cSUR-UT Series: Library for Sustainable Urban Regeneration
Volume 1

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By the process of urban development in the 20th century, characterized by suburban expansion and urban redevelopment, many huge and sophisticated complexes of urban structures have been erected in developed countries. However, with conventional technologies focused on the construction of structures, it has become difficult to keep urban spaces adaptable to environmental constraints and economic, social and cultural changes. In other words, it has become difficult for conventional technologies to meet social demands for the upgrading of social capital in a sustainable manner and for the regeneration of attractive urban space that is not only safe and highly efficient but also conscious of historical, cultural and local identities to guarantee a high quality of life for all. Therefore, what is needed now is the creation of a new discipline that is able to reorganize the existing social capital and the technologies to implement it.

For this purpose, there is a need to go beyond the boundaries of conventional technologies of construction and structural design and to integrate the following technologies:

(1) Technology concerned with environmental and risk management
(2) Technology of conservation and regeneration with due consideration to the local characteristics of existing structures including historical and cultural resources
(3) Technologies of communication, consensus building, plan making and space management to coordinate and integrate the individual activities initiated by various actors of society

Up to now, architecture, civil engineering, and urban engineering in their respective fields have, while dealing with different time-space scales and structures, accumulated cutting-edge knowledge and contributed to the formation of favorable urban spaces. In the past, when emphasis was put on developing new residential areas and constructing new structures, development and advancement of such specialized disciplines were found to be the most effective.

However, current problems confronting urban development can be highlighted by the fact that a set of optimum solutions drawn from the best practices of each discipline is not necessarily the best solution. This is especially true where there are relationships of trade-offs among such issues as human risk and environmental load. In this way, the integration of the above three disciplines is strongly called for.

In order to create new integrated knowledge for sustainable urban regeneration, the Center for Sustainable Urban Regeneration (cSUR), The University of Tokyo, was established in 2003 as a core organization of one of the 21st Century Centers of Excellence Programs funded by the Ministry of Education and Science, Japan, and cSUR has coordinated international research alliances and collaboratively engages with common issues of sustainable urban regeneration.

The cSUR series are edited and published to present the achievements of our collaborative research and new integrated approaches toward sustainable urban regeneration.

K. Hanaki (Ed.)

Urban Environmental Management and Technology

Springer

Keisuke Hanaki, Ph.D.
Professor
Department of Urban Engineering,
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku,
Tokyo 113-8656, Japan

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Preface

The environmental aspect of cities is nowadays well recognized as a critical element of urban development, management and regeneration. There are various environmental issues related to cities, and they have been analyzed in an individualized manner. Many types of technologies, such as wastewater treatment, have been developed to solve particular environmental problems. However, many of these problems are related to each other, and social and economic aspects are also important for urban regeneration.

A holistic view combining knowledge of various urban environmental factors such as water, heat, energy, air, materials and waste, and a practical approach based on such understandings are essential to manage contemporary urban environmental issues, from a local scale to a global scale.

The University of Tokyo has been conducting the 21st Century COE (Centers of Excellence) Program on Sustainable Urban Regeneration. Transdisciplinary courses have been offered for graduate students from the departments of Urban Engineering, Civil Engineering and Architecture to present a holistic view of urban regeneration.

This book is based on the contents of the transdisciplinary course on environmental management and technology. I hope that its content will be useful for undergraduate and graduate students and for experts and policy makers in developed and developing countries.

Shinichiro Ohgaki
Project Leader, COE Program on Sustainable Urban Regeneration
The University of Tokyo

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Part I　Water Environment

1. Water Management in Sustainable Buildings

Motoyasu Kamata

Masayuki Mae

Department of Architecture, The University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN

1.1 Introduction

In Japan, since World War II, better water systems have been developed and the amount of water used has increased rapidly. Nationally, rainfall is relatively plentiful and the cost of water service is not expensive in many regions. So people are not very sensitive about water conservation in regards to buildings. In that context, the main interest of designing the water system in a building has been to assure comfort by determining the proper number of fixtures and the system capacity.

In some regions like northern Kyushu or Shikoku, however, rainfall is scarce and severe water shortages happen almost annually. In those areas, water saving technology is considered very important. Recently, water shortage has become a global issue, and water saving technology is considered very important.

In this chapter, a survey of water consumption in Japanese buildings will be presented. Then, water saving technologies will be introduced. Mainly there are two methods to reduce water consumption. The first is to develop a fixture and system which consumes less water. The second is to make efficient use of rain and grey (recycled) water. If a “sustainable building” is being designed, selecting the right piping material and system is also crucial, so some new methods for cold water supply and sewage will also be presented in this paper.

1.2 Water equipment in old Japanese houses

1.2.1 Toilets

Before WWII, the usual toilet in Japan was an outhouse, not a water closet. Excrement was stored in wooden or ceramic pots and used as fertilizer.

