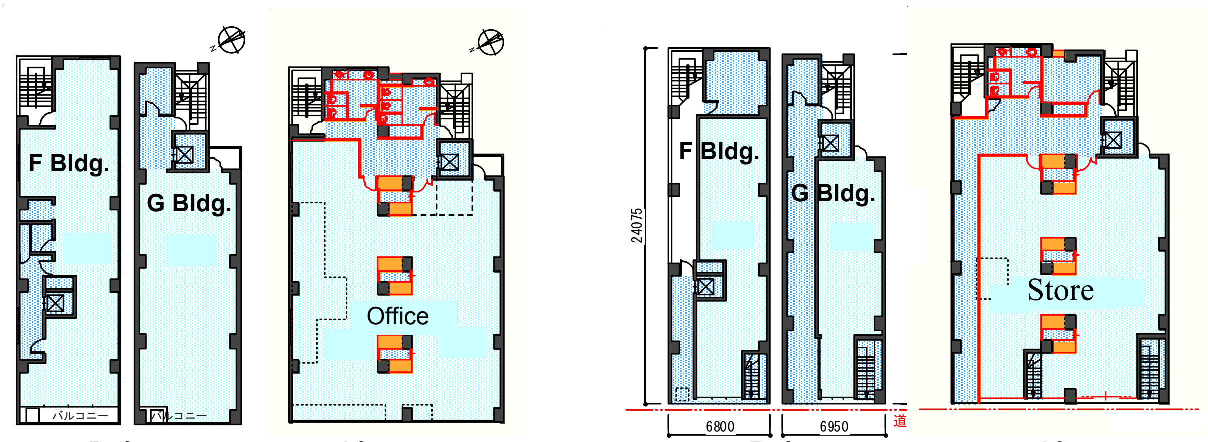
Figure 1 Typical Buildings Considered in This Study

2. Effect of Connection of Buildings

2.1 Space Utility

When we see the floor plan of these buildings we notice that the space utility is inefficient. The floor area is about 100 – 200 m^2, and in such small space, each floor contains an elevator, a stair, and toilets, which occupy large part of the floor. If these facilities can be shared by two buildings, the commercial space for offices and stores can be extended, resulting in an economical benefit. Figure 2 shows one example. As the difference in the floor level of these buildings is small, the office space can be unified on the upper floor as described in (a). The total office space is extended by eliminating the core of the F building. A balcony for fire evacuation can be converted to an office space. The core is unified and becomes more convenient and the two way evacuation paths are secured. As the location of columns in the plan has differences, the connected building has irregular column space in the center of the combined office. This vertical void space, however, can be used as duct spaces and light core.

The ground floor plan of these buildings shows extreme inefficiencies as described in (b). In this case the elevator core is located on the back of the building, and a corridor of about 2m wide is located from the street all the way to the back, leaving only 4-5 m wide store space on the side. It means that about 30% of the commercial space on the ground floor is occupied by the corridor. When combined, one of the corridors can be converted to a store space and used commercially. The combined store floor offers much more attractive space than the narrow space in the separate buildings.



Before After Before After

a) Upper floor b) Ground floor

Figure 2 Improvement of Space Utility by Connection of Buildings

The advantages of connecting buildings in the architectural planning are summarized as follows:

①. Office and commercial space can be extended by combining the floor to fit more effective use and can expect higher rent.

②. Corridors, stairs, elevators, water cores can be re-arranged or eliminated to save spaces for utilities and can be converted to commercial space.

③. Balconies for fire evacuation can be converted to a commercial space, while two way evacuation paths can be achieved by using the stairs of other building.

2.2 Seismic Retrofit

Tall-narrow buildings have disadvantages in structural performance, against wind force, traffic vibration, and earthquake ground motion, as the stance is narrow and unstable. Especially buildings designed according to the old design code before 1981, suffered serious damages in the 1995 Kobe earthquake and were proved to be weak under earthquakes. To strengthen these weak buildings by adding shear walls or braces, sacrifice in the space is needed. During the renovation period, the tenants have to be moved to a temporally place. If two buildings are connected structurally, the width of the structure becomes double, and the vibration of the buildings can be reduced, especially the reduction in the overturning moment and resulting vertical force are beneficial for the structural performance. If the space between the buildings is more than approximately 80cm, the joint work using this space is possible. It means that the seismic retrofit work can be done from outside without vacating the tenant during the renovation.

To clarify the effect of connection on the improvement of the seismic performance, earthquake response analyses are conducted. Figure 4 shows four analysis cases and the model buildings. Case 1 and 2 are connection of an old building and a new building. The ‘Old building’ means a building designed by the old design code before 1981and the ‘New building’ is a building designed by the new building code after 1981. The heights of the model buildings are similar in Case 1 while they are different in Case2. The Case 3 and 4 are the connection of old buildings, where building heights are similar in Case 3 and different in Case4. In each case three patterns of condition, separate, rigid connection, flexible connection with viscous dampers, are considered. Nonlinear structural models are constructed and a synthetic earthquake motion is applied. The details of the analysis are described in the reference.

Figure 3 Patterns of Buildings for Seismic Retrofit

Table 1 Type of Connection and Damage Level

		No connection		Rigid connection		Soft connection		result
		Old	New	Old	New	Old	New	
Old+New	Case1	severe	moderate	moderate	moderate	moderate	no	rigid○, soft◎
	Case2	severe	moderate	severe	moderate	moderate	no	rigid×, soft◎

		No connection		Rigid connection		Soft connection		result
		Old	Old	Old	Old	Old	Old	
Old+Old	Case3	severe	moderate	moderate	moderate	severe	moderate	rigid○, soft×
	Case4	severe	moderate	severe	moderate	moderate	no	rigid×, soft◎

The numerical results are summarized as follows:

①. Rigid connection of buildings of different height induces whipping and the response of the upper part is increased. The joint of such buildings with viscous damper is appropriate.

②. While the rigid connection of old and the new building of similar height is effective for the retrofit of the old building, the response of the new building, which has a deformation capacity, increases due to the concentration of the earthquake energy. The soft connection with damping devices is more desirable. As the vibration periods of the old and new building are different, a large deformation of the damper is induced enabling a large energy dissipation effect. The deformation of both the old and the new building can be reduced.

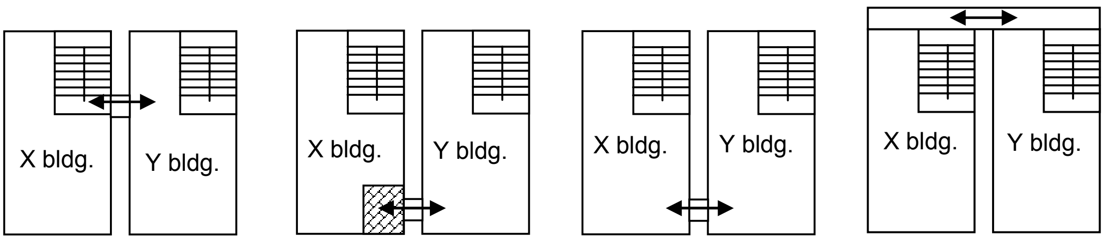
③. The connection of two old buildings with similar height, the effect of the damper is limited, as the difference of the deformation of two buildings is small. The rigid connection of these buildings is effective for the retrofit, yet it should be noted that the softer building tends to increase in the deformation.

2.3 Fire Evacuation

For fire evacuation the most effective way is to secure the double evacuation paths in the horizontal direction. Small buildings, however, usually does not have dual evacuation paths. A connection to the neighboring building can supply the second evacuation path. On the other hand we have to make sure that the spread of fire and smoke to the neighboring building through the connected path is prevented by appropriate measures.

There are four connection patterns of two buildings as described in Fig. 4:

- Room – stair: The Y building acquires the second evacuation path by the connection, yet the X building still have only one evacuation way. As this type of connection is only beneficial for one side of the buildings, there is no incentive for the owner of the X building and this scheme may not be feasible.
- Room-balcony: Spread of fire or smoke through the path may not happen and the safety level is high. If the balcony is not large enough, however, congestion during the evacuation may happen.
- Room –room: The congestion may not be a problem during the evacuation. If the owner/user of each building is different, an agreement and arrangement to open the path in the event of fire has to be done in advance.
- Room-evacuation path-room: Buildings are connected through a path or a balcony attached outside. Lock and alarm system should be pre-arranged that the other building is open to allow the people to enter for exit in the event of fire. Protection of this path from fire and smoke from the building on fire has to be considered.



a) Room – stair   b) Room-balcony   c) Room –room   d) Room-evacuation path

Figure 4 Pattern of Connection for Fire Evacuation

Simulation of the evacuation time for buildings is conducted. The model is the F building and G building described in Figure 2, but for the purpose of improving fire safety, partial connection by a bridge is assumed. The fire is assumed to start on the second floor of the G building and each floor contains 27 people (F bldg.) and 28 people (G bldg.) On the floor on fire, the occupants of the G building evacuate two ways, to the stair and to the F building through the bridge, and all the occupants of the G building evacuate in 15 seconds. On other floors, all the occupants are assumed to evacuate through the F building using the bridge. The occupants of the G building can vacate in 20 seconds to the hallway. All the occupants of the F and G building use the stair of the F building to the ground in 480 seconds. This type of partial connection is effective to improve the safety in the case of fire. An appropriate measure has to be made to prevent the stair case from the invasion of smoke.

a) Initial Condition   b) Floor on Fire (15 sec)   c) Other Floor (20 sec)   d) Time needed for Evacuation

Figure 5 Simulation of Evacuation During Fire

3. Case Study

3.1 Typical Case of Connecting Two Buildings

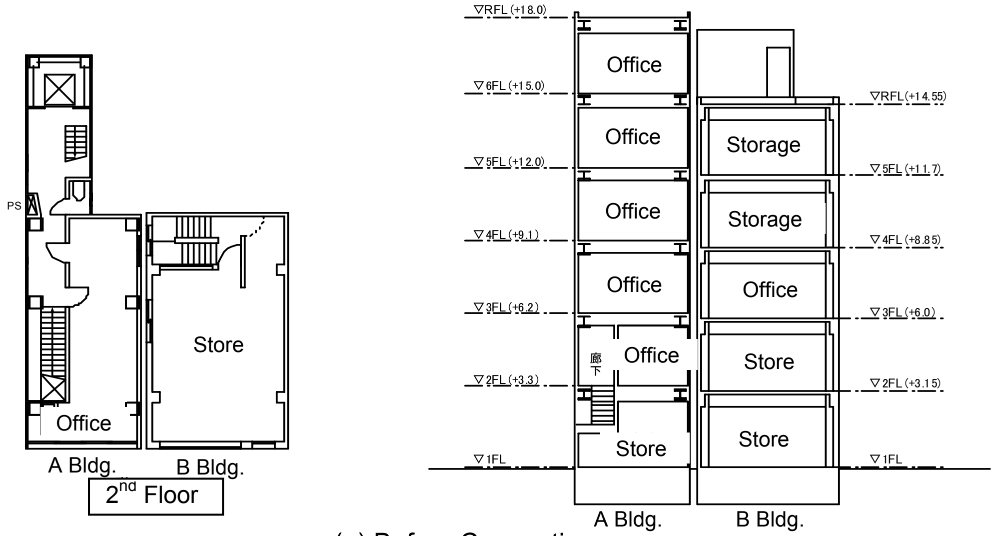
Connection of two buildings located in the center of commercial area of Tokyo is planned. Table 2 summarizes the properties of these buildings. The A building, 24 years old, has an elevator and each floor is rented separately for a store on the first floor and for an office on the 2nd to 6th floor. The B building, 40 years old, does not have an elevator and the stair is located on the rear of the building. As the access to the upper level is limited, the whole building is rented to a boutique, which uses the 1st and 2nd floor as a store, 3rd floor as an office, and 4th and 5th floor as a storage space. Both buildings are owned by a single owner and a more effective use of these buildings is examined.

Table 2 Properties of Buildings

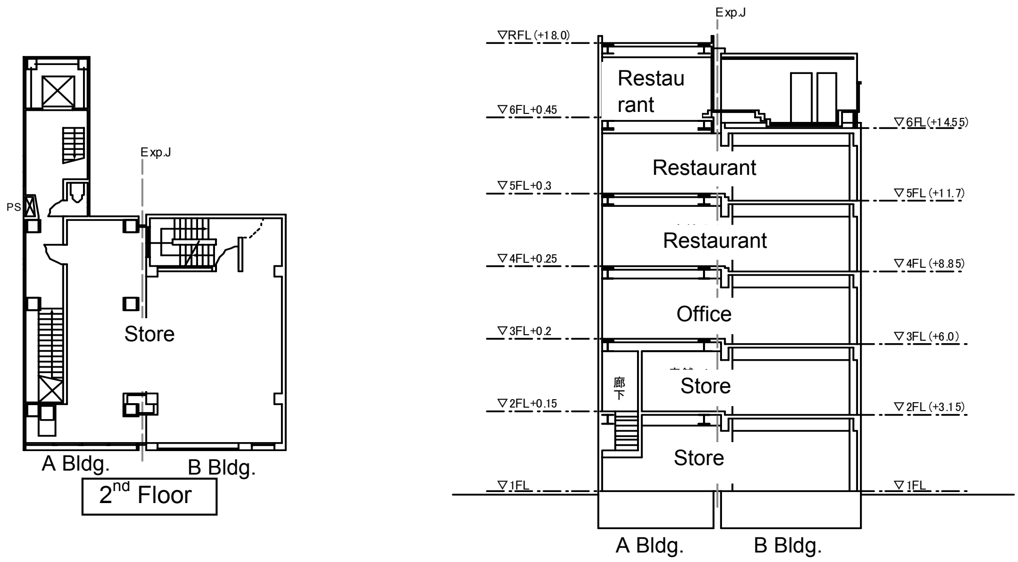
	A building	B building
Land area	61.2 ㎡	51.1 ㎡
Number of floor	6/B1	5
Floor area (/land area)	54.0 ㎡ (88.2%)	45.5 ㎡ (89.0%)
Total floor area (/land area)	300.95 ㎡(479.9%)	234.80 ㎡(459.5%)
Structural type	Steel	Reinforced concrete
Completion	October 1981	September 1964

Figure 6 shows the floor plan and the cross section before and after the connection. While the floor area of each building is less than 50 m^2, each floor has a stair, a kitchen, and a water core, which reduce the space for commercial use. Especially the upper floors of the B buildings are not effectively used and the connection of two buildings may improve the value of these buildings. The floor levels of these buildings are not very different and the connection of floor is possible. The space between these buildings is about 25cm, and the work in this space is not possible. In the structural aspect, the A building is designed by the new building code and supposed to have a sufficient seismic resistance. The B building, on the other hand, is designed by the old building code and the seismic performance is questionable. The scheme of the connection is summarized as follows:

1) Each of 1st to 5th floors is connected to form one space, and by unifying the water core, the commercial space is extended.
2) By using the elevator of the A building, direct access to each floor becomes possible. As each floor can access two stairs, the 6th floor can be used as a commercial space.
3) The 4th to 6th floor including the roof deck is converted to a restaurant, so that a larger rent is expected.
4) As the structural type and expected seismic performance is different, structural connection is not included. The seismic retrofit of the B building is planned separately.



(a) Before Connection



(b) After Connection

Figure 6 Connection of Two Buildings

3.2 Connection for Improving Fire Evacuation

Applied for a block of a city, connecting buildings can be an effective way to improve the safety against fire. A block in the center of Tokyo, where entertainments and bars are highly concentrated is selected as the case study site. In this area a big fire took place in 2001 resulted in a serious fatality of 44 people. Figure 7 shows the plan view of the block. One block is composed of 9 buildings of different storey from 2 to 10. In the center of the block is a narrow path of 1.5m wide, which serves as an underground sewage and service path on the ground. Above ground is used as piping space, air intake and outlet, and the space for placing air conditioning machines. The lesson learned from the 2001 disaster is the importance of multiple evacuation paths. The creation of the evacuation path above the path is planned as one of the ways of connecting existing buildings. The evacuation path is allocated every two floor and connected to each building through an opening of 60cm wide and 75 cm high. For some buildings connection of the path to the staircase is more convenient. The floor level of each building is different, but the difference of height from the floor to the path can be limited within 50 cm, allowing the occupant to move out to the path without much difficulty. The path is made of steel grating to prevent the stuck of smoke and to keep the function of ventilation from the buildings. Emergency stairs are placed connecting the path to the ground level. Figure 8 illustrates a schematic view of the evacuation path.

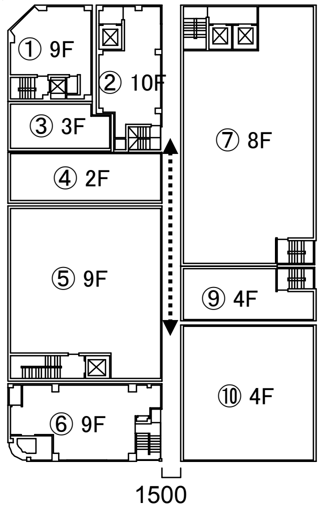


Figure 7 Plan View of Block

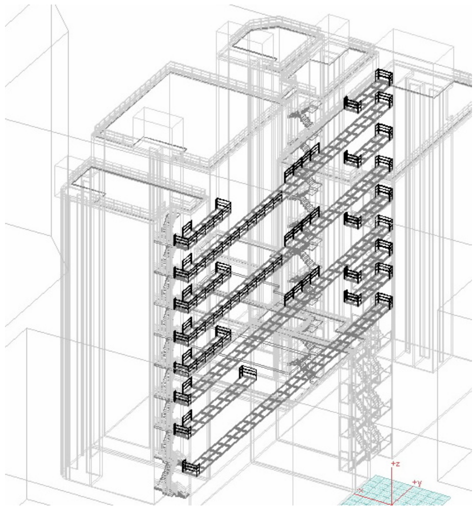


Figure 8 Schematic View of Evacuation Paths

3.3 Planning of a Block using Connection of Buildings

In Osaka city the size of a block is about 1.5 times larger than in Tokyo. The plan of the buildings is even narrower with the depth of about 30 m, compared to the depth in Tokyo of about 20 m. Usually buildings in Osaka has a core in the center and commercial spaces in the front and in the rear. The commercial space in the rear is not very convenient for use. Therefore connection of such building on the back, compared to the connection side by side in Tokyo, is an effective way of improving the value of buildings. Figure 9 shows one of the typical blocks in Osaka, which has a back path in the center of the block. Especially the area around the back path is not comfortable and convenient. The scheme of improvement of the block is that each building offers a small void facing the back path and the aggregate of such void forms a large void in the center of the block. As the comfort of the center of the block is improved in this way, the traditionally office spaces in the middle of the block can be converted to a residential space. This could be one of the solutions of the high vacancy rate of the Central Osaka area. In the process of renovation and re-construction, the creation of such void could be encouraged to finally create a comfortable residential space as described in Figure 10.

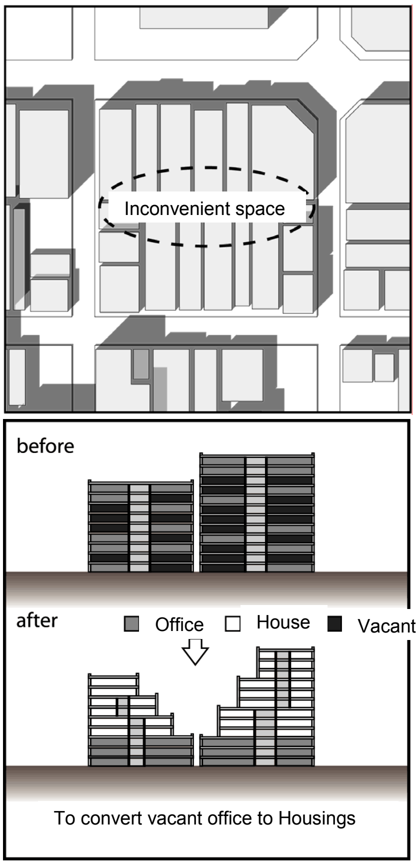


Figure 9 Creation of Open Space in a Block

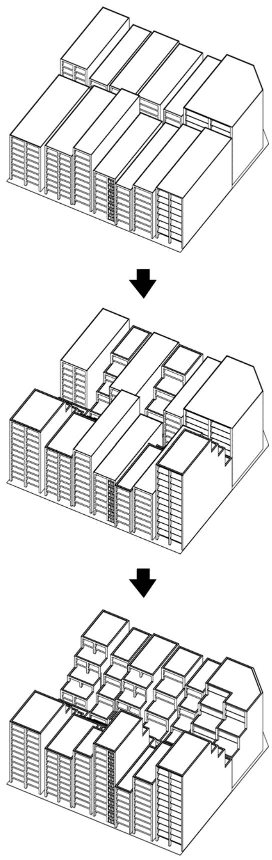


Figure 10 Schematic View of Process

Conclusions

Basic concept of the connection of buildings and some case studies are presented. The case studies show that each buildings and sites have different problems, so that an appropriate way of connection, such as improving space utility, retrofit seismic performance, creating dual evacuation paths, sharing equipment, or combination of these measures, has to be examined.

The conclusions of this study are summarized in the following way:

①. By the connection of buildings standing side by side, an improvement of space utility is expected by reducing spaces needed for stairs, elevators, water cores, balconies, and corridors. The combined space could offer a larger commercial space which fit the market needs.

②. The seismic retrofit could be performed by the connection of two buildings, which could be easier than the retrofit of independent buildings. If the space between the buildings is large enough, the retrofit work could be performed in this space without interrupting the activities insides the buildings.

③. The connection of buildings offers dual evacuation way in the horizontal direction, which improves the safety against fire. A partial connection of buildings by a bridge is effective for this purpose.

④. Application of connection of building concept could lead to the improvement of a city block in the way of fire safety and in the enhancement of comfort and convenience.

Other than the technical aspect of the connection of buildings such as described in this paper, social and economical aspects have to be established to actually perform this concept.

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ANALYSIS ON THE CHARACTERISTICS OF HOUSING STOCKS IN BEIJING OLD CITY -CASE STUDY: 'EIGHT STREETS IN JINGSHAN' AREA-

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Keywords: Beijing old city, 'Eight Streets in Jingshan' area, 'Conservation Planning of 25 Historic Areas in Beijing Old City', Correlative analysis

Summary

'Conservation Planning of 25 Historic Areas in Beijing Old City' was published in 2002 to tackle the circumstances of a rapid disappearance of traditional courtyard houses in Beijing. This study, by utilizing the result of the survey works of Beijing Municipal City Planning Commission for this planning, aims to clarify the correlation among various attributes (distribution of the inhabitants, building ownership, historical and cultural value of existing buildings, condition of existing buildings, height of buildings, building area, site coverage, conservation and renewal plan) of the housing stocks in 'Eight Streets in Jingshan' area which is one of the historical areas in Beijing.

One of the findings of the quantitative analysis in this paper is that housing stocks in this area can be characterized by 2 categories. Ones are the buildings of greater historical and cultural value, with smaller size and of larger site coverage, but of poorer condition. The others are the buildings of better condition, with larger size and of smaller site coverage, but not in harmonious with historical and cultural style. The attitude of ownership suggested that buildings of the former category tend to belong to work units, and the latter tend to belong to government and private owners.

1. Purpose and Method of this study

In Beijing old city, traditional courtyard houses have been major components of the city since the 13th century. However, these courtyard houses are now the subjects to rapid disappearances due to the fact of large-scale urban redevelopments and the superannuation of existing buildings.

To tackle this circumstance, Beijing Municipal City Planning Commission published 'Conservation Planning of 25 Historic Areas in Beijing Old City' (hereafter termed as 'Planning') in 2002. This was based on the detailed research works on the existing buildings, which is an important document to know the conditions of the housing stocks in Beijing old city.

1.1 Purpose of this Study

Under the current circumstances of rapid urban transition and privatization of housing stocks, this study aims to quantitatively clarify the relationship among various attributes of housing stocks in Beijing old city by utilizing the results of the survey works of Beijing Municipal City Planning Commission for the 'Planning'.

Out of 25 areas in total, the site selected for this study is called the 'Eight Streets in Jingshan' area, only where the 'Planning' opened the information on the building ownership to the public.

1.2 Method of this Study

The present analysis is carried out by means of the CAD software. The data on buildings and their attributes are reproduced by the authors according to the 'Planning' (Figure 1). It should be noted that the analysis is focused on the residential buildings, which account for 68% of the total area of the buildings (152,900/330,360sqm).

