STUDY ON OUTSIDE CONFIGURATIONS OF BUILDINGS AND ITS MATERIALS TOWARD DEVELOPING ENVIRONMENTAL DWELLING SPACES

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Abstract

Biodiversity was introduced as a major objective in worldwide conservation strategies at the conference in Rio de Janeiro in 1992, and 155 states signed the conservation on it. Biodiversity is quite important for humankind because ecosystem service consists in biodiversity. It was thought that only natural areas supported biodiversity before that, however, many papers have been nowadays revealing that urban areas also hugely contribute to it. Thus, activities for preserving and restoring urban biodiversity have took place all over the world as of today. Despite those activities, the circumstance of urban biodiversity has been decaying year on year. It can be safely said that the biggest cause is that almost all of urban areas are covered by impermeable surfaces such as concrete or asphalt, because creatures and plants cannot live on such areas. In addition, current urban areas are two or three degrees C hotter than suburban areas, and consume more electric power for running air-conditioners. It is called "Urban Heat Islands" related to global warming. These negative phenomena have put fragile species into extinction.

This present thesis aimed to (a) explore methods for restoring urban biodiversity and developing low-energy buildings by means of altering the outside of buildings without any dramatic changes of urban formations and (b) proposal to the future urban planning toward sustainable society encompassing those methods.

The Chapter 1 made the statement on the background and purpose for this thesis as described above in detail.

The Chapter 2 investigated on the cooling effect of green roofs which

have been newly installed in urban areas in Japan during the past decade. Almost all of the green roofs aim to improve indoor thermal environments in midsummer, and about half of them are extensive roofs (soil layer of between 25 and 100mm) with lawn grass or sedum. In the Middle East countries or the southern part of India, however, irrigated-soil covered roof without any plants is the mainstream in order to maximise the amount of evaporation on the rooftop. Due to this, the author hypothesised that extensive green roof was not able to hugely affect indoor thermal environment. As the result of comparative experiments by use of miniature green roofs, 500 × 500[mm], the hypothesis were verified. Next, contributions of am irrigated light soil of depth 50[mm], sunlight reflection and green wall by loofa (*Luffa cylindrica*) for cooling inside a building were assessed by means of six Green Cube, 2500×2500×2500[mm]. Inside temperatures and electricity consumption for running an air-conditioner in each of the six cubes were monitored. As a result, to cover roofs with irrigated soil may be the most beneficial way because of lower cost for installing and maintenance than any green roofs, with only slightly lower performance. Next, it was shown that green wall was in first place, followed by irrigated light soil and sunlight reflection, in order of effective approach for achieving a desirable indoor thermal environment, in terms of metrics for both inside temperature and electricity consumption for running the air-conditioner. Beside, in case of combining treated roof and walls, the effect of cooling potential was naturally higher. Thus, it can be seen that irrigated soil-covered roof plays a role to cooling inside temperature and reducing consumption of the air-conditioner. Although the environmental functions of green roofs are often highlighted (e.g., mitigation of rainwater runoff, reducing Urban Heat Islands and so on), the cost-effectiveness is not superior due to the fact that installation and maintenance costs are so expensive. There are a number of inexpensive alternative ways to achieve similar environmental aims. It should be noted that green roof gets to be essential only in the case of rehabilitating urban biodiversity under the condition that open space in urban area is usually small.

In the Chapter 3, the author outlines brown/biodiverse roofing in the UK, which is a relatively new type of extensive roofing for provision of mimic brownfields for brownfield wildlife, benefiting from techniques that offer diverse habitats under the severe conditions resulting from the thin substrate layer. To promote biodiversity, a variety of substrates are used, including a chalk and subsoil mixture, loamy topsoil, and gravel. In addition, crushed brick favours ruderal vegetation and can thus be used to replicate the brownfield biodiversity that was in place before development began. The brown/biodiverse roof aims to provide vegetal and animal species with habitats while somehow managing to grow vegetation without any irrigation system or fertilizer. It was reported that spiders, beetles, bees, wasps, ants and so on, which can be seen at brownfields, were found on Laban Dance Centre (brown/biodiverse) roof in London despite the fact they do not have a very long history. It should be noted that green roof industries in Japan consider the concept of brown/biodiverse roofs.

In the Chapter 4, as the result of the Chapter 2 that wall has more significant possibilities for cooling inside environment than rooftop, the author focuses on Shikkui, a Japanese traditional architectural material. Although it is known that inside dwellings with Shikkui walls are comparatively cooler than the others, modern dwellings have yet to utilise their characteristics due to poor academic analysis on the material. Thus, this Chapter aims to reveal the heat release characteristics of Shikkui and pave the way for utilising it as an energy-saving technology. As a result of calculating the amount of heat release characteristics from Shikkui with the use of the temperature difference between Shikkui and Siding experimental houses, it was 4.8×10^{4}J. It can be safely said that Shikkui contributes to energy saving in summer. In addition, it is thought that weather conditions (e.g., solar radiation, wind, temperature, humidity and so on), which are related to evaporation on Shikkui, directly affect the heat release characteristics from Shikkui.

The Chapter 5 plans a distribution of brown/biodiverse roofs in order to restore existing networks among green spaces at Shimoitozu area (54ha) in Kitakyushu City. As the result of the planning by means of Graph Theory and Gravity Modeling, it was found that installments of brown/biodiverse roofs (total 0.035ha) can improve a connectivity among green areas (total 1.4ha) within the site. On the other hand, the author calculated a Shikkui's potential for cooling, supposing that a part of dwelling walls within the site was replaced with Shikkui walls. As a result, 6.9×10^{10}J was obtained as a Shikkui's potential for cooling during daytime hours within the site.

The Chapter 7 describes the conclusion of this thesis and future issues in this research field.

Chapter 1

Overview

1.1 Background

Biological diversity (biodiversity) was introduced as a major objective in worldwide conservation strategies at the conference in Rio de Janeiro in 1992 (Zerbe et al. 2003), and 155 states signed the conservation on it (Lorimer 2006). Afterward, the need for concerted actions on the environmental question, as reflected in the issues of climate change and depletion of resources, has been officially recognised by the international community in events like the convention (Ferrante & Mihalakakou 2001). International efforts to preserve the natural environment are mainly concerned either with large, biodiverse and relatively untouched ecosystems or with individual animal or vegetal species, endangered of threatened with extinction (Chiesura 2004). According to UK Biodiversity Partnership (2007), in 1994, UK became the first country to produce a national biodiversity action plan, UK Biodiversity Action Plan. Central to this vision is recognition of the interconnections between living species (including people), their particular habitats, the services that they provide for us and their dependence on our guardianship. Besides important environmental services such as air and water purification, wind and noise filtering, or microclimate stabilisation, natural areas provide social and psychological services, which are of crucial significance for the livability of modern cities and the well being of urban dwellers (Chiesura 2004). All of the human activities are directly or indirectly linked with ecosystem services which nurture biodiversity.

In spite of having held global activities to restore biodiversity, the situations have been going into a decline year on year so far. It is thought that the biggest reason is the urbanisation which destroys, degrades and fragments native ecosystems and landscapes, replacing them with a heterogeneous matrix of urban development, parks, roads, and remnant forest fragments varying in size, isolation and quality (Collinge & Palmer 2002, Garden et al. 2010, Kong & Nakagoshi 2006, Lundholm 2006, Oberndorfer et al. 2007). In addition, it expends a huge amount of energy and materials required to sustain the built environment, cause climate change which has the potential to have significant impacts on the distribution of species and on the composition habitats (Berry et al. 2002). Due to this, urbanisation, which arises from the rapid expansion world's urban population, threatens many ecosystems, habitats and species (Kong et al. 2010).

Urban areas are among the most modified and complex of landscape, yet they still maintain a significant diversity of wildlife. Urban ecosystems can be of high value to a variety of other organisms or to several other aspects of biodiversity (population structure, genetic diversity) (Savard et al. 2000). Some species cope with, and survive in, urban areas better than others (Wood & Pullin 2002). Sattler et al. (2010) note, urban areas host many arthropod species and cannot be regarded as species-poor environments. Certain freshwater habitats located inside the great urban complex still create favorable conditions for populations of rare, highly specialised leech species. In particular, divergent littoral zone, the shallow water, seems to be the main factor determining high taxonomic diversity of leech assemblages (Koperski 2010). Urban biodiversity is supported by urban forest patches, parks, linear trees (riversides and roadsides), small green spaces (public and private gardens), other low intensity used spaces (cemeteries and unused plots) and water areas (Chiesura 2004). Although some urban areas should currently support high native species diversity, the long-term persistence of this diversity in urbanising regions is at risk as development continues to expand, degrade, and replace native ecosystems (Garden et al. 2010, Koperski 2010, Natural England 2007). In particular, green space is the most important area to sustain various ecosystem services in urban area. It obviously supports vegetation and "unsealed" surfaces, and can ameliorate the detrimental effects of urbanisation on species assemblages by preserving or creating habitat, and by maintaining corridors for movement through the urban matrix (González-García et al. 2009, Small et al. 2006). Moreover, green spaces in the long-settled parts of the developed world can provide "natural experiments" on the ability of protected areas to maintain biological diversity, revealing the historical processes of ecological change and species loss resulting from the influence of human activity (Drayton & Primack 1996).

As urban development increases, however, valuable green spaces for urban dwellers and wildlife are often reduced in area and fragmented into smaller and more isolated patches (Fernandez-Juricic 2000, Marzluff & Ewing 2001, Wood & Pullin 2002). It is likely that the absence of green spaces is characteristic of most contemporary cities globally (Georgi & Dimitriou 2010). In Germany alone, for example, an estimated 129 hectares of green spaces disappeared per day for building purposes (Grimski & Ferber 2001). Species richness abundance, genetic variation, gene flow within and between species populations of fragmented habitats are related to (a) patch area, (b) habitat connectivity and (c) patch continuity over time (Angold et al. 2006). If these areas become separated from one another by barriers such as large expanses of buildings and other human structures, species extinction may occur (Esbah et al. 2009), because the majority of the remnant urban wildlife is located in small fragments of indigenous vegetation that have been set aside during development (Rudd et al. 2002). Even in London, which has many parks and green spaces, including some with extensive tracts of semi-natural habitat, the wildlife distribution is uneven with deficiencies often seen in the poorest inner-city communities (Grant 2006). As a result, species distribution and dispersal are interrupted by discontinuities in urban greenways (Angold et al. 2006), and many faunae and florae in urban areas disappear. For example, migrating songbirds increasingly encounter landscapes where fragmentation has resulted in small habitat patches embedded in an urban matrix (Matthews & Rodewald 2010). Some factors, which are critical for butterflies, such as larval food plants and adult nectar sources, change greatly between sites with different levels of development (Blair & Launer 1997). Net movement of beetles across patch boundaries is strongly influenced by boundary contrast and may be affected by patch shape when boundary contrast is low (Collinge & Palmer 2002). Small et al. (2006) imply that rare and non-flying species may be affected by isolation, taking longer to reach sites. Aguilar et al. (2006) indicate that sexual reproduction of flowering plants is considerably negatively affected by habitat fragmentation, regardless of the different ecological and life-history traits and the different types of habitat, like mistletoe species. Nearly all its species rely on animals for pollination and seed dispersal, and most also provide food for animals, including several obligate mistletoe feeders

(Briggs 2003). Pollinator declines have affected plant populations, therefore, will have a clear agricultural impact (Science 2006). This is why the quality of urban environments, and particularly of urban green spaces, is increasingly seen as an important issue (Gaston et al. 2007).

Furthermore, the more urban biodiversity becomes monoculture, the more non-native species easy invade urban areas with climate change. According to Greller et al. (2006), it is possible that *Geum Vernum* is invading our area from the south, extending its natural range in eastern North America as a response to warming winters. In Forest Park Woodland, New York, an extremely low regenerative potential for all the oak and other traditional canopy trees amid highly abundant pioneers and a successfully colonising nonnative invasive tree, *Phellodendron amurense* (Glaeser 2006). New Zealand especially exhibits dramatic example of loss native ecosystems, today the number of naturalised nonnative plants is the same as the number of indigenous vascular plants (2500), and 20,000 exotic species are used in cultivation (Ignatieva 2010). Invasive nonnative species can have serious and damaging effects on other components of biodiversity and social and economic interests (UK Biodiversity Partnership 2007). Along with habitat loss, therefore, invasive species are considered a major cause of loss of biodiversity and species extinction (Simmons et al. 2007).

Naturally, we have to conserve biodiversity because; our survival depends on it (life-support services), our economy and lifestyles depend on it (product and regulation services), it inspires and enriches our lives (aesthetic/spiritual/cultural services) (UK Biodiversity Partnership 2007). To the extent that loss of plant biodiversity in the real world means a reduction in the ability of ecosystems to fix CO_2 (Naeem et al. 1994).

Sattler et al. (2010) indicate that species richness correlates with the resilience of an ecosystem and its ability to maintain its functions when faced with future, yet unknown impacts and threats, too. Moreover, as the proportion on urban residents increases every year worldwide, the nature of urban ecosystem would become increasingly important in shaping people's views about natutal ecosystems (Savard et al. 2000)

However, determining which of the above factors may be most important for species persistence is not an easy task, since they are, to some extent, interrelated. Similarly, defining "habitat", its quality, size, and isolation cannot be easily achieved for many species, either because their requirements are unknown or they are complex (Wood & Pullin 2002). Regionally native plants, additionally, might offer a more sustainable and alternative, but native substitutes for common landscaping plants are often rejected by the landscape design industry (Simmons et al. 2007). It is likely that attention to the natural components and the green spaces of the urban structure are still poor (Chiesura 2004). Lastly, there was broad agreement amongst respondents that urban areas were ecologically and constitutively different from rural one (Harrison & Davies 2002). That is to say, we have not been able to, in effect, restore and preserve urban biodiversity like the past achievement in rural and natural areas, so far.

1.2 Objective

As mentioned in the Background, urbanisation has been negatively affecting urban biodiversity (ecological service). Fig.1-1 and Fig.1-2 show the temporal changes in green areas at Tobata district in Kitakyushu city from 1922 to 2000. It is easy to find out about the fact that green areas has been replaced by urbanised one, and this phenomenon at Tobata district would similarly occur at other cities all over the world.