After WWII, as the water service and the sewerage spread, water closets became popular. At first, squat toilets (Fig.1.1) were the most popular partly because people hesitated to touch a seat others had sat on. But as time passed, sitting toilets (Fig. 1.2) became preferred. Lately, squat toilets are becoming the ones only adopted in the public buildings.

Fig.1.1. Traditional squat toilet

Fig.1.2. Sitting toilet

1.2.2 Baths

Before WWII, baths were installed only in luxurious houses. Most people used public baths. Private baths for ordinary houses were introduced in 1955, in "Jutaku Kodan" ("Public Corporation for Housing", now "Urban Renaissance") apartments. Baths were the first fixtures to use hot water in ordinary Japanese houses (Fig. 1.3).

If you wanted to use the bath in Fig. 1.3, you would have to fill the wooden bathtub with cold water first. Then you would light the gas-boiler to heat the water. The bath is extremely small, so it could fit in the very small space reserved for the bathroom. It is also very dangerous, however, because the built-in gas boiler inhales the indoor air for combustion and sometimes releases lethal CO gas into the bathroom. There is also no safety from over-heating. No shower is attached. By today's standards, this kind of boiler is extremely inconvenient and perilous.

At that time, however, these kinds of baths were welcomed with enthusiasm by middle-class families, and were considered the most important hot water appliance. In time, bathtubs became larger, and used newer materials like FRP (Fibre-Reinforced Plastic) (Fig. 1.4). Newer versions also have an attached shower.

Fig. 1.3 Bathtub from late 1955

Fig. 1.4 FRP Bathtub from 1970

1.2.3 Kitchens

In traditional houses, the kitchen was a place only for women and not considered an important space when compared with the rooms for the husband or guests. So the kitchen was placed in the northern part of the house, a rather dark and cold place (Fig. 1.5). Many houses did not have any water faucets, so women had to bring water buckets in by hand. After WWII, the liberation of women became very important, and modernizing the kitchen was the one of most interesting issues for architects. In "Jutaku Kodan" apartments, the kitchen was moved to the more comfortable, brighter southern part of the house and equipped with modern items like sanitary stainless steel sinks and electric rice cookers. To save space, the kitchen and dining room were merged into the "Dining Kitchen" (DK). By these improvements, the DK was expected to function as the centre of family members' daily life and became the symbol of modern housing.

Hot water appliances in the kitchen were introduced in the 1960s. A small kitchen gas boiler was developed and set up for washing dishes (Fig. 1.6). These boilers had the same problems the bath boilers had. Kitchen boilers consumed indoor air as they burned and emitted CO_2 and CO gases into the kitchen, which polluted the room environment. There was no control of hot water temperature, nor any safety measures to avoid imperfect combustion. Despite these faults, these gas boilers were welcomed by housewives and became a common sight.

Fig. 1.5 A kitchen in 1930

Fig. 1.6 A kitchen in 1960 with a gas boiler

1.3 Present Condition of Water Usage Japan

1.3.1 Cold Water Usage

As the water closet, bath and other appliances pervade, daily life has become fairly convenient for many people. But these improvements to the living standard also raised the volume of water usage in buildings.
The increase in the amount of "domestic water" is shown in Fig. 1.7. This value includes not only the amount used at home, but also the one con-

sumed in public places like commercial buildings, hospitals, restaurant or so. Recently, the amount of "domestic water" used per person per day is estimated at 320~330 litres.

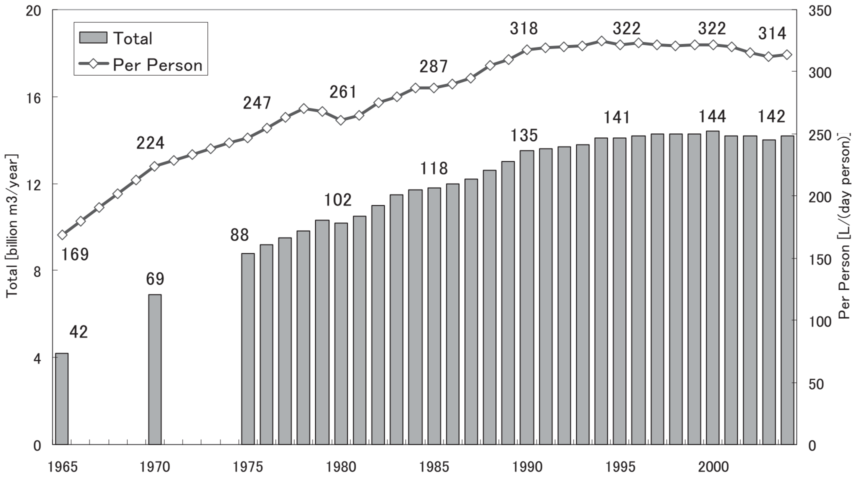

Fig. 1.7 Domestic water consumption (including housing and public buildings) [1]

Fig. 1.8 shows the water usage in public and residential buildings. Each amount is standardized by floor area (m^2) per day. It is obvious that the amount varies widely due to building type. The amounts in restaurants and cafés are prominent. The amount in terminal train stations is also huge, because many people gather and use the toilets. In houses or offices, the amount is relatively small.