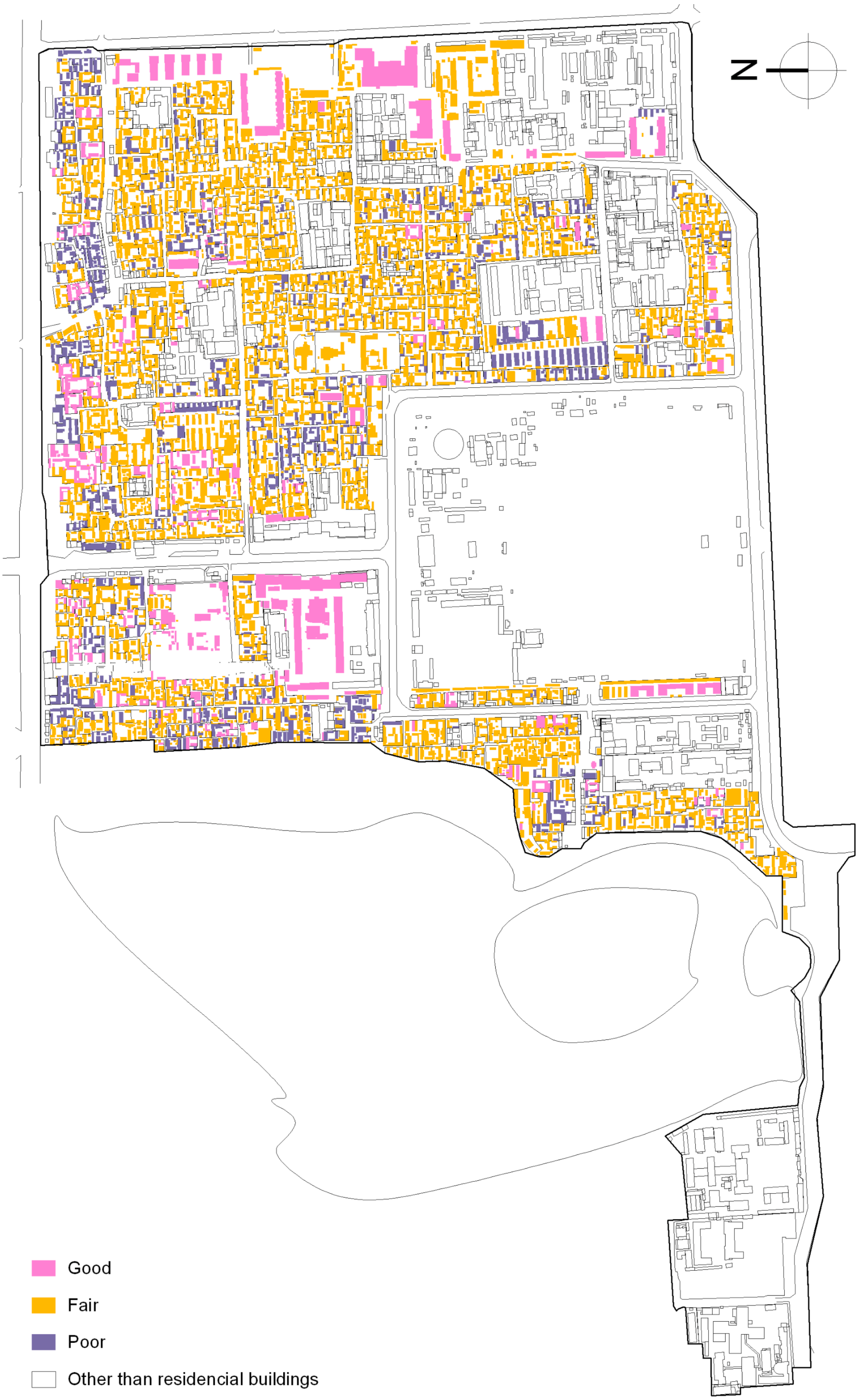

Figure 1 'Eight Streets in Jingshan' Area (The colored attributes shows the [Condition of Existing Buildings])

2. Analysis of the Correlation among Attributes of the Buildings

Table 1 shows the result of the simple calculation of each attribute. This offers basic information for the analysis of the correlation among these attributes in the following sections.

Table 1 Simple calculation of each attribute (by building area)

Attribute	Classification	Percentage (%)
Distribution of the Inhabitants	< 2 persons/100sqm of land	10.6
	2-4 persons/100sqm of land	20.9
	4-7 persons/100sqm of land	51.0
	7-10 persons/100sqm of land	14.0
	> 10 persons/100sqm of land	3.6
Building Ownership	Government ownership	42.7
	Work unit ownership	33.2
	Private ownership	24.1
Historical and Cultural Value of Existing Buildings	Registered heritage	1.3
	Traditional and modern buildings of historical and cultural value	4.3
	Traditional buildings in harmony with historical and cultural style	65.2
	Modern buildings in harmony with historical and cultural style	7.5
	Buildings not in harmony with historical and cultural style	21.7
Condition of Existing Buildings	Good	15.3
	Fair	68.5
	Poor	16.3
Height of Buildings	1 story	89.8
	2-4 stories	5.7
	> 5 stories	4.5
Building Area	< 25sqm	18.1
	25-50sqm	28.4
	50-100sqm	28.2
	100-500sqm	18.2
	> 500sqm	7.2
Site Coverage	0-40%	5.0
	40-60%	56.2
	60-80%	35.2
	80-100%	3.5
Conservation and Renewal Plan	Buildings of historical heritage	1.7
	Buildings that should be conserved	8.8
	Buildings that should be renovated	66.3
	Buildings that can be temporary reserved	10.4
	Buildings that should be renewed	11.5
	Buildings that should be arranged in façade along streets	1.3

2.1 Analysis of the Correlation between [Condition of Existing Buildings] and Other Items

The ‘Planning’ classifies [Condition] under three levels of {Good}, {Fair} and {Poor} in accordance with its quality and contentment of principal structural parts (such as structures and roofs) and other building components (such as fixtures and equipments).

2.1.1 Correlation with [Historical and Cultural Value of Existing Buildings]

Figure 2-1 shows the correlation between [Condition] and [Value]. This figure indicates that most buildings of greater historical and cultural value belong to the classifications of {Fair} and {Poor} by [Condition] that require some improvements.

2.1.2 Correlation with [Building Area] and [Height of Buildings]

What is the actual meaning of {Fair} and {Poor} buildings? Figure 2-2 and 2-3 indicate that smaller buildings of {1 story} are inferior by [Condition].

The reason for this might be attributed to a set of policies installed by the government between the 1950s and the 1970s. In Beijing, from the end of the 1950s to the middle of the 1970s, house rents were brought down under the national policy, which defined the housing as welfare. In addition, at the end of the 1970s, the government enacted another policy to permit the residents to make additions to their house buildings in order to address the serious housing shortage problem. According to the Beijing Municipal City Planning Commission (2002), these policies caused the lack of funds to improve the traditional courtyard houses, resulting in the present crowded and low condition of buildings.

2.1.3 Correlation with [Building Ownership]

In the urban area of China, there are three main categories of [Building Ownership], namely {Government ownership}, {Work unit ownership} and {Private ownership}. The work units mean the social structures that used to be government institutions. They have often provided free or subsidized houses for their employees since the 1950s.

Concerning the correlation between [Condition] and [Ownership], buildings of {Work unit} are superior in [Condition] (Figure 2-4). Although Alexander et al. (2004) points out that buildings of private ownership are generally better in condition because the ownership motives the residents to improve their properties, it seems that it is not the case of 'Eight Streets in 'Jingshan' area for the present.

2.2 Analysis of the Correlation between [Building Ownership] and Other Items

2.2.1 Correlation with [Height of Buildings], [Building Area] and [Site Coverage]

Figure 3-1 and 3-2 supports the above finding of why the buildings of {Work unit} are superior in [Condition] (Figure 2-4). The figures show that the buildings of {Work Unit} are characterized as multi-storied ones and larger in size, suggesting that these buildings with this particular ownership were constructed in relatively recent years.

On the one hand, buildings of {Government} and {Private} have similar tendency concerning [Height], [Building Area] and [Site Coverage] (Figure 3-1, 3-2 and 3-3).

2.2.2 Correlation with [Distribution of the Inhabitants]

On the other hand, however, different tendency is found between these two classifications concerning [Distribution], which suggests that the former has less floor area than the latter (Figure 3-4). This is one of the reasons why the government's current policy encourages private ownership to take over the public ownership by using market-oriented approach.

2.3 Analysis of the Correlation between [Conservation and Renewal Plan] and Other Attributes

2.3.1 Correlation with [Historical and Cultural Value of Existing Buildings]

Figure 4-1 indicates clearly that the 'Planning' took a different approach to manage existing buildings according to its [Evaluation]. For example, an approach of {Conservation} is implemented mainly to the {Buildings of historical value}, {Renovation} is a main management option for {Traditional buildings in harmony with historical and cultural style}, {Temporary reservation} approach is dominant for {Modern buildings in harmony with historical and cultural style}, and about 50% of buildings classified as {Buildings not in harmony with historical and cultural value} are subject to {Renewal}. In total, {Renovation} (upgrading the [Condition] as well as keeping its [Value]) are the most popular option.

2.3.2 Correlation with [Condition of Existing Buildings], [Building Area] and [Building Ownership]

Despite its poorer historical and cultural value, there are some buildings with better condition and larger stock size. Such buildings are found to be mainly classified as both {Work unit ownership} and {Temporary Reservation}, suggesting that there is a dilemma for the 'Planning' to keep these stocks as valuable floors for the dwelling (Figure 4-2, 4-3 and 4-4).

These stocks of work unit ownership are also subject to the same policy of encouraging the private ownership.

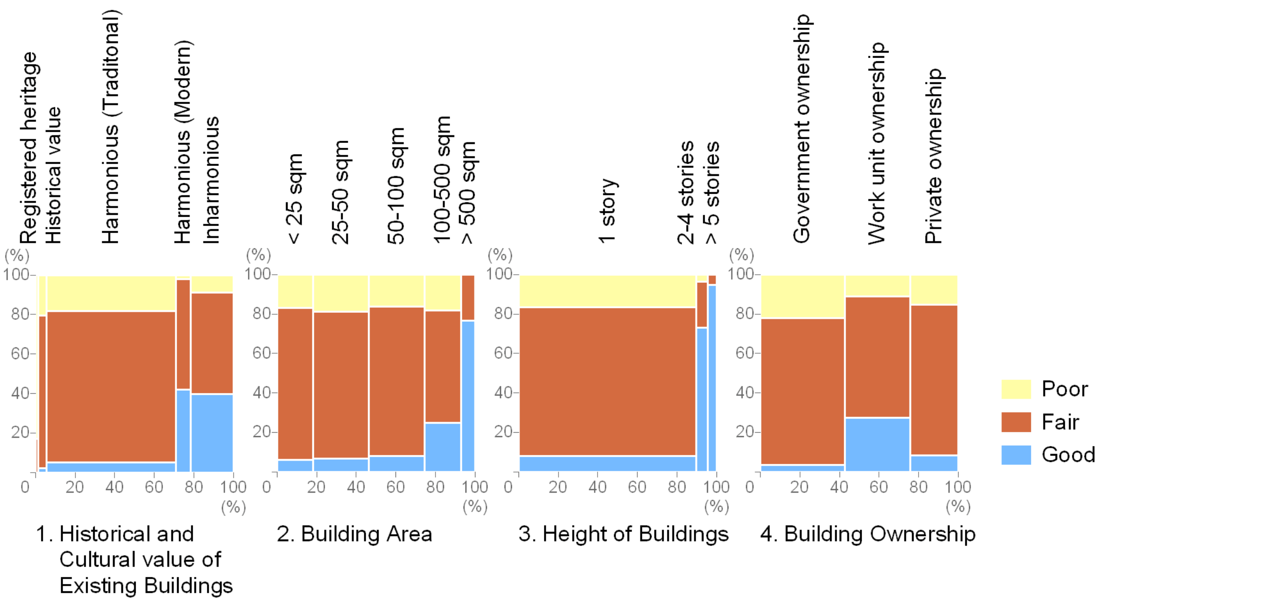

Figure 2 Correlation between [Condition of Existing Buildings] and Other Attributes

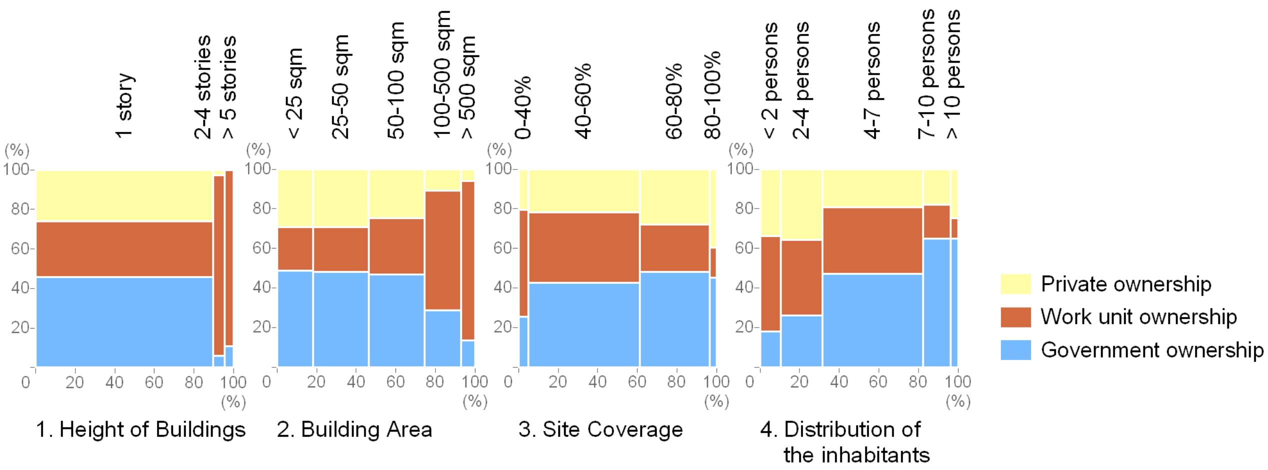

Figure 3 Correlation between [Building Ownership] and Other Attributes

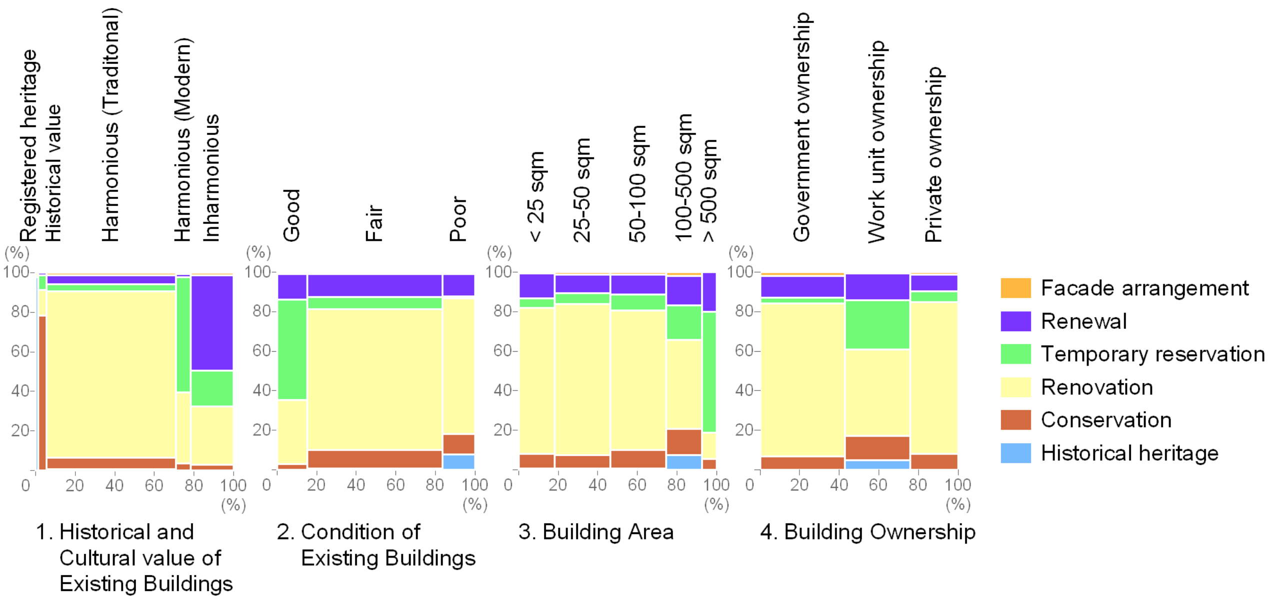

Figure 4 Correlation between [Conservation and Renewal Plan] and Other Attributes

3. Conclusions

The present quantitative analysis clarified the following findings:

- Housing stocks in 'Eight Streets in Jingshan' area can be characterized by 2 categories. Ones are the buildings of greater historical and cultural value, with smaller size and of larger site coverage, but in poorer condition. The others are the buildings of better condition, with larger size and of smaller site coverage, but not in harmonious with historical and cultural style.
- The attitude of ownership suggested that buildings of the former category tend to belong to work units, and the latter tend to belong to government and private owners.
- The most popular management option for the former is the renovation of the existing buildings, and for the latter is the temporary reservation as well as the renovation.

China is undergoing a rapid transition of managing stocks. After the introduction of market economy, house buildings in urban area including Beijing old city, which the government and work units have mainly owned, are on the process to be sold to the private residents. Under this situation, each resident is expected to be responsible and play wider roles to form the sustainable urban built environment. The themes are how the residents can achieve the improvement of their living environment together with keeping historical and cultural backgrounds of the traditional courtyard houses.

Acknowledgements

This study was conducted as a part of the activities of 'Center of Excellence for Sustainable Urban Regeneration' (The 21st COE Program, Graduate School of Engineering, The University of Tokyo). The authors are grateful to Dr. Bin Lu (Peking University), Dr. Xuehui AN, Huapu LU and Shao LEI (Tsinghua University) who join to support these activities, as well as Dr. Kenichiro NAKARAI and Dr. Noriko AKITA (The University of Tokyo) who jointly conducted the field survey of Beijing old city in October 2004.

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A NEW ATTEMPT OF AN OPEN BUILDING TO REALIZE THE SOUND USE OF CONDOMINIUM STOCK

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Keywords: stock, condominium, sustainable, remodeling,

Summary

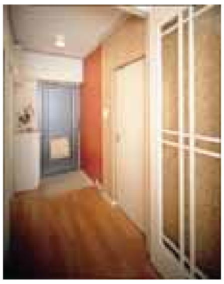
The history of the construction of condominium housing units in Japan is at most 50 years old. The stock of condominium housing units already exceeds 15 million. Those more than 20 years old that require either repair or renovation are almost 3 million units. It is estimated that this number will double within five years. Social demand for making sound use of the housing stock will increase in the future. On the other hand, approximately 83 million tons of demolished building waste is annually produced. This figure will drastically increase due to the repair or renovation of the above-mentioned building stock in the future.
For themes confronting the stock of condominiums, the Sekisui Chemical Co., Ltd. has developed an infill package model, “NEXT-Infill”. This model can be used for eco-friendly skeleton remodeling of existing buildings (retaining only the building structure) and has been tried and tested as a package. The model has two layers: a “base infill” to address the basic building service (insulation, acoustics, ventilation, and dehumidifying) and a “lifestyle infill” to address social requirements (facility renewal and changeable plans). The design is based on the open building concept.

コメント：or ‘building services’ would be better.

コメント：In English, ‘livelihood’ means what you do to earn a living, i.e. your job. I think here you mean ‘social requirements’

Before

After



1. Concept of the Infill System

We would like to introduce the industrialized infill package model, the "NEXT-Infill System", which was developed by Sekisui Chemical Co., Ltd., to provide sustainable housing. This system consists of two layers: a base infill system to support basic building service (insulation, acoustics, and ventilation) and a lifestyle infill to support social requirements(facility renewal and flexible plans).

Structural members are planned so that used materials can be shipped back to our company's factory for either reuse or recycling when the building is remodeled in future. By fully utilizing the technical know-how of each layer that we have accumulated as a provider of prefabricated housing, we have standardized the building materials, the unit construction method, and the convertibility of buildings. As a result, we can satisfy the cost performance of housing construction and construct a house in 2 weeks.

The following figure shows the abovementioned concept and the composition of, and system used in, each layer.

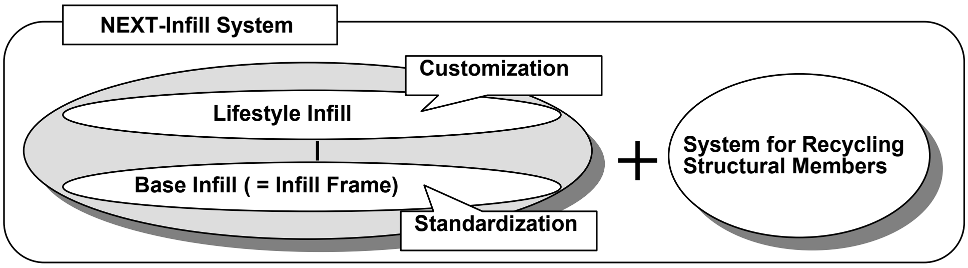


Figure 1 Concept of the "NEXT-Infill System".

2. Technology to construct a living space in a twisted skeleton

2.1 Development of the six-phased frame in a skeleton

We build an infill unit within an existing building that has secular deformation and create living spaces that are practically the same as modern housing units. We also improve the building's basic performance for living with insulated walls and acoustic floors. This infill unit is designed on the basis of the concept of industrializing the units used for finishing the building. The floors, walls, and recessed and projecting ceiling corners of the infill unit are built with self-supporting members. By connecting these members, a cubicle-shaped infill unit is formed within the skeleton. The infill unit is completed by installing new panel members onto the frame. A base infill is built by assembling a few infill units (see Fig. 2). By using this unit construction method, the construction period and construction costs are reduced to half those of ordinary construction methods.

コメント : OK?

コメント : the finished portions? the units used for finishing the building? The finishing materials?

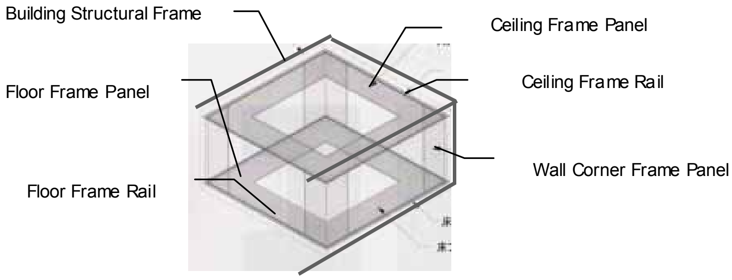


Figure 2 6 Hexahedral Infill Frame Model.

2.2 Joining by the Dry Construction Method

Using dry-joining by screwing and insertion of panels.
As the wall units are made in panels, it is easy to change the floor arrangement and it is possible to reuse the panels. Few mixed waste materials are produced when the house is demolished.

2.3 Developing Resources for Recirculating Building Materials

More than 60% of building materials can be reused during the next building remodeling period by using the structural panels and placing-type floor materials that we have developed from waste wood and plastic pieces as recycled resources. This system can be set up by installing partition walls, placing-type floor materials, and water supply and drainage piping systems using completely dry construction methods.

We have developed structural panels and placing-type floor panels using waste wood and plastic pieces and have been using these

Development of Recycled Floor Material

Placing-type floor material with waffle-shaped back.
The supports can be installed in any place

Development of Recycled Wall Material

Strong wall material made of wood chips arranged toward one direction.
Strong enough to keep screws and nails.

Photo 1 Recirculating Building Materials

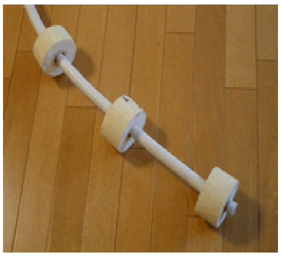
3. Technology to establish interface between infrastructure of skeleton and a living space to be constructed

3.1 Development of Technologies for Variability

The floor pre-construction method is used to maximize the freedom of the design in response to planning that involves resident participation. As a result, a simple, variable infill unit is realized. It has the following features:

1) Variability of the floor plan, for example in the locations of partition walls, and pre-molding of wiring at the building edges
2) Variability of water supply and drainage facilities, such as pressurized draining unit (20-mm-diameter pipe)
3) A simple pipe installation method that uses steel-reinforced polyethylene pipe and elastic pipe supports without the need for fixtures.

(resilient pipe supports)



(metal-reinforced polyethylene pipe)

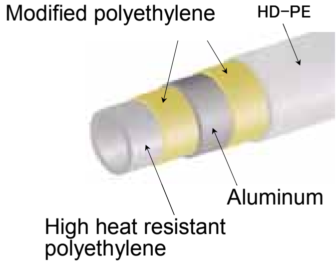


Photo 2 placing-type piping systems

Table 1　　Comparison of Polyethylene pipe

	Bridged polyethylene pipe	Metal-reinforced polyethylene pipe	Remarks
Oil resistance	No worry about oil resistance because no plasticizer		PE pipes were shipped to sewage treatments
Chemical resistance	Polyethylene is generally considered excellent		
Working temperature	95 ℃	95 ℃	
Working pressure	0.65 MPa	0.8 MPa	
Liner expansion coefficient	23 ＊ 10-5	5 ＊ 10-5	
Minimum bending diameter	300mm (20A)	100mm (20A)	
Function to maintain shape	No	Yes	

3.2　Pressure drainage system of small diameter

We have developed a highly efficient and low noise pressure drainage system. Unlike the conventional system that drains water using power after it is pooled in a reservoir, the newly-developed system drains water each time water-related equipment is used. It improved design freedom of a housing unit considerably because it does not need a vent pipe.
The newly developed drainage system can be placed under a low floor because it done not need a slope not to mention that the drainage pipe has a small diameter, which makes it possible not to obstruct constructing a space in a stock building.