While urbanisation is the huge issue for urban biodiversity (ecological service), almost all of the people cannot live without urbanised areas. Fig.1-3 illustrates the interrelationship between urbanisation and urban environment for dwellers. With the advance of urbanisation, convenience for dwellers has improved and quality of ecosystem service has decreased. It should be noted that urban planners maximise the total amount of the quality of ecosystem services and convenience for dwellers. The state of maximising it is defined as “Sustainable City” in this present thesis. The contemporary situation of urban areas, at least in Japan, would be “Too Urbanised” rather than “Sustainable City”.

For example, there are already a lot of roads in all of the urban areas in Japan, in order to go to everywhere with car. Although some new highway construction projects might make current traffic networks slightly smarter, our lives would not be dramatically improved. On the other hand, the quality of ecosystem services, which has been already poor, could be significantly damaged by those projects. In this case, the total amount of the quality of ecosystem services and convenience for dwellers should decrease.

As you know, the simplest way to push the current too urbanised situation to sustainable city is to create much green area. However, it is difficult to implement it, as of today, because a lot of buildings have occupied urban areas. That means there is no open space. It would need more time to create much green area on the ground in urban areas. At the same time, the contemporary urban energy system (especially air-conditioning system) is not effective against zero emissions of carbon dioxide. Namely, climate change has been advancing day by day, which has negative impact on urban biodiversity (especially native animal and vegetal species). More recently, climate change has been linked to Urban Heat Island and its impact on building environmental design (Kolokotroni et al. 2007, Li et al. 2011). Consequently, it is quite important for our future to develop new technologies for stopping the current negative situation in urban biodiversity as soon as possible.

This present thesis aims to (a) explore methods for restoring urban biodiversity and developing low-energy buildings by means of altering the outside of buildings without any dramatic changes of urban formations and (b) proposal to the future urban planning toward sustainable society encompassing those methods.

Fig.1-1 Green Area at Tobata District in 1922

Fig.1-2 Green Area at Tobata district in 2000

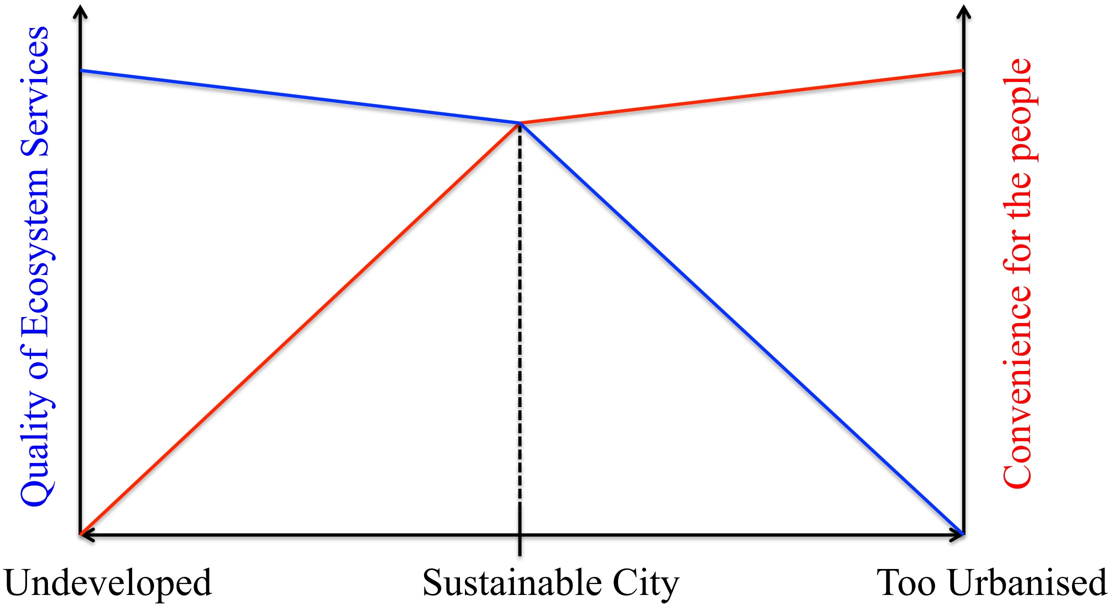


Fig.1-3 Interrelationship between Urbanisation and Urban Environment for Dwellers

Chapter 2

Green Roofs for Urban Areas: Effect of Irrigated-Soil Covered Roofs for Cooling

2.1 Introduction

Urban green spaces can be important elements contributing to urban sustainability (Esbah et al. 2009), because they can contribute to the reduction of various types of pollution, the improvement of microclimatic conditions, the absorption of storm-waters and the prevention of flooding, along with the urban biodiversity. In terms of the improvement of the microclimate in urban spaces, deciduous trees offer shade during summer, and the suitable selection of the right species can enhance cooling through evapotranspiration, reducing the temperature by up to 3.1 degrees C. Evapotranspiration creates pockets of lower temperature in an urban environment, known as the "phenomenon of oasis". Conversely, it permits the sun to shine through the branches during the winter (Georgi & Dimitriou 2010).

Nowadays, increased urbanisation has had and continues to have a negative impact on urban green spaces (Kong & Nakagoshi 2006), and affects the urban microclimate (Georgi & Dimitriou 2010) as represented by "Urban Heat Island". The phenomenon is caused when the heat from the sun is absorbed into buildings by the roof and then released back into the air resulting in urbanised city centres one or two degrees C hotter than suburbs and rural areas (Wilkinson & Reed 2009), consequently requiring further electricity consumption for running air-conditioners. A large proportion of this energy is used to maintain internal building temperatures through heating and cooling systems (Castleton et al. 2010). The spectrum of environmental impact produced by the use of energy resources in urban areas ranges from effects at a local level, such as the urban heat islands, to regional and global effects, such as the global climatic change (Ferrante & Mihalakakou 2001).

As urban development increases, however, valuable urban green spaces are often reduced in area and fragmented into smaller and more isolated patches (Fernandez-Juricic 2000, Marzluff & Ewing 2001, Wood & Pullin 2002). Thus, it is quite important to restore urban green spaces with several benefits, but there are rarely enough open spaces due to urban densification. This is why rooftops of buildings, which had not been regarded as space for planting of vegetation before, have been utilised as a type of open space, and then green roof has become one of the rapidly developing urban ecological engineering fields.

Green roofs are mainly divided into two types: intensive and extensive (MacIvor & Lundholm 2011, Molineux et al. 2009, Nagase & Dunnett 2010, Schrader & Böning 2006, Wilkinson & Reed 2009).

Intensive green roofs are characterised by a thick layer of growing medium or substrate (more than 200mm), in which a wide range of plants and vegetation can be grown, particularly if irrigation is available. However, the relatively heavy weight of the substrate requires additional structural support on the building and therefore only a limited range of buildings can be used for installing an intensive green roof.

On the other hand, extensive green roofs are generally substrate-based with a vegetated layer or a sedum mat, either on its own with a sponge membrane for moisture retention or with a substrate base; offering between 25 and 100 mm deep root zones due to restrictions by weight loading on a building’s structure. However, because of the thin substrate layer, the extensive roof environment is a harsh one for plant growth; limited water availability, wide temperature fluctuations, high exposure to wind and solar radiation create a highly stressed. As a result, a relatively small range of plant species is normally used for extensive green roofs. Sedum species and other species of the sedo-scleranthetea plant community are common and very suitable plants for using on an extensive green roof (Castleton et al. 2010, Oberndorfer et al. 2007). While ensuring some degree of success under stressful growing conditions, the widespread use of green roofs with them also has disadvantage that are typical of any ecological system with limited species diversity.

According to Japanese Ministry of Land, Infrastructure, Transport and Tourism, the total green roof area in Japan has been increasing steadily during the past decade (Fig.2-1). Almost all of these green roofs aim to improve thermal environment of midsummer (Iijima 2008), and about half of these roofs are extensive roofs with lawn grass or sedum (Japanese Ministry of Land, Infrastructure and Tourism 2009). However, regarding Sedum it can be killed by Japanese hot and humid summer, and disturb Japanese biodiversity because it is not a Japanese native plant. As well, it has been reported that evapotranspiration velocity from soil area without any plants is similar to one from lawn grass or sedum areas, therefore in terms of mitigating urban heat islands irrigated-soil may be key, regardless of plants (Ferrante & Mihalakakou 2001, Ohno et al. 2006).

Furthermore, regarding not only sedum but also all plants, the process of evapotranspiration takes place in the plants' leaves rather than in the soil, drawing energy from the environment and not directly from the soil-covered building. In contrast, the watered-soil layer on a roof can indeed be used as an effective means of evaporative cooling and has the particular benefit of producing this cooling during the hottest hours of the day (Al-Turki et al. 1995, Pearlmutter & Rosenfeld 2008). Furthermore, plants in green roofs prevent watered-soil from evaporating for cooling. In terms of cooling purposes, the role of plants on roofs is for shading (Ferrante & Mihalakakou 2001, Palomo & Barrio 1998). Therefore, it has been suggested that cover-materials other than plants could provide the wetted soil surface with substantial shading, without limiting the potential for cooling by evaporation, that is to say, the possible ways of reducing this energetic liability is to "eliminate" the exposed roof by shading the roof area with some structures like tight weave mesh or in some way sheltering it with a substantially thick layer of soil (Pearlmutter & Rosenfeld 2008). The reductions in energy usage and external surface temperatures of roofs can also lead to a reduction in the urban heat islands of the city centres (Wilkinson & Reed 2009).

Although several tests for substantiating the effect of evaporative roof for cooling has been implemented so far (Al-Turki et al. 1995, Pearlmutter & Rosenfeld 2008), comparative experiment of alternative strategies for converting the theory into residential environment of human scale has never progressed. This chapter aims to monitor how indoor thermal environment is affected by irrigated-soil covered roof by means of experimental houses, and via an outside configuration of building in the Japanese urban area to explore the achievement of thermal comfort by encompassing natural methods and engineering technology.

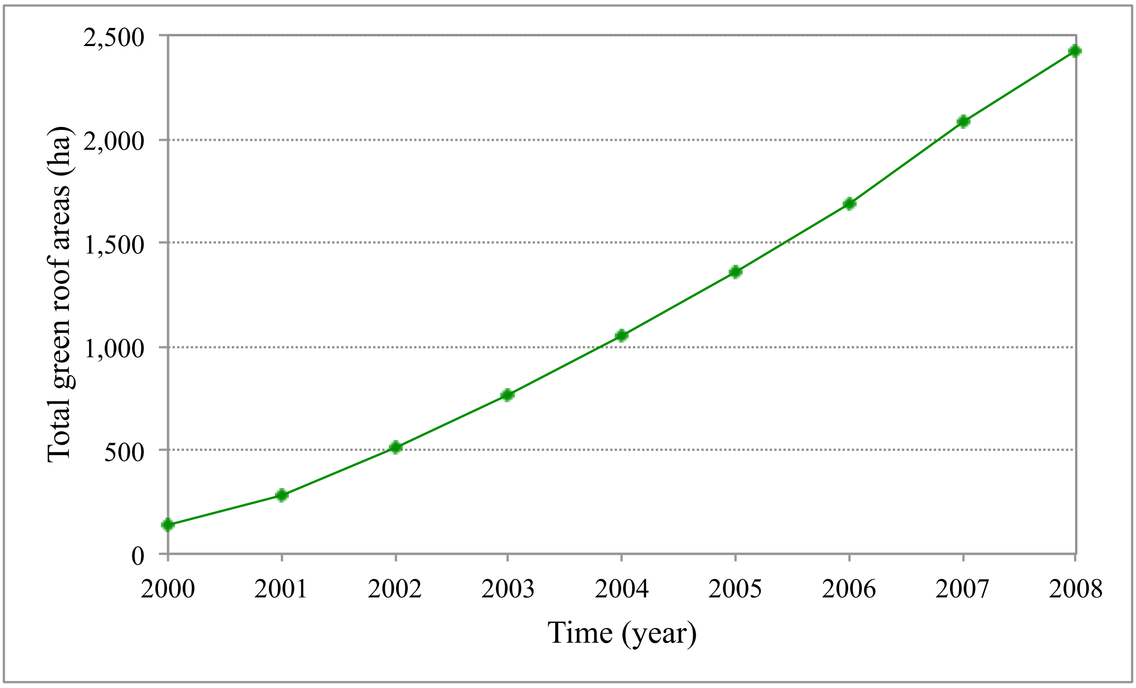


Fig.2-1 Process of Total Green Roof Areas in Japan (Japanese Ministry of Land, Infrastructure and Tourism 2009)

2.2 Methods

2.2.1 Preparatory Experiment

The preparatory experiment aimed to monitor the effect that plants on roofs have on cooling inside buildings and research possibilities for Japanese native plants for green roofs, which has taken place at the rooftop of civil engineering building at Tobata Campus of Kyushu Institute of Technology, from 24th August 2007 to 2nd September 2007.

2.2.1.1 Plants for Covering Roof

We selected Plantain (*Plantago asiatica* L.) as a Japanese native plant for green roofs, because the plant can endure severe condition on roof to be alive at cracks between asphalts or concretes, and efficiently cover soil with leaves due to perennial and rosette plant. In order to compare it with representative plants of existing Japanese extensive green roofs, Lawn (*Zoysia tenuifolia* Willd.) and Sedum (*Sedum mexicaum* Britt.) were adopted.

2.2.1.2 Experimental Setup

Four cells were composed of the following components (sorted by lowest to highest): a Styrofoam box, 150*250*150 (mm); a drainage layer (FD DRAIN LN; produced by TAJIMA ROOFING LTD.), 500*500 (mm); a root barrier membrane (FD FILTER; produced by TAJIMA ROOFING LTD.), 500*500 (mm); and light soil (FD SOIL; produced by TAJIMA ROOFING LTD.), 50 (mm). In addition 5th cell was exposed without a set of miniature green roof. Temperature sensors (ECH2O PROBE; produced by DECAGON DEVICES, INC.) were set in each Styrofoam box, a meteorological sensor (VANTAGE PRO2; produced by DAVIS INSTRUMENT) was set close to the cells. Except the 5th cell, the others were given 700ml irrigation to soil twice a day, 5:30 and 17:30. Table 2-1 shows the conditions of miniature green roofs.