Fig. 1.9 shows the breakdown of water usage according to type. In houses, the proportion of toilet, bath, laundry and kitchen are almost the same. In many building types, toilet water usage is the largest type. In department stores and restaurants, the kitchen consumes a considerable amount. In offices and hotels, the amount for air-conditioning is also high, which is mainly used in cooling towers for evaporation.

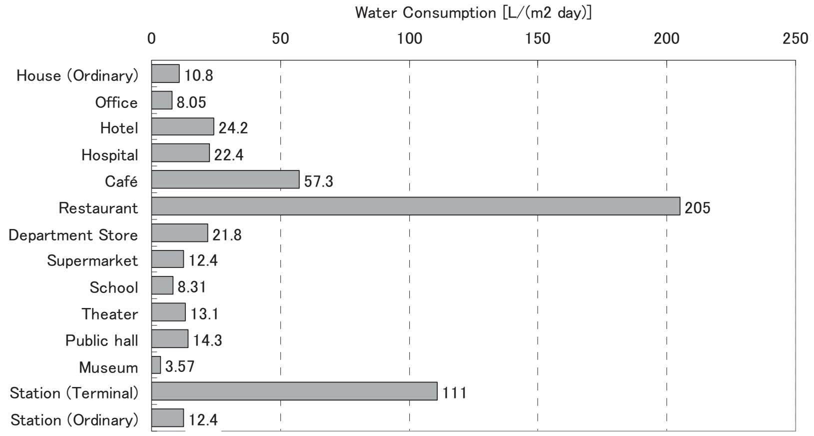

Fig. 1.8 Water consumption in public and residential buildings [2]

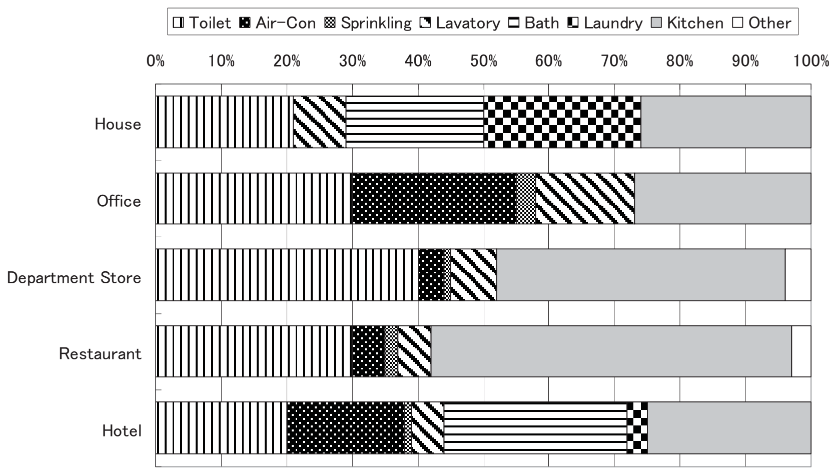

Fig. 1.9 Breakdown of water usage [3]

Fig. 1.10 shows the result of a recent survey by the committee in “Better Living” foundation regarding the amount of water used in one home per day, classified by house size. The total amount is 342.7 L/day in small 1K or 1DK homes, and 762.0 L/day in 3LDK homes. This shows that if the home is larger, the amount is larger. This is very understandable.

However, if you deal with the amount per person, a different trend appears. The amount of water used per person each day is also shown. More than 200L of water is used by each person daily, and this figure becomes larger in small houses often inhabited by just one person. In smaller houses, water in the bathtubs or laundry machines can be shared only by a small number of people. You can guess that that decreases utilization efficiency