Photo 3　　pressurized small-diameter drainage piping system placing-type piping systems

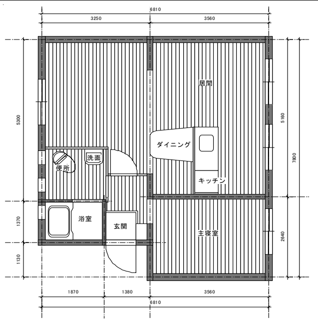
Table 2　　Developped Pump Specifications

Item	Specifications
Motor	Direct current brushless motor
Outlet diameter	25mm
Revolving speed	2500rpm
Specified outflow amount	45L/min
Maximum power consumption	180W
Maximum output	145W
Outer dimension (pump)	L220 ＊ W100 ＊ H150mm
Mass	6.5kgf

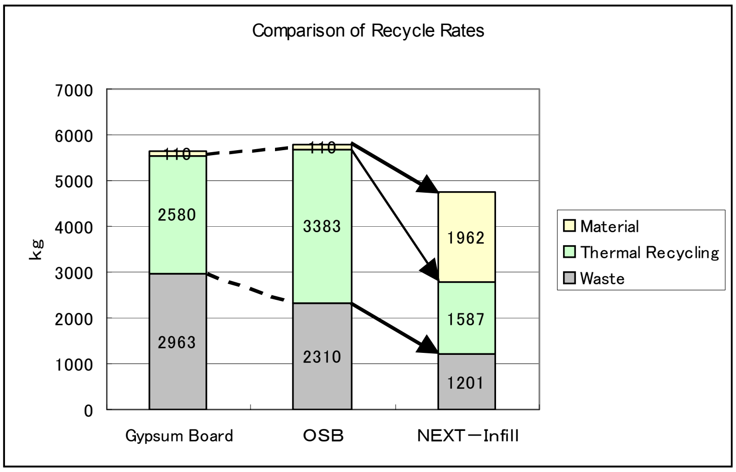
4. Evaluation of Sustainable building

4.1 Evaluation of Environmental Load

(Studied by the Ojima Research Laboratory of Waseda University in 2003)

Evaluation Plan	Evaluation Item
	Evaluation Item 1. Amount of Recycled Material 2. Recycling Rate 3. Amount of CO_2 Emission Relative Evaluation of Infill Method 1. Infill built with gypsum board as the main material 2. "NEXT-Infill" System 3. Infill built with oriented strand board as the main material

The total amount of material required is less and the amount of material recycled is greater.
As the floor pre-construction method requires less material to be removed, the total amount of material used for remodeling the house would be less

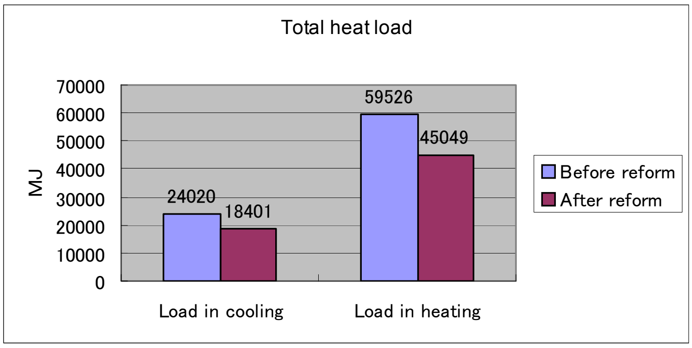


1. Reduced total amount of material to be demolished.
2. Large reduction in waste material.
3. As houses built by the dry joining method can be easily disassembled, the amount of waste material can be reduced compared with the conventional method.
4. As the floor pre-construction method means that only a small amount of material is removed during remodeling, the total amount of material to be demolished during future rebuilding would be less.

Figure 3 Comparison of Recycle Rates .

4.2 Improvement of energy conservation (Heat insulation)

Japan needs to make greater efforts to decrease CO_2 emissions because it recorded a higher increase rate of CO_2 emissions in the private sector in comparison with the requirements set by the Kyoto Protocol.
This model incorporates a frame space inside the skeleton. As shown in the asterisked part in the exhibit, it improved the heat flow rate on the wall remarkably. According to estimation made on the top floor of an existing building, a 24 percent reduction of load both in cooling and heating can be expected



(Studied by the Takeda Research Laboratory of Tokyo University of Sciennce in 2005)

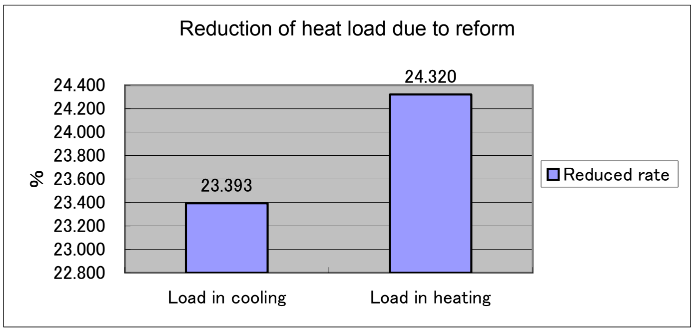


Figure 4 Total heat load .

(Studied by the Takeda Research Laboratory of Tokyo University of Sciennce in 2005)

Figure 5 Reduction of heat load due to reform

5. Pursuit of Variability in the Lifestyle Infill from the Resident's Viewpoint

Residents' housing preferences are diverse, so well-coordinated proposals are always required. A lifestyle infill must be flexible enough to satisfy the preference of each resident. As one solution to satisfying residents' preferences, we have adopted the interior-styling system developed by our firm. (See Fig. 3)

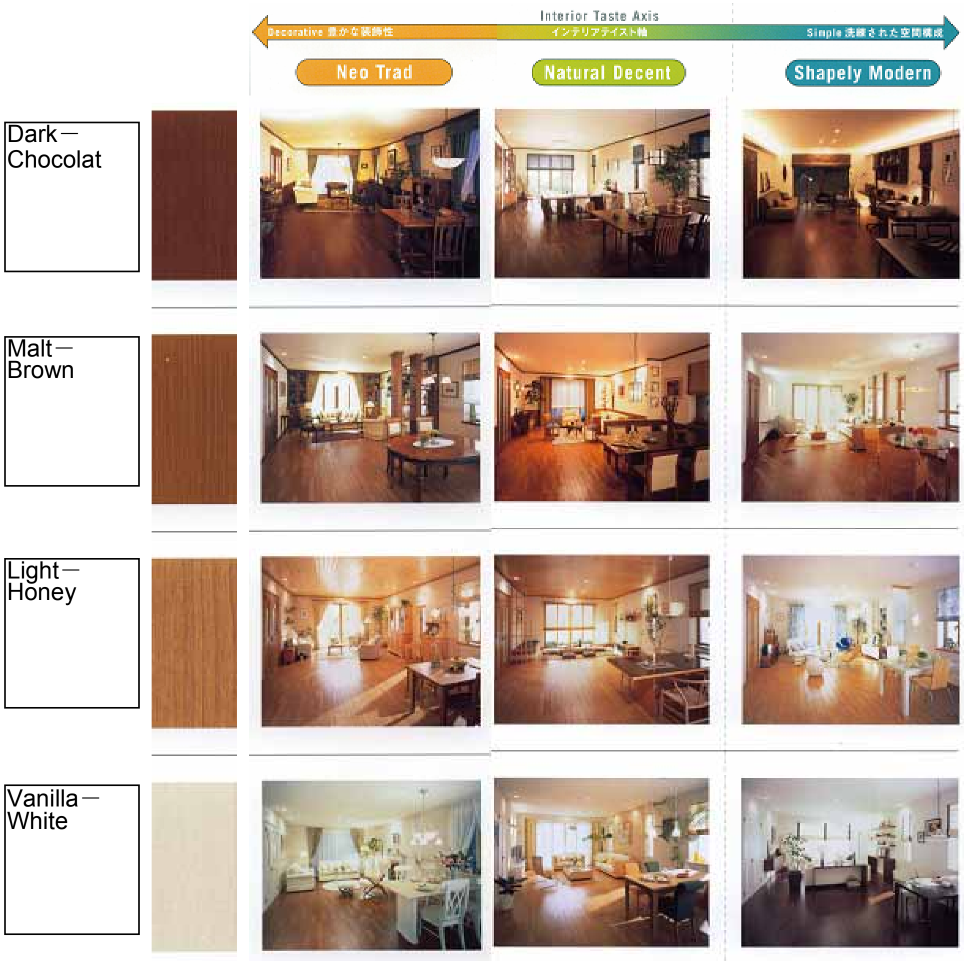


Figure 6 SEKISUI Interior Style System

6. Application for future

This Infill package model may be adopted for the increasing trend of construction of new S and I separation type condominiums. We would like to contribute to the realization of a sustainable society by developing a new Infill service industry.

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AIJ2004, pp. 985-988.

AN OPEN BUILDING APPROACH TO REVITALISING BUILDING STOCK —CONVERTING OFFICES INTO DWELLINGS

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Keywords: conversion, building stock, office building, rent gap, vacancy rate, performance specification

Summary

Due to the recent completion of a number of major business centre developments, vast floor areas of existing office buildings in Tokyo are being left vacant. Under present circumstances, it is expected that converting offices into dwellings will be more viable solution to regenerate redundant buildings. The "Open Building" concept can be most effectively applied to the "conversion" projects, but a number of new provisions must be made beyond what we have experienced with purely housing projects, because the initial configuration of the base-building is basically out of control, and performance levels required for each of the two building types are not the same. Investigated first in this paper is to try to typify existing office buildings in terms of the characteristics of the base-buildings themselves. This was done by surveying office buildings in the areas in central Tokyo where significant rent gaps were observed. Based on the first step, identifying the required performance items and their level differences, three sub-system classes, i.e. services, claddings and infill components, and their performance specifications are established. This paper finally presents some examples of detailed model design based upon actual buildings representing the base-building types and project types. These case studies are also used to verify the appropriateness of the specifications.

1. Introduction

The rent gaps between office buildings and residential buildings can be observed in the center of Tokyo due partly to the change in the industrial structure and crucially to oversupplying the office floor in 2003. Under the circumstances, the instances of converting offices into flats have emerged and a lot of architects, general contractors and real estate companies have recently recognized “conversion” as a viable solution.

The "Open Building" concept can be most effectively applied to the "conversion" projects which inevitably involves possible occasions for re-conversion, but a number of new provisions must be made beyond what we have experienced with purely housing projects, because the initial configuration of the base-building is not well defined, and performance levels required for the residence are different from those of the office.

In this paper, based on the field survey about vacant office buildings in Chiyoda-ku, Chuo-ku and Minato-ku located in the center of Tokyo, the existing office buildings are typified to make the characteristics of the base-buildings clear, in addition to the physical settings of those, not depend on the base-building type, clarified. In the second step, the required performance items of sub-system classes: services, claddings and infill components, are related to the types and physical settings of the base-buildings. Finally, some examples of detailed model design representing the base-building types are presented in order to verify the appropriateness of the specifications.

2. The Characteristics of Existing Office Buildings in Tokyo

2.1 Outline of Field Survey

The survey areas: Iwamotocho (Chiyoda-ku), Kodenmacho (Chuo-ku) and Toranomon (Minato-ku), where the vacancy rate was at high, were selected. In these areas, 221 existing office buildings with vacant floor were investigated by collecting their floor plan and basic data on advertisement boards of real estate agents, on the web sites and front of shops, and measuring their frontage and floor height on sites.

Table 1 shows the results of field survey on office buildings in Tokyo. They have small floor area basically, and the incidence of large buildings, such as the typical floor area of is above 600 square meters, is decreasing quickly. It is expected that half of smaller buildings are under the severe condition on natural lighting due to facing only one road.

It is clear that many office buildings with vacant floor can not keep the ceiling height 2.6 meters, which is the minimum requirement for present offices, because of their floor height below 3.4 meters. They are outdated as a present office building, but most of them have the adequate floor height for changing into dwellings. Since present apartment houses in Japan need the floor height approximately 3 meters to keep the ceiling height 2.4 meters at least.

According to Building Standard Low which was substantially revised on the regulation of building structure in 1981, in changing the use of buildings constructed before 1980, their seismic performance must be improved. The result of field survey indicates that one third of projects converting office buildings into dwellings in Tokyo, at least, must be accompanied with the repair of their structure.

Table 1 Results of The Field Survey in Tokyo

Typical floor area	38 percent is below 100 square meters and 76 percent below 300 square meters 8 percent is above 600 square meters
Frontage	65 percent is below 12 meters Peak of distribution is approximately 8 meters
Floor height	82 percent is below 3.4 meters and 8 percent below 2.8 meters Peak of distribution is approximately 3.1 meters
Front road of building	36 percent faces one road and 54 percent of it has the typical floor area below 200 square meters
Construction year	54 percent was constructed in 1980's and 33 percent was constructed until 1980

2.2 Classifications of Base-buildings

In order to analyze the influence of base-buildings to conversions, it is available to typify existing office buildings. In this paper, two kinds of classification, by the size of typical floor and the location of roads and core, are proposed. Especially, the former classification is more important not only to identify the required performance items for sub-systems but also to estimate the change of rentable floor area ratio. The latter is needed to define the plan type with diminishing the rentable floor area substantially in converting into dwellings.

2.2.1 The Area of Typical Floor

Four types are classified by the area of typical floor, as shown in Table 2 (1). Most of S-type may be converted to one residential unit in a floor. It is virtually impossible to subdivide one floor into a few units because most of their frontage is less than eight meters. On the other hand, LL-type is the group of the largest buildings, which can not be observed numerously in the middle rise office market in Tokyo. By our field survey, it is estimated that the ratio of LL-type is less than eight percent.

The difference between M-type and L-type is related to Building Standard Low. In Japan, to keep the escape route on fire safe, two stairways must be installed in a building which has rental space above 200 square meters in a floor. The boundary area of typical floor between M-type and L-type is 250 square meters: the quotient of 200 square meters divided by the number of typical rentable floor area ratio.

2.2.2 The Location of Roads and Core

In converting offices into flats, the lighting regulation of Building Standard Low constrains the subdivision of residential units. The lighting condition of a building is due basically to the location of roads faced on it, and partly to the location of core. Five types shown in Table 2 (2) are divided by the following steps: Firstly existing office buildings are classified into four types by the former, and only the type of fronting one road is sub-classified by the latter secondly. The lighting condition of base-buildings fronting one road is relatively inferior to others, and the location of core may affect them largely. This is the reason why the sub-classification applies to the type of fronting one road.

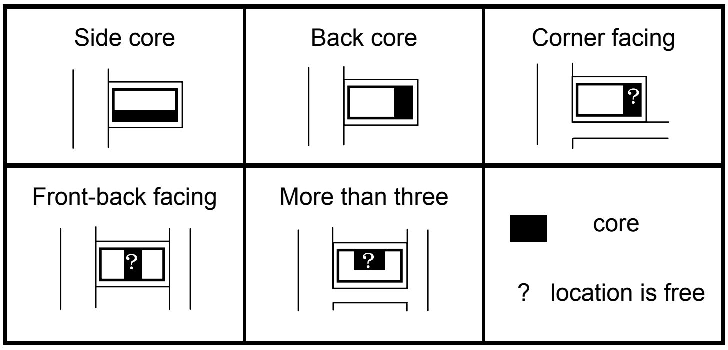
By our field survey, it is expected that each of S-type and M-type occupies approximately 35 percent in the middle rise office market in Tokyo, and, by another classification, each of Side core type, Back core type and Front-back facing type occupies almost 20 percent. However this result doesn't necessarily represent the distribution of office types in other Japanese cities. For example, office buildings belong to Front-back facing type are not observed in Osaka at all.

Table 2 Classifications of Base-buildings

(1) The area of typical floor

S-type < 100 m^2
$100m^2 \leqq$ M-type < 250 m^2
$250m^2 \leqq$ L-type < 600 m^2
600m2 ≦ LL-type

(2) The location of roads and core



2.2.3 The Relationship between Types and Attributes, concerning Base-building

Some attributes of base-buildings depend on types shown on Table 2(1), and others not. It is able to observe three relationships between base-building types and its attributes, as shown on Table 3. The attributes connected with base-building types strongly, are basically related to the size of building, and ones with the significant reflection of them, are relatively to the site conditions. However space to the neighboring building, and space from front road to wall surface, is independent of them.

Table 3 Types and Attributes of Base-building

(1) Depend on Base-building Types

Type		S	M	L	LL
Number of Floors	Ave.	5.6	6.8	7.5	9.5
Covered Area (m^2)	Ave.	68.5	163.1	380.0	1060.0
Frontage (m)	Ave.	6.4	11.2	15.5	31.0
Depth (m)	Ave.	11.0	16.1	23.8	36.5
Total Floor Area (m^2)	Ave.	366.9	1091.4	2797.2	10127.8

(3) Independent of Base-building Types

Space to The Neighboring Building (mm)	Ave. 614	65 percent are included in the range from 300 to 1000 mm.
Space from Front Road to Wall Surface (mm)	Ave. 805	39 percent less than 200 mm, 29 percent from 200 to 400 mm, and 22 percent from 400 to 1000 mm.
Buildings with Columns Backward from Exterior Wall	83%	65 percent faces the façade side.
Buildings with Balcony	55%	
Buildings with Setback	83%	

(2) The Significant Reflection Observed

Type		S	M	L	LL
Number of Front Roads	Ave.	1.6	1.7	2.1	2.7
	Note	Buildings fronting one or two roads occupy 87 percent. All buildings fronting more than three roads are included in L-type and LL-type			
Width of Front Road (m)	Ave.	10.3	12.3	13.9	18.6
	Note	Many of S-type fronts the narrow road as less than 8 meters.			
Ratio of Depth to Frontage	Ave.	1.6	1.2	1.3	1.1
	Note	M-type and LL-type include many buildings with relatively shallow depth.			
Floor Height (mm)	Ave.	298	308	326	321
	Note	Many of each type are included in the following range: 2800-3100 mm (S-type), 2800-3300 mm (M-type), and 3000-3400 mm (L-type).			
Typical Structure	%	RC:46	RC:62	SRC:53	SRC:100

3. Development of Performance Specifications for Converting Offices into Dwellings

3.1 The Required Performance Items on Sub-systems

In order to develop the performance specification for converting offices into dwelling, total building system is divided into the four sub-systems: supports, claddings, infill and services, in spite of not discussing the support sub-system here. Each sub-system embraces the following components.

Supports: skeleton, foundation and piles

Claddings: envelope (sash, exterior wall, balcony and roof), compartments of dwellings (party wall, wall fronting common corridor and entrance door), common corridor and common stair way

Infills: interior of dwelling (finishing and substrate of floor, ceiling, partition and cabinet), kitchen cabinet and bus unit

Services: plumbing, ventilation, air condition, gas, electric, fire extinguishing and elevator

The definition of sub-systems, listed here, is different from the general theory of Open Building, which introduces the hierarchical structure into the dwelling environment: urban tissue, supports and infill, according to the level of agreements concerning housing process. For example, the common piping for water supply and drainage belongs to services sub-system, but supports. In case of conversion, it is important not only to focus on the level of agreements but also the correspondence between the required performance items and sub-systems. This is the reason why services and claddings are added as a sub-system.

By using these four categories, it is possible to correspond with performance items and sub-systems more clearly, as shown on Table 4. However they are not one-to-one. This suggests that, in converting existing buildings, a required performance basically extends over some sub-systems, and needs to be fixed by them.

Table 4 Correspondence between performance items and sub-systems

Level	Performance items		Changing points of existing settings for residential use	Services	Claddings	Infill	Supports
Dwellings	Air conditioning		Removing former equipments, installing new ones into each dwelling	○			
	Sound	Inter-dwellings	Improving sound insulation			○	○
		Noise			○	○	
	Lighting		Extending openings		○	○	
	Information		Installing new equipments	○			
	Variable ways of dwelling		Settings for SOHO, etc.			○	
	Ventilation		Changing or adding equipments	○	○		
	Partitions		Installing new ones			○	
	Draft		Changing or adding equipments		○		
	Heat		Adding heat insulation material		○		
	Vibration		Improving vibration isolation of floor			○	○
	New ways of using space		Using the vacancy to the neighboring building and roof effectively	○	○		○
	Space for equipments		Keeping the space for heat changing equipments of air conditioning	○	○		○
	Pipe space		Adding new pipe space	○			
	Party wall		Installing new ones			○	○
	Plumbing		Removing former equipments, installing new ones into each dwelling	○			
	Electric		Changing equipments	○			
	Gas		Removing former equipments, installing new ones into each dwelling	○			
	Entrance		Installing new ones, setting mail boxes up		○		○
	Elevator		Removing former equipments, changing numbers of cage	○			
	Common area	Transforming to individual area		○		○	○
		Amenity					○
Buildings	Load to environment		Reducing energy consumption	○	○		
	Two ways for escape on fire		Changing the second floor plan in case of L-type or LL-type		○		○
	Seismic reinforcement		Corresponding with present regulation				○
Urban	Townscape		Renewal of facade		○		○

3.2 Case Studies on Sub-systems

3.2.1 Study on Services Sub-system: Forced Drainage Piping System

It is able to observe two kinds of requirements for services sub-system, in transforming offices into dwellings. One is to expand the capacity of services for residential use and keep the space for new components. This is typically needed on plumbing and ventilation system. Another is to change their control from central way to local, which will cause the problem on management of converted buildings because of involving the transfer of ownerships concerning components.

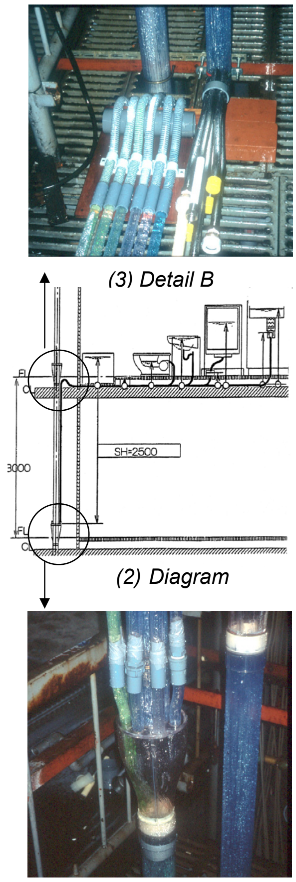
In this case study on services sub-system, drainage piping system is picked up, as needs to keep the space for new components. It is expected that gravity drainage system is not suitable to any conditions of conversions, in spite of generally installed in Japanese buildings. In case of gravity system, the length of horizontal pipe, inclined at one fiftieth, is limited to set it up into the underfloor space. On the other hand, the location of main vertical pipe is depending on existing pipe space. Therefore, it is necessary to add the forced drainage piping system to the menu of drainage in order to cover all conditions.

In Japan, the new way of forced drainage system, which uses the siphonage but electric power, is developing, and expected to bring good solutions for conversions. To add this system to the drainage menu, the suitable condition for adopting it must be identified. The suitability for new drainage system is primarily related to the attributes depends on the size of base-buildings, as shown on Table 5, because the limited length of horizontal pipe has been verified by experiments less than five times of floor height.

On Table 5, S-type and M-type are sub-divided by seven meters of the frontage into the narrow group (- n) and wide group (- w) because two peaks around five meters and ten meters are observed in each distribution of frontages. In conclusion, new drainage system is suitable for L-type and LL-type. However this is based on the assumption that it is possible to set new main pipes at the space to the neighboring building. To use this space for piping, more than 600 millimeters is needed for setting and maintaining it.

Table 5 Recommendations for Applying New Drainage System

Attributes of Base-building			Suitability	Note
Items	Types	Typical		
Frontage(m)/Depth(m) (Ratio of depth to frontage)	S-n	5/10(2)	△	Narrow frontage enables to Incline piping
	S-w	8/10(1.3)	△	Gravity system is basically suitable
	M-n	6/20(3.3)	△	Narrow frontage enables to Incline piping
	M-w	11/14(1.3)	○	Gravity system is basically suitable
	L	15/22(1.5)	◎	Forced system is needed except buildings with large floor height
	LL	31/37(1.2)	◎	
Estimated dwelling units per a floor	S-n	1	△	Gravity system is suitable
	S-w	1−2	○	
	M-n	1−2	○	
	M-w	2−3	○	
	L	3−5	◎	
	LL	Approximately 10	◎	
Floor height(mm)	S-n	2,800	◎	In adopting the new drainage system, the length of horizontal pipe is limited to less than five times of floor height
	S-w	2,900	◎	
	M-n	3,000	◎	
	M-w	3,100	◎	
	L	3,300	◎	
	LL	3,200	◎	
Total evaluation	S-n		△	〈Index〉 ◎ Suitable ○ Advantages △ Not Needed
	S-w		○	
	M-n		○	
	M-w		○	
	L		◎	
	LL		◎	
Space to The Neighboring Building (mm)		Less than 400	◎	It is difficult to set main pipe
		More than 400	◎	It is possible to set main pipe



(3) Detail B

(2) Diagram

(1) Detail A

Fig.1 Experiment of New System

3.2.2 Cladding Sub-system: Double Skin Façade

It is needed for claddings sub-system not only to renew the appearance of façade but also to supply various functions: natural ventilation, heat insulation, pipe space for vertical main piping and keeping the escape route on fire. Especially, base-buildings facing one road only, which occupied one third of office buildings in Tokyo, may require more functions for façade cladding than general apartment houses.