2.2.2 Main Experiment

The main experiment aimed to monitor how indoor thermal environment is affected by watered soil-covered roof by means of experimental houses, which has taken place at the Eco-energy Trial Unit "Green Cube" at Tobata Campus of Kyushu Institute of Technology, from 11th August 2009 to 5th September 2009 (Fig.2-2).

2.2.2.1 Green Cube Project

The experimental facility (Green Cube Project) was constructed to conduct diverse experiments on next generation energy system with natural energy in 2009 at Tobata Campus of Kyushu Institute of Technology. The Kyushu Institute of Technology Environmental Management Centre has been widely running the Green Cube Project so that any researchers from all faculties on campus and private companies can take part in the project with their original technologies.

Fig.2-3 shows the front and side elevational views of an experimental house. Metal frames were set up on a concrete slab, and then glass panels were set in walls and a roof. The connections between frame and glass edges were sealed with a caulking material. In addition, a glass door was fixed up on the east sidewall so that researchers can get in and out the house for experimental preparation and so on. For constructional reasons, the east sidewall other than the glass door is made of the same material as metal frames.

2.2.2.2 Plant for Covering Wall

We selected Loofah (*Luffa cylindrica* (L.) Roem.), because the plant can grow up easily and blind the walls with large leaves. Each seedling was planted in each flowerpot, afterward, set along each wall which has a support net for helping Loofha to climb the wall.

2.2.2.3 Experimental Setup

The effect of irrigated soil covered-roof for cooling inside temperature was monitored by means of combining irrigated soil covered-roof, sunlight reflection coating-roof and green wall. The irrigated soil covered roofs were composed of a drainage layer (FD DRAIN LN; produced by TAJIMA ROOFING LTD.), 2500*2500 (mm); a root barrier membrane (FD FILTER; produced by TAJIMA ROOFING LTD.), 2500*2500 (mm); and light soil (VIVASOIL; produced by TOHO-REO CO., LTD.), 50 (mm). The sunlight reflection coating-roofs were painted sunlight reflection coating (HAISTA-SHATARO; produced by HITACHI CHEMICAL INDUSTRIAL MATERIALS CO., LTD.) on the steel plates. A meteorological sensor (VANTAGE PRO2; produced by DAVIS INSTRUMENT) was set on the field of these experimental equipments. The irrigated soil covered-roofs were irrigated with 10000 ml once a day, 10:00. The flowerpots planted seedlings of Loofah were given 750 ml irrigation to the soil twice a day, 10:00 and 16:00. Table 2-2 shows the conditions of experimental houses.

2.2.2.4 Electricity Consumption

Power consumption data (Standard RS-485) measured by the electricity consumption meter was sent to IP network converter via a wireless terminal and onto the campus LAN. We monitored electricity consumption of each cube operating each air conditioner with 27 degrees C setting from 10:00 to 18:00 for sunny days only during the experiment.

Table 2-1 Conditions of Miniature Green Roofs

	Roof condition
A1	Irrigated soil 50mm and Plantain
A2	Irrigated soil 50mm and Sedum
A3	Irrigated soil 50mm and Lawn
A4	Irrigated soil 50mm
A5	Bare

Fig.2-2 Green Cube Project at Tobata Campus of Kyushu Institute of Technology

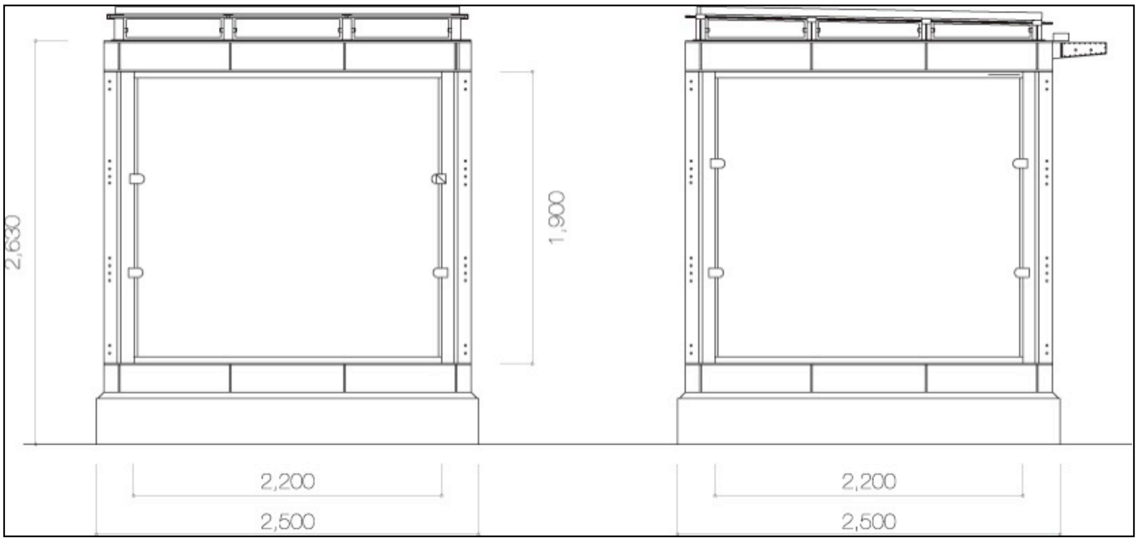


Fig.2-3 Front and Side Elevational Views of an Experimental House

Table 2-2 Conditions of Experimental Houses

	Roof condition	Wall condition
Cube 1	Irrigated soil 50mm	Loofah
Cube 2	Untreated	Loofah
Cube 3	Sunlight reflection	Untreated
Cube 4	Sunlight reflection	Loofah
Cube 5	Untreated	Untreated
Cube 6	Irrigated soil 50mm	Untreated

2.3 Results & Discussion

2.3.1 Preparatory Experiment

Fig.2-4 shows the temporal changes in each temperature on 24th August 2007, from 6:00 to 18:00. Unfortunately, other days during this experimental period were not sunny all the day. We, therefore, selected the date because continual sunshine was important for the experiment.

Firstly, it can be seen that while A5 temperature rapidly rose with increasing solar radiation flux, the others mildly rose like the outdoor temperature. That A5 temperature rose as high as over 41 degrees C was due to the direct sunlight.

Secondly, observing A1, A2, A3 and A4, it is shown that the temperature in A2 is slightly lower than the others. The cause is thought that Sedum effectively protected the soil surface from direct sunlight and made insulations of air pockets like mulching material, because Sedum’s three-dimensional volume was more massive than Plantain and Lawn. However, the effect of A2 advantage for cooling was only around 1 degrees C compared to A1, A3 and A4, therefore it can safety be said that in extensive green roofs the type of plants hardly affect the function for cooling.

It can be concluded that given the fact that Sedum can disturb Japanese urban biodiversity, to adopt Sedum for green roofs is not beneficial. In addition, in Japan the law for controlling invasive alien species has been in force since in June 2005 and updated year on year. On 1st February 2010, twelve types of alien plants have been restricted (Ministry of the Environment 2010). Sedum has not been restricted yet, however, Ministry of the Environment has continued to collect more information on other alien species, and the number of restricted species has increased year on year. Thus green roofs covered by nonnative plants like Sedum may not be a sustainable way. In terms of cooling, to cover roofs with irrigated soil may be the most beneficial way because of lower cost for installing and maintenance than any green roofs, with only slightly lower performance. Furthermore, according to Palomo & Barrio (1998), to select light soil can reduce the thermal conductivity as well as weight, because a less dense soil has more air pockets and is hence a better insulator (Castleton et al. 2010). Finally, in case of needing plants for soil covered-roof, own native plants should be adopted as covering plant instead of nonnative plants.

2.3.2 Main Experiment

2.3.2.1 Indoor Temperature

Fig.2-5 shows the average indoor temperatures without air conditioners, during five hours from 11:00 to 16:00, for six sunny days.

Firstly, comparing between Cube 3 and Cube 6, it can be seen that irrigated soil covered-roof is more effective than sunlight reflection roof regarding the cooling effect. Furthermore, the former is also superior to the latter in terms of providing insects and plants habitats. However, the way to paint roofs for sunlight reflection is so easy, and roofs with steep slope can’t be covered with soil. Thus, in general it is sensible to consider soil covering for flat or gently sloping roofs, with other roofs painted for sunlight reflection.

Secondly, comparing between Cube 1, Cube 2 and Cube 4, Cube 4 (with sunlight reflection roof and loofah walls) temperature was much lower than the others. It is, however, highly possible that Cube 4 is affected by the shade of a tree due to the fact that there is a big tree to the east of

Cube 4. The tree covered Cube 4 with shade for the whole morning. In addition, green coverage of Cube 4 was the highest in the three cubes (Table 2-3). Therefore, it can be anticipated that it would have been similar to Cube 1 and Cube 2 if those cubes were under exactly same conditions. To sum up the result of Cube 1, Cube 2 and Cube 4, it is important for improving indoor thermal conditions to block building from direct sunlight. The greater the area of blocked direct sunlight, the greater the cooling effect.

2.3.2.2 Electricity Consumption

Fig.2-6 shows the average electricity consumptions and indoor temperatures, during five hours from 11:00 to 16:00, for eight sunny days, during which air conditioners were operational. Despite some influence from inherent variation in performance of individual air conditioner units, the results follow those of average temperature without air conditioner (Fig.2-5) closely. Consequently, it was proven that irrigated soil covered-roof can reduce electricity consumption for cooling as well as sunlight reflection painted-roof. According to Castleton (2010), the thicker the soil substrate on the roof, the better it reduces heat gain/loss into/out of the building. In addition, green walls can enhance the effect for cooling. It is argued that in case it is difficult to cover walls with plants, another ways to blind walls should be used instead of plants. Because the role of plants at walls in this experiment mainly was to protect from direct sunlight like a curtain.

The introduction of electro-mechanical air conditioning systems into the building, with their great energy expenditure, has become the standard alternative used to natural cooling (Palomo & Barrio 1998). Meanwhile, a climatic conscious design of outdoor spaces and the appropriate use of natural components are key elements to reduce the outcome of unsound evolution of urban areas where impermeable surfaces and denuded landscapes determine undesirable climatic effects and unhealthy life conditions (Ferrante & Mihalakakou 2001).

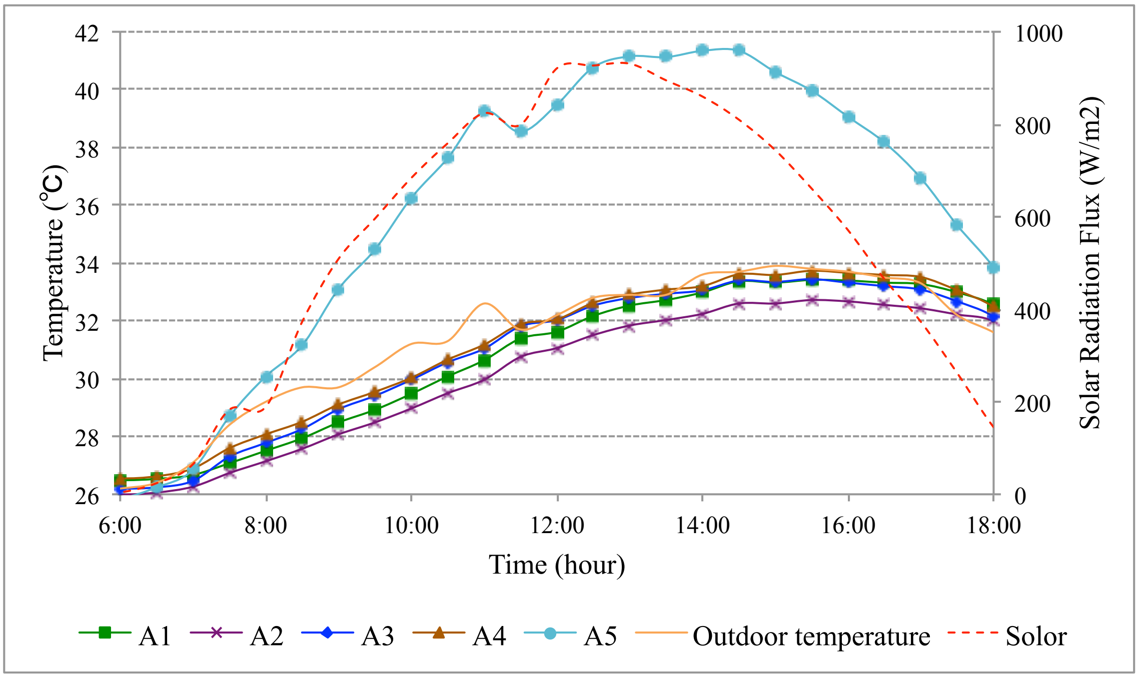


Fig.2-4 Temporal Changes in each Temperature on 24th August 2007

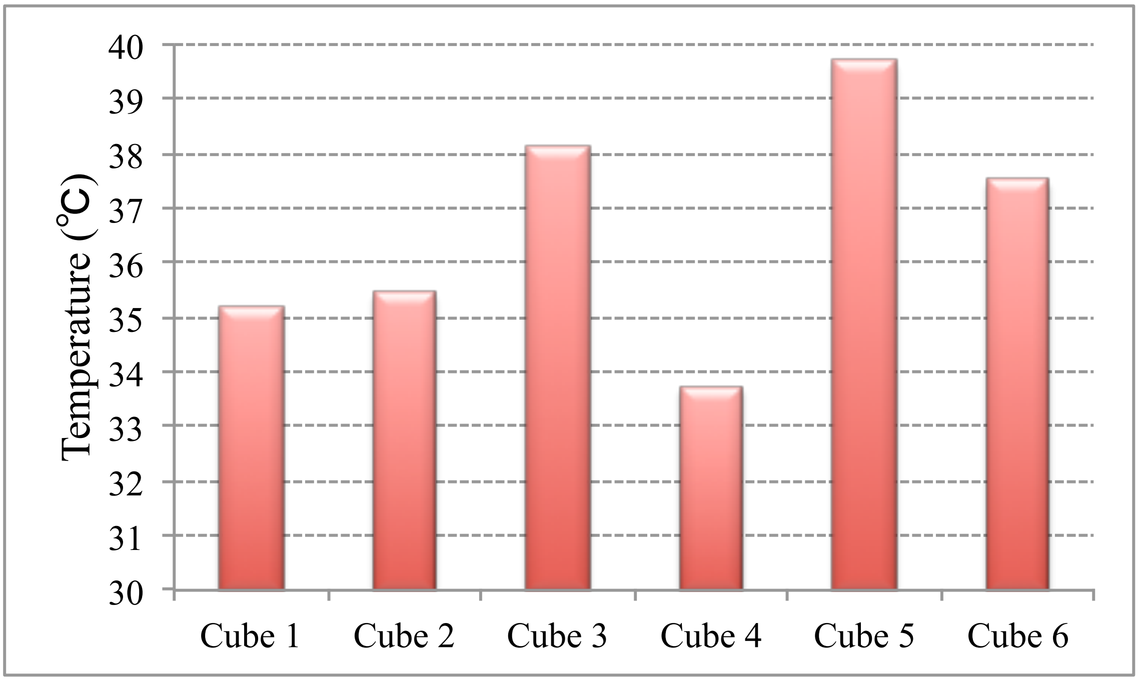


Fig.2-5 Average Indoor Temperatures without Air Conditioners, during Five Hours from 11:00 to 16:00 of Six Sunny Days