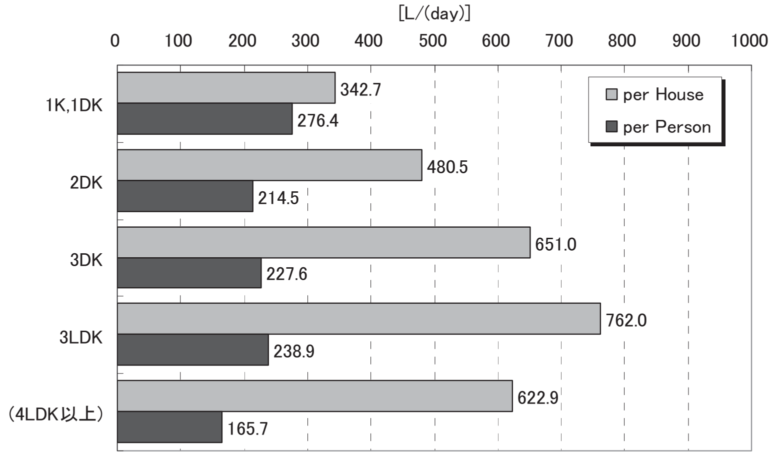

Fig. 1.10 Water consumption in residences (1～4: number of bedrooms, K: kitchen, DK: kitchen dining room, LDK: living-dining room with an attached kitchenette) [4]

1.3.2 Hot Water

As hot water equipment like bathtubs and kitchen boilers have gotten popular, hot water consumption has increased steadily. Hot water consumes not only water itself, but also a lot of energy like gas, electricity, or oil.

Fig. 1.11 shows the result of recent research on hot water consumption. Similar to cold water consumption, larger houses consume larger amounts. Houses with one person consume 186.8 L/day; houses with four people consume 444.9 L/day. However, if you measure the amount per person, 4-Person homes consume only 111.2 L/day, much smaller than 1-Person homes. This shows the same trend we already observed for cold water.

As you can guess, hot water consumption varies dramatically in different houses. Fig. 1.12 shows the volume and proportion of hot water consumption for each type of usage. The volume and breakdown of different types of water usage are widely different in each house.

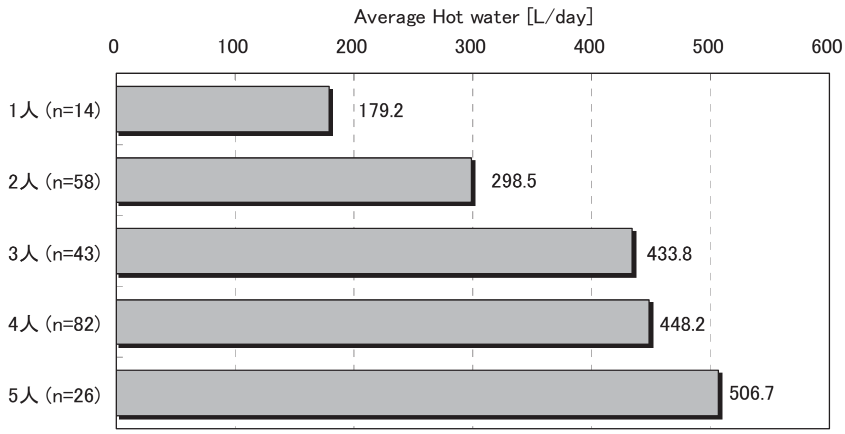

Fig. 1.11 Hot water consumption in residences [5]

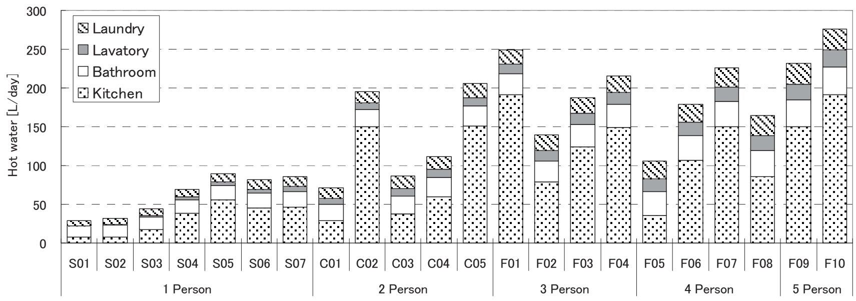

Fig. 1.12 Hot water consumption in houses (Annual Average) [6]

When the hot water supply system and equipment are designed, proper flow rate and temperature for each usage, like showers or kitchen faucets, are indispensable for safety and comfort.

For a long time, standard data was derived from American standards. But it was often criticized that Japanese preferences for hot water could be different from Americans'. So, a committee in The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (SHASE) carried out a test to determine the proper flow-rate and temperature for each usage. The result is shown in Table. 1.1. Now, these values are used widely to determine the capacity of boilers or diameter of pipes for buildings in Japan.

Table 1.1 Optimum temperature and flow rate for each type of water usage [7]

Usage		Optimum	
		Temperature [C^o]	Flow Rate [L/min]
Dish Washing	Ordinary faucet	39.0	7.8
	Shower type	39.0	5.0
Face washing		37.5	8.5
Laundry with hands		39.0	10.5
Shampoo		40.5	8.0
Taking a shower	hand-held	40.5	8.5
	attached to the wall	42.0	Fig 1.26

1.3.3 SHASE Standard

Until the 1970s, Japanese designers and engineers referred to the plumbing code of the USA for deciding the capacity of water system and sanitary condition in buildings. But as the difference of the actual state of Japanese buildings became obvious, SHASE (The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan) established its own code based on the surveyed data of Japanese buildings.