This requirement is satisfied by integrating multiple functions into a cladding sub-system, or installing a series of existing components concerning each function. The former is more advanced and effective than the latter, in approaching difficult problems. In this case study, it is attempted to apply the double skin façade to conversions, as an instance of integrated approach.

The double skin façades applied for base-buildings are divided to three types by the condition of new skins. It is able to add a new skin to the outside of existing wall or inside, and, in case of the former, to make its cavity separated by each floor or extended over all floors. Their suitability is related to the conditions around exterior wall which extremely influence the works for setting new skins, but dependent on base-buildings types basically.

Table 6 Suitability for Double Skin

	Types of Double Skin	New Skin	Outside		Inside
		Cavity	Extended	Separated	
Conditions around Exterior Wall	Columns Backward from Exterior Wall	Yes	○	○	◎
		No	○	○	△
	Setback	Yes	×	◎	○
		No	○	○	○
	Balcony	Yes	△	◎	○
		No	○	○	○
	Space from Front Road to Wall Surface (mm)	Less than 200	×	×	○
		More than 200	◎	◎	○
	〈Index〉 ◎ Suitable △ Possible (with incommodities) ○ Possible × Unsuitable				

The double skin enables to supply more functions, as its cavity is wider. It is possible to set the pipe space up in the space more than 400 millimeters, and keep the escape route on fire in more than 800 millimeters. On the other hand, the orientation influences the efficiency of natural ventilation by the cavity. It is estimated that the double skin directing to the east or west can achieve the good performance as a ventilator.

3.2.3 Infill Sub-system: Floor System for Insulating the Sound

Infill sub-system primarily carries out the following two roles: arranging the interior space for residential use and implementing the shortage of performance which relies on other sub-system basically. The former is achieved not only by usual interior components but also special ones satisfying the requirements accompanied with conversions: partition system with opening for lighting inner rooms, components for supporting both of daily living and SOHO use, and detachable components from property as supplied by the lease system.

The typical case of implementing the performance is observed in the floor system. As a case study concerning infill sub-system, the sound insulation and vibration isolation of floors are picked up here. They are basically relying on supports sub-system. However most of base-buildings have thicker slab and longer span than apartment houses, which cause the decline in acoustic performance. Table 7 shows the conditions of supports needed to improve the acoustic performance.

Table 7 Needs of Improving Acoustic Performance

Attributes of Supports		Evaluation	Note
Structure of Slab	RC Slab	○	〈Index〉 ◎ Always ○ Sometimes △Not Necessary
	RC with Deck plate	◎	
Thickness of Slab	Less than 150 mm	◎	
	150－180 mm	○	
	More than180 mm	△	
Span of Columns	Less than 4 m	△	Larger vibration occurs at larger slab area
	4－8 m	○	
	More than 8 m	◎	
Completion Year	Before 1981*	—	* The vibration of slabs may be Isolated in improving supports
	After 1982	—	

To implement it, two types of construction method are available. One is by the dry construction: approaching to infill sub-system and the other is by the wet: improving the supports sub-system itself. Table 8 shows the comparison with typical methods for improving the acoustic performance. Generally speaking, it is able to achieve its purpose effectively by the wet. But this meaning frequently requires reinforcing the support due to the weight of itself. In case of applying the dry, it is needed to respect the consistency with services sub-system in order to keep the piping route on slabs.

Table 8 Comparison with Typical Methods for Sound Insulation and Vibration Isolation concerning Slabs

Principle	Damping The Vibration above Slabs		Controlling The Vibration of Slabs			Obstructing The Sound from The Upper Floor
Method	Adding Insulation and Concrete on Slabs	Improving Substrate	Thickening Slabs	Adding Beams	Adding Dynamic Damper	Insulating by Ceiling
Type	Wet or Dry	Dry	Wet	Wet	Dry	Dry
Weight	Heavy	Middle	Heavy	Heavy	Light	Light
Site Works	Curing Term Needed	Easy	Curing Term Needed	Difficult	Easy	Easy
Occupied Space	Small	Relatively Small	Small	Definite Area	Small	Large
Performance Management	A Little Difficult	Easy	Easy		Difficult	A Little Difficult
Cost		High	Low			

4. Examples of Detailed Model Design

4.1 Outline of Studies

Table 9 indicates the profile of detailed model design based on actual office buildings, to study the feasibility of converting offices into dwellings in Tokyo, and verify the appropriateness of the specifications concerning sub-systems. The six base-buildings were selected as represent base-building types shown on Table 2(1), and converted wholly or partially.

Table 9 Profiles of Detailed Model Designs

No.	Profiles of Base-building						Studies of Conversion		
	Constructed year	Size	Front Road	Total Floor	Typical Floor	Structure (Floors)	Converted Area	Use	Note
A	1986	M-type	Others	2,100m^2	205m^2	SRC(9)	Partial	Rental	Reuse of existing air conditionings
B	1961	L-type	Corner Facing	5,766m^2	492m^2	SRC(10)		SOHO	Floor area ratio
C	1990	S-type	Back Core	537m^2	74m^2	S (8)	Whole	Long-term Rental	Horizontal extension
D	1974	M-type	Front-Back	2,765m^2	214m^2	S (12)		Leasehold	
E	1960	L-type	Front-Back	2,678m^2	341m^2	RC (6)		Rental	Land leasehold
F	1972	LL-type	More Than Three	4,664m^2	655m^2	RC (9)		SOHO	Large rental units

4.2 Verifying the Appropriateness of Sub-systems

4.2.1 Services Sub-system

In six case studies, only B-building needs the forced drainage system, which belongs to L-type. However, E-building and F-building included in L-type or LL-type enable to apply the gravity system, due to keeping new pipe shafts in themselves. By comparing B-building to E-building or F-building, the remarkable difference is observed concerning converted area. The former is partially converted, but the latter is wholly. This result indicates that the suitability of drainage systems depends on not only the size of base-buildings but also the scope of converted area.

The pipe shafts of B-building are kept in the east side, nearby service balconies. The drainage piping from each unit inevitably extends over the common corridor to them. Under this condition, two meanings of piping are available: keeping the route under slab or over ceiling, as shown in Fig.2. The former applies to the forced drainage system by siphonage power as well as electric, but accompanies the difficulty with clearly dividing *detail A* into the individual ownership and common. On the other hand, the latter enables to divide the ownership on *detail B* clearly, but the forced drainage by electric power must be used.

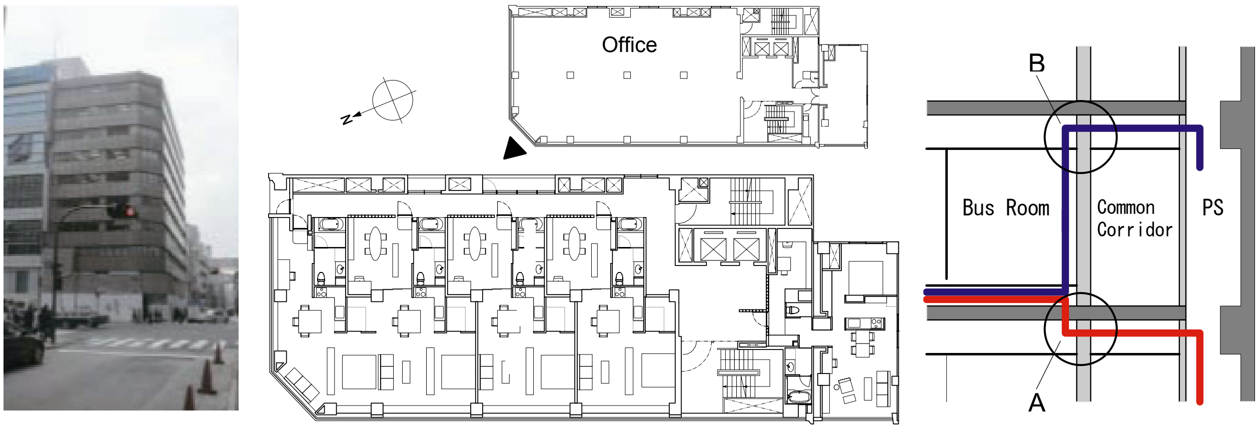


Fig.2 Model Design on B-building

4.2.2 Claddings Sub-system

The double skin façade was studied in the conversion of C-building. Usually, it is difficult to add the new skin to this building, which has the setback enforced by the shape regulation. However, it is possible by the deregulation on this area to extend the setback part, in changing office use into residential. This is the reason why the double skin is studied in this building.

The unique attempt can be observed here. Most of the cavities kept in the double skin have been used only for exhausting heat or collecting. But, in this case study, it is intended that both of functions are carried out by planning two kinds of cavity: extending over all floors and separated by each floor. The combination of them enables to change the route of air flow, as the season changing.

Further, this ventilation system is integrated with the floor system for isolating the vibration, keeping 400 millimeters height from the floor level to slab in order to set floor beams up in it. Through the underfloor space, the fresh air flowing in cavity would be introduced into the inner space of converted C-building. The ventilation ability of this system has been simulated by CFD analysis. It is verified that the combination system of cavities could collect heat effectively in winter, but not exhaust well in summer. In conclusion, to realize it actually, more improvement is needed.

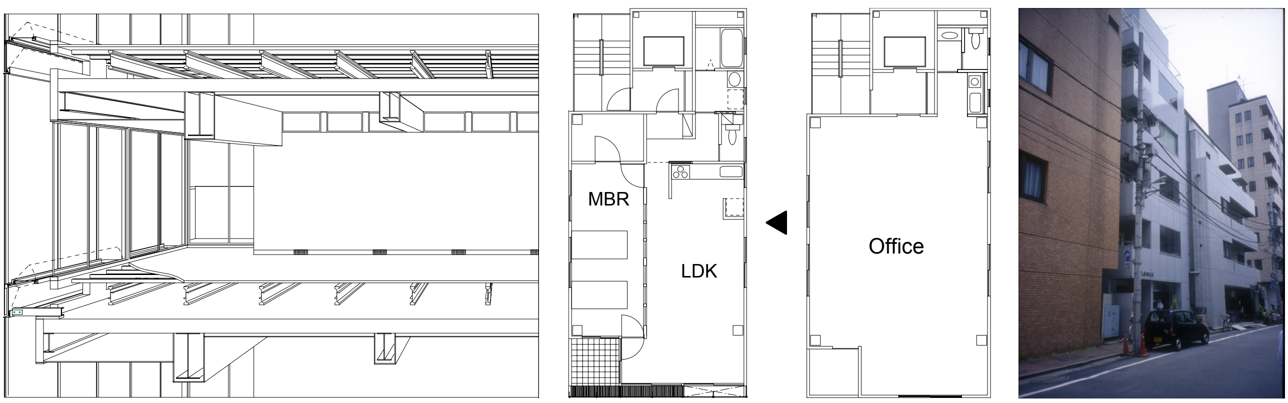


Fig.3 Model Design on C-building

4.2.3 Infill Sub-system

Spite of the six methods for insulating sound shown on Table 8, only the meanings of improving the substrate of floorings and thickening the slab is virtually available because of enabling to achieve the expected performance easily. It is expected that the former will decrease 5dB of floor impact sound, and the latter 10dB, generally. In six case studies, the method of improving the substrate of floorings applies to four buildings: A, B, E, and F-building, which have almost seven meters span of columns, and 150 millimeters thickness of slabs. On the other hand, it is necessary for C and D-building constructed by steel structure to decrease more than 10dB of floor impact sound. The thickness of their slabs is reduced to less than 150 millimeters partially because the deck plate was used as a slab form. Further, the span of D-building is almost twelve meters.

The meaning of thickening the slab applies to D-building, but C-building. The increase of weight accompanied with this meaning affects hardly the cost of converting D-building. Since the seismic reinforcement must be carried out due to its structure not satisfying the present criteria of Building Standard Low. It includes the repair required by the increase of weight incidentally. But, in converting C-building, the increase of weight with insulating sound is not acceptable. The extra strength of its structure is never kept because of used for extending the setback part. In conclusion, the sound insulation of C-building is carried out by the unknown meaning of isolating the floor vibration by special floor beams, as shown in Fig.3. This suggests that to develop the light weight methods for insulating the floor impact sound entirely is needed for supporting conversions.

5. Conclusions

In this paper, by applying the Open Building concept, the requirements for sub-systems have been clarified in order to convert offices into dwellings effectively. The basic idea of Open Building is to divide total building system into the part occupied by individuals and by common. But it is impossible to divide it clearly according to the ownership because, in changing the use, the ownership of some parts is moving to the other. Therefore, it is necessary to introduce the category of *services* and *claddings* as a sub-system, which extends over ownerships frequently.

To establish the performance specification of sub-systems, it is important to correspond with the required performance and the attributes of base-buildings. In case studies: the forced drainage system, the double skin façade and the flooring system for insulating sound, the examples of performance specifications are suggested concretely, and represent three relations to the types of base-buildings. And it is likely that the appropriateness of the specifications is verified in the detailed model designs.

In the future, it is required more and more by converting the building stock to revitalize the urban center of many cities in Japan. Especially, the conversions of offices into dwellings are expected to play the great role, which transform the existing industrial city into the residential. By developing the effective sub-systems, they can contribute considerably to the revitalization of obsolete areas.

Acknowledgments

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Development of new building systems using innovative structural materials Part1: An approach and strategy to develop sustainable building systems to promote urban revitalization

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Summary

This paper presents findings in the studies that were pursed in New Building Structure Research and Development of the Association of the New Urban Housing Technology (ANUHT), in cooperation with the Japan Iron and Steel Federation (JISF) and the Japanese Society of Steel Construction (JSSC). Our target here is to develop new building systems using innovative structural materials by illustrating future visions of sustainable buildings in 21st century. Comprehensive researches have been performed based on investigations with typical models of urban revitalization to identify further research and development issues on new building systems using innovative structural. The paper aims to present current visions and strategies to develop sustainable building systems using innovative structural materials, which can promote urban revitalization. Firstly an approach to develop sustainable building systems using innovative structural materials is described. Secondary current processes to develop sustainable building systems are explained by illustrating future visions of society, lifestyle and supporting industry. Thirdly, a strategy to develop technical and organizational issues is proposed from a viewpoint of sustainable development. Finally, further research issues to develop sustainable building systems are presented.

1. Introduction

One of the current challenges in the field of urban revitalization is to integrate excellent innovation concept and innovative technologies. Many sophisticated concepts such as skeleton/infill, open building, two-stage supply system, and urban skeleton system have been carefully studied and practically implemented. When these concepts are integrated with current innovative technologies such as innovative material technology, ubiquitous network computer technology and distributed energy supply system, new concept of innovative building system will be realized. Our focus here is an integration of such sophisticated concept and innovative material technology to attain higher sophistication of sustainable buildings.

Reviewing past innovative technology developments in building construction, new building systems and structural systems have been realized by development and utilization of new structural materials, such as high-strength concrete, high-tension steel and lightweight materials. Current innovative structural materials to be used are super high-strength concrete, super high-tension steel are ultra fine-grained steel so called ultra steel, and innovative composite materials represented by carbon fiber reinforced plastics (CFRP).

Future sustainable buildings will also well depends on the development of new building systems in which innovative structural materials are optimally applied. These innovative structural materials have feature of not only high-strength as twice as ordinal concrete and steel, but high durability as twice as ordinal concrete and steel, high rigidity and high corrosion resistance.

Consequently new building systems are expected to make their lifetime longer and reduce amount of materials by developing non-welding joint between building components which allow them to be reused. The buildings designed by innovative structural systems can be viewed as sustainable buildings. The new building systems aim to reduce the time and cost of construction and greatly to extend facility performance, functionality, aesthetics, affordability, sustainability, and to increase responsiveness to changing business demands.

The Council for Science and Technology Policy, which was formed to develop Japan's grand strategy in the field of science and technology under the leadership of Prime Minister Koizumi, recommended that relevant governmental agencies should work together to promote commercial exploitation of nanotechnology and materials science. The recommended materials science research is aimed at designing buildings with truly innovative structural properties, esthetics and characteristics.

A five-year interagency project started in 2004 with a goal of commercializing the new building structures in 2010. The concept of the innovative building structures includes buildings with (1) mixed use of residences, offices, and retail services, (2) easy modification of interior structures, including floor height, and (3) reduction of wastes by eliminating the need for connections among structural components. These building structures are expected to play a key role in urban revitalization that is being promoted by the commercial sector.

Association of New Urban Housing Technology was awarded grants form the Ministry of Land, Infrastructure and Transport, and invited the member companies to join the research activity on innovative building structures in 2003. 16 member companies formed the preparatory committee and working group in 2004. Finally, a total of 21 companies discussed deliberately and proposed a five-year development program starting from 2004.

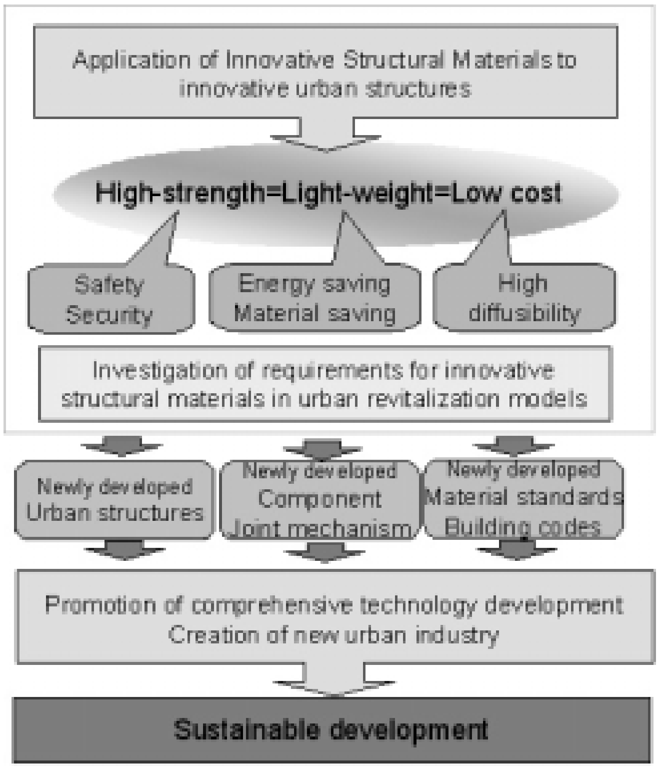


Figure 1 A scenario for sustainable development by innovative structural materials

2. Innovative Structural Materials in Urban Revitalization

The innovative structural designs are largely dependent on new structural materials. Among them, high-performance steel and advanced complex functional materials show particular promise because of their improved service performance, durability and maintainability. These features enable us to design and develop the following building structures.

(a) Due to their lightweight and high strength, new structural materials enable us to construct buildings with span twice wider and 1.5 times higher than conventional buildings.

(b) Combining high-strength main structure and high-flexible substructure meets demand for the use of open space flexibly.

(c) Few connections allow rapid assembly and disassembly of buildings, which reduces wastes of structural members and components.

Thin, high-performance steel sheets have emerged as the material of choice for modern automobile choice. However, construction industry still regards high-performance steel as an unproven material because of (1) high development cost, (2) uncertain demand, and (3) no clearly defined quality standard.

Conventional steel must satisfy the current severe requirements for plastic deformation region. Steel manufacturers argue that the requirements are not necessary for high-performance steel that has twice the strength of conventional steel. If the quality standard is established with consideration given to the unique characteristics of high-performance steel, the manufacturing process will be simplified to reduce the cost to 30%. The lower cost will increase demand substantially. Considering the virtuous circle, comprehensive approaches should be taken to expand use of innovative structural materials, such as high-performance steel and CFRP.

In addition to reduction of development cost, the demand side – Ministry of Land, Infrastructure and Transport and construction industry- has other requests for the supply side - Ministry of Economy, Trade and Industry and steel manufactures. The supply side must determine what they can do within the context of existing regulation and technology. Achieving the best balance between the demand and supply is inevitable to the development of innovative structural materials.

Association of New Urban Housing Technology undertakes research on the demand side, while the Japan Iron and Steel Federation and the Japanese Society of Steel Construction conduct research on the supply side. The first priority in the 2004 research activity is to measure the current position and future direction of the project against the research results.

3. 21st-century Urban Development Scenarios

Table 1 Features of innovative building structure

	Conventional building structure	Innovative building structure
Strength of material	1	double strength
Earthquake protection	Elastoplastic structure at seismic level 6	Elastic structure at seismic level 7
Life-span	60 years	100N years
Span	1	Half as long again
Number of columns	1	50%
Alternative applications	Unable	Variable
Introduction of public spaces	Separated structure (sectional surface rights)	Integral structure (sectional space rights)

Innovative structural materials are expected to improve urban landscape of long-term value in everything from resource efficiency to neighborhood amenities and services, safety and security, jobs and business opportunities, and improved education and transportation – in other words, social elements that are important to sustain, provide for and empower a better quality of living. On the other hand, an aging society with a decreasing birthrate is redefining the conventional perceptions of the way we live in the city. With very rapid changes in economic and social paradigm, the 21st urban development scenario should highlight the importance of "lifestyle vision", "social vision", and "industry vision".

- Lifestyle vision: Green living to create a community that supports diverse lifestyles and interacts with a natural environment.
- Social vision: Community livability to create a city as a place attractive to live and work.
- Industry vision: Market appeal to create business opportunities to maintain and sustain social developments.

The following cities and building construction will meet the above requirements.

(a) Robust building structure capable of making the public feel safe and secure in the event of large-scale disasters.

(b) Adaptive building structure capable of making easy conversion of former use to new use in a resource-efficient manner.

(c) Structural design capable of providing a better quality of living, and in turn, leading to orderly urban development

(d) Resources recycling/reuse to reduce wastes generated from maintenance, repair, and alternation of buildings and civil infrastructure.

The development of innovative structural materials has two-fold objectives: to mitigate concerns for existing cities and building structures; and to develop sustainable cities and buildings based on the resources recycling concept.

(a) Mitigation of concerns for existing cities and building structures

Today, many cities and building structures share concerns for the earthquake resistance, real estate crisis, inflexibility to accommodate changing needs, destruction of serviceable buildings, inattention to cultural and historical value, and high cost of demolition. Innovative structural materials are expected to develop new urban living replaced with existing cities and buildings.

(b) Sustainable cities and buildings based on the resources recycling concept

The supply system of innovative materials should be established to develop the urban infrastructure inevitable for the creation of a safe, sustainable, resource-efficient city and building. Therefore, the government and relevant industries must work together to take comprehensive approaches toward this end.

Our project focuses on the development of structural systems to make a city or a building safe, sustainable, and resource-efficient by using innovative material-based building structures. The demand research is conducted to determine the requisites for the construction system.

4. Applicability of Innovative Building Structures

4.1 Urban redevelopment models

Innovative material-based building structures will provide a solution to urban revitalization in the 21st century. The applicability of the innovative building structures is examined for the following four areas.