Table 2-3 Green Coverage of Green Walls on 17th August 2009

	Green coverage(%)
Cube 1	63.0
Cube 2	68.2
Cube 4	76.5

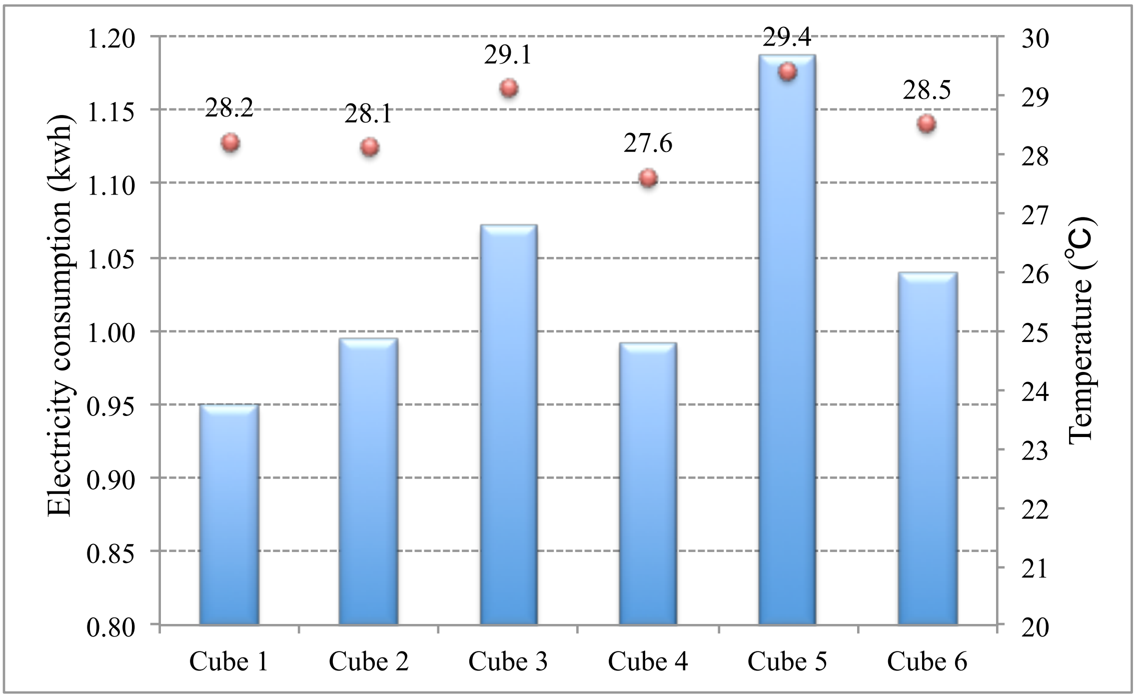


Fig.2-6 Average Electricity Consumptions and Indoor Temperature, during Five Hours from 11:00 to 16:00 of Eight Sunny Days, under Air Conditioners Rnning

2.4 Conclusion

At the start of the 21st century, rising energy costs coupled with increasing concerns about global warming related to CO_2 emissions, resulted in increasing interest in alternative, low and non-carbon based energy sources. Improving energy use efficiency is becoming increasingly important for combating rising energy costs and for fulfilling carbon emission reduction aims in the industrial sector. However, the ways to achieve this are never simple as they involve complicated ecosystem components. There are numerous problems, which modern society must face in seeking to secure a sustainable energy supply while also seeking to reduce the influence of energy use on climate changes and species diversity losses (Dovi et al. 2009). The first step to avoid these problems is to increase the amount of open spaces and permeable surfaces as much as possible (Ferrante and Mihalakakou 2001).

Although the environmental functions of green roofs (e.g., mitigation of rainwater runoff, reducing urban heat island and so on) are often promoted, the cost-effectiveness is not superior to alternatives due to the fact that installation and maintenance costs are so expensive. There are a number of inexpensive alternative ways to achieve similar environmental aims. It should be noted that green roof gets to be essential only in the case of rehabilitating urban biodiversity under the condition that open space in urban area is usually small. Despite ground-level sites having slightly more species and higher abundance overall, insect diversity within each of the four taxon assemblages described in s study did not significantly differ between intensive green roofs and ground-level sites (MacIvor & Lundholm 2011). It can be concluded that green roofs should be focused on conserving and restoring urban biodiversity using own native plants. Most of the modern urban environmental issues represented by the urban heat island can be resolved by replacing impermeable surfaces with permeable surfaces without huge cost.

Chapter 3

What are the Brown/Biodiverse Roofs? A Conservation Action for Threatened Brownfields Supporting Urban Biodiversity

3.1 Introduction

As noted in Chapter 2, although the environmental functions of green roofs (e.g., mitigation of rainwater runoff, reducing urban heat island and so on) are often promoted, the cost-effectiveness is not superior to alternative due to the fact that installation and maintenance costs are so expensive. There are a number of inexpensive alternative ways to achieve similar environmental aims. It should be noted that green roof gets to be essential only in the case of rehabilitating urban biodiversity under the condition that open space in urban area is usually small. Green roofs are mainly divided into two types: intensive and extensive (Molineux et al. 2009, Nagase and Dunnett 2010, Schrader & Böning 2006, Wilkinson & Reed 2009). However, the both have negative aspects respectively in terms of enhancing urban biodiversity (for details to Chapter 2).

In this chapter, the author outlines brown/biodiverse roofing in the UK, which is a relatively new type of extensive roofing for provision of mimic brownfield for brownfield wildlife, benefitting from techniques that offer diverse habitats under the severe conditions resulting from the thin substrate layer.

3.2 What are Brownfields?

In urban areas, the origin of brownfields (Fig.3-1) is principally demolished buildings (houses and factories), although the definition also includes landfills, sand or gravel pits, industrial dumps, former collieries and railway lands (Small et al. 2003). To sum up, brownfield refers to land that was previously developed for housing or industry but has, to differing degrees, been abandoned and recolonised by different ecological assemblages (Lorimer 2008, Schadek et al. 2009).

How did brownfield sites appear? Firstly, many buildings destroyed by bombing raids during World War II were not immediately rebuilt, and these vacant sites were colonised by wildlife (Grant 2006). Secondly, the process of industrial change has resulted in the creation of brownfields across Europe, particularly in urban areas (Grimski & Ferber, 2001). As London's industry and docks declined, other sites were cleared and subsequently colonised by diverse vegetation (Grant 2006). While parks and gardens come to mind as obvious refuges for nature, plants and animals are often more adventurous with regard to the places they colonise and use (Kadas 2006). As our world becomes increasingly developed, many species of wildlife adapt in unpredictable ways (Brack Jr. 2006).

While brownfield is typically considered to have no or negative economic value, recent research suggests that there are many ecosystem services provided by such habitats (Robinson & Lundholm 2012). Brownfields provide habitat conditions similar to more natural habitats, and they may help maintain populations of some rare species (Eyre et al. 2003). Furthermore, compared with lawns and urban forest, the brownfield site showed higher levels of ecosystem service provision for indicators of habitat provision, both plant species and invertebrate diversity (Robinson & Lundholm 2012). In the UK, brownfields include some of the most species-diverse habitats left (Kadas 2006), and are thought to support a minimum of 12-15% of Britain's nationally rare invertebrate (Small et al. 2003). Eyre et al. (2003) surveyed a total of 78 brownfields for beetles between 1991 and 2001 throughout England, as a result generating a total of 182 records of 46 nationally rare species (16 ground, 10 rove and 20 phytophagous species). A number of these species are more usually associated with other, more natural habitats such as riverine sediments, sandy heaths and chalk grasslands. They note, brownfields are important habitats for beetles, and there is evidence that the situation is similar for other invertebrate groups. Wasteland habitats associated with urban brownfields are of intrinsic importance, relying on the codification of these habitats as distinctive habitats characterised by suits of species and abiotic conditions that fulfill a range of scientific criteria (Harrison & Davies 2002).

From the 1980s to the present day, however, with UK government policy encouraging reuse of abandoned sites such as brownfields, these sanctuaries for nature have been increasingly redeveloped (Grant 2006). The UK government has set a target of building 60% of new dwellings on previously developed land (Lorimer 2008). Redevelopment of brownfields is widely acknowledged as one of the major tools to achieve sustainable development (Grimski & Ferber 2001). Because one of the reasons for emergence of brownfields is economic structural change and the decline of traditional industries, they are frequently coupled with severe loss of jobs and, as a direct consequence, decline of the neighbourhoods around derelict sites or even of whole cities. Although new parks and green spaces have occasionally been created within redeveloped sites, these are, unfortunately, nearly always ecologically impoverished, lacking the diversity provided by the original vacant sites (Grant 2006).

Due to this, the amount of brownfields with nature conservation value in Britain is set to decrease dramatically under current home-building and regeneration policies (Harrison & Davies 2002, Small et al. 2003). Huge swathes of industrial brownfield along the Thames Estuary are slated for redevelopment, and this will have an immense impact on wildlife (Kadas 2006). A challenge that faced brownfield conservationists in East London was to persuade local residents and policy makers that valuable species and ecological assemblages could be found inhabiting brownfield sites in the city (Lorimer 2008). Angold et al. (2006) suggest that planners can have a positive impact on urban biodiversity by slowing the pace of redevelopment and by not hurrying to tidy up and redevelop brownfields.

Fig.3-1 Brownfield in the City of London. There areas are quite important for urban wildlife

3.3 Brown/Biodiverse Roof

One of the most successful strategies that has been employed by the third constituency in its efforts to campaign for urban biodiversity and brownfield conservation has been to compromise with developers of brownfields and to persuade them to install wildlife-friendly mitigation technologies on roofs of buildings (Lorimer 2008). This is brown/biodiverse roof (Fig.3-2), which is usually constructed for habitat mitigation in the UK, especially in London, as the only litigation obliging constructors to install brown/biodiverse roofs comes from conservation of a rare bird species, the black redstart (Molineux et al. 2009). The black redstart is listed as a priority species for the London Biodiversity Action Plan sponsored by the London Biodiversity Partnership, as a Bird of conservation concern, and a Red Data Book species (London Wildlife Trust 2001). They are reliant on old vacant lots and brownfields and are thus now under threat from regeneration of much of their breeding ground (Gedge 2003, London Wildlife Trust 2001).

The roof membrane for each section is generally made of butyl rubber and protected by a nonwoven polypropylene geotextile fleece supported by a plywood deck (Grant 2006). To promote biodiversity, a variety of substrates are used, including a chalk and subsoil mixture, loamy topsoil, and gravel. In addition, crushed brick favours ruderal vegetation and can thus be used to replicate the brownfield biodiversity that was in place before development began (Lorimer 2008). The brown/biodiverse roof aims to provide vegetal and animal species with habitats while somehow managing to grow vegetation without any irrigation system or fertilizer.

Fig.3-2 Brown/Biodiverse Roof at Royal Holloway, University of London

3.4 How to Enhance Biodiversity on Extensive Roofs

Firstly, from associated brownfields and other valuable vegetated areas, the top 150 mm of substrate must be carefully removed and appropriately stored so that some of the existing vegetation, seed bank and soil organisms can be conserved (if suitable) for subsequent use on extensive roofs (Brenneisen 2006); for example, white and biting stonecrops have some of the most spectacular flowering displays and are very attractive to bees, butterflies and other insects (Natural England 2007). In addition, adaptation of spider and beetle fauna to natural soil and other substrates such as sand and gravel from riverbanks seemed to be a factor for successful colonisation (Brenneisen 2006).

Secondly, small logs laid across the substrate will not only provide shelter for insects but also create nesting sites for many small bees and wasps that burrow into dead timber (Natural England 2007, Robinson & Lundholm 2012).

Thirdly, designing brown/biodiverse roofs so that they have varying substrate depths and drainage regimes creates a mosaic of microhabitats on and below the soil surface and can facilitate colonisation by a more diverse flora and fauna (Brenneisen 2006). There is increasing use of locally derived lightweight granular waste materials as sustainable sources for roof substrates (Oberndorfer et al. 2007).

Lastly, Fig.3-3 is a diagram of a typical cross-section of a brown/biodiverse roof, showing use of diverse soil surfaces and substrates to create a mosaic of wildlife habitats for colonisation by a more diverse flora and fauna.