The original plumbing code of Japan was called “HASS 206.” This standard has been revised three times in 1982, 1991 and 2000. The name of HASS 206 was changed to “SHASE-S 206” in 2003. This manual is constantly referred to in designing the water system in buildings and became one of most important codes available for ensuring the sanitary condition of drinking water.

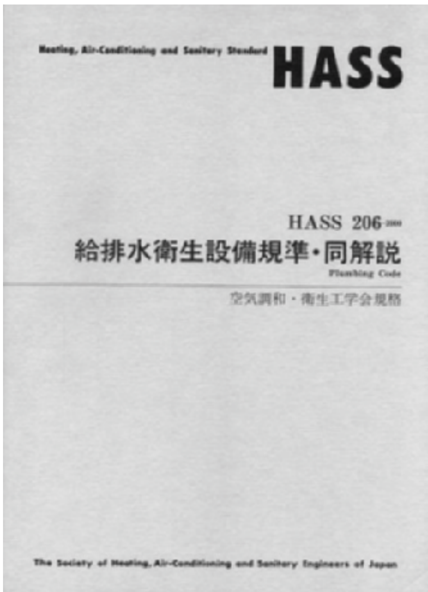

Fig. 1.13 HASS 206-2000

1.4 "CASBEE"(Comprehensive Assessment System for Building Environmental Efficiency)

The term "sustainable building" includes many aspects of architecture. Regarding water systems, it usually means efficient and environmentally-friendly systems which consume less energy.

In 1997, the Kyoto Protocol was announced to restrain the progress of global warming. According to that protocol, Japan has to decrease CO_2 emissions by 6 percent in 2010 compared to the rate of 1990. On the other hand, energy consumption in buildings has been increasing steadily and rapidly. To persuade building designers to consider saving energy, the "CASBEE" was developed [8]. CASBEE is the quantitative evaluation method to balance between building quality and environmental load. The former is called "Building Environmental Quality and Performance" (Q); the latter is called "Building Environmental Loadings" (L).

CASBEE can be used to evaluate the balance between "Q" and "L." If a building achieves a lower "Q" by emitting a higher "L," it is a low-performing "bad" building. If a building attains a higher "Q" through a lower "L," it is a high-performing "good" building. The balance of "Q" and "L" is called "BEE," and CASBEE's main objective is improving "BEE" to achieve good building performance by using less energy (Fig. 1.14).

The total scores are rated from "S," the best, to "A", "B" and "C," the worst. To achieve a higher score, designers are recommended to introduce "Reduction of Building Environmental Loadings" (LR) technologies.

Recently, the Japanese government has been very eager to reduce energy consumption in order to meet the goals of Kyoto Protocol. The Japanese Ministry of Land, Infrastructure and Transport strongly persuades developers to use CASBEE to measure energy performance and adopt more efficient and environmentally friendly systems and devices in buildings.