(a) First priority urban redevelopment areas (City center redevelopment area)
17 districts (approx. 3,500 ha) in Tokyo, Yokohama city, Nagoya city, and Osaka designated as the first priority urban redevelopment area

(b) Third priority urban redevelopment areas (Crowded with wooden housings area)

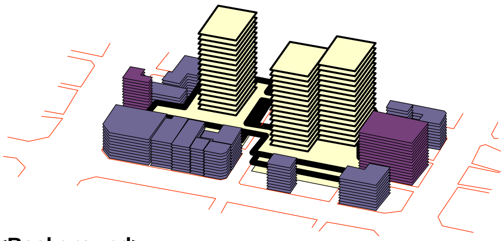
Districts that are the most dangerous among those designated as the third priority urban redevelopment area (a total of 8,000 ha nationwide, including approx. 2,000 ha in Tokyo and Osaka)

(c) Other priority urban redevelopment areas (Waterfront development area)
Waterfront districts in Chiba, Tokyo, Yokohama, and Kawasaki, which comprise 4,400 ha

(d) Existing housing stocks area (Housing stocks renovation area)

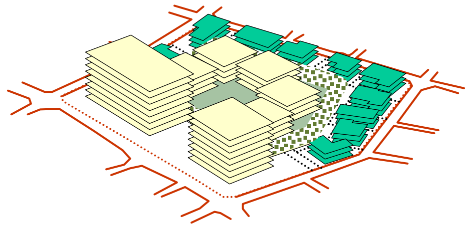
Improvement and reconstruction of 2.18 million public housing stocks and other dilapidated public housings through the utilization of PFI and private knowledge

a. City center redevelopment area



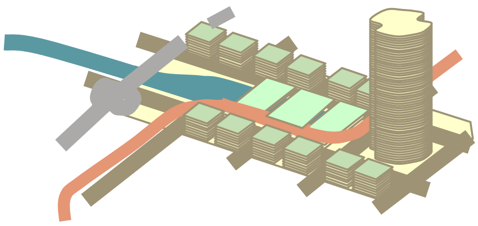
<Background>
A decline in economic vitality, low birthrate, aging housing stocks, lack of natural environment (green space, etc.), scarce public spaces, many small plots
<Applicability>
Super skyscraper that contains residents, offices, tenants, and multilevel parking garage, high-story apartment complex with one-below grade offices and two-below grade parking garage and tenants, renovation to reflect the original heritage
<Effects>
Development of high-story apartment complexes that enjoy public amenities and a natural environment, creation of a city to provide jobs, residence and entertainment, revitalization of a city through renovation to reflect the original heritage

b. Crowded with wooden housings area



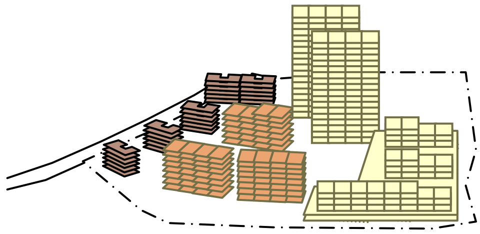
<Background>
Crowded with wooden housings that are to be collapsed and burned in the event of large earthquake, many small streets that give obstacles to extinction, escape, and construction of fireproof house, decline in attractiveness and vitality of the district due to an increase in aging population and a decrease in young people
<Applicability>
Low- and mid-story apartment complex with a basement level that expand blocks as necessary, mid- and high-story buildings along major streets
<Effects>
Creation of safe and disaster-resistant cities, development of comfortable living environment, increase in population, traffic safety and convenience with the introduction of pedestrian dedicated sidewalks, recovery of commercial vitality

c. Waterfront development area



<Background>
Large ex-commercial lands left to be unused or used inefficiently, insufficient use of advantages from the development of traffic infrastructure, no preventive measures to disasters in waterfront districts
<Applicability>
Creation of a compact urban structure by buildings with fourth sub-basement level and hyper buildings
<Effects>
Development a compact city to provide better access between jobs and homes, better access to public transport, and better environmental outcome with minimal infrastructure investment and energy use

d. Housing stocks renovation area



<Background>
More aging residents who have lived since 1965 when the initial public housing development project started, dwelling unit scale, facilities and parking spaces that do not meet requests from young people, difficulty in investment on the renovation due to fixed low rents
<Applicability>
Expansion of the housing with a hybrid skeleton technique and super skyscraper that contains residents and multilevel parking garage through the efficient utilization of original heritage and infrastructure
<Effects>
Low-cost renovation of dilapidated housing thorough barrier-free, improvement in basic housing functions, introduction of value-added function, and support-infill design

Figure.2 Investigated urban redevelopment models

4.2 Investigation of innovative material-based building structures

Table 2 shows relationship of urban redevelopment models and issues that were studied with innovative building structures. Through the investigation, requirements for innovative materials and innovative material-based building structures, as well as organizational issues were identified.

These requirements for innovative material-based building structures are categorized into the following two urban structure models.

(a) Vertically mixed use

Businesses, housing, and civic uses are mixed “vertically” by constructing offices and residences above retail or parking space. This vertical architecture has two types: multi-story structure, where main structural frame is formed every three stories: and standard structure, where main structural frame is formed every story.

(b) Horizontally mixed use

Businesses, housing, and civic uses are mixed “horizontally” by connecting different uses adjacent to each other with public spaces above parking garage. This horizontal architecture has two types: long span urban structure, where main structural frame is formed twice as long as usual spans: and short span urban structure, where main structural frame is formed half as long again as usual spans.

With the combination of these mixed use zonings, we will be able to find solutions to problems with traditional zoning, such as relocation of subsidiary streets, integration of public open space, efficient use of energy, and reduction in waste of structural components.

4.3 Features of Innovative material-based building structures

Through the investigation, the following features with the innovative material-based building structures are identified:

(a) Multi-purpose

The proposed high-story building is comprised of residences, offices, tenants and the like. The interior can be divided according to the space functions, and electricity and water consumption is controlled at each block for energy savings.

(b) Stepwise development

Stepwise development approach can be taken to reflect the original heritage into the renovation.

(c) Integration of public open space

Commercial sector can promote the renovation with consideration given to the integration of public open spaces, such as green belt, plaza, and parking garage, with the building.

Table.2 Applicability of the innovative building structures to urban redevelopment models

Urban redevelopment models / Innovative building structures		City center area redevelopment model	Crowded with wooden housing area redevelopment model	Waterfront business area redevelopment model	Existing public housing stocks redevelopment model
Vertically mixed use urban structure	Hyper building system			X	
	Super-high-rise building system	X		X	X
	Mid-rise and low-rise building system		X		X
Horizontally mixed use urban structure	Multi-story urban structure system	X		X	
	Standard story urban structure system		X		
	Parking deck system				X
	Sky-deck system	X			
Improvement system for existing housing stocks		X			X
Integration system with public open space	Parks	X	X	X	X
	Subways	X		X	
	Parking	X	X	X	X
	Roads	X		X	

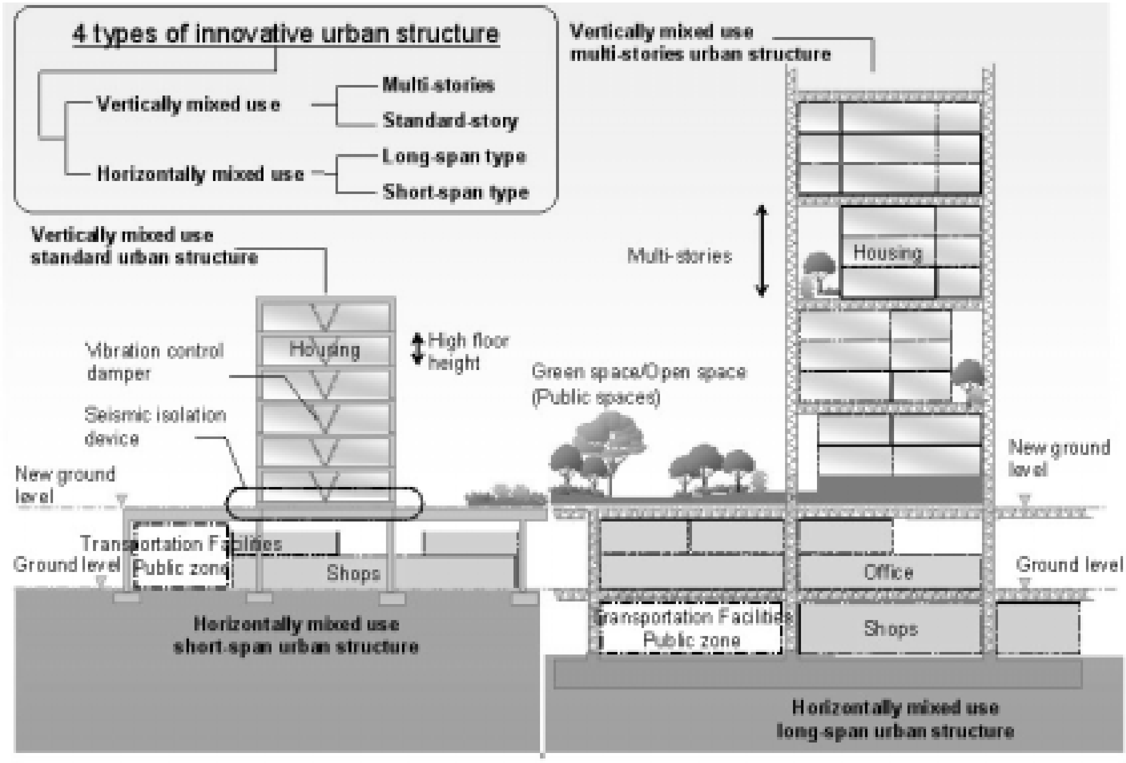


Figure.3 A Conceptual view of Innovative urban structures

5. Technical and Organizational Issues

We need to address both technical and organizational issues to implement the urban development scenario described above within a time frame of five years.

5.1 Technical Issue

Major technical issues to be developed is classified into the following three categories:

(a) Innovative material-based structural components and elements, that is reusable and recyclable as social infrastructures stocks

- A production / processing / examination method of a super high strength structural materials, components and products.
- A new JIS / ISO standard for innovative materials and innovative material-based building components.

(b) Multi-functional, flexible, and long-life building systems that support to maintain and to improve urban functions.

- A design method with structure system corresponding to changes in building use.
- A design method and performance validation method with a super quakeproof structure system against the Japanese earthquake intensity scale of 7.
- Design method and performance evaluation method of Joint mechanism depending on characteristics of high strength and high performance materials.
- Infill and cladding system corresponding to high performance structure systems.
- Interface systems to incorporate a developed structure system in an existing building structure.
- Construction methods for reusable building systems.

(c) Maintenance and revitalization technologies for urban functions that create a new urban building industry.

- A performance and quality confirmation method in structural components when they are reused.
- A disaster prevention planning method corresponding to the performance and design for plastic deformation against the Japanese intensity scale of 7.
- A property management method for combined building structures.
- Monitoring and inspection methods of structure performance, disaster prevention performance and environmental performance at city block level.

As described above, a new quality standard should be established for innovative materials developed by steel industry and other relevant industries. For this reason, national and industrial research institutes must work together to take a comprehensive approach to the development of new construction designs and methods, including connection techniques, as well as the development of performance assessment and verification methods. In addition, research must be conducted on the combined use of high-performance steel and existing concrete or advanced composite materials. These efforts would make it possible to develop a lightweight, smart reinforcement for the improvement in seismic resistance and hybrid reinforcement connecting multiple slender buildings.

Housing manufacturers also conduct their own research on infill and façade, given the fact that the urban development scenario needs interior functionality and exterior beauty that cannot be achieved through the development of new building structures.

5.2 Organizational Issue

One of innovative ideas is that public observers and commercial participants work together to develop techniques to promote the businesses to lease foundation structures and other equipment as follows:

(a) Building codes and regulations

Investigations of material criterion, performance criteria and design criteria with innovative building structure are required to establish new method for performance evaluation and verification in building codes.

Stepwise authorization and examination methods of building construction should be established, when skeleton and infill or connection of existing buildings and new buildings is applied for authorization of an urban redevelopment project in multi-step processes.

Investigations of measures to install and guarantee public spaces in an innovative building structure as special zones are also relevant.

(b) Law concerning the registration of real estate

Measures for ownership of skeleton and infill to be guaranteed and secured separately are carefully examined. Regulation of contract life to utilize an innovative building structure should also be studied.

(c) Supportive measure to establish a new housing market

Execution of leading urban redevelopment projects, applications of innovative building structures to public works, considerations of preferential tax treatment for long-lived building structures, and investigation of financing techniques for an infrastructure development are necessary to establish a new housing market.

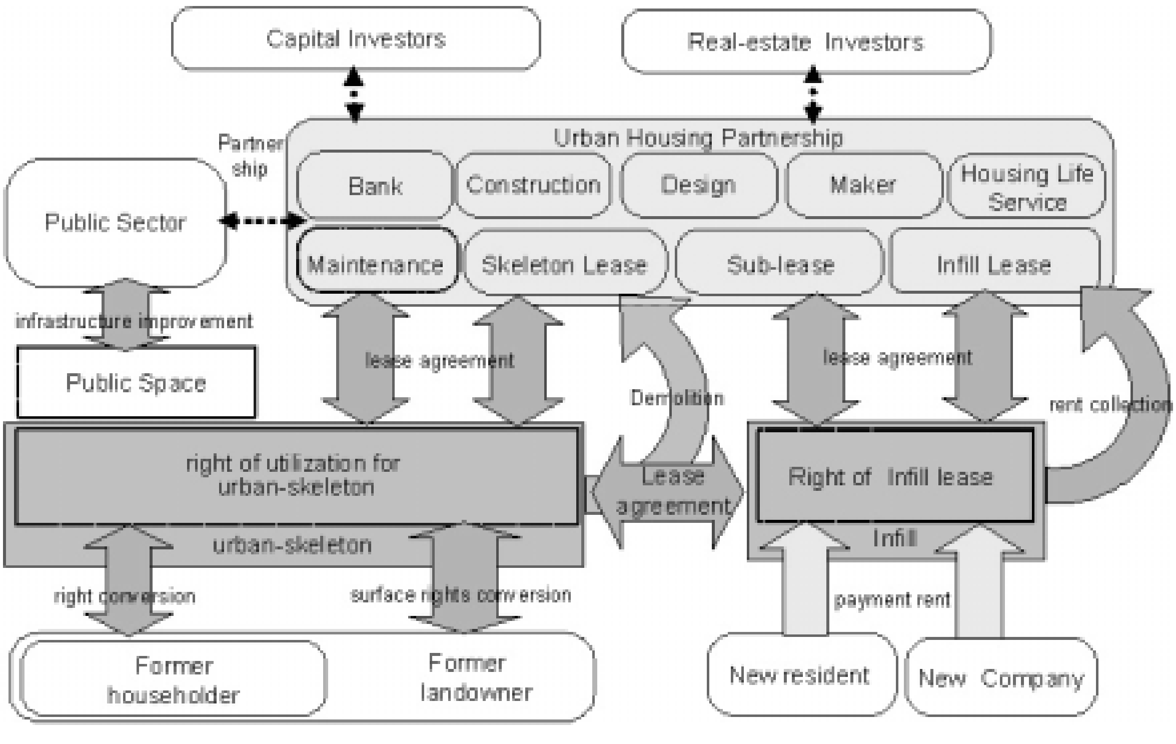


Figure.4 An expected business model with innovative material-based building structures

6. Approaches to the Commercial Application of Research Results

The five-year interagency project differs from traditional national projects in that an emphasis is placed on the development of the environment where research results can be smoothly commercialized.

The urban development scenario envisaged needs a new regulatory framework to promote the commercial application of research results. The regulatory changes include new standards on materials, performance and design for plastic deformation against the Japanese intensity scale of 7, analysis techniques for the integration of existing and new building structures, and streamlined procedures to file inspections and applications for tissue, skeleton and infill. Accordingly, the government must reexamine current real estate laws, as well as construction laws and standards.

In addition, future plan calls for pilot business projects and public works using new building structures to form a commercial market at the earliest stage.

According to the Council for Science and Technology Policy, innovative material-based building structures are to contribute to the construction of stronger disaster-resistant, better cost-effective social infrastructure because of its improved service performance, durability and maintainability. The government and industry are required to work together toward the development of relevant technologies.

Keeping recovery of economic vitality and creation of new markets in mind, Association of New Urban Housing Technology continues to promote research projects for applications of innovative materials in the urban development in cooperation with the governmental agencies and universities, as well as the Japan Iron and Steel Federation and the Japanese Society of Steel Construction.

7. Conclusion

An approach and a strategy to develop new building systems are briefly described through investigations in urban redevelopment models. The new building system is illustrated as combination of horizontal and vertical urban structures using innovative structural materials.

Features of innovative material-based structures are identified as to enable multi-purpose use, step-wise development and integration of public spaces. To implement new building systems, technical and organizational issues are to be solved with a clear scenario of research and development with innovative material-based structures. The scenario should be promoted as a national project with cooperation of government and industry.

Since the essential subject to develop new building systems using innovative materials is to solve environmental issues and human settlement in cities by introducing social infrastructures in high flexibility, performance and sustainability. The innovative materials and new building systems are to be applied in various types of urban redevelopment projects, to realize future sustainable buildings and urban structures with high economic ripple effect

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OPEN BUILDING AND COMMUNITY HARVEST: NEW DEFINITIONS OF WHAT CAN COMPRISE A BASE BUILDING

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Summary

The levels of Open Building—*land use, urban tissue, base building, fit-out, and furnishings/equipment*—seek to differentiate the complexities of building construction in ways which acknowledge the distribution of decision making control and attend to the reality of the continuing transformation of building use over time. *Base building*, by convention, comprises the structural system, the placement of vertical chases for primary metabolic elements (air ducts, plumbing, electrical runs, and elevator shafts) and the location of code-mandated fire stairs. In the face of growing concern for sustainability and the need to account for the throughput of material and environmental resource use, it is necessary to reconsider the elements defining the *base building* and, in so doing, to make possible the harvest of the on-site force flows of nature in support of occupant activity. This redefines the rule structures for patterning *land use*, shaping the volumetrics of *urban tissue*, and determining the construction assembly of the *base building*.

This paper examines the opportunities available for including technologies of water harvest, ventilation management, daylight use, solar-thermal energy collection, and electrical production as armatures of the *base building*. Discussion is provided of differing scales of application of the concepts as they relate to the making of *urban tissue* and as they constrain, or at least influence, the technologies of building *fit-out*, thus tying the hierarchy of distributed decision-making to the complexities of environmental response.

1. Introduction

1.1 Defining the Fixed and Variable

A key component in the levels of definition of open building at every scale is the distinction of fixed and variable elements. And to differing degrees, at each stage of the design-decision process, virtually every element must be determined to be either fixed or variable. At the scale of *land use*, the elements include topography, surface water, and geologic features; for *urban tissue*, the elements are the patterns of streets and surface rail, as well as the underground infrastructure—water supply, sewage collection, energy distribution, phone service, internet cabling, and subways; for *base building*, the elements include the walls and roofs of the building shell and the elements of internal physical structure—columns, beams, bearing walls, sheer walls, wind bracing, mechanical, electrical, plumbing, and/or the occupant circulation and conveying system chaseways; for *fit-out*, the elements include the space partitioning and mechanical terminals; for *furnishings/equipment* the elements include task lighting and material finishes. At every scale, the design decision to fix an element in size and place establishes the physical armatures upon which further decisions in space and time are made. Examples are many.

1.1.1 Land Use

The powerful influence of streets and underground infrastructure as *land use* armatures is dramatized in stories of the rebuilding of cities devastated by natural disaster. A case-in-point would be the rebuilding on the Florida Panhandle after Hurricane Andrew. The replacement of housing and commercial districts involved clearing of site plats to enable new construction to “hook up” to the underground utilities and once again enfront the streetscapes that were largely undisturbed by the passage of the devastating winds and substantial rainfall. In similar fashion, time and again, residents have repopulated floodplain areas throughout the world by “drying out” the flooded houses and/or by rebuilding the missing dwellings whose foundations remained in place. In fact, by the time of presentation of this paper, a similar story will have unfolded on the heels of the tsunami in Indonesia; the established street grids and underground utilities will once again have served as the armatures upon which the urban tissue will be (re)constituted.

1.1.2 Urban Tissue

In addition to the *land use* patterning as driven by the site plats, physical infrastructure of street grids, rail lines, and underground services, the codification of zoning, building set-back and height restrictions also conspire to assure a rebuilding of the *urban tissue* to reflect, if not match, the grain and volumetric pattern of buildings obliterated by the natural disaster. In the heat of the rebuilding and with the desire to reclaim lives otherwise torn apart, few questions are asked regarding the grain, density, or form of that *urban tissue*; the images from memory and the legalistic constraints of building regulation function as conceptual (not physical) armatures which assure a replication of that which existed before.

1.1.3 Natures Resource Flows

However, these conventional descriptions of the fixed and variable elements of *land use*, *urban tissue* and *base building*—whether physical <u>or</u> conceptual—overlook an opportunity to address the more substantial issues of how built form must respond to, and ultimately integrate with, the force flows of nature; these comprise not only the climatic variability (and the need to establish human comfort using the natural ventilation, solar collection or shading, and/or humidification of occupied space), but also the harvestable resources (such as waterfall, daylight, and energy), as useable on-site throughputs.

Broadening what is included in the definition of the armatures of *land use*, *urban tissue* and *base building* recasts the complexity of considerations and redefines the boundaries for the distribution of decision-making control in both the origination <u>and</u> the transformation of building use in space and time.

More clearly enriching open building by defining what constitutes the physical and conceptual armatures of the fixed and variable yields the potential to embrace the tenets of green, sustainable, and/or regenerative building performance. An ordered distribution of decision-making control naturally follows.

2. Decision Making in Time

2.1 Scaling the Interventions

The initial design stage of any green, sustainable, or regenerative project requires an assessment of the balance of resource harvest availability against the projected demands/needs of building occupants. Essentially, this becomes an examination of the trade-off of opportunities associated with the seasonal climatic fit and the day-to-day human comfort. This linkage between climate and human comfort traditionally has been studied under the rubric of bio-climatic design; design of the building for the metabolics of occupants to compensate for the temperature and humidity variability in a climate zone.

As a result, designers are confronted with two scales of decision-making in time: (1) the choices which determine the degree of fixed behavior/response by the *base building* shell to the climate variability and (2) the choices attendant to the occupant activities, schedules of use, and physical densities.

However, a simple climatic assessment which sets the strategies for intervention on behalf of human comfort requires additional forms of analysis to expand occupant response to include <u>all</u> available resource harvests. Specifically, the widespread and frequently varying intensities and duration of rainfall, the illumination from the sky, the variability of the speed and directionality of prevailing wind flow (from one season to the next), and the ubiquitous presence of low-concentration radiant energy from the sun can comprise what amounts to design decision-making about priorities of response to the environmental factors—in time.

2.1.1 Seasonal and Diurnal

Certainly, the volume of storm water as a non-potable gray water supply, the ventilation effect of prevailing wind flows (using air buoyancy and stack effect), the varying luminosity of the skyvault, the thermal value of radiant solar energy, and the electrical production potential of that resource, all point to opportunities to fix in place the <u>seasonal</u> conversions of the incoming supply streams of water, wind, light, and sun. But, the force flows of nature must be considered also in terms of the diurnal operational response, and require strategic use of armature elements to assure effective day-to-day 'valving' of flows.

Patterning the size and placement of the environmental armature elements to effect a reasonable balance of the seasonal and diurnal environmental response then requires thoughtful choice about what is fixed and what is variable.

3. Decision Making in Space

3.1 Envisioning the Flows

Decisions about resource access and conversion also comprise what amounts to design decision-making about priorities of response to environmental factors—in space.

The potential for the harvest of water, wind, daylight, solar thermal, and solar electrical production are shaped in part by the selection of street pattern and the inherent limitations of the built volumes associated therewith. And, given the inherent geometric characteristics of these descriptors for the respective imprints of natural force flows, it is possible to determine reasonable shapes of what can be called harvest envelopes and to correlate them one to another in the making of urban form.

3.1.1 The Harvest Envelope Paradigm

The classical harvest envelope in wide use since the 1970s energy crisis is, of course, the solar envelope, which is derived by using the pattern of street grid as a delimiting device in plan and the angularity of the solar axis bracketed by season and hourly availability as the delimiting factor for volume to formulate an imagined boundary within which buildings on any given urban block can be aggregated without restricting access to the sun for buildings on adjacent properties.

3.1.2 Water

In similar fashion, water harvest envelopes can be determined on the presumption that rainfall is essentially vertical and the option for resource collection, storage and use is driven by the inherent public/private distinction of street grid and site plat, and the need to organize channels of flow.

3.1.3 Wind

The harvest envelope associated with wind flow and ventilation is somewhat more complex and mimics the operational dynamic of the solar envelope. Wind directions change on an hourly and seasonal basis, and must be examined to determine the trending patterns. Wind roses are traditionally used to illustrate the percentage of time of the year during which the wind can be presumed to come from prevailing directions and within presumed ranges of speed/strength. The directionality is significant in setting the desirability of ventilation during the warm, humid seasons of the year and the desire to prevent such throughput of wind flow during the cold, dry months of the year; the speed is significant as it relates to the length of wind shadow effected around and over objects.

3.1.4 Light

The target capture of skyvault illumination from the interreflection of light within the atmosphere during overcast, as well as clear sky conditions, is a function of the subtended solid angle intercept within the hemispheric geometry of the skyvault. The interreflection of light off ground surfaces and vertical planes of surrounding buildings adds considerations. Within the more general description of geometry of exposure, one must consider also the magnitudes of the source energy. Overcast skies differ substantially from clear skies. Generally speaking, the zenith is brightest in overcast weather, and the horizon is brightest in clear weather. Actual measured values of illumination intensity are constrained further by the latitude of a given building site, and can vary considerably from one season to the next.

3.1.5 Sun

The functionality of the solar harvest envelope is a result of recognizing the angularity and dynamic variability of the sun's position in the skyvault during the full cycle of the year. By making the delimiting assumptions of street boundary, acceptable adjacent building shading, and hours of the day for optimal collection, the solar envelope represents a reasonable approximation of "good fit" for the conversion of available solar energy over the course of each day from one season to the next.