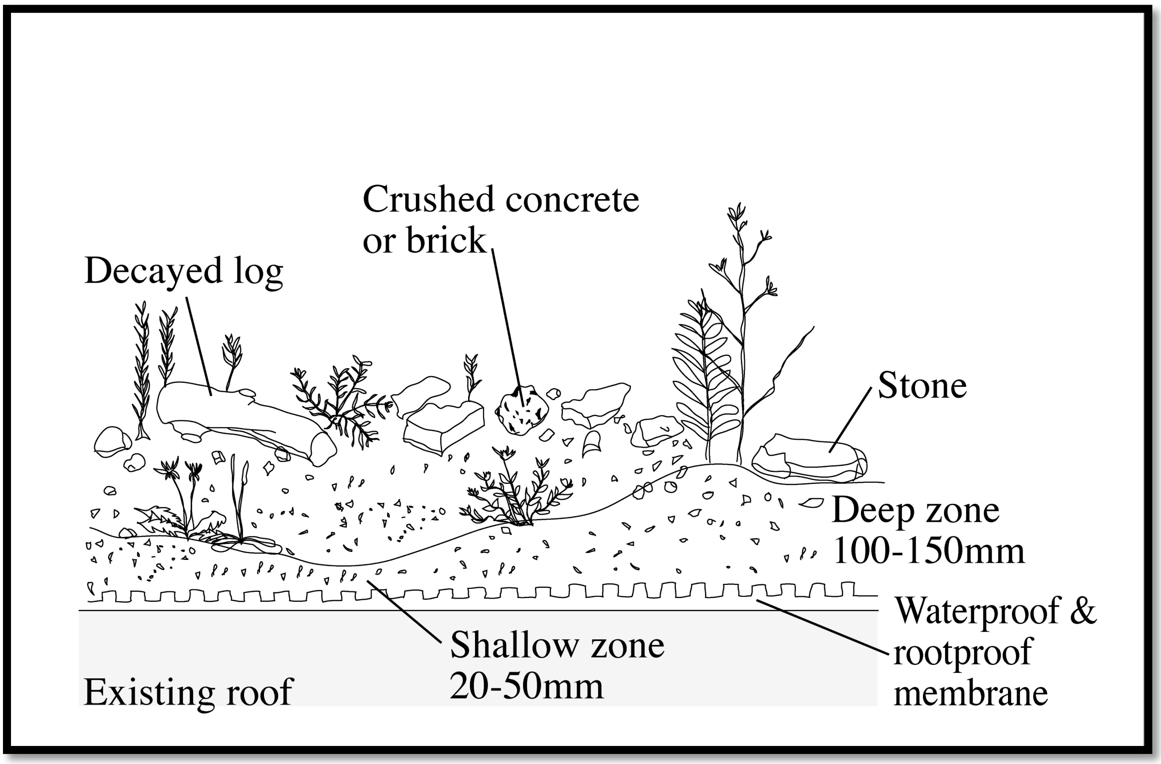


Fig.3-3 Typical Cross-Section of a Brown/Biodiverse Roof

3.5 What Kinds of Wildlife can Brown/Biodiverse Roofs Host?

It was reported that spiders, beetles, bees, wasps, ants and so on, which can be seen at brownfields, were found on Laban Dance Centre (brown/biodiverse) roof in London (Kadas 2006). As spiders are predatory, they occupy a mid trophic level in the food chain. The presence of spiders would suggest a varied invertebrate fauna present at the survey site. At Royal Holloway, University of London, moss forests, which provide cover for thousands of microscopic animals and habitat for other invertebrates (Natural England 2007), can be seen on brown/biodiverse roofing (Fig.3-4). In addition, it was reported that ground-nesting birds utilised brown/biodiverse roofs as a nesting location (Brenneisen 2006), though this example is from Switzerland.

Unfortunately, however, there is still a lack of information about wildlife on brown/biodiverse roofs due to the fact they do not have a very long history. Brown/biodiverse roofing needs more time to be investigated because of its dependence on successions. In the presence of soil, rainfall and sunlight, whether on rooftops or not, successions suitable for each environment will take place over time.

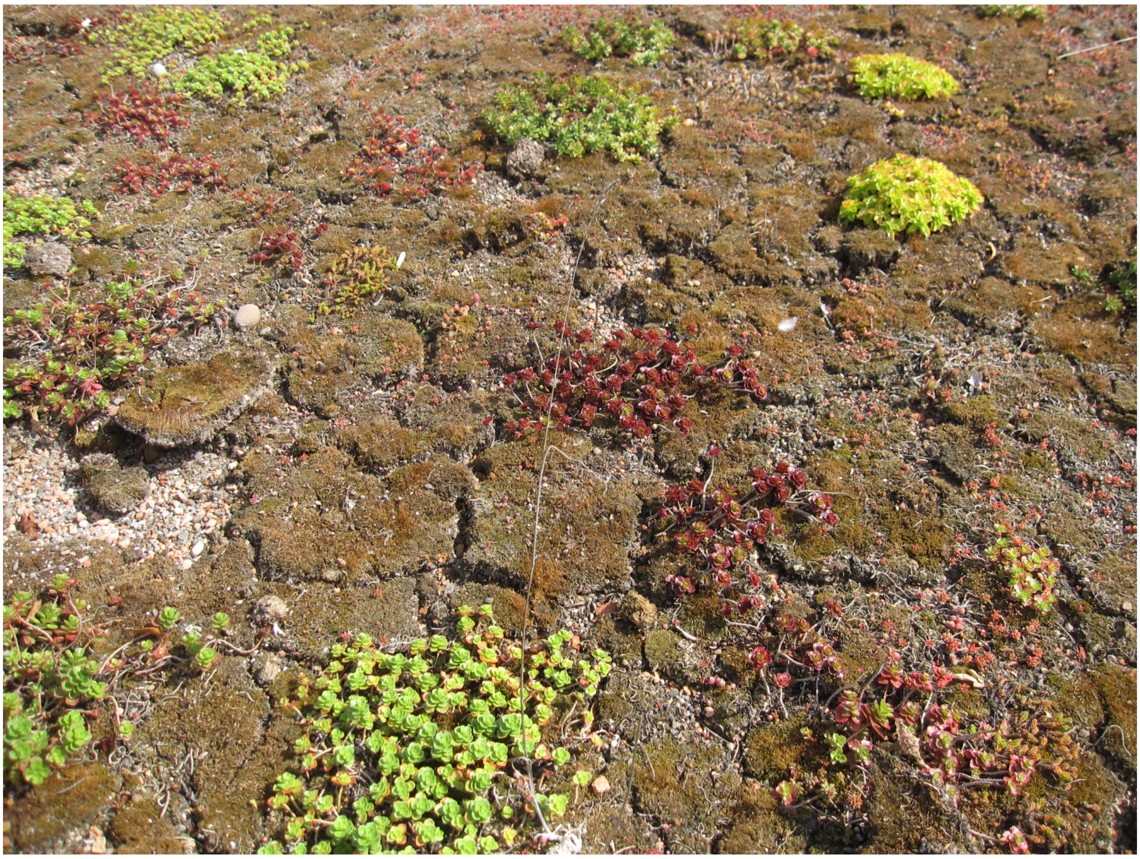


Fig.3-4 Unplanted Mosses at the Brown/Biodiverse Roof at Royal Holloway, University of London

3.6 Comparison of Cost and Ecological Functions

It should be noted that green roof industries consider the concept of brown/biodiverse roofs. Table 3-1 shows the requirements of each roof type in terms of frequency of maintenance, and construction and maintenance costs based on Fujita (2003). Although no data costs of brown/biodiverse are available, it is clear that the construction cost of brown/biodiverse roof is lower than of extensive roof with lawn, and the maintenance cost of brown/biodiverse roof is also lower than that of extensive roof with sedum, because they do not need any artificial vegetation layer but rather depend on succession. It is not always true that a soil layer without any plants has no ecological value; for example, there are some invertebrates which favour areas beneath stones or logs as their habitats.

In terms of ecological function, roof surfaces are assumed to be arranged in the following order: intensive roof, brown/biodiverse roof, extensive roof such as lawn or sedum, impermeable roof (Fig.3-5). If budgets allocated for creating extensive roofs with lawn and sedum can be used for brown/biodiverse roofs, there will be much more permeable areas in urban area. In urban environments, vegetation has largely been replaced by dark and impervious surfaces (Oberndorfer et al. 2007). Many of the well-known urban environmental problems are caused by loss of biodiversity and natural habitats, mainly as a result of surface sealing through construction measures, increased loads of heavy metals and organics, and emission of greenhouse gases (Schrader and Böning 2006). Those problems can be partially mitigated by altering the buildings' surficial properties (Oberndorfer et al. 2007). The first step to avoid these problems is to increase the amount of open spaces and permeable surfaces as much as possible (Ferrante and Mihalakakou 2001).

On the other hand, intensive roofs should be efficiently installed at equal distances to provide “stepping stone” in urban areas not having enough open scape. They can support more complicated biodiversity than brown/biodiverse roofs by offering valuable wildlife sanctuaries and providing better connectivity between existing habitats (Kim 2004). Some water areas should also be simultaneously installed, coupled with them if possible, because the combination of water and vegetation provides greater habitat diversity (Hunter and Hunter 2008). Despite the fact that intensive roofs are more beneficial for the urban environment, cost problems still remain, unfortunately (see Table 3-1). Because of this, it is quite important to combine brown/biodiverse roofs with intensive roofs.

However, some animals cannot reach the rooftop areas due to their restricted mobility, and earthworms are unable to survive on extensive roofs due to the limited substrate depth; they perish during high temperatures in summer because they cannot migrate to deeper and cooler regions of the soil (Brenneisen 2006). Thus, brown/biodiverse roofs or intensive roofs should never be considered a justification for destroying natural or semi-natural habitats on the outskirts of cities and beyond (Schrader & Böning 2006). Those roofs are only a method to delay the weakening of urban biodiversity.

Table 3-1 General Maintenance Frequency and Costs of Construction and Maintenance Required by Roof Type (assuming 200 m^2) (Fujita 2003)

	extensive roof with lawn	extensive roof with sedum	intensive roof with shrub	intensive roof with tree and lawn
construction cost	15,000~20,000 JPY/m^2	20,000~30,000 JPY/m^2	30,000~40,000 JPY/m^2	50,000~70,000 JPY/m^2
yearly maintenance cost	1,800 JPY/m^2	650 JPY/m^2	2,000 JPY/m^2	4,500 JPY/m^2
(maintenance breakdown)				
overall check	3 times per year	3 times per year	3 times per year	12 times per year
drainage cleaning	3 times per year	3 times per year	3 times per year	12 times per year
pruning	—	—	2 times per year	2 times per year
lawnmowing	3 times per year	—	—	3 times per year
fertilization	2 times per year	—	once a year	2 times per year
weeding	2 times per year	once a year	2 times per year	2 times per year
adjusting pole supporting tree	—	—	—	4 times per year
pest control	—	—	once a year	every time pests happen
irrigation system check	4 times per year	—	4 times per year	12 times per year

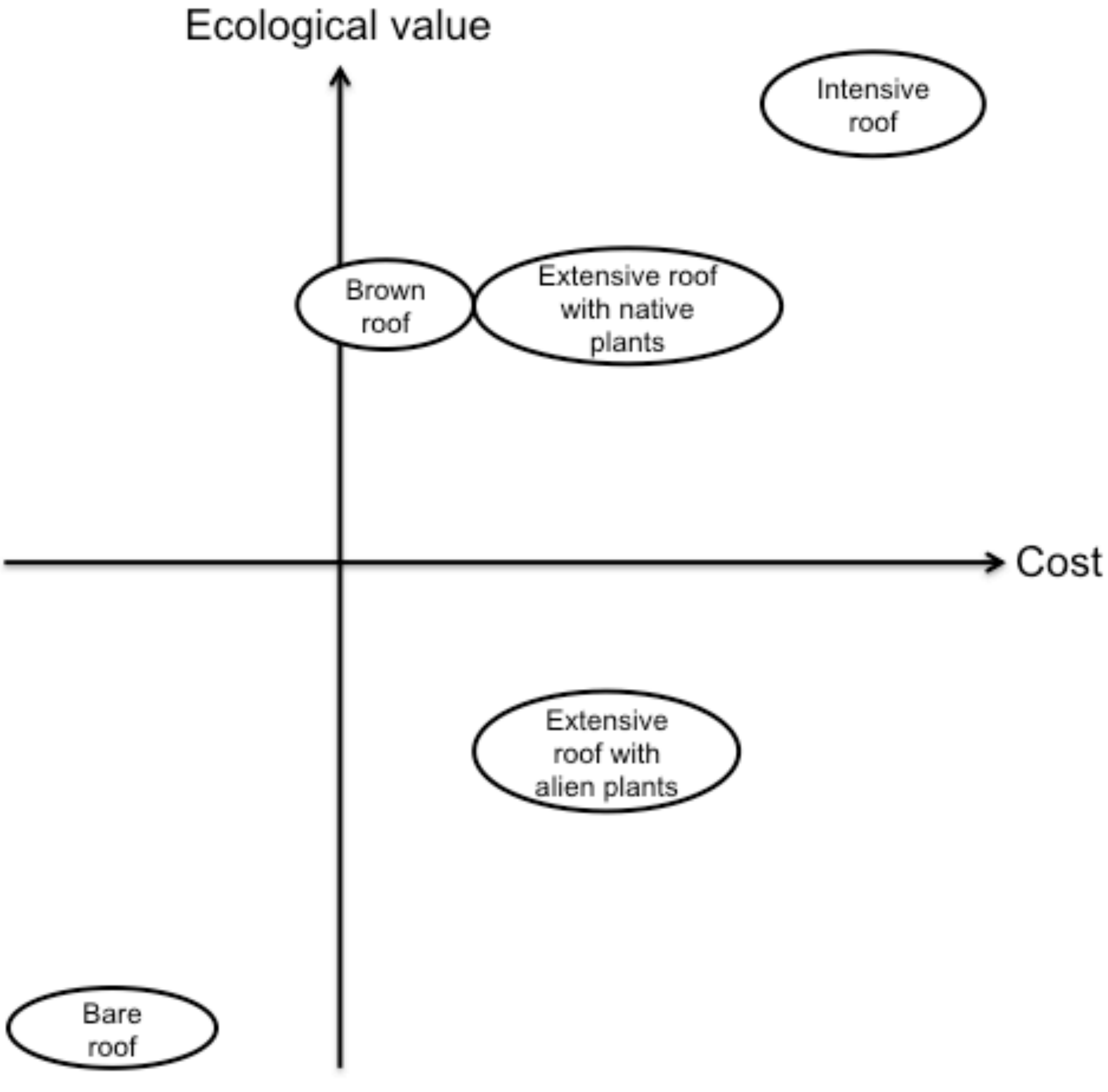


Fig.3-5 Correlation Diagram among Various Types of Roofs

3.7 Applicability to East Asia

Green roof industries are appropriate for management of grow of monoculture vegetation (sedum or lawn) on extensive roofs with frequent maintenances. However, this trend has two disadvantages in terms of both ecology and engineering. Firstly, planting of monocultures on green areas naturally tends to decrease species diversity (Kadas 2006). Furthermore, sedum can be killed by hot and humid summers in East Asia, and may also disturb biodiversity because it is not a native plant. Secondly, one function of green roof is to cool the building by shading the roof surfaces by vegetation, which may reduce evaporation from the soil surface (Oberndorfer et al. 2007). In fact, a watered-soil layer on a roof without any plants can indeed be used as an effective means of evaporative cooling and has the particular benefit of producing this cooling during the hottest hours of the day (Al-Turki et al. 1995, Pearlmutter & Rosenfeld 2008).