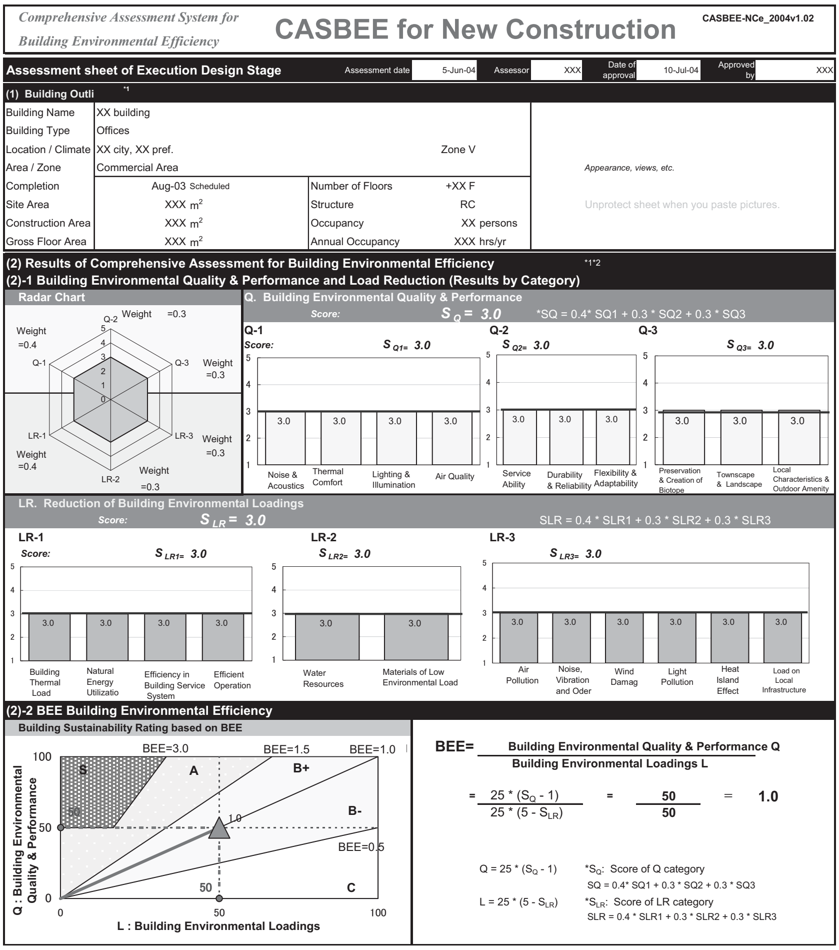

Fig. 1.14 CASBEE's total score

In the CASBEE system, water is an important factor. Fig. 1.15 shows the categories related to water systems in Q and LR. In Q-2, “Quality of Service,” items like service life, reliability and flexibility are listed. In LR-1, “Energy,” hot water efficiency is listed. In LR-2, “Resource & Materials,” water saving technologies are listed.

(4) Score — Execution Design Stage	Entire Building and Common Properties: Score	Entire Building and Common Properties: weighting coefficients	Residential and Accomodation sections: Score	Residential and Accomodation sections: weighting coefficients	Total
Concerned categories					
Q Building Environmental Quality & Performance					3.0
Q-2 Quality of Service		0.30			3.0
2 Durability & Reliability	3.0	0.31		-	3.0
2.2 Service Life of Components	3.0	0.33		-	
3 Necessary Renewal Interval for Plumbing & Wiring Material	3.0	0.29		-	
2.3 Reliability	3.0	0.19		-	
2 Water Supply & Drainage	3.0	0.20		-	
3 Flexibility & Adaptability	3.0	0.29		-	3.0
3.3 Adaptability of Facilities	3.0	0.38		-	
2 Ease of Water Supply & Drain Pipe Renewal	3.0	0.17		-	
LR Reduction of Building Environmental Loadings		-			3.0
LR- Energy		0.40			3.0
3 Efficiency in Building Service System	3.0	0.30		-	3.0
3.4 Hot Water Supply System	3.0	0.05		-	
LR- Resources & Materials		0.30			3.0
1 Water Resources	3.0	0.15		-	3.0
1.1 Water Saving	3.0	0.40		-	
1.2 Rainwater & Gray Water	3.0	0.60		-	
1 Rainwater Use Systems	3.0	0.67		-	
2 Gray Water Reuse System	3.0	0.33		-	

Fig. 1.15 Water related Q and LR items

The details of each category in “Q” and “LR” are shown in Fig. 1.16, Fig. 1.17 and Fig. 1.18. If higher-level implements are selected, a higher score in each category can be obtained. CASBEE sums up each category’s score and classifies the total score from “S” to “C.”

Many items are evaluated in CASBEE, even only regarding water systems. Items covered range from pipe materials to water saving equipment and water recycling technology.

2.2.3 Necessary Renewal Interval for Plumbing & Wiring Materials — Weight (default)= 0.29

Level 3	Entire building and common properties Offices Schools Retailers Restaurants Halls Hospitals Hotels Apartments Factories
Level 1	(Inapplicable)
Level 2	(Inapplicable)
■Level 3	15 years
Level 4	16 years or more, less than 30 years
Level 5	30 years or more

Fig. 1.16 Service Life of Components (Durability & Reliability in Q-2)

2.3 Reliability

2.3.2 Water Supply & Drainage Weight (default)=2.0

	Entire building and common properties	
	Offices Schools Halls Hospitals Hotels Apartments Factories	Retailers Restaurants
Level 1	None is applicable to the efforts to be evaluated.	None is applicable to the efforts to be evaluated.
Level 2	(Inapplicable)	(Inapplicable)
Level 3	Applicable to one of the efforts to be evaluated.	Applicable to one of the efforts to be evaluated.
Level 4	Applicable to two of the efforts to be evaluated.	(Inapplicable)
Level 5	Applicable to three or more of the efforts to be evaluated.	Applicable to two or more of the efforts to be evaluated

Efforts to improve the reliability of water supply & drainage

Building Type	Offices Schools Halls Hospitals Hotels Apartments Factories	Retailers Restaurants
Score	**Level 3**	**Level 3**
	1) Water-saving equipment is used. This is limited to cases where it is used on a majority of the installed equipment. Water-saving devices are those approved as Eco Mark products, or	
	2) Plumbing systems are separated as far as possible to reduce the portions that become unserviceable in the event of a disaster.	
	3) The building has a pit for temporary waste water storage, in case main sewerage is unavailable after a disaster.	
	4) The building has two separate tanks, one for water reception and one elevated tank.	
	5) Planning enables the use of well water, rainwater, gray water etc.	
	6) Provision of a rainwater storage tank to provide domestic noncommercial water in the event of a disaster. . (Not applied to "Retailers" and "Restaurants.")	
	7) The building is equipped with a simple filtration system allowing conversion of rainwater to potable water in the event of a disaster. (Not applied to "Retailers" and "Restaurants.")	