4.0 Geometric Registration

4.1 Using of the Tartan Pattern in Plan

By convention, open building designs use a tartan grid pattern to differentiate space and margin areas; elements of built form are "registered" to this grid as a dimensional and zonal modulation for placing the elements of passive and active metabolic systems.

4.1.1 Space and Margin Placement

A natural distinction can occur between space and margin placements of elements of resource harvest at the scale of *urban tissue* and at the scale of *base building*. Armatures associated with the public domain of *urban tissue* would be those linked in some way to the (above ground) street grid, and/or the tunneling and distribution of underground utility and transportation infrastructure. Fixed elements of resource conversion associated with *base building* would be those tied to the construction of the building shell, encompassing both the roofscape and facades. And yet, the implicit distinction of public and private decision-making associated, respectively, with the urban transportation grid work and the site plat building volume are not absolute; they comprise three types of consideration.

4.1.2 Air Rights

As part of the more general strategy of *urban tissue* resource conversion, air rights can be used to place the harvest armatures permanently over the site plat areas and/or the street grid; the resource harvest thus can become a right of the public domain and/or a privately-held right of access.

4.1.3 Distributed or Aggregated

As a first-order intervention, one must assess the generalized potential of resource conversion as dictated by the relative geometry and magnitude of the available force flows of nature. As a second-order intervention, it is helpful to think in terms of the distribution of such conversion—enabling either a point-of-use distribution or a more centralized aggregation of the collection and storage elements.

4.1.4 Orientation

In considering the fixity of elements as *urban tissue* armature or as *base building* armature, the role of cardinal orientation is significant; the geometries of the sun, wind, and light play out in differing ways on east/west versus north/south <u>streets</u>; similarly, north-, east-, south-, and west-facing <u>facades</u> experience radically different impacts from the sun, wind, and light.

4.2 Using the Tartan Pattern in Elevation/Section

It is possible also to identify space and margin patterns in elevation as striations of "interstitial spandrels" and "occupant spandrels" within which the harvesting armatures can be placed. These zones are implied respectively by the nature of structural and mechanical service runs within the <u>floor/ceiling sandwich</u> and the *fit out and furnishings/equipment* elements located within the floor-to-ceiling <u>occupied zone</u>. Each of these spandrel areas can be manipulated to affect opacity and transparency, and a resulting yield of water, ventilation, daylighting, solar-thermal, and solar-electric production.

5. Armature Placements

5.1 Formalizing the Architectural Order

The plan, elevation, and section patterning of the tartan grid offer means for registering the distribution of armature elements as a function of two other considerations: the incremental modulation of the harvest and the more formalist ordering ideas of architecture. Many such formal systems for defining the architectural order of buildings are used by architects. One of the more profound categorizations developed by students and faculty at the School of Design at North Carolina State University in Raleigh, North Carolina uses a hierarchical cascade of *elements*, *relationships*, *ordering ideas*, and *parti*.

5.1.1 Elements

By category, these would include *entrance*, *circulation*, *massing*, *structure*, *services*, *space definition*, and *natural light*. The intent of such list is to isolate those primary elements of plan formulation or built volume which serve to anchor and/or otherwise function as fixed armature elements in determining the other variable registrations of building components in the design decision-making.

5.1.2 Relationships

This next level of analysis seeks to address a more complex correlation of factors in the making of architecture. The categories used under this heading include *building-to-context*, *circulation-to-use*, *plan-to-section*, *unit-to-whole*, *inside-to-outside*, and *repetitive-to-unique*. These categories talk less of physical armatures and more of conceptual armatures by which designs can be organized.

5.1.3 Ordering Ideas

This category, at yet a higher level of abstract organizational assessment, includes the concepts of *symmetry/balance*, *point/counterpoint*, *grid/geometry*, *hierarchy*, and *layering*. These typically comprise the more artistically compositional and obviously less pragmatic/operational analytical patterns drawn from plan, elevation, and section. These ideas inherently comprise themes for organization, and notably talk to the deeper meanings within an architectural fabrication.

5.1.4 Parti

This last category contains the highest level of inference drawn from within this analytical system. It comprises "*…the dominant idea of the building which embodies the salient characteristics of that building; the parti diagram encapsulates the essential minimum of the design, without which the scheme would not exist, but from which the form can be generated*". The parti is largely gestural, extractable only by reducing the complexity of built fabric to a singular—readily diagrammed—formal expression. Certainly, in the case of renowned architects, the parti is that one driving idea that transcends virtually every one of their building designs and transforms over time, achieving a high level of sophistication in its interpretation. The more mature work of architects are readily linked to their early work through the content emphasis embodied in parti diagram.

5.2 Modulating the Architectural Order

The intersection points, edges, and space areas of the tartan pattern provide the fundamental definition by which to address the question of spatial distribution, or aggregation of the resource harvest, storage, and use. This translates the modulation of measurement into a formal architectural language by which *urban tissue*, *base building*, and facility *fit-out* can be designed. This language of proportional metrics can be readily integrated with the system of architectural order discussed above.

6.0 Example Armature Constructs

6.1 Singular Armatures

Each resource harvest has its own implicit fit with public and private domains and rights of use for the urban block form of *base building* and the corresponding patterning related to *urban tissue*.

6.1.1 Water

Water harvest armatures are driven by concerns for the intensity and duration of waterfall on an episodic, seasonal basis. Depending upon the extreme ranges of climates, the collection, storage, and use of the resource may be scaled to particular seasons, or may be proportioned to account for the annual cycle of fit between availability and use. Water harvest armatures are primarily located in the horizontal striation of the roofscape; the canopy areas over building entries, public access ways, and localized features of building façade can also be used. The water harvest armature also requires a linear aggregation of flow much in the spirit of the stems of a leaf or the branching of a tree; and this again, ties to the concern for the localized versus more centralized placement of the storage device. The water harvest armature is most effective as a large surface area whose sheet flow is aggregated at reasonable points of vertical gathering for shunting to storage.

6.1.2 Ventilation

The dominant wind streams as sources of ventilation require both points of input and points of outflow in order to effectively cross-ventilate, stack ventilate, or otherwise "scrub" the occupied air bubble within the many floors of the urban block *base building*. In this case, the primary aspects of the armature construct involve towers that rise above the more general roofscape of the urban tissue and are spaced apart enough to enable good interaction with the various directions of the prevailing wind. The intake towers typically offer the opportunity for introducing water as a humidification tool when used in arid climates; the outflow towers typically rely on airfoil design of the tower tip so as to accommodate the varying directionalities of the prevailing wind and to assist in creating the differential pressures needed to achieve a venturi effect to "pull" air from the building.

6.1.3 Daylight

The universal availability of skyvault illumination from both overcast and clear sky conditions, is constrained only by the proportionality of building heights to street widths within the *urban tissue*. The four cardinal orientations of *base building* façades, as compared to the zenith orientation of roofscape, offer an inherent differentiation of morning, noon, and evening light access as compared to the more general uniformity of the skyvault above. The effect of other surrounding surfaces, including ground plane and nearby facades, can shade or accentuate the interreflection of light on the facades or roof plane.

Roofscape armatures for daylight control typically differentiate the angular shadow-casting light of the sun from the more diffuse skyvault illumination. These armatures can be localized or centralized, but the rule-of-thumb regarding the lateral depth-of-penetration of daylight into any occupied zone is a function of head height of the aperture. Thus, the frequency of placement of the daylighting armatures and the breakdown of the urban block form of the *base building* must be disciplined by that ratio.

Skyvault-type roof apertures (monitor/skylight/clerestories), typically rely on the proportionality of opening to overhang and the proportionality of interreflecting surfaces within the floor/ceiling sandwich construction dimensions—as noted for the horizontal, interstitial striation discussed in section 4.2 above.

The armature elements on the building façade, seek to differentiate the horizontal striation/banding of the view glass from the more highly-placed glazing used for daylight penetration. These latter glass lights typically sit above light shelf devices which are located on the exterior and/or interior of the building façade to reflect light against the ceiling surface, to achieve greater penetration into the occupied zone.

6.1.4 Solar Thermal

The use of the sun's thermal energy for space heating is constrained by the nature of building type and occupant need; skin load dominated buildings typically can make good use of the solar thermal resource, whereas internally load-dominated buildings typically try to shade, filter, or otherwise reject this income stream. The primary consideration in effective solar collection and storage is the ratio of aperture to exposed thermal mass within the occupied zone, and the shuttering or blanketing of the aperture during those hours of the evening, night, and early morning—when the intensity of the incoming radiation is of a modest value, and the ability to move or otherwise redirect that income energy stream to zones in locations remote from the immediate solar aperture.

6.1.5 Solar Electrical

Production of electrical current using photovoltaic panels struck by the sun, offers the opportunity for point-of-use collection and load service at the perimeter zones of the urban block form of the *base building*. Photovoltaic panels can be constructed of opaque, insulated, and framed substrate materials, or the PV cells can be applied directly to a transparent glazing, thus achieving some degree of hybrid use—electricity production <u>and</u> daylight transmission. The PV armatures typically are optimized for tilt at latitude +15 degrees for wintertime service, latitude -15 degrees for summertime service, or at a tilt equal to the latitude angle itself for year-round average performance. In some instances, flattened-arch roof profilings of PV cells have been used to harvest the skyvault illumination and/or the reflected amplification of hard sunlight from surrounding surfaces onto the PV cells.

Although the direct current flowing from the PV arrays can be stored in batteries for later use, the typical application is to run the power stream through an inverter and to plug it directly into the grid, thus serving to “run the meter backward”; the grid thereby effectively serves as a storage battery.

6.2 Integrated Armatures

In addition to configuring armatures to capture any one resource, a related move is to design a multi-functioning role for each armature element; for example, water catchment channels can compliment wind-driven stack effect, or wind catchment devices can be integrated with solar-thermal harvest, or sun shades can also function as daylighting devices and/or can encompass photovoltaic electrical production.

The challenge is to define that which will be a public/shared decision about armature type and placement—the water envelope, wind envelope, daylighting envelope, solar envelope, and electrical envelope aspects of primary urban form-making—as contrasted against that which will be a privately-controlled design choice such as the interstitial scales of shell treatment—i.e, the use of intelligent skins in single or double-envelope layering. These in turn can be correlated with the individual decision-making of user fit-out; for example, the material (product) choices (for light shelves, partitionings, and furnishings) which can contribute to the distribution of light deep into the floorplate area.

7.0 Conclusion

The key consideration in adopting the use of environmental resource harvesting armatures as newly-defined elements of the *base building* (and *urban tissue*) depend upon the decisions to be made about public versus private decision space and time. In those cases where elements of environmental armature are schemed to respond to seasonal conditions, this typically would align with a decision on behalf of the public good. The placement of the armature elements would be made early in the design process, and become the fixed elements to which occupants and future users must respond when configuring/reconfiguring the various levels of the open building response to changing user need. In the case of the day-to-day “valving” of resource flows, the material technologies and armature types are those that require occupant intervention for effective performance. These most readily fall within the domain of the more private occupant decision space and time, and comprise elements of the ultimate *fit-out* and *furnishings/equipment* placements in the *base building*.

Clearly, if attention is drawn to this new complexity of armature typing, a new language of open building begins to emerge, and that language harbors the potential for a meaningful approach to designing green, sustainable, and/or regenerative building performance.

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Demountable and Interchangeable Construction System: R. M. Schindler's Panel Post Construction

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Abstract
Architects as well as manufacturers have proposed numerous researches and experimentation of demountable and interchangeable construction system for the development of sustainable housing. Many alternatives have been proposed with the capability of being adjusted to the change of circumstances and technologies. The components are designed for being erected, disassembled, shipped, re-erected, and reused without special tools and waste. This approach definitely encourages the move towards an environmentally just and sustainable future. Among other projects, Rudolph M. Schindler's Schindler Shelters, his designs for low-cost, mass-producible housing, stands out the most within the above subject. This project illustrates Schindler's long-time interest in flexible design strategies and integrated construction systems which underpin his Space Architecture. In the Shelter project, systematic design strategies were used to achieve flexible layouts for mass-produced dwellings. The Panel-Post construction system was developed as a means of achieving this goal; this system uses unit components and allows for interchangeable assembly of its parts. This article reconstructs the archival material related to the project by analyzing housing layout variations to reveal the underlying logic of Schindler's scheme, and by fabricating scaled models to simulate the construction process.

Keywords: Schindler Shelters, Panel Post Construction, Flexibility, Interchangeability, Demountability

Introduction

During the early twentieth century in the U.S., research on prefabricated housing construction and design made considerable headway in the development and growth of prefabricated housing.[1] Development of innovative housing solutions continues to generate interest in design investigations along with the use of technology to produce diversity and spatial flexibility in designs.[2] Despite heightened awareness of prefabricated housing, the variety and quality of designs have been lacking.[3] This may be due to the narrow focus on cost efficiency and standardization in manufacturing. As a result, the predominant perception is that prefabricated housing offers only repetitive housing of poor design quality. Although prefabrication has been seen as a means of promoting a more diverse housing typology, the gap between design and production still remains large. According to Burns, "The sense of richness and complexity that should characterize the industrialization of housing production is lacking."[4] In Ahrentzen's view, for democratic choices to be possible among diverse people, housing diversity is a necessity.[5]

Beginning in 1933, Schindler undertook the design for his Schindler Shelters under his own initiative, in response to a program for the Subsistence Homesteads division of the Department of Interior which focused on low-cost housing projects.[6] Mass prefabrication of housing was under significant consideration in the U.S. due to the economic depression and growth population in urban areas. The Roosevelt administration became aware of a wide range of housing-related issues including severe housing shortages, the deterioration of existing housing conditions, the growth of slums, and homelessness.

The concern for low-cost public housing was reflected in the approach of contemporary architects in developing construction systems and unique housing designs. Theodore Larson compiled examples of contemporary housing in his article, "New Housing Designs and Construction Systems" in *The Architectural Record* (January 1934). These examples included Buckminster Fuller's Dymaxion Houses, George Fred Keck's House of Tomorrow, and Richard Neutra's One-plus-two Diatom House.[7] More research on prefabrication continued in the 1960's and 1970's, particularly by Lucien Kroll, Ezra Ehrenkrantz, and N John Habraken.[8] However, there was little mention of Schindler Shelters.

For Schindler, efforts to develop a new construction system for housing needed to address not only reduced construction costs, but also, improvements in building efficiency, speed of fabrication, interchangeability of parts, reduction of labor, durability, better design, and finally, personalized housing designs. He wrote, "The system shall permit individualization of house and garden. Unless a personal relation can be established between a house and occupant, both will become meaningless cogs in a social machine without cultural possibilities." Not wanting prefabricated housing to lose the "charming" quality of the freestanding individual house, Schindler was adamant that there be "No rabbit hutch housing."[9]

In the Schindler Shelters, Schindler advocated a low-cost housing system that involved systematic design strategies and integrated construction systems. Throughout his career, Schindler maintained that design strategies were universal vehicles to organize space and space forms.[10] The construction system was a technical strategy to realize the space form, "an integral part of the conception of a building."[11] Schindler was technically innovative, pushing systems of construction beyond conventional wisdom, however his theory of 'Space Architecture,' was at the heart of innovative experiments using new materials and techniques.[12] The development of new construction systems was essential for Schindler because conventional or standard construction systems were not always suitable for the execution of his vision of Space Architecture.

Compositional Strategy

Schindler designed the Schindler Shelters beginning in 1933. He devised a basic scheme with a center hall which allowed much flexibility of arrangement, and demonstrated this with a number of different layouts. The basic spatial scheme of the unit plan placed a hall in the center of the unit with a clerestory above for ventilation and lighting. Clerestory windows for the bath, living room, and kitchen were also provided. On one drawing Schindler noted that the "kitchen, utility, bath and hall [were] standard arrangements."[13] These spaces were consolidated as a core unit to concentrate the plumbing systems into a single wall. These units could be fully fabricated at the time of manufacture, shipped to the site, and assembled in place. All other rooms varied in size and arrangement, and were positioned in a pinwheel pattern around the central hall. The closet partitions opened alternately into one room or another and could be easily removed for spatial flexibility, optimizing the use of interior space to accommodate different needs. Finally, the garage was a separate unit which could be added to any side of the house.

Utilizing the basic unit, Schindler applied its potential to the design of a number of variations on a street.[14] (Figure 1.) The shelters line both sides of the street and the garages are added in different locations. Shrubs border each lot property, defining private yards for each unit. Schindler also illustrated other unit variations, including three-bedroom and two-story designs.

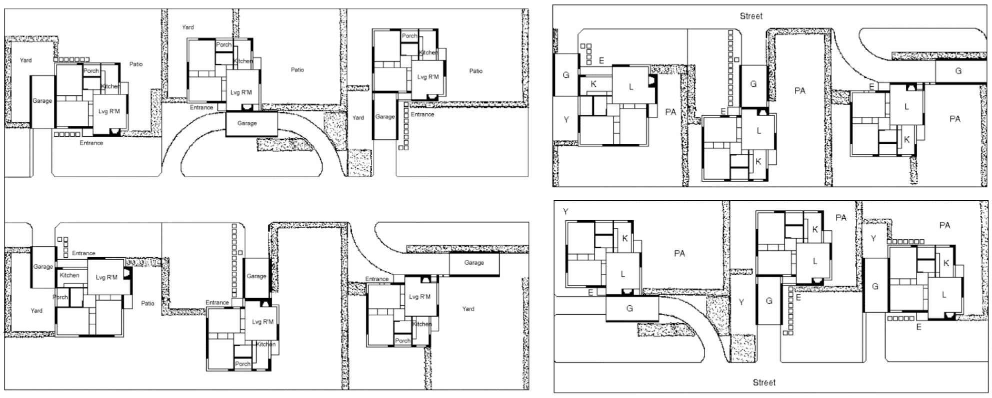


Figure 1. Six housing layout of the Schindler Shelters redrawn by the author

These original schemes initially utilized Neal Garrett's patented shell construction system, which used concrete hollow double-wall construction for the walls, partitions, floors, and roof. [15] As a result, the entire house became a monolithic shell resembling a building made of one material without any joints. All plumbing is contained in one wall and interior closet partitions were constructed with plywood as factory units.

The Garrett construction system was based, uncharacteristically for Schindler, on a 5-foot unit module. According to Schindler, the unit of dimension was the choice of the architect. He wrote, "[The space architect] needs a unit dimension which is large enough to give his building scale, rhythm and cohesion." Schindler had developed his own proportional system which he called a space reference frame.[16] In this system, Schindler recommended 48 inches (4-foot) as the basic unit, to be used with 1/2, 1/3, and 1/4 subdivisions. He chose these dimensions for two reasons. First, he thought the unit must be related to the human figure (6-foot) to satisfy all the necessary sizes for rooms, doors, and ceiling heights. For example, the standard door height was 6 feet 8 inches (1 2/3 units), and the standard room height was 8 feet (2 units), or 9 feet 4 inches (2 1/3 units) with the clerestory. Second, for practical reasons, the 48-inch module fit the standard dimensions of common construction materials available in California at that time. Schindler used the unit system as early as 1920.[17] Since then, the unit was consistently employed with very few exceptions.

Schindler's system offered various advantages in rational planning and construction and was grounded in two principles. First, all locations and sizes of the parts with respect to the whole were precisely identified during the construction process. Thus, no obscure or arbitrarily unrelated measurements were involved in the unit system. Second, the unit system offered the means to visualize space forms in three dimensions. He emphasized that "[the] last, but most important [part of the unit system] for the 'space architect,' must be a unit which [the architect] can carry palpably in his mind in order to be able to deal with space forms easily but accurately in his imagination." This led him to search for a basic unit of length for the building, where the dimensions were integer multiples or subdivisions of the basic length. In his system, there needed to be coordination between the architects of the buildings and the manufacturers of the components.

As early as 1935 Schindler replaced the Garrett system with one that he designed himself that was more cost efficient and flexible, the Panel-Post construction system, which used wood posts and plywood, and was based on his standard 4-foot module.[18] The modules of the unit plan were clearly marked with numbers and letters on the drawing. (Figure 2.) While the vertical module was usually identified with an elevation grade on Schindler's drawings, no grade mark was presented in the Panel-Post construction system because the heights of wall panels were predetermined as a set of modules.

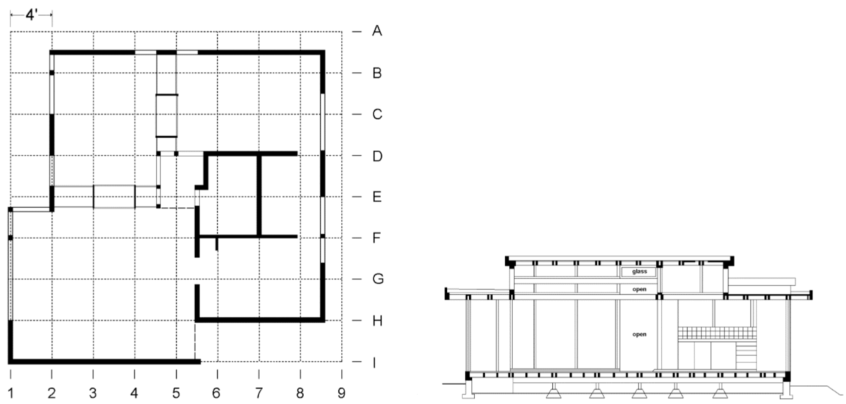
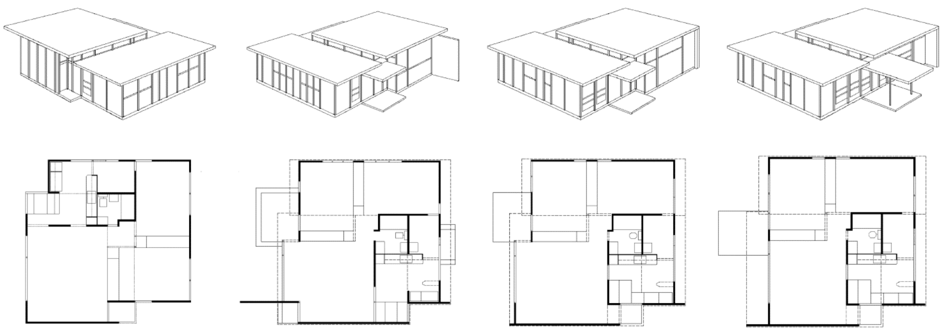


Figure 2. Basic *parti* of unit variations without a garage and cross section between the living room and the kitchen. Drawings are redrawn by the author.

Based on the unit *parti*, four variations of the standard two-bedroom unit were suggested by Schindler. The variations were based on slight modifications of room size with additional architectural elements. (Figure 3.) By rotating and mirroring the basic unit and adding a garage, Schindler could achieve a multitude of unit plans and their variations. (Figure 3a and b.) Additional elements include pergolas, a cantilevered entrance or deck, and a built-in flower box, which could also be attached to each unit as options to increase visual protection, varied exteriors, and privacy. Thus, the number of housing unit possibilities that could be developed was immense; Schindler provided only a few examples.



a b c d

Figure 3. Rudolph M. Schindler, Panel Post Construction, Four variations of a standard two-bedroom unit with their axonometric. Drawings are redrawn by the author.

Schindler provided four different housing prototypes using the Panel-Post construction system for different households. (Figure 4.) The variations derived from the basic unit plan, yet differed in sizes. These schemes were not fully developed, but they were sketched. Although the garage was attached to the kitchen in four schemes, it could also be attached or detached to any side of the unit.

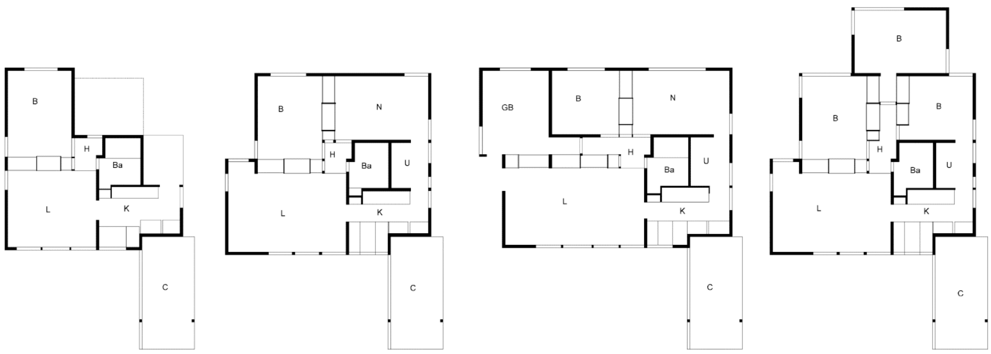


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Figure 4. The Schindler Shelter schemes with the Panel Post Construction, dated in 15 August 1942. a. One bedroom house, 480 sq/ft. b. Standard two bedroom house, 730 sq/ft. c. Three bedroom House, 890 sq/ft. d. Three bedroom house, 904 sq/ft. Drawings are redrawn by the author.