Misunderstanding regarding the function of green roofing such as those mentioned above should be avoided.

At the same time, it can be predicted that it will be quite important to pay attention to brownfields wildlife in the near future, in countries facing severe population decline, especially Japan and Republic of Korea, where there is a possibility that brownfields will increase. Surveys on the current state of brownfields need to be conducted. There is no information regarding the kinds of ecosystems that develop at brownfields. If some rare species are discovered, such as at brownfields in London, how can we conserve these precious habitats? Brownfields do not seem to have aesthetic value, thus developers will not want to leave them. Conversely, ecologists will somehow conserve them they are. There is therefore a wide perception gap between developers and ecologists, as for other environmental and ecological issues. The precedent offered by brownfields in London should be helpful for ecological urban planning in East Asia.

Chapter 4

Basic Study on the Heat Release Characteristics from Shikkui: A Japanese Traditional Architectural Material

4.1 Introduction

In recent years, facing the risk of global warming and of the depletion of fossil fuels, reduction in energy consumption along with sustainable development is priority for many countries. In particular, building sector accounts for 45% of worldwide energy use (Zhai & Previtai 2010), so research to reduce energy consumption in the sector through climate responsive strategies without compromising human comfort is essential (Nguyen et al. 2011). The negative effect to our living environments imposed by the modern architectural activities in the last 100 years, requires reexamination and judgment (Gong et al. 2010).

Vernacular architecture is used to describe structures built by people whose design decisions are influenced by traditions in their culture. It varies widely with the world's vast spectrum of climate, terrain and culture, and contains inherent, unwritten information about how to optimise the energy performance of buildings at low cost using local materials (Zhai & Previtai 2010). Therefore, it can be said that vernacular architectures in every area are products of accumulated experiences and practices for many centuries and can constitute a continuous source of knowledge (Oikonomou & Bougiatioti 2011). Now, the researchers in the field of energy efficient and sustainable design in various part of the world, e.g., in Vietnam (Nguyen et al. 2011), China (Borong et al. 2004, Liu et al. 2011), Tibet (Zhang et al. 2009) and India (Singh et al. 2009, Dili et al. 2010), are investigating structures and materials of vernacular architectures.

In Japan, Shikkui with heat release characteristics, which is composed of slaked lime, straws, bittern and so on, has been used as a wall material due to the fact that Japanese climate, which are rainy and humid all through the year, makes indoor conditions uncomfortable especially in summer. Shikkui, a wet construction method, tends to be expensive because of requiring much time and specialised technique for construction. Therefore, reasonable and versatile siding panel containing a lot of chemicals derived from oil, a dry construction method, has been superseding Shikkui since around 50 years ago (Miyano & Miyano 2007). With improvement of airtightness, however, dew condensation, ticks, fungi, and chemicals (e.g., formaldehyde) cause hypersensitivities like atopy and allergy. The phenomena called “sick building syndrome” make dwellers unhealthy and still remain one of the Japanese social issues (Yokobayashi & Sato 2008).

Recently, moisture control, air cleanup and heat release characteristics of Shikkui have tended to be reviewed (Kuwashima & Koshiishi 2004). Airtight and insulation dwellings depending on air conditioners require massive amounts of electricity in summer, and the development of energy-saving technology in modern dwellings is a significant challenge. Although it is thought that Shikkui might be able to contribute to energy-saving technology, modern dwellings have yet to utilise their characteristics due to poor academic analysis on Shikkui.

This chapter aims to reveal the heat release characteristics from Shikkui and pave the way for utilising it as an energy-saving technology, by means of monitoring the temporal changes in indoor temperature and humidity of an experimental cube composed of Shikkui.

4.2 Methods

4.2.1 Experimental Cubes

An experimental cube composed of Shikkui was built with a Japanese traditional dry construction method in order to monitor the temporal changes in indoor temperature and humidity. Meanwhile, an experimental cube composed of siding panels, which are a general modern housing material, in order to similarly monitor the temporal changes in indoor temperature and humidity, for comparison. The two cubes are a part of the experimental facility (Green Cube Project), which was constructed to conduct diverse experiments on next generation energy system with natural energy in 2009 at Kyushu Institute of Technology (Tobata campus) (see Fig.2-2). Two out of nine cubes were used for this present study (No.7 and 9).

Three glass panels were removed from the No.7 cube (hereinafter called “Shikkui cube”) and Shikkui walls were constructed on them. Fig.4-1 shows the woven Take-komai, Fig.4-2 shows the completed Shikkui cube, and Fig.4-3 shows the sectional view of Shikkui wall. “SHIROKABE-NAKANURI” and “SHIROKABE” made by TAGAWA SANGYO Co., Ltd. were used as the wall material. As well, all of the east side was not replaced with Shikkui. In addition, a Styrofoam board (thickness: 30mm) was fixed on the glass roof in order to block sunlight and a steel plate (thickness: 0.35mm) was fixed on the Styrofoam in order to protect from damages.

As in the case of Shikkui cube, three glass panels were removed from the No.9 cube (hereinafter called “Siding cube”) and siding walls were constructed on them. Fig.4-4 shows the completed Siding cube and Fig.4-5 shows the sectional view of Siding wall. As well, conditions of the east side and roof were equal to Shikkui cube.

Although the negotiation between the Green Cube Project members and Kyushu Institute of Technology took place in order to cut down many trees surrounding the experimental cubes (see Fig.2-2), it did not reach an agreement. Therefore, the both cubes were shaded by trees, around 6:00 to 7:00, 7:30 to 9:00, and 15:30 to 17:00 in experimental day. In spite of the fact that the both cubes are slightly away each other, the significant difference of solar radiation between these two cubes were not observed.

During the experiment, the both doors were completely closed. However, there are no dwellings with perfect airtightness not only in Japan but also all over the world. In the same way, Shikkui and Siding cubes do not have perfect airtightness in this study. At the junctions of doors, tiny vapor can move from outdoor to indoor and vice versa as much as general doors.

4.2.2 Monitoring of the Indoor Temperature/Humidity and Outdoor Solar Radiation

A temperature/humidity sensor made by KN Laboratories, Inc. (product name; HYGROCHRON) was set up at the centre of each cube in order to monitor the indoor temperature and relative humidity. Besides, an equipment for monitoring weather condition made by Davis Instruments (product name: Vantage Pro 2) was set up at about three meters south from the No.8 cube, about one meter above ground level, in order to monitor outdoor temperature, relative humidity, and solar radiation. All of the data were recorded every 5 minutes, throughout the day, 7th July 2010.

4.2.3 The Amount of Heat Release

The amount of heat release from Shikkui cube was calculated as the amount of heat by use of the temperature difference between Shikkui and Siding cube. It is formula (a) for calculating the amount.

$$Q=d\times V\times c\times \Delta t \qquad (a)$$

Q: Amount of heat release (J)

d: Air density ($g\ /\ m^3$)

V: Volume (m^3)

c: Specific heat ($J\ /\ g\cdot K$)

Δt: Temperature difference (K)

4.2.4 Discomfort Index and Degree

Discomfort index was calculated by use of the monitored temperature and relative humidity. It is formula (b) for calculating the index.

$$DI = 0.81T + 0.01U(0.99T - 14.3) + 46.3 \qquad (b)$$

T: Temperature (°C)

U: Relative humidity (%)

In this present study, the condition under discomfort index over 80, which means that people feel sweaty, was defined as “discomfort condition”. Discomfort degree, an original index, was calculated by use of integration value of discomfort index with duration of time under discomfort condition. It is formula (c) for calculating the degree.

$$DIH = \int DIdt \qquad (c)$$

DIH: Discomfort degree

Fig.4-1 Woven Take-Komai Made of Bamboo on Shikkui Cube

Fig.4-2 Completed Shikkui Cube

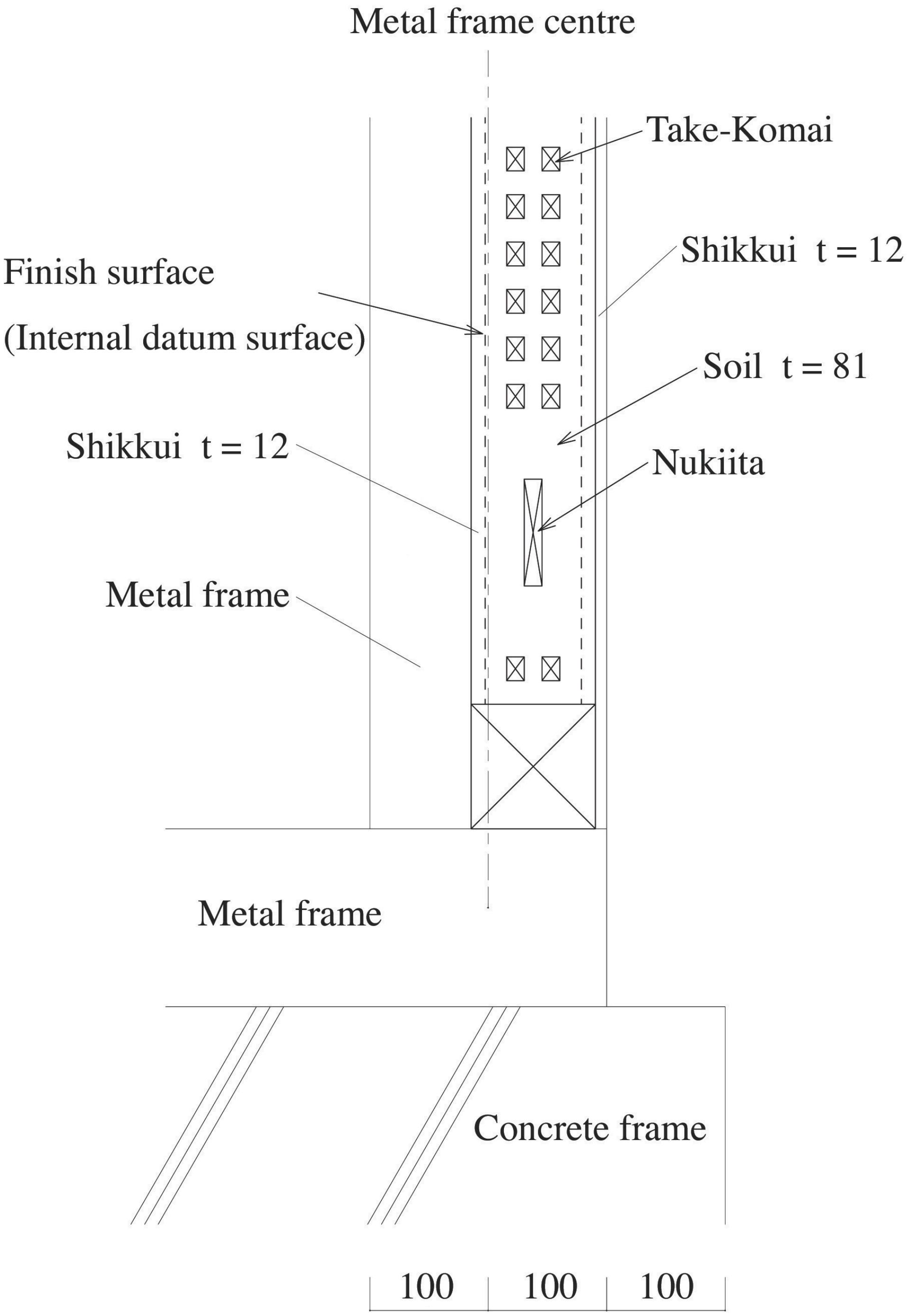


Fig.4-3 Sectional View of Shikkui Wall

Fig.4-4 Completed Siding Cube

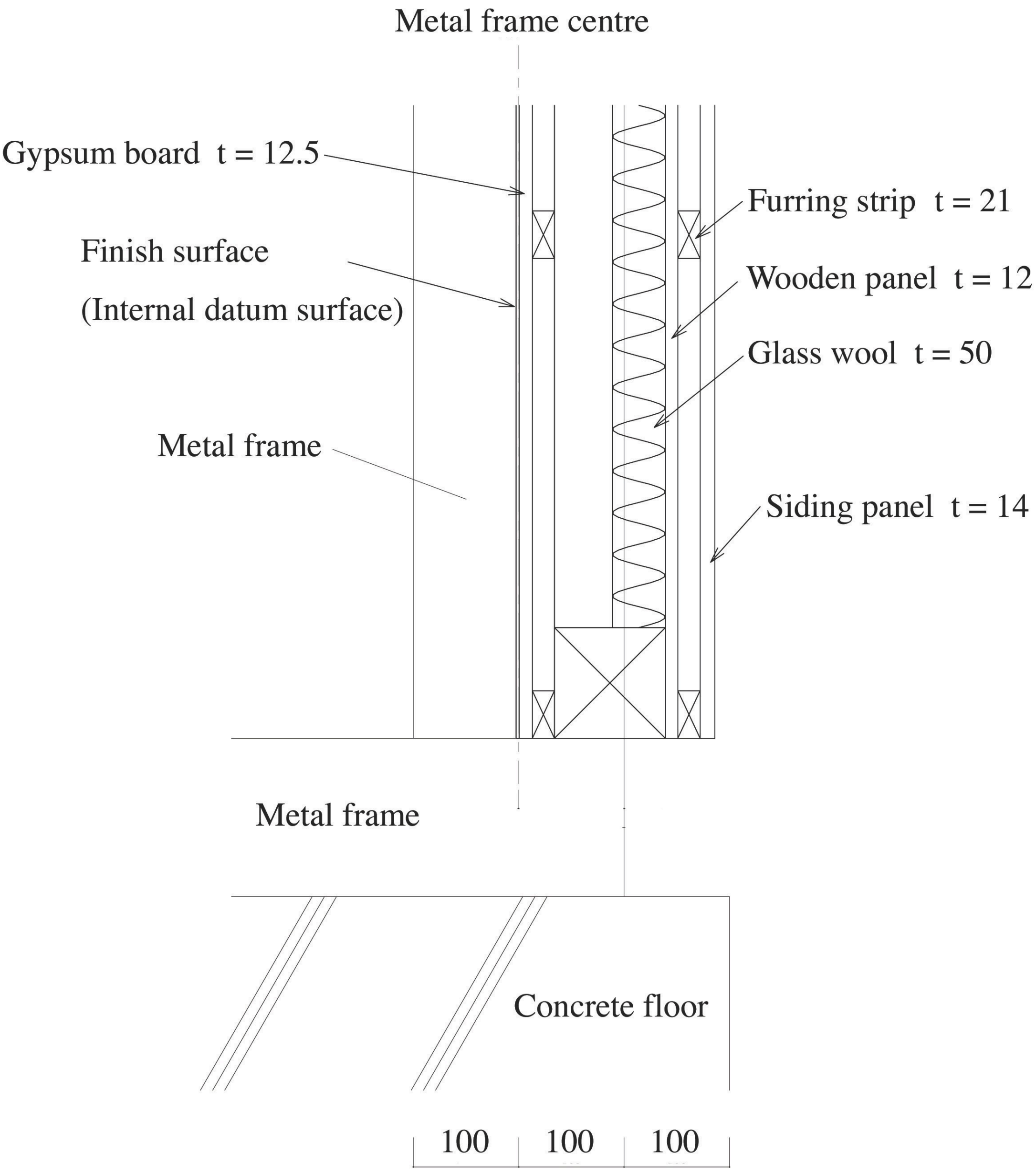
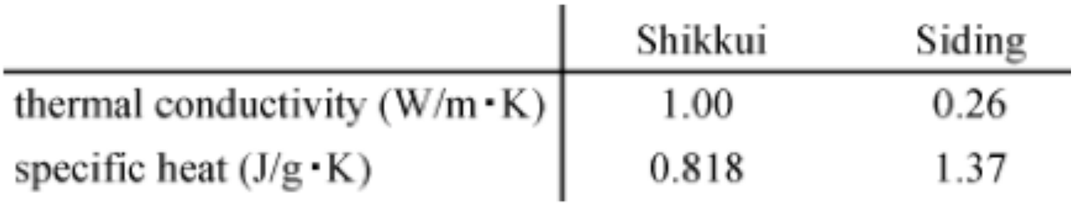