Fig. 1.17 Reliability (Durability & Reliability in Q-2)

1 Water Resources

1.1 Water Saving Weight(default)= 0.40

Level 3	Offices Schools Retailers Restaurants Halls Hospitals Hotels Apartments Factories
Level 1	No systems for saving water.
Level 2	(Inapplicable)
■Level 3	Major faucets are equipped with water-saving valve.
Level 4	In addition to water-saving valve, other water-saving equipment (such as flush-mimicking sound systems, water-saving toilets) is used.
Level 5	(Inapplicable)

1.2 Rainwater & Gray Water

1.2.1 Rainwater Use System Weight(default)= 0.67

Level 3	Offices Schools Retailers Restaurants Halls Hospitals Hotels Apartments Factories
Level 1	(Inapplicable)
Level 2	(Inapplicable)
Level 3	No systems for using rainwater.
Level 4	Rainwater is used.
Level 5	Rainwater usage brings the rainwater usage rate to at least 20%.

1.2.2 Gray Water Reuse System Weight(default)= 0.33

Level 3	Offices Schools Retailers Restaurants Halls Hospitals Hotels Apartments Factories
Level 1	(Inapplicable)
Level 2	(Inapplicable)
Level 3	No systems for reusing gray water.
Level 4	Gray water is reused.
Level 5	In addition to gray water reuse, there is equipment to reuse sewage.

Fig. 1.18 Water Resources (In LR-2)

1.5 Water saving technologies

The items adopted in CASBEE are considered very important components to realizing the goal of sustainable buildings. It is useful to know the details of the water saving technologies.

1.5.1 Toilets

Water saving closet and urinal

As already mentioned, toilets use a lot of water in all types of buildings, so the development of less water consuming toilets is the most important goal. But it is not very easy to implement because less water consumption means less cleansing and transportation ability. To achieve a good balance, the shape of the bowl and flushing methods are carefully designed (Fig. 1.19). By this effort, the water necessary to flush has decreased remarkably (Fig. 1.20). Adoption of these water saving toilets is very effective and strongly recommended. But the sewage system for the items, like pipe tilt, should be designed to assure good transportation performance.

Regarding urinals, the water flow pattern has been improved to ensure enough cleansing using less water (Fig. 1.21). If the cleansing is not thorough enough, clotting from urine can easily block the sewage pipes. So automatic flushing systems are designed carefully to flush minimal water periodically, even without usage.

Fig. 1.19 Water saving toilet

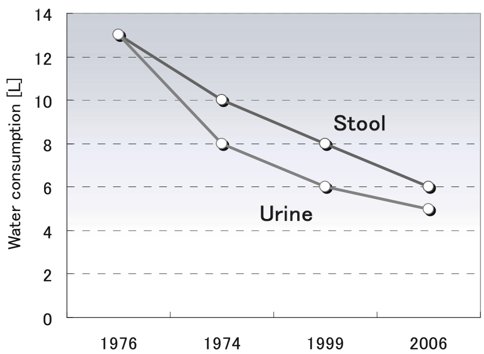

Fig. 1.20 Progression of water saving [9]

Sound mimicking device

In Japan, many women consume twice the volume of water than men when using the toilet. Because women want to conceal noise in the toilet, they flush the toilet soon after sitting. That means women flush the toilet at least twice. To avoid the waste, sound mimicking devices (Fig.1.22) have been introduced into women's stalls. This device makes a flushing sound, so there is no need to flush real water only to hide the noise.

Fig. 1.21 Water flow in urinal

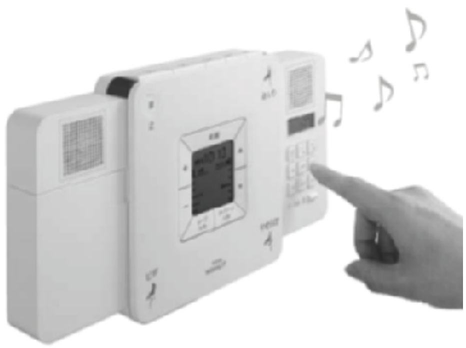

Fig. 1.22 Sound mimicking device

1.5.2 Residential Bathrooms

High-insulation bathtubs

As already mentioned, baths were the first hot water appliance in ordinary Japanese houses. Even these days, many Japanese prefer taking baths to showering.