The stylistic appearance of the Panel Post Construction schemes resembled projects that Schindler experimented with earlier in Park Moderne (1929-1938) designed in Calabasas. (Figure 5.) Cabin #1 and a typical cabin (dated 1929 on the drawing) closely resembled the Schindler Shelter unit plan in their spatial configuration. Interestingly, one of Schindler's detail drawings demonstrated that the Panel Post Construction system was tested in one of the Park Moderne designs.[19]

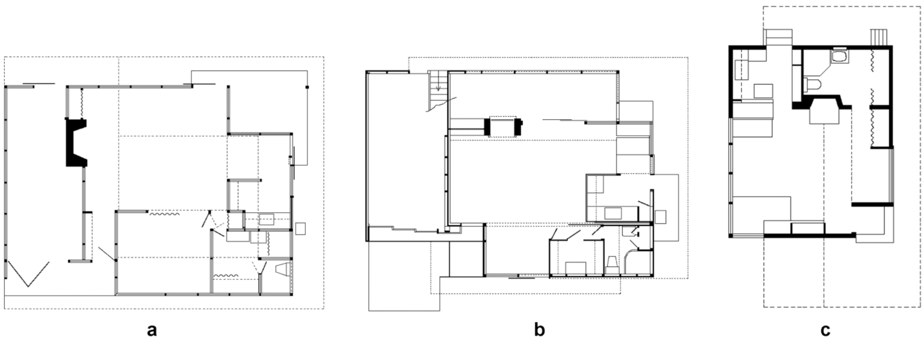

Figure 5. R. M. Schindler. Park Moderne (1929-1938), Calabasas: a. Cabin #1. b. Typical Cabin. c. Cabin #3

Panel-Post Construction System

Schindler was aware that differences in design stemmed from differences in basic approaches to construction systems in prefabricated houses. The concrete-based Garrett system proved too expensive and Schindler's alternative timber-based Panel-Post construction system reduced construction costs. Schindler believed: "[The] consequent increase of efficiency and the use of machinery reduces COSTS and furnishes a better product."[20] However, the Panel-Post construction system was not explained or published until 1943 in *California Arts and Architecture* under the title "Prefabrication Vocabulary."[21] In the article, Schindler detailed the construction features of the system, under 34 headings, illustrated with unit panel drawings, perspectives of the houses, and cross-sections.[22]

The Panel-Post construction system was a full-fledged prefabrication process for mass-production. All prefabrication of building components was made in an off-site factory, and later assembled on site. To increase mobility, an attempt was made to cut the weight and bulk of the components. According to Schindler, the prefabrication "permitted easy packing" and was light in weight. Heavy lifting equipment to handle the components was not necessary and the materials could be loaded into the space of a standard truck. All components and their details were greatly simplified. Assemblage of components on site was easy and simple, as was the altering or replacement of components. Thus, there was less need for a highly skilled work force or special heavy machinery.

Schindler classified the structural system by its major components: the floor panel, post, vent board, base, roof panel, floor panel, wall panel, sash panel, door panel, end-rafter, and fascia. In order to be efficient and practical, there were only nine components; Schindler favored a minimum number of pieces and a maximum size for each piece. (Figure 6.)

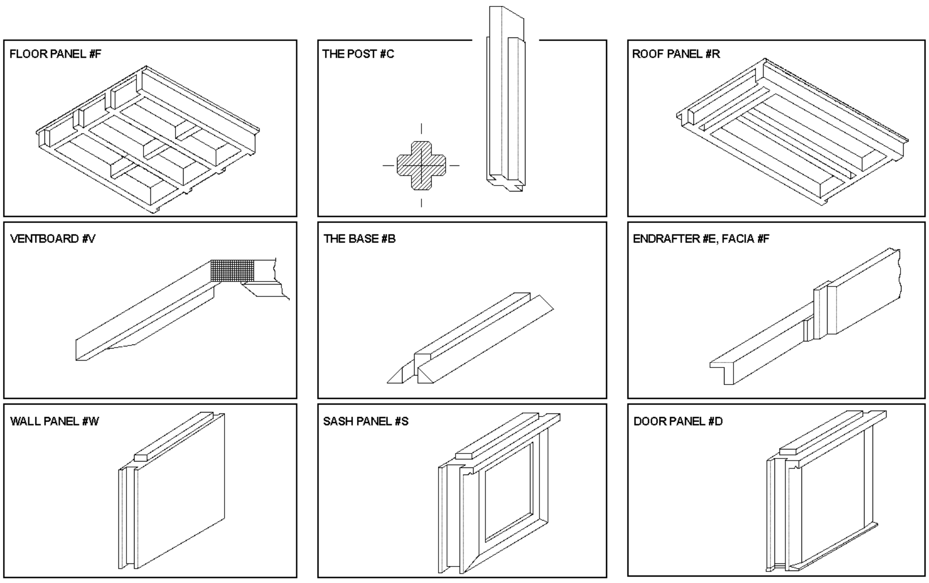

Figure 6. Unit components of the Panel-Post construction redrawn by the author (Garland no. 2582).

The posts carried vertical structural loads. They functioned as the structural skeleton that supported the roof and the wall, window and door panels. Joint details were extremely simple to produce and easy to erect in the field. (Figure 7.) The posts were shaped like crosses and erected at standard distances based on 4-foot module to allow the panels to be inserted into the grooves of the post. When set in place, the panels were interlocked with the four-way post. It was a true kit-of-parts solution to the affordable housing problem.

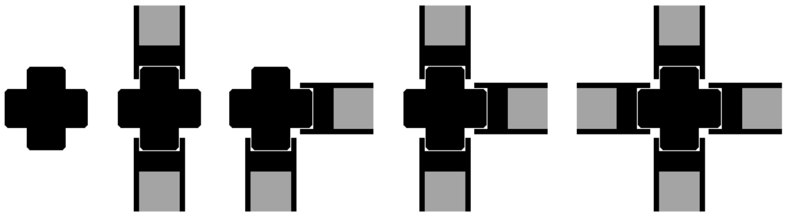

Figure 7. Panels and Post: Four ways of joining system

Partitions and panels could be made of cheap and easily altered materials, such as plywood, boards, etc. They formed a non-load bearing wall system. Wall panels were double sided, made with 1/2-inch stained plywood. Studs were set at 16" apart. Insulation materials were added between studs as in a typical sandwich panel.[23] Window and door sash panels, with headers and studs at each jamb, were designed as units to be inserted between vertical posts. Floor panels were finished with stain or covered with linoleum.

In many respects, the Panel-Post construction system seemed to foreshadow many other similar ones, including the General Panel System developed by Konrad Wachsmann and Walter Gropius in 1941.[24] In this system, the entire house was composed of interchangeable structural panels with a four way jointing system. The wedge-shaped joining elements were set in a pinwheel form.

In the Panel-Post construction system, dimensions of all components were related to Schindler's space reference frame. Since dimensional coordination between all the components is essential in prefabrication, the application of a modular design is fundamental. Although variable, basic dimensions of all components in the Panel-Post construction system were multiples and subdivisions of the 4-foot unit. For example, a variety of wall panels were 1', 2', 3' and 4' in width. The heights of wall panels were based on 16" increments, which were 1/3 of the unit module. (Figure 8.)

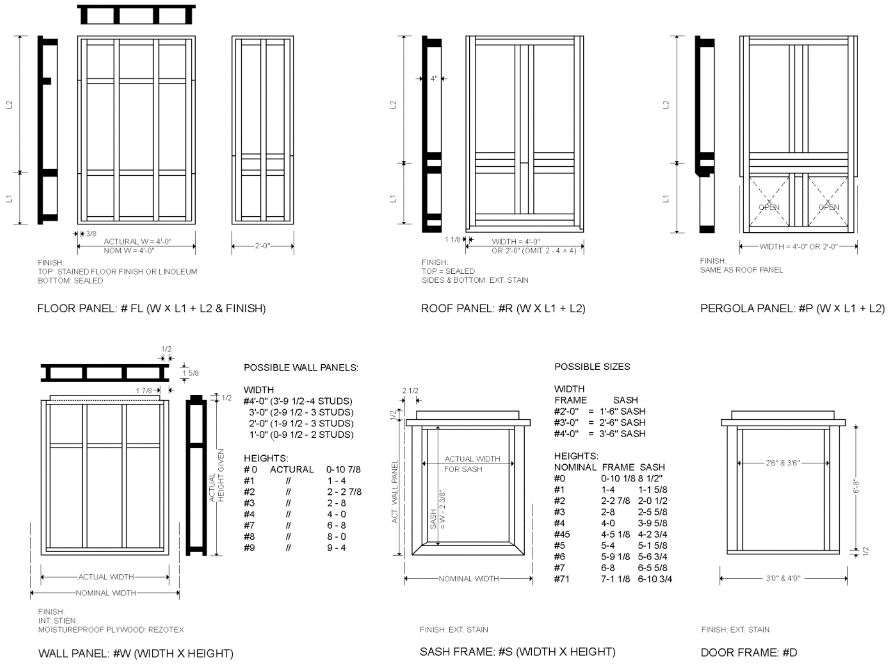

Figure 8. Details of the floor, roof, pergola and wall panels, sash and door frame redrawn by the author (Garland 2585).

Since these components would be positioned according to the 4-foot unit square grid, the actual size of building components ended up a little shorter than the four-foot unit module due to the thickness of the post. (Figure 9.) Because of this, Schindler used both the actual dimension and the nominal dimension to avoid dimensional confusion when the components were fabricated and assembled.[25]

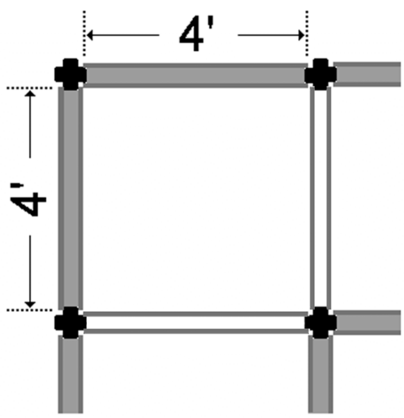

Figure 9. The way that components are positioned according to the 4-foot unit square grid

Most revealing in the Panel-Post construction system was the fact that all panel units were easy to detach, assemble, and exchange by caulking rather than nailing or stapling joints to make them weather tight. According to Schindler, the joints should be "inconspicuous but permanently accessible and renewable without marring the finish of the building."[26] His cross-section isometric presented an illustration of how the components came together. (Figure 10.) These components could be assembled with relative ease and little waste into various structures.[27] For Schindler, the panel-post unit could be used or reused for different buildings. He posited: "My system for prefabrication [uses] a skeleton of structural posts connected by exchangeable wall panels of various materials including glass. The system achieves permanent flexibility and allows changes in the ceiling heights of the various rooms, allowing better architectural articulation outside and inside."[28]

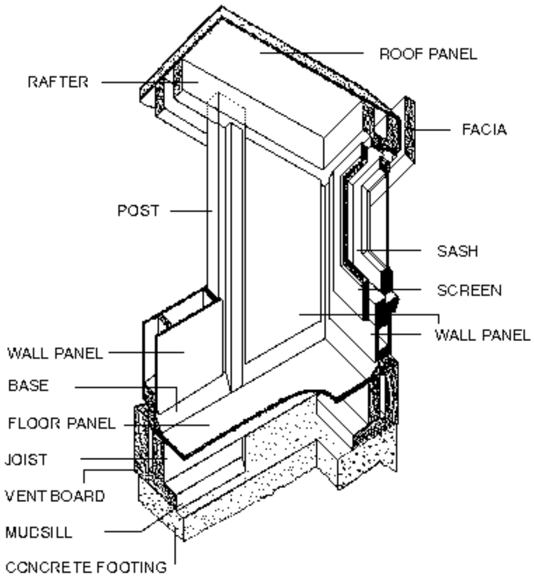

Figure 10. Cross-section of a typical panel and post connection redrawn by the author (Garland no. 2581)

Once the building was erected, infrastructure, including electrical, plumbing and heating systems, was installed. Mechanical systems and power connections were to be accessible from the exterior to accommodate easy "repairs, alterations, and modernizations." Plumbing and pipes of lightweight material could be laid out and pre-installed within the components. Thus, the efficiency of construction was increased and the amount of onsite labor was reduced accordingly.

Although “closets, cupboards and cabinets [were to] be prefabricated units” as built-in or freestanding furniture, they were not necessarily prefabricated units within the Panel Post Construction system. Instead, Schindler felt it would be better to leave homeowners free to choose their built-in closets and kitchen cabinets as add-ons, satisfying their family needs. This increased each homeowner’s freedom of choice. [29]

Schindler’s idea was an integrated system of construction with interchangeability at its heart. This construction strategy was designed to attract the government or builders of large tracts of houses. However, despite its construction and economic efficiency, prefabrication was not extensively used in the 1930 and 40s.[30] Perhaps, Schindler’s Panel-Post construction system was ahead of its time.[31]

To clarify Schindler’s construction system, this author has attempted to construct a partial model of the system at half scale, after a careful reading of various drawings, in particular, cross section and plan drawings obtained from the Schindler archive.[32] The system’s components were constructed with basswood, and then assembled piece by piece to demonstrate a construction sequence in which tectonic and demountable qualities could be observed.

The reconstruction not only reenacts the construction process of the system but also illustrates a complete design, indicating locations of panels and connection details. (Figure 11.) First of all, once the concrete foundation is poured and has dried, bentboards with mudsill plates are bolted to the foundation. After floor panels are lowered into place, bases, posts, wall panels, sash and door panels are positioned according to the design. On top, roof and pergola panels are set in place, and endrafters and fascias are anchored to the roof panels. Finally, roofing materials with insulation underneath, cover the plywood roof sheathing. All panels are glued to structural members. No nails are used to connect the components but all voids are sealed. This process echoes Schindler’s words: “No attempt shall be made to conceal the joints … All attempts of the ‘knock-down’ systems to simulate monolithic construction will end in failure. Articulated joints will facilitate alterations and repairs.” The procedural logic of the construction process is so clear that it speaks without ambiguity.

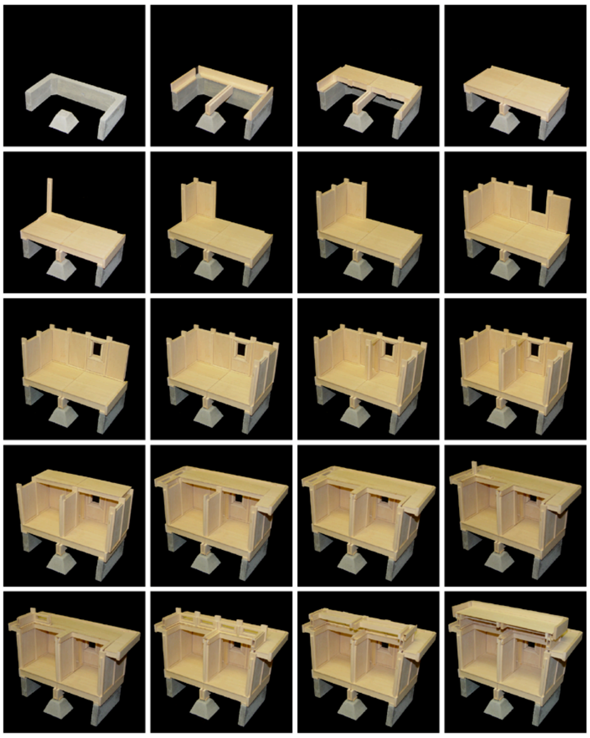

Figure 11. Panel Post Construction system: ½ inch scale model reconstruction of components with their step-by-step assembly (Model is constructed by Jacob Kwon).

Advances in computer technology make it possible to verify the whole construction process in which a standard unit is assembled with precise measurements, and to illustrate the spatial flexibility, diversity, and interchangeability of the housing design in a short time frame. Once an inventory of building components is fabricated in the computer, a multitude of unit variations can be easily constructed. (Figure 12.)

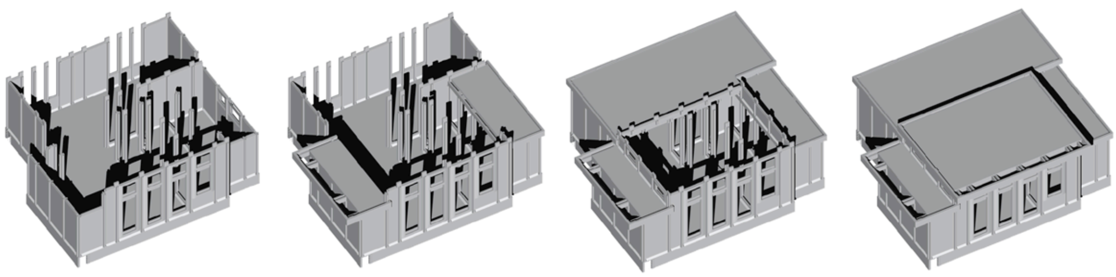

Figure 12. Computer generated unit model with the Panel Post Construction system

Conclusion

This study proposes that Schindler's Panel-Post construction system was, and could still be, an excellent solution to the contemporary low-cost housing problem in design and construction. One of the merits of the Panel-Post construction system is the systematic use of design strategies and the extraordinary variety of flexible space layouts. The kit-of-parts prefabrication is a solution to efficient and accurate construction and economy of costs. When Schindler's space reference frame, which is a proportional system, is incorporated with his principles of spatial organization, it can help to guide diverse spatial layouts of the components in housing design and planning. The interplay of Schindler's construction systems and design strategies demonstrates its potential for continued application in the development of a housing of quality and diversity.

This study can also play a significant pedagogical role in promoting an ongoing discourse concerning the development of housing options. These lessons could be applied as canonical solutions and pedagogical references to the wider understanding of the structure of complex housing problems as well as to the development of new housing typologies, which can then be adapted for contemporary housing developments.

Endnotes

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[1] See Albert Bemis and John Burchard, *The Evolving House: Vol. III. Rational Design* (Cambridge: The Technology Press, 1936) and Brian Finnimore, *Houses from the Factory: System Building and the Welfare State 1942-74* (London: Rivers Oran Press, 1989).

[2] See, for examples, James Tice, "Theme and Variations: A Typological Approach to Housing Design, Teaching, and Research," *JAE* 46/3 (1993): 162-175. Ezra D. Ehrenkrantz, *Architectural Systems: A Needs, Resources, and Design Approach* (New York: McGraw-Hill Publishing Company, 1989). Manuel Gausa, *Housing: New Alternatives, New System* (Basel, Boston, and Berlin: Birkhaüser Publishers, 1998).

[3] Avi Friedman, *The Grow Home* (Montreal & Kingston: McGill-Queen's University Press, 2001).

[4] Carol J. Burns, "A Manufactured Housing Studio: Home/On the Highway, *JAE* 55/1 (2001): 51-57.

[5] Sherry B. Ahrentzen, "Choice in Housing: Promoting Diversity," *Harvard Design Magazine*, (Summer, 1999): 62-67.

[6] The program was undertaken under the National Industrial Recovery Act of 1933 initiated by the Franklin D. Roosevelt Administration. The Subsistence Homesteads was undertaken to develop experimental housing projects to decentralize the heavy industrial population resulting from the severe and prolonged depression of the 1930s. In fact, Schindler sent his plans to the Subsistence Homesteads division of the Department of Interior for their review. On January 10, 1934, L. Brandt returned the following comment to Schindler: "We would however call to your attention the fact that your designs show rather small kitchens. We believe it very important that the kitchens in subsistence homesteads should be the largest room in the house, as this becomes the workshop for the entire family." Schindler disagreed in his January 18, 1934 letter: "I realize the smallness of the kitchen and intended to increase its size for subsistence farm purposes. However I do not agree with the usual plan which makes the kitchen the mainroom of the house. Only the quick meals should be consumed in the kitchen. The evening meal which is of social importance. Should not be taken in an atmosphere of greasy pots and dirty dishes. This is why I made the partition between kitchen and livingroom removable." Correspondence between Schindler and Brandt is in the Architecture and Design Collection (ADC), University of California, Santa Barbara (UCSB). See Jin-Ho Park, *The Architecture of Rudolph Michael Schindler: The formal analysis of unbuilt work* (Ph.D. diss., University of California, Los Angeles, 1999) and Judith Sheine, *R. M. Schindler* (New York: Phaidon, 2001), pp. 94-95.

[7] Schindler in his 'Space Architecture' commented on Fuller's Dymaxion house "entirely from the viewpoint of facile manufacture." Schindler opined that Fuller was "putting the cart before the horse." See Rudolph M. Schindler, "Space Architecture," *Dune Forum*, (February, 1934): 44-46, and *California Arts and Architecture*, 47 (January, 1935): 18-19.

[8] See Lucien Kroll, *The Architecture of Complexity*, Peter Blundell Jones, trans (London: B.T. Batsford Ltd, 1986). Ehrenkrantz, *Architectural Systems: A Needs, Resources, and Design Approach*. N John Habraken, *Supports: An Alternative to Mass Housing* (New York and Washington: Praeger Publishers, 1972), and N John Habraken, et al, *Variations: The Systematic Design of Supports* (Cambridge: The Laboratory of Architecture and Planning at MIT, 1981)

[9] Rudolph M. Schindler, "Prefabrication Vocabulary," *California Arts and Architecture* 60 (June, 1943): 32-33.

[10] Lionel March and Judith Sheine, eds., *R M Schindler: Composition and Construction* (London: Academy Editions, 1993).

[11] Rudolph M. Schindler, "The Schindler Frame," *Architectural Record*, 101 (May, 1947): 143-6.

[12] See Schindler, "Space Architecture," pp. 44-46 and pp. 18-19. Also, Rudolph M. Schindler, "Answer to questionnaire from the school of Architecture, University of Southern California," (1949) R.M. Schindler Papers, ADC, UCSB.

[13] Garland Architectural Archives, *The Architectural Drawings of R.M. Schindler: the Architectural Drawing Collection, University Art Museum, University of California, Santa Barbar*a, ed., by David Gebhard, (New York: Garland Publication, 1993): Drawing no. 3179.

[14] Schindler noted on the drawing (Garland no. 3153) in the upper case: "PLAN SHOWS SOME VARIATIONS OF LAYOUT & STREET FRONT DESIGN DUE TO CHANGE OF LOCATION OF GARAGE ONLY. FURTHER VARIATIONS POSSIBLE: 1) USE OF SEVERAL BASIC TYPES, 2) REVERSAL OF EXPOSURES (MIRROR PICTURE), 3) ADDITION OF PERGOLAS, ETC., 4) COMBINING OF HOUSES INTO GROUPS, 5) COLOR OF BLDG, 6) PLANTING." The spatial variations of the Schindler Shelters can be analyzed and described with regard to symmetry. Among variations, one of the units was a reflection and rotation of another unit with some adjustment of elements. The overarching advantage of these variations is that an enormous variety of units could be obtained with simple planar symmetry transformations including reflection, translation, rotation, and glide reflection. Furthermore, the symmetry strategy could be expanded for numerous possibilities of laying out shelters on a city block to maximize a variety of streetscapes. See Jin-Ho Park, "Symmetry and Subsymmetry as Characteristics of Form-Making: The Schindler Shelter Project of 1933-42," *Journal Architectural and Planning Research*, 21/1 (2004): 24-37.

[15] Using light metal forms, wire mesh, and cement plaster, two one-inch thick slabs are used to form double wall panels. These two panels were connected and braced by a steel truss-like system spaced 16 inches apart. Thus, it formed panels16 inches wide by 6 feet long weighing 12 pounds each. Although light and thin, these double walls were strong enough so that they work as structural supports. The detailed construction technique and process of the Garrett system were well explained by Lewis Goss in an article, "The Garrett plastered House – A Frameless, Reinforced Unit" in *Progressive Contractor*, in July 1933. Schindler was not the only architect who adopted the Garrett construction system. Raymond M. Kennedy used the system in his design, although it looks very

different from the Schindler Shelter. See *the Los Angeles Times Sunday Magazine* (May 7, 1933).

[16] Rudolph M. Schindler, "Reference Frames in Space," *Architect and Engineer* 165 (1946): 10, 40, 44-45. The first draft of the article was written and sent to Frederick Heath, Jr., who was the chairman of the subcommittee on Modular Products with a letter dated August 17, 1944. Schindler wrote, "Your [F. Heath, Jr.] KIND LETTER OF JULY 20[TH] SPURRED ME TO ORGANIZE MY IDEA OF THE UNIT PLAN AND I AM ENCLOSING THE RESULT." Schindler types in uppercase. Heath Jr. responded to Schindler's article as "the excellent presentation."

[17] Schindler's 1920 Free Public Library competition project attests to one of the first application of this system. See Jin-Ho Park, "Schindler, Symmetry and the Free Public Library, 1920." *Architectural Research Quarterly* 2/2 (1996): 72-83.

[18] The Panel-Post construction system was copyrighted in 1936 (Schindler applied for the copyright in 1935). In a letter to the Bureau of Patents in 1938 (June, 20), Schindler inquired about whether he could patent the system and referred to the copyright there, Class 1, No. 13836, April 1936, ADC, UCSB. In it, Schindler said that he developed the scheme in 1935.