Fig.4-5 Sectional View of Siding Wall

Table 4-1 Primary Property of both Shikkui and Siding



	Shikkui	Siding
thermal conductivity (W/m・K)	1.00	0.26
specific heat (J/g・K)	0.818	1.37

4.3 Results

4.3.1 Temporal Changes in the Temperature and the Amount of Heat Release

Fig.4-6 shows the temporal changes in the temperatures and the solar radiation. When comparing the outdoor temperature with the indoor temperature of Shikkui cube, Shikkui cube was lower than outdoor during 7 hours between 7:05 and 14:05, and the maximum temperature difference was 3.2 degrees C at 9:10. On the other hand, when comparing the outdoor temperature with the indoor temperature of Siding cube, Siding cube was lower than outdoor during 1.5 hours between 7:50 and 9:15, and the maximum temperature difference was 1.0 degrees C at 8:45.

Next, when comparing the indoor temperatures of Shikkui cube with one of Siding cube, Shikkui cube was lower than Siding cube during around 13.5 hours between 6:10 and 19:45, and the maximum temperature difference was 5.8 degrees C at 11:30. The solar radiation was recorded during 14 hours between 5:30 and 19:30, so the above duration almost corresponded to the duration that Shikkui cube was lower than Siding cube. Besides, after calculating the heat release from Shikkui cube with the use of the difference in temperature between Shikkui and Siding cube from 6:10 to 19:45 according to formula (a), 4.8×10^4 J was obtained.

Fig.4-7 shows the temporal changes in the solar radiation and the difference in temperature between Shikkui and Siding cube. The temperature difference was shifted as well as the solar radiation. Consequently, it can be safely said that the higher solar radiation is, the wider the temperature difference becomes.

4.3.2 Temporal Changes in the Absolute Humidity and Discomfort Index,

Discomfort Degree

Fig.4-8 shows the temporal changes in the absolute humidity and the solar radiation. From 0:00 to 6:00, Shikkui cube was about 3.0 g/cm^3 higher than Siding cube. As the solar radiation rises the difference started to be close, and Siding cube exceeded Shikkui cube at 10:45. After the maximum absolute humidity difference (Siding cube > Shikkui cube), 1.1 g/cm^3, was recorded at 12:30. Afterwards, as the solar radiation drops the difference conversely started to be wide. Siding cube dipped below Shikkui cube at 14:20, and then Shikkui cube had been about 4.0 g/cm^3 higher than Siding cube since 19:30.

Fig.4-9 shows the temporal changes in the solar radiation and the difference in the absolute humidity between Shikkui and Siding cube. As well as Fig.4-7, it was observed that the solar radiation was, the wider the absolute humidity difference became.

Fig.4-10 shows the discomfort indices of Shikkui and Siding cube. Regarding discomfort degree, while Shikkui cube was 23.2, Siding cube was 35.8. Regarding the length of time under discomfort condition, while Shikkui cube was during around 9 hours between 13:05 and 22:20, Siding cube was during around 10 hours between 9:55 and 20:00. Although the discomfort degree of Shikkui cube was lower than the one of Siding cube, there was no significant difference regarding the length of time under discomfort condition.

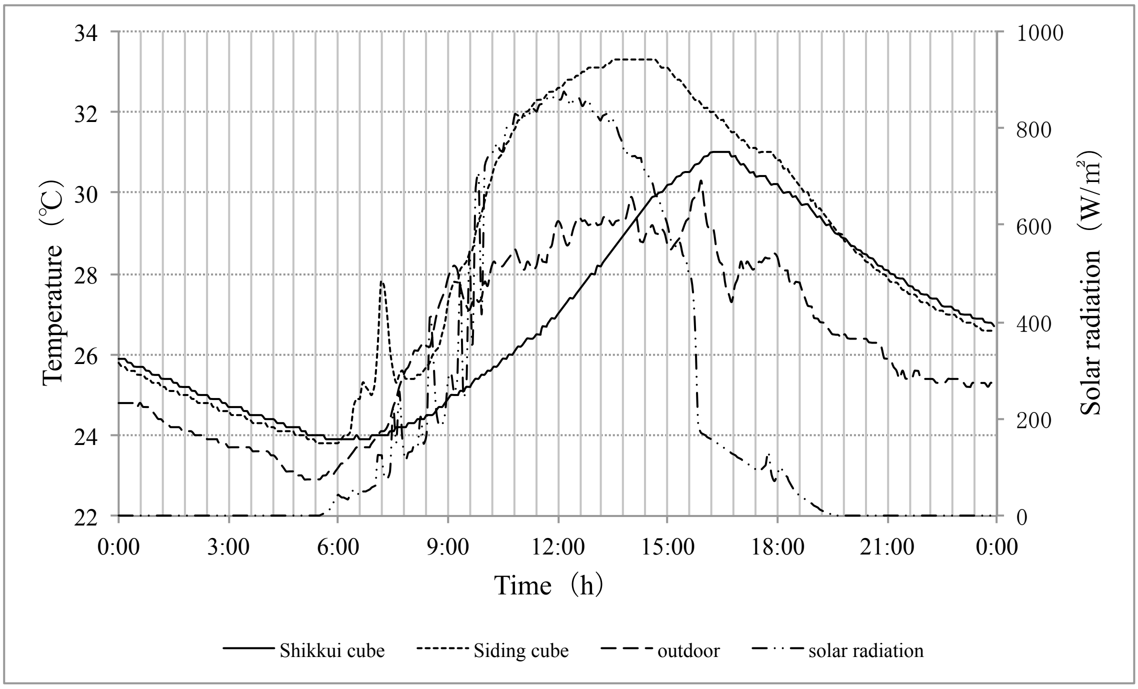


Fig.4-6 Temporal Changes in the Temperatures and the Solar Radiation

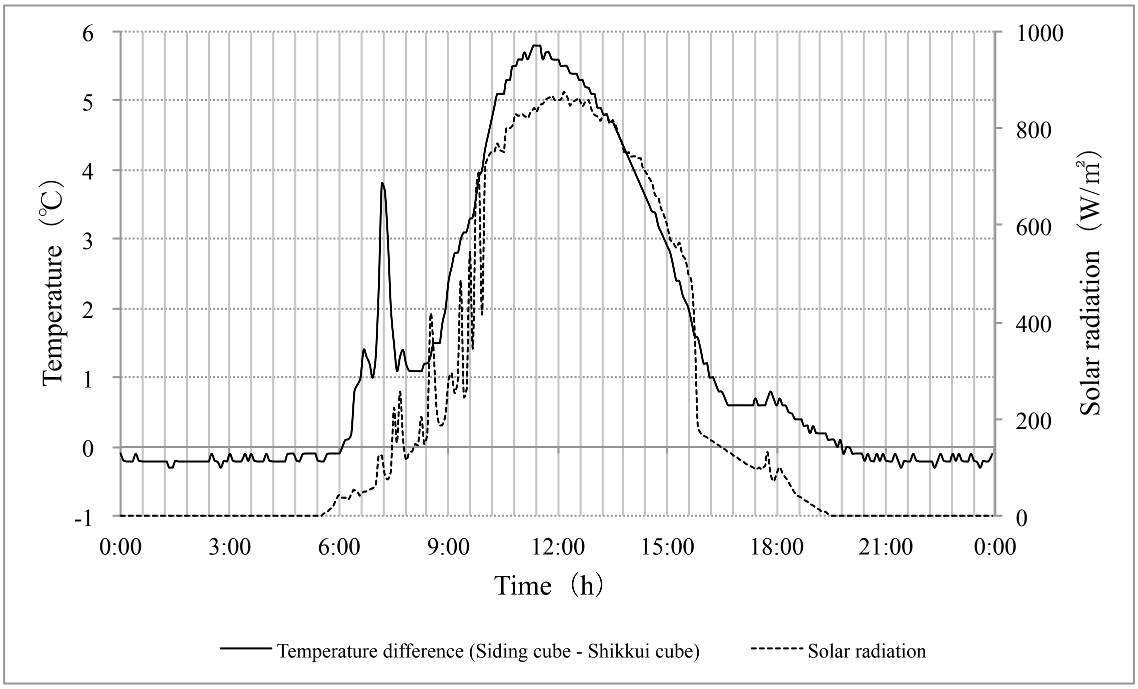


Fig.4-7 Temporal Changes in the Solar Radiation and the Difference in Temperature between Shikkui and Siding Cube

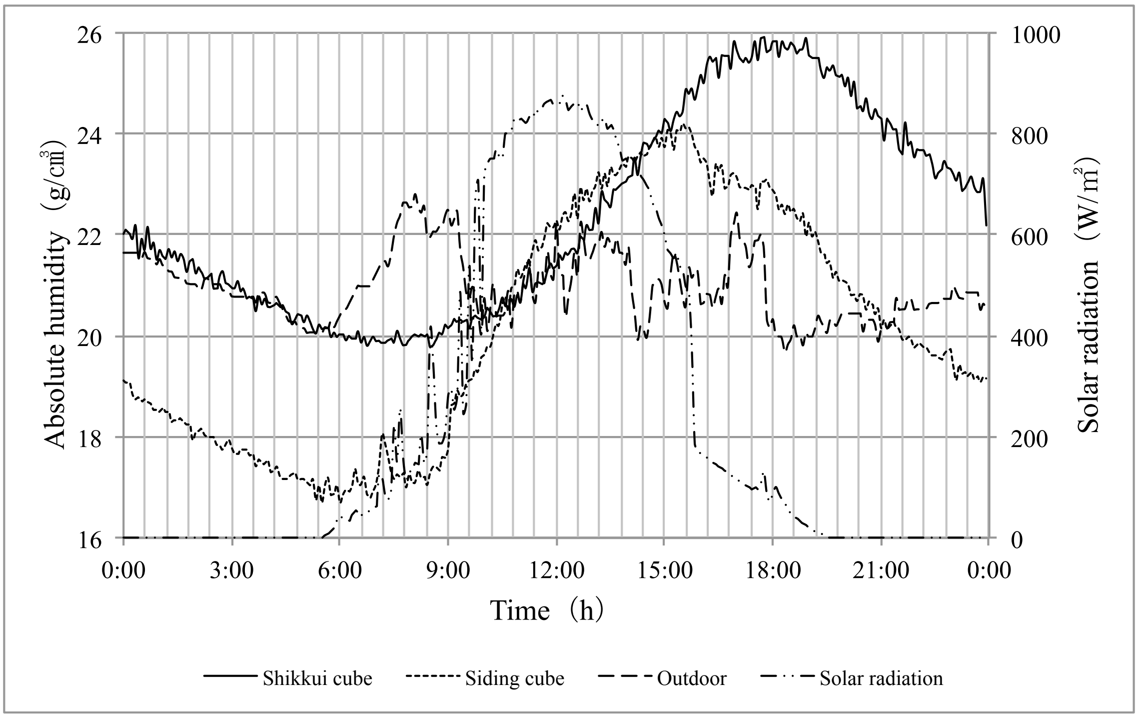


Fig.4-8 Temporal Changes in the Absolute Humidity and the Solar Radiation

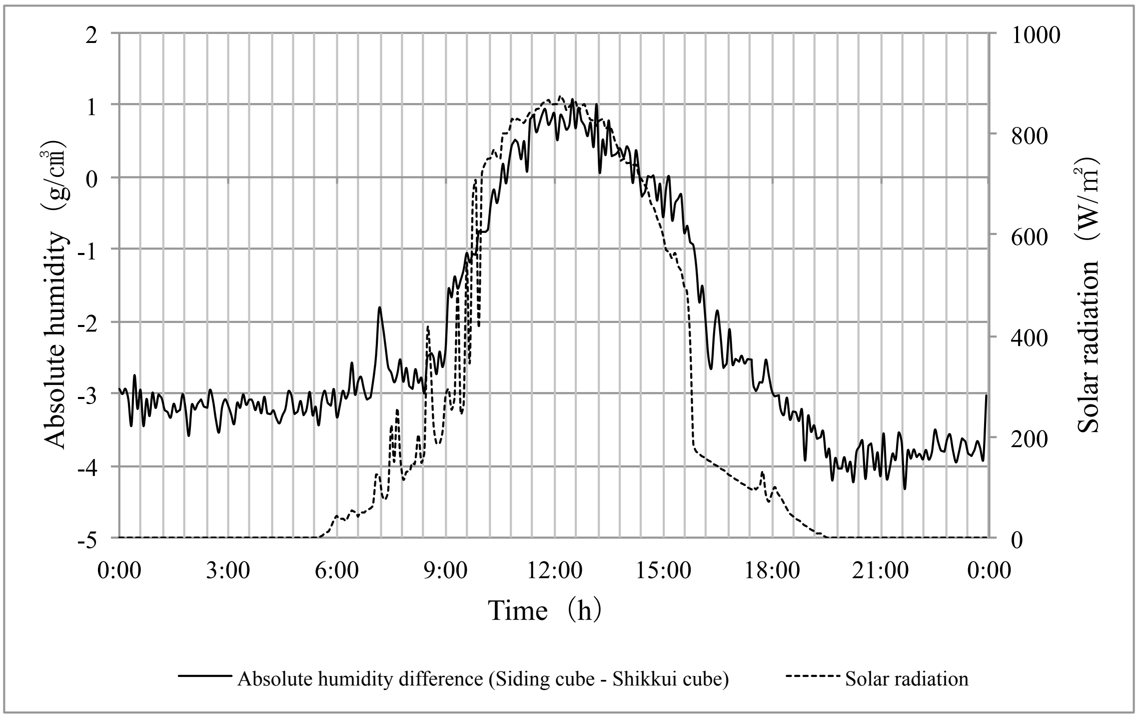


Fig.4-9 Temporal Changes in the Solar Radiation and the Difference in the Absolute Humidity between Shikkui and Siding Cube