To save energy consumption in the bathtub, improvements to heat insulation are effective. For Japanese, it is very common for family members to share the same hot water in the bathtub. But especially in winter, the hot water in the bathtub can get cold rapidly, so reheating is needed to keep a comfortable temperature.

High insulation bathtubs are designed to decrease the heat flow from inside by using double insulation on the bottom and side walls (Fig. 1.23). The top cover is also specially made to assure high performance. Compared with ordinary bathtubs, the temperature drop is decreased to less than one-third (Fig. 1.24).

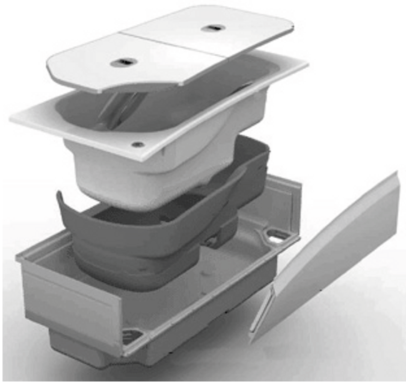

Fig. 1.23 High-insulation bathtub

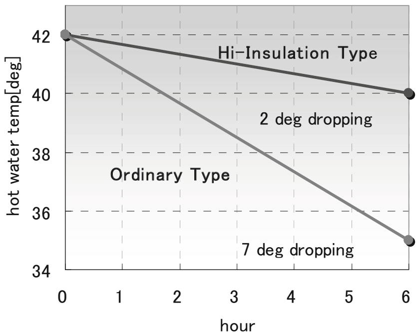

Fig. 1.24 Temperature drop [9]

Water-saving showerhead

Many people take a shower when bathing, and some young people prefer only showering now. To save hot water consumption in the shower, the development of a showerhead that satisfies users using a lower flow rate is important. Fig. 1.25 shows the relation between holes in the showerhead and optimum flow rate as the result of the examinees test. By adjusting the holes in the showerhead, optimum flow can be reduced without displeasure.

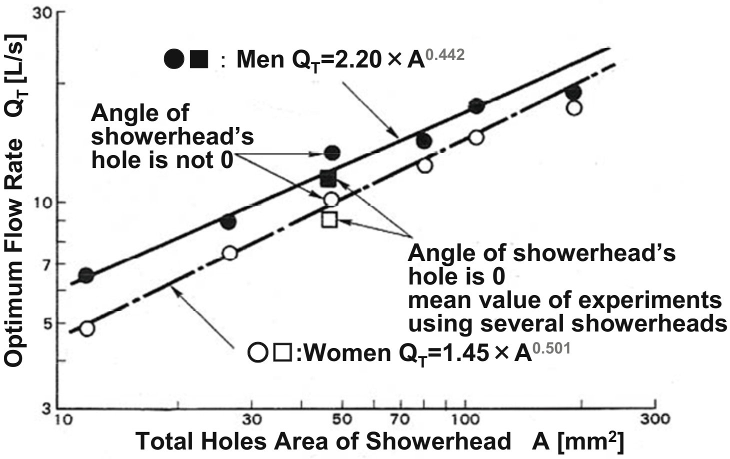

Fig. 1.25 Relation of total hole area and optimum flow rate of showerheads [10]

Some users are reluctant to pause the water during a shower even when they do not need it, because it is troublesome to turn the faucet's handle. Switch type showers (Fig. 1.26) were developed to eliminate that inconvenience. In some experiments, switch type showers reduced the water consumption by more than 20% in each season (Fig. 1.27).

Fig. 1.26 Switch type shower

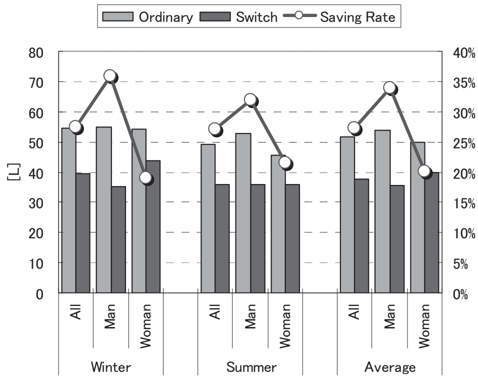

Fig. 1.27 Water saving effect [10]

1.5.3 Non-residential Lavatory

Automatic water saving faucet

Water saving in lavatories is important, especially for public buildings, which can be used by many guests. Automatic faucets are strongly recommended to avoid useless flowing. But in some cases, it is difficult to install because no electricity is available to power the automatic faucet. The faucet in Fig. 1.28 is a self power-generating faucet. Through water flow, power is generated and stored to operate itself (Fig. 1.29). This kind of faucet can be installed in any lavatory and is very effective in saving water.