[19] Garland 2537.

[20] Schindler, "Prefabrication Vocabulary," pp. 32-33.

[21] Ibid

[22] The 34 headings include: Building, Prefabrication, Purpose, Individualization, Production, Standardization, Transportation, Field Work, Simplicity, Speed of Erection, Regulations, Climatic Conditions, Soil Conditions, Building Plan, Modules, Flexibility, Salvage Value, Construction Joints, Weather-Proofing, Vermin-Proof, Mechanical Equipment, The Units, Materials, The Post, The Base, The Wall Unit, The Openings, Trim, The Roof, Built-Ins, Finish, Space Forms, Clerestory, Panel-Post Construction.

[23] Garland no. 2585.

[24] See Konrad Wachsmann, *The Turning Point of Building* (New York: Reinhold Publishing Corporation, 1961).

[25] Habraken gives a further discussion of the concept of the nominal dimension. N John Habraken, et al, 1981, pp.95-103.

[26] Schindler, "Prefabrication Vocabulary," pp. 32-33.

[27] Nevertheless, since the system has never been technically proven in practical use, the components and their assemblage must be subjected to a variety of physical and

structural tests and evaluations, including weather tightness, fire resistance, wind resistance, acoustical resistance, adequate racking strength, and heat transmission, when applied to actual housing construction.

[28] Schindler, "Answer to questionnaire from the school of Architecture, University of Southern California," (1949) R.M. Schindler Papers, ADC, UCSB.

[29] According to O'Brien (1999), "The extensive use of manufactured products in no way limits the space for making architecture." For O'Brien, architects should take the role of coordinators or consumers to select and accommodate manufactured products between manufacturers and clients in a given project. James P. O'Brien, "Consuming Sweets: The Work of Architecture in the Age of Selection Among Manufacturers' Manufactured Differences," *JAE* 5/1 (1999): 25-34.

[30] *The Architectural Forum* (December, 1934): 400-407.

[31] Schindler continued to apply the Panel-Post construction system in his consecutive residential projects. For example, the system was tested presumably on one of the Park Moderne projects in 1935-1938 (See Garland no. 2537) and the residence for J. Sollin in 1938 (See Garland no. 3272).

[32] Garland no. 2583 and 2584.

THE DRIVERS FOR ADAPTIBLE BUILDING IN THE 21ST CENTURY

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Summary

In the 20th century the philosophy of flexible and adaptable building was developed. New technologies like reinforced concrete enabled the separation of load bearing frame and infill. New services such as electricity and potable water supply required a certain degree of adaptability. Changing family sizes and increasing wealth made flexibility an issue. The old drivers such as family size development, wealth growth, new household appliances and communication technology may continue to justify flexibility. But these drivers may loose impact while future developments may be even stronger drivers. A study was done for possible new drivers. New technologies will again have a great impact on housing design. But in stead of a growing need for space, the new services may need less space than the old ones. Also new developments in family life will have an effect on the nature of required flexibility and adaptability. In particular a growing number of self employed people will ask for an other design and other options in respect of adaptability.

1. The old drivers

It is difficult to predict with some certainty the impact of future developments in technology and society on construction. An understanding of the drivers and their effects in the past may be helpful. Here under three main drivers for flexibility in design and construction in the 20th century are recapitulated.

1.1 New technologies

Le Corbusier was among the first architects to plea for a separation of load bearing structure and infill. He could propose such a separation because new technology made his concept possible. His famous sketch of the Domino House was typically benefiting of the opportunities of reinforced concrete. In his days a new technology – concrete - provided architects with a new structural concept giving them opportunities which would have been impossible without concrete. Traditionally limestone, brick, rock and wood were the typical materials available for construction.

1.2 New society

In the sixties and seventies of last century the Dutch architect John Habraken and his SAR research institute made the next step. For them not a new technology, but a changing society was the driver for a new architectural concept. They understood that the changing needs of families during their life-cycle were a reason to design houses with provisions for future adaptation to new circumstances. [Kendall, 2000]

1.2 New concerns

In the nineties CIB founded working commission 104. The subject of study is Open Building Implementation. In the same time the Dutch Government launched the IFD-programme for Flexible, Industrial and Demountable construction. Environmental care was identified as a new driver for flexibility. Buildings should be demountable to make re-use of building materials possible after use. Flexibility was considered to be a condition for feasible refurbishment. And refurbishment lengthens the life-cycle of a building and postpones the moment when demolishing a building is inevitable.

1.3 New appliances

Later in the 20th century the development and massive market penetration of new home appliances such as washing machines, dryers, dishwashers and microwaves became a driver for flexibility. The appliances caused a need for rearrangement of cabling, ducting and piping. A new driver for flexibility. Finally in the nineties new communication technology penetrated the houses. And again cabling had to be added to the standard equipment of houses. So three drivers forced designers and constructors to provide adaptable houses, changing family live, new appliances and new communication technology.

2. The new drivers

Houses are in most wealthy countries build for an estimated life-span of 100 years. In reality most houses are now a days outdated long before the end of that period. When we look back one century great differences are seen in society and in technology. Houses build in the early decades of the 20th were designed in a time when most houses were not connected to central energy supply systems. Waste water was not collected in central sewage systems. Ventilation was based on natural draft only. Communication systems such as telephone, radio, and television were not available. Families counted an average number of members somewhere between 5 to 10 children. Many couples had even much more children. Grandparents lived in many cases with their children and grandchildren under one roof.

It is very likely that in the 21st century again many paradigms of family life will change. That also the available technologies will change again goes without doubt. We even see that technology and culture are changing at a continuously increasing speed. For designers and for investors it is of mayor importance to foresee correctly what changes will occur and how these changes will determine the requirements of future generations.

2.1 New technologies

It is hard to predict what technologies will be available in 10 years time. A prediction for the life span of a house is virtually impossible. The best we can do is watch what is going on and look for trends. Actual trends that may be relevant for construction are wireless controls and miniaturizing of all equipment.

Figure 1, miniaturized air ducts.

2.1.1 Communication

We see a growing use of wireless communication. Mobile telephones are quickly gaining market share. Fixed telephone may be outdated soon. Most televisions are already wireless controlled. Computers are wireless connected with keyboard and mouse. It is likely that finally all appliances and lighting will be switched and steered with distant controls. When most communication will be wireless in future a great deal of all the copper lines in houses have no function any more. The only cabling left will be for power supply. Here another revolution is going on. Telephone sets, keyboards, radio's and alarms are powered with batteries. This makes these apparatuses independent from power outlets. More equipment may follow. After some time most electrical equipment will operate on rechargeable batteries. The need for socket outlets will be less than now and we may wonder if power supply lines are still a mayor driver for flexibility.

2.1.2 Power supply

Another tendency is related to the need to reduce power consumption based on oil and gas. Natural resources will one day be exhausted. This day may come before the end of this century. In that case power generation is likely to be based on privately owned generation systems like solar cells. Making connections to exterior power supply will be impossible then. What will be left is the connection between private power generators and equipment.

2.1.3 Waste water treatment

The disposal of waste water is in most cities organized by public authorities. Big sewage treatment plants are available to separate solid materials and biological remains from water. It will be much cheaper and is certainly environmentally much better when each household recycles its own waste water. Waste water may be recycled in the kitchen or bathroom. Technologically this is already possible. So it seems not far away before this happens. If that is the case connections to sewer lines are not needed any longer.

2.1.4 Air conditioning

What is left of the services infrastructure are the air ducts. Here miniaturizing may solve the problem of inflexible ducts. For submarines the technology for small diameter air exhaust has already been developed. Here limited space forced the designers to alternative solutions. In housing the same technology and next generation products may reduce air ducting to diameter less then an inch. But air recycling in stead of exhaust and replenishment may be an even more promising way to flexible systems. Ductless air conditioning based on an in house recycling system is not unlikely to become available at competitive prices. Air recycling hoods for kitchens are already for sale. Why should this technology after some further development not finally replace all air exhaust systems?

2.1.5 Effect on flexibility

We must wonder what the effect of these changes will be. Are cables and ducts still a factor in flexibility if systems change as supposed? Seen the above we may conclude that systems designed to accommodate re-arrangement of cabling and ducting will loose its function. Flexible floor system may not be required to meet the needs of future tenants. Also plinths systems with built-in cable lines could loose their market.

2.2 New society

Not only technologies will change. Also the life style of the tenant will be subject to change. And new style of living will be a driver for flexibility in the use of houses.

2.2.1 Employment

The relation between employers and employees is changing quickly. In the 19th and 20th century the number of self employed people decreased. The industrialization was a reason to concentrate work in big organizations. The economy of scale forced many small businesses to mergers. Clients forced small shopkeepers with a shop adjacent to there home to move to shopping centers. Environmentalists drove small workshops to industrial areas. The number of self employed working from their homes was reduced to almost nobody. But the tendency changed over the last decade. Big employers tend to reduce their labor force. The risk connected with well protected employees is to big for many of them. They redesign their business concept to flexible networks of small companies and independent consultants. In line with this development the number of self-employed people is growing. An good example for this development is found in our own sector. Architects and structural engineers were till recently happy with a staff of project leaders, draftsmen, secretaries, and site supervisors. Several now use call centers, distant secretaries, drafting services, and other temporary staff. They work in a network of service providers. Office cost are close to nothing, an irregular flow of assignments is not their problem any more, the cost of social security is for the account of the employees themselves. This tendency is expected to progress for some time in the near future. As a result the demand for houses, adaptable to accommodate an office room or a small workshop at home can be considered as a new driver for flexibility.

2.2.2 Postponed marriage.

Young people marry later than before. A hundred years ago marriage at 20 was normal. And youngsters move directly from the parents house to their own family house. So all houses were family houses. Now a days marriage at 30 is more common. Young people first move from their parents to a students house. After graduation they often move several times before they settle for a more permanent stay. More often young couples move to a shared home without the intention to start a family. And when they finally marry this alliance lasts on an average shorter that in the good old days. This new dynamic attitude to partnering has already generated a new market for flexible houses. In particular the growing number of singles is a relevant part of the market. The young generation is not interested in flexibility after occupation. They will move to another place or to another partner before the need for change of their house becomes manifest.

2.2.3 Postponed move to elderly homes.

Another factor will be the longer stay in their private houses of elderly people. This is caused by a new vision on care for an aging society. Keeping people as long as possible in their houses is the emerging policy. Remote observation techniques enable this policy. And economizing on public funding is also a driver. This policy goes together with a new need for flexibility. Houses should be adaptable to the requirements of the elder people and their nurses.

2.2.4 Increased career opportunities

A century ago people often had the same profession as their father and grandfather. They never changes to another job. 40 Years of employment with the same employer was more rule than exception. As a consequence the wealth of a family was stable. Nowadays people are more ambitious. They plan a career. It is now unusual to grow in income over the years. This goes together with a growing demand for luxury, also in housing. The actual situation is likely to continue. But not all will enjoy a growing wealth. Shorter duration of employment contract and self employment will cause more variation in income over the years. Consequently more often adaptation of the cost of living will be required. For an increased wealth there are solutions such as building additional rooms on top of, or adjacent to the house. For reduced wealth the only option now is moving to another house. A solution may be in the construction of load bearing frames for housing without any pre determined split into apartments. When space is rented per square meter, tenants may choose to rent an adjacent number of square meters or renounce of a part of the rented surface.

2.2.5 Reluctance to change

A study by the Inprest research project team found that people are reluctant to change their houses. Workman in the house and the hinder of dust and noise are a constraint to changing the interior. It was found that a substantial number of interviewed tenants preferred moving to another house above refurbishment. [Inprest 2005] This outcome could be the result of a changed attitude towards roots. The youngsters of to day are used to moving. They are not strongly connected to a certain city or geographic area. If this reluctance to moving becomes a trend, flexibility cannot be considered anymore as a concept to serve tenants. But it will still be the right concept for real estate owners to lengthen the life-cycle of their investment.

2.2.6 Effect on flexibility

Some of the changes in family life will have an effect on the demand and appreciation for flexibility. But not all changes are drivers. Also for family life styles it is hard to look far ahead in the future. One of the questions to answer is: will people continue to do a lot of work as DIY. are and possibly many other yet unpredictable factors - may create new drivers for flexible and adaptable houses and may require a whole renewed approach to Open Building. We should try to understand where our clients are going as early as possible.

3. New processes

Not only the demand side of the market will change. Also the supply site is in permanent transition. Though developments in the production process of houses are not going very quickly they certainly happen. The tendency over the past decades was a move from building on site to the assembly on site of pre fabricated elements. This so called off-site production is gaining market share and will certainly grow further over the forthcoming years. If houses are finally completely made in factories the options for flexibility will change. [ECTP 2004]

Figure 2, off-site produced demountable units.

3.1 Industrialization

It is possible that houses in future will be composed by stacking pre-fabricated units. Such units cannot be modified easily, but they can be replaced by others. A widely accepted standardization of units is a condition for flexibility on construction based on units. If standardization is successfully introduced there may be a future market for second hand housing unit. Also separate façade units could be available at a second hand market. In The Netherlands there was recently already a proposal for such a stock yard of used façade elements. [CIB WC 104, 2004]. Contractors offer already a take back service for semi permanent office units and temporary homes.

Figure 3, facades bought from a second hand stock.

3.2 Client focused process

The new age came together with a growing awareness on the supply-side of the construction industry of the need to meet clients expectations. Clients got much better informed then ever before through Internet. They have a perfect instrument at hand to compare prices and qualities. Meanwhile protection of industries is abolished on a world wide scale. This development to a more client focused approach will certainly continue for some time. To please clients a conversion of the industry to mass customization will be inevitable. Mass customization is almost identical to flexibility in the design and construction stage. We may wonder do clients also consider flexibility during occupancy an important feature.

3.2 Transportable homes

A new tendency that should be mentioned here also is transportation of homes to a new site. Mobile homes exist already for a long time. They are rather small when compared to fixed houses. Retired people in America and Australia tend to exchange their fixed dwelling for a mobile home. New is that some companies offer now to the transportation of small houses. In New Zealand a new service is provided. House Haulage removes houses. Even houses that were build without any provision for later removal are disconnected from their foundation. It appears that there is a growing market for this service. Of course a removal of a full house is only possible in a country where roads are not narrow. It is a solution for rural areas. In New Zealand even stock yards of second hand houses are found. And there are facilities for refurbishment of second hand houses. If this tendency develops further a new driver for flexibility is emerging.

Fig 4, transportable homes

4. Conclusions

The forthcoming century will undoubtedly bring new requirements for flexibility. These requirements will be driven by the new circumstances of live. New technologies and new societal needs will be the main drivers. But what this new drivers will be in hard to predict. When actual developments in comfort technologies continue the need for provisions to accommodate cabling and ducting may be reduced if it does not become fully super flues. When ongoing developments in society continue as is, there may be a limited need for flexibility by youngsters, as they prefer to move above adaptation of existing homes. The need for adaptability by elderly people may grow. And people may more than before look for houses adaptable to requirements originating from their professional occupation.

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Warming Up Exercises in Support of Open Building Teaching

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Abstract

Warming-up exercises are a good way to ease into studio teaching. They can be used in architecture studio courses. Can and should such warming up exercises become stand-alone teaching modules, taught outside the studio in classes dedicated to design exercises and design methods?

I'd like to offer come comments about why I think this is an important question for architectural educators and for W104.

Introduction

Warming up exercises in architectural designing are similar to solfege (ear training), counterpoint and practicing etudes in music school. When brought to bear in musical composition and performances, they pay off. But, by themselves, these exercises cannot produce excellent musicians, but might produce good technicians.

In sports, athletes train with specific exercises and "plays" to get ready for the game or the match. If the training is good, these exercises can "go to sleep" while the play is underway in earnest, operating from the background, so-to-speak. By themselves, they do not produce star athletes.

In architectural curricula, students routinely do exercises in structural design, in environmental controls, and in digital media. If the training is good, these exercises can inform the work in the design studio, empowering students to make better and more sophisticated, interesting schemes.

Thus, a good argument can be made that such exercises are an important prelude for any design studio project.

Warming-up Design Exercises

However, if structural exercises or digital media exercises exist and are not subject to debate, there is little in the way of a common understanding of what warming up exercises focused on designing might consist of.

In fact, most architectural educators will argue that you can't separate design exercises from the design studio project, with its site, its program of functions and so on. You can't teach design moves per se, the argument goes, because designing is highly personal and fundamentally unsystematic, specific to the situation, synthetic and too complex to be reduced to exercises like students do in structural design courses.

But such arguments only go to show that we don't have a very good idea of what designing – or design teaching - is about. If we did, we would not be afraid of "chunking" the whole of the design activity into meaningful and discrete exercises, understanding that the artistry of designing eventually depends on but goes beyond a grounding in design knowledge – exactly what the design exercises are intended to build.

So, even discussing design exercises is difficult. But the effort may be worthwhile and I would like to encourage those among us who teach design to undertake the development of warming up exercises along these lines, as a kind of experimentation in teaching.

If we would take this further, we might develop warming up design exercises on such topics as:

• ***the development and use of limited kits of parts following certain rules of deployment;***

• the use of bands and zones as aids to the arrangement of elements; or
• the establishment of a kit of parts and their rules of composition by one person (or team) and their use by another designer;
• the exploration of a building type;
• explorations of variations of windows in a given opening in a wall;

…and so on. I'm sure each of you could figure out some that would interest you and that would support your teaching priorities.

John Habraken – in a yet unpublished "thematic design tutorial" based on his Thematic Design course at MIT - has suggested that such exercises follow "rules of behavior":

1) PARTIAL ELABORATION.

It is possible to elaborate (to 'move with') only part of a given configuration leaving the other parts as they are. This makes us appreciate a given form as a configuration of parts the composition of which is flexible. Of course, we want to keep in mind the whole, but we can do partial explorations to find out about the potential of the configuration. Remember that each partial configuration that can be worked with while keeping other parts constant establishes a degree of freedom for us to exploit.

2) STEP BY STEP DEVELOPMENT.

Rich and elaborate configurations can come from small 'moves' one after the other. The idea that good results can come from an incremental development where we do not know yet where we will come out, is often frightening for those not used to it. We tend to believe we must somehow 'know' what the end result will be. But if we knew, we would already have done our design. We may have a general direction but must trust the process of elaboration and exploration. We enter into dialogue with the form and in a dialogue we may change our mind because we see new things we did not see before.

3) MAINTAIN RELATIONS.

Thematic transformations, as opposed to radical substitutions, tend to maintain relations between parts as they were established in the beginning. We may substitute a lintel with an arch, but both elements keep the same spatial relation to the column. We may place a base between the shaft and the floor but the shaft remains above the floor. Position relations tend to be the most constant feature of a thematic configuration. Indeed, they usually seem self-evident. Changing such relations, if at all meaningful, will establish a different theme: it is an abortion of what we were working with.

4) WORK FIRST WITH WHAT SEEMS LEAST IMPORTANT ARCHITECTURALLY.

In a column/beam configuration, the column is the most characteristic part; therefore we should not transform it first. Remember, a theme is set and you want to explore its variations. Fighting the given architectural definition will not do that. You want to *explore its potential. Once a column is chosen, it is more rewarding to ask ourselves what base and roof can do. Because the column is so powerful we respond to it to see what we can do for it. Thus: work to reinforce the most important choices you already made.*

5) LOOK FOR NEW OPPORTUNITIES.

By making the floor of the portico move independently from the wall at the periphery on which the columns rest, we gained more freedom to move. We discovered that the platform could be seen as more than one element. Usually new freedom to move is gained by a new interpretation of what we already have.

6) DO NOT INTRODUCE FOREIGN ELEMENTS.

It is good to introduce new elements to make the whole richer, but these should grow from what is done in a natural way. What is there will suggest what will come.
In the exercises (of this stack) we find that the introduction of 'non thematic' elements can be meaningful and important. But first we must explore the thematic potential of the given configuration. And even non-thematic elements usually have some kinship with those already in play. The best transformation is one where we say, 'of course, this is what the form wants to do....'

7) SUSPEND JUDGEMENT, EXPLORE.

Stay out of the way of the form. Do not impose yourself by trying to force a result. Learn to listen to what the theme has in store. The designer must, ultimately, decide what is good and what is not. But making such judgments too hastily or too early will make us lose interesting opportunities. Whatever you do will bear the mark of your personality. The directions you go into, the things you see in the form will all reveal you. To be in control of the design means to work with it following your intuition. Again, it is not necessary to know what the end result will be: you will discover it. Meanwhile you want to come to know the configuration you are working with.

Certainly, these rules of behavior are not the only possible rules by which warming-up design exercises might be developed. I'm sure you might each have additional or substitute rules. But I would also venture to say that the rules of behavior suggested above would, if followed by faculty in their own efforts to develop their own design exercises, produce a revolution in architectural education!

Open Building Design Exercises

But, if these are examples of general design exercises, and general rules of behavior, what does an open building way of designing suggest, in the way of appropriate warming-up design exercises and rules of behavior?

It should be clear that an open building way of designing shares many design moves and skills with architectural designing in general. In fact, when pressed, it is not easy to say what the difference is, if, like me, you think that open building is generally a good way to go for designing a sustainable, fine-grained built environment, prepared for incremental change.

That being said, an open building way of designing certainly must deal with more than the conventional factors taught in architecture schools. Open building design teaching must address at least these matters:

> *1. Capacity*
> *2. Distributed design, and*
> *3. Levels*

These three features of all open building design processes seem therefore to be at the heart of the design exercises that I am suggesting we especially need to develop, to support our open building teaching.

Over the years, I have experimented with how to teach an open building way of designing. Recently I have begun to use warming up exercises with modest success. Students generally seem to like them after a while and to recognize why we do them.

So far, these efforts have been trapped in the studio culture. I don't for-see a time during my career when this can change. Remarkably little scholarship in architectural pedagogy exists, in the first place, as precedent to build on in respect to questioning the studio as the sole locus of design teaching. Few have had the temerity to question the sacred cow of the studio or to experiment with teaching designing outside the studio.

In the second place, most architecture curricula are so tightly packed and so dominated by the studio time (12 hours in class per week in the typical US school), that there is no place for a series of developmental design exercise courses without radical surgery or the adept insinuation of teaching modules.

And third, because almost everyone on an architecture faculty is supposed to know how to teach a design studio, there would be hard-fought battles about who would teach these design exercise courses, quite a different story from the question of who is qualified to teach the structures course sequence with its exercises.

The point of these comments is this.

If we see a general demand for a more fine-grained environment in which change and distributed design are recognized as ever-present and inevitable, then architects need to be ready to deliver high quality professional services to match.

If we see forces at work in the way built environments come into existence and change that require new ways of coordination and a reawakened understanding of patterns, types and systems, then architects need to shed many obsolete concepts and get in touch with reality.

I am not confident that our schools of architecture are ready, at least those in the United States. I'm reasonably confident that the story is not much different elsewhere. This doesn't mean that individual teachers are not experimenting and questioning the status quo, often at their peril.

If you believe as I do that open building offers important tools and methods, then we have the responsibility to develop effective teaching methods to match. The idea of warming-up design exercises may be one part of the story. In fact, I am sure they are.

Conclusions

What is next for W104?

One choice is to close up shop, declaring that our objectives have been accomplished - that open building is being implemented.

Almost ten years after this commission started, many of the things we have advocated are happening. We see commercial application of open building and open building – like practices taking hold. In Finland, a developer wants to build open building projects on a regular basis, and is willing to pay for it. In the Netherlands, there is widespread evidence of adoption of open building practice if not in name then in fact. Het Oosten continues to lead the way, but there are other commercial developers making the commitment to open building. In Switzerland, the adoption of an open building approach to building procurement by the Canton Bern signals an important move, starting with the design of a major hospital. In Japan, Sekisui Heim is launching a commercial infill system, and a recent book shows 101 S/I projects constructed in Japan. Even in the US, there is increased interest in open building and disentanglement, even if there is as yet a large degree of ignorance of what is happening internationally. And in Russia, there are the Free Plan Apartments, in which residents hire their own architects to design their own flats, in empty buildings designed by prominent architects.

Instead of disbanding, we might shift focus to the problems of teaching open building. Or we might seek new links with other CIB Commission such as Building Economics, Architectural Management, and others, and encourage those experts to use open building projects as case studies for analysis. We might continue to focus on the conversion and upgrading of the old building stock.

Or we might shift our emphasis to the urban tissue, where the problems of politics, finance, and large scale planning are paramount – where "architecture without buildings" is the question. This emphasis might include the continuing traumas of developing countries where populations continue to migrate to the sprawling urban centers, but could also include the regeneration of existing cities in more developed societies.

Finally we might shift our attention away from housing to other use types such as the architecture of health care, a looming problem in all societies around the world, asking how open building can be put to the service of more agile and patient-centered care environments.

We meet in Eindhoven in July 2006. There we will celebrate the 10^{th} year of this commission. It is appropriate that at that celebration we know what we want to do next. To that end we need a good dialogue, perhaps mediated through the new W104 website.

Thank you