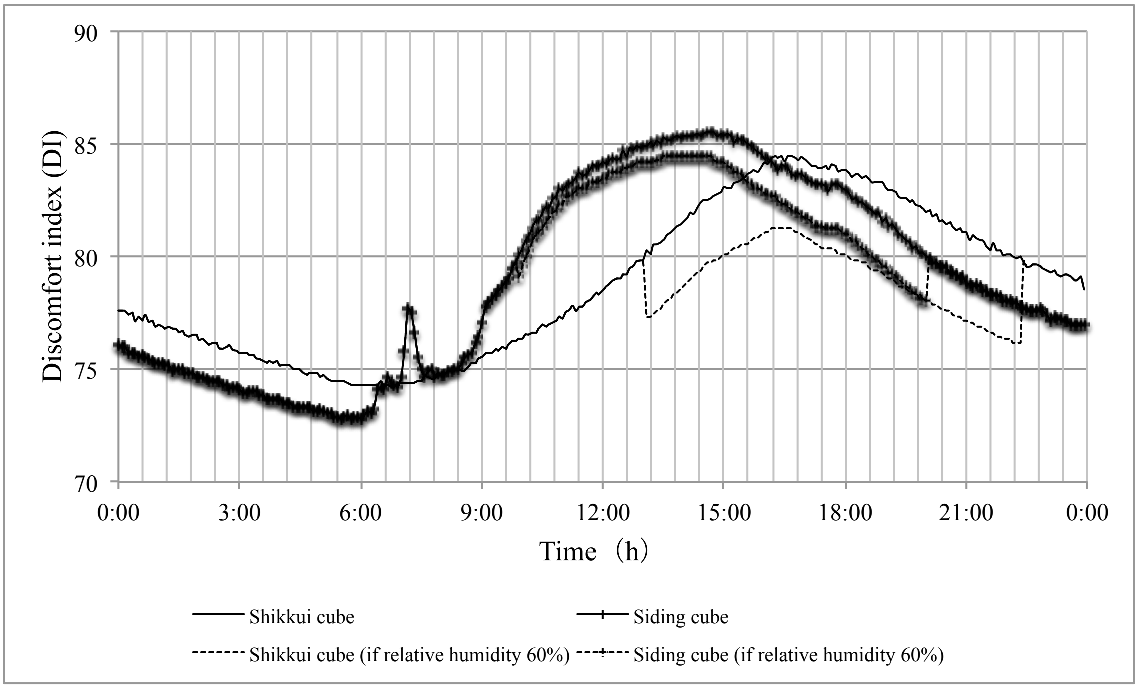


Fig.4-10 Discomfort Indices of Shikkui and Siding Cube

4.4 Discussion

4.4.1 Heat Release Characteristics and Mechanism from Shikkui

This confirmed phenomenon that the differences in temperature and absolute humidity between Shikkui and Siding cube becomes wide as solar radiation rises, indicates that the heat release feature of Shikkui becomes activated as solar radiation rises. In other words, it is thought that solar radiation enhances the evapotranspiration on external surface of Shikkui walls and then the heat caused by evapotranspiration prevents indoor temperature rising. The heat release characteristics from Shikkui are composed of two distinct parts, one is the amount of heat release revealed by this study, the other is evapotranspiration enhanced by solar radiation.

According to Kuchitsu and Morii (2005), earthen walls can exchange moisture with surrounding air. Shikkui wall, a type of earthen wall, can allow moisture to move back and forth between inside and outside because of many microscopic uninterrupted air bubbles in Shikkui wall. After external Shikkui walls become dry, internal one become dry due to the fact that moisture in the wall moves to the external side. After that, the dried internal surface starts to absorb moisture from indoor air or floor. As a result, Shikkui cube can decrease indoor temperature by means of vaporisation heat, which moisture from indoor air or floor is continuously released at the external wall with. According to Ito et al. (2006), a similar phenomenon was confirmed by an experiment for developing a planting container made of Shikkui. It is reported that the soil temperature in the planting container is decreased by means of vaporisation heat, which moisture from the soil is continuously released at the external container with.

The mechanism for cooling with vaporisation heat implies that the heat release characteristics become activated as the evapotranspiration at the external wall increases. Namely, it is thought that weather conditions (e.g., solar radiation, wind, temperature, humidity and so on), which are related to evapotranspiration, directly affect the heat release characteristics from Shikkui.

However, moderation of indoor temperature rise of Shikkui cube depends to a large extent on endothermic nature into Shikkui walls having large thermal capacity. Therefore, this heat transfer phenomenon of resulting from Shikkui is attributed to not only heat release characteristic but also endothermic nature from Shikkui. Further investigation into the phenomenon is needed for the discussion encompassing all factors of cooling effect from Shikkui.

4.4.2 Heat Buffering Effect

In Fig.4-6 and Fig.4-8, the indoor temperature and absolute humidity of Siding cube tended to be moved up and down depending on sharp changes in outside temperature, outside absolute humidity, and solar radiation. On the other hand, the indoor temperature and absolute humidity of Shikkui cube did not depend on it. For instance, in Fig.4-6, while the maximum indoor temperature of Siding cube was 33.3 degree C between 13:30 and 14:40, the one of Shikkui cube was 31.0 degree C between 16:10 and 16:40. Furthermore, although the indoor temperature of Siding cube sharply rose when the solar radiation sharply rose at around 7:00 due to trees surrounding the both cubes, the one of Shikkui cube was stable. It is thought that the phenomenon, caused by Shikkui's absorption and desorption of moisture, is the heat buffering effect from Shikkui against changes in the outdoor temperature and absolute humidity.

The above heat buffering effect from Shikkui can contribute to the development of a comfort dwelling space. For instance, when a relationship between an incidence angle of sunlight and a dwelling wall is straight like the afternoon sun, an indoor temperature can sharply rise. In that case, if the energy of sunlight is used for evaporating moisture which is stored in the inside of Shikkui, the sharp rise in indoor temperature will be avoided. When the heat release feature caused by evapotranspiration is applied to modern dwellings, the heat buffering effect should be considered for its designs.

4.4.3 Moisture and Discomfort Index

While the discomfort index of Siding cube was boosted by high temperature, the one of Shikkui cube was boosted by high relative humidity.

If Siding dwellings are without any air conditioners, its indoor temperature and relative humidity rise due to the design for enhancing performances of thermal insulation and waterproof. As thermal insulation can prevent heat transfer from outdoor into indoor and vice versa, evidently solar radiation heat through glass windows or metal parts (e.g., frame, door and so on) tends to remain in Siding dwellings. Due to this, inside temperature of Siding dwelling naturally rises higher than Shikkui dwellings. Probably, Siding dwelling without any glass windows and metal parts should be lower than one with them. However, they are necessary equipments for dwelling. That is to say, Siding dwellings are premised on air conditioners which need electricity consumption.

On the other hand, as Shikkui or other wet construction methods have the heat release characteristics, a rise in the indoor temperature is rather suppressed. However, if Shikkui dwellings are without any ventilation routes for moisture, the discomfort index rises due to high relative humidity. That is to say, Shikkui dwellings are premised on the ventilations, so Japanese traditional dwellings with Shikkui walls have good ventilation functions.

If the relative humidity of Shikkui and Siding cube under "discomfort condition" were decreased to 60 %, they would be each of the dashed line on Fig.4-10. As a result, while the discomfort degree of Siding cube decreased to only 24.4, the one of Shikkui cube decreased to 2.2. Moreover, regarding the length of time under "discomfort condition", while Siding cube decreased to during only around 8.5 hours between 10:10 and 18:35, Shikkui decreased to during around 3.0 hours between 14:55 and 18:05. Those results indicate that Shikkui dwellings are premised on the ventilation for moisture.

4.5 Conclusion

This chapter revealed the heat release characteristics from Shikkui and paved the way for utilising it for modern dwellings.

(a) The heat release characteristic from Shikkui cube was 4.8×10^4 J as a result of calculating it with the use of the mean temperature difference between Shikkui and Siding cube.

(b) Compared to Siding cube, the amount of heat release of Shikkui cube increases as the solar radiation rises.

(c) The buffering effect from Shikkui was verified because the indoor temperature and absolute humidity of Shikkui cube were not sharply moved up and down depending on the sharp changes in the outdoor temperature and absolute humidity.

(d) There is a possibility of substantially decreasing the discomfort index of Shikkui dwellings by means of some ventilations for moisture even though the indoor condition of Shikkui dwellings tend to be humid compared to Siding dwellings.

Even so moisture is essential for the Shikkui's heat release characteristics and buffering effect, it causes discomfort index to increase. When the heat release characteristics from Shikkui are activated, most of the moisture in Shikkui walls is released to the outside. On the other hand, when not in the above mode, they are released to both the inside and outside.

Besides, it can be safety said that Shikkui is for creating comfortable dwelling environment in summer rather than winter. Before inventing contemporary home electronics, to heat indoor air was much easier than to cool it because of "fire". When fire is used for heating in a room, carbon monoxide should be one of the biggest issues. These functions such as heat insulation and airtightness are so dangerous for dwellers when using fire in a room. Hence, Shikkui dwelling might be cooler than Siding dwellings in winter. That means the way to heat a whole room such as an air conditioner is totally incompatible with Shikkui dwellings. When Shikkui is used for modern dwellings, the way to heat a part of room such as “Kotatsu” should be more effective than air conditioner in terms of energy saving.

Lastly, this present study was not able to reveal the amount of moisture which Shikkui can absorb and release, the ratio of absorbed moisture to released moisture, the accurate transfer route of moisture, and the relationship between all of those things and weather conditions. If the above matters are verified, more effective ways for utilising Shikkui for modern dwellings should be suggested. As a further study, the quantitative approaches for verifying the transfer of moisture in Shikkui need to be conducted.

Chapter 5

Proposal to the Future Urban Planning toward Sustainable City

5.1 Introduction

Land and conservation management is increasingly concerned with regional-scale habitat analyses (Bunn et al. 2000) due to the fact that high-density development and rapid urban sprawl have affected the urban vegetation's composition and biodiversity (Kong et al. 2010). As a result urban areas, unfortunately, provide an excellent opportunity to study the effects of habitat fragmentation, because urban green areas are typically surrounded by completely hostile man-made matrix, even though gardens in suburban areas may provide additional resources for some organisms (Öckinger et al. 2009). For example, Sandström et al. (2006) note there is a clear increase in the number of bird species as well as individuals from centre to the surroundings of the city in south-central Sweden. This fact visibly indicates that urban forests are an important component of the urban landscape in terms of bird species diversity (Savard et al. 2000).

Habitat fragmentation caused by urbanisation can be extreme within urban ecosystems, and fragments of natural vegetation may be too small or even too isolated to support some species (Savard et al. 2000). If they become isolated, small populations can lose genetic variation through inbreeding and genetic drift, and will become increasingly prone to extinction (Rouquette & Thompson 2007). In other words, as sites become more isolated, dispersing individuals become less likely to find suitable habitat (Rouquette & Thompson 2007). Thus, seed dispersal and wildlife movements have a potentially profound effect on the population dynamics and constitute an essential survival process in patchy habitats (Angelibert & Giani 2003, Keller et al. 2010, Rouquette & Thompson 2007, Rudd et al. 2002).

Dispersal of wildlife is usually risky, and there will always be a balance of risk between living longer in an already occupied habitat and risking resources in an act of colonisation (Angelibert & Giani 2003). Dispersal will be efficient if the benefits of reaching a better site exceed the cost from the risk of death during dispersal (Angelibert & Giani 2003). Furthermore, whether or not patches can be recolonised depends on the availability of dispersing individuals and the ease with which these individuals can move about within the landscape (Kindlmann & Burel 2008). Due to this, new habitat should be created between the existing sites to reconnect the extant populations, and connectivity should be a key component of all management planning (Rouquette & Thompson 2007). In particular, it is often said that greenways (corridors) provide an opportunity to reduce the impacts of habitat fragmentation (Linehan et al. 1995). Given that the primary function of greenways is to provide linkages, they represent one of the most effective tools in preventing fragmentation and perhaps species loss at the regional level. It cannot be overemphasised that greenways should not be seen as the end-all solution to wildlife conservation problems, but can be a cost-effective complement to an existing open space reserve system. It is an argument that current land use zoning schemes fail to account for biological diversity and may actually encourage fragmentation (Linehan et al. 1995). However, it is difficult to implement it, as of today, because a lot of buildings have occupied urban areas. That means there is no open space. Increasing urbanisation creates the need to sustain urban biodiversity (Schadek et al. 2009).

At the same time, the intensive urbanisation also causes regional climate change, “Urban Heat Island”, which is mainly related to both the usage of air-conditioners in summer and the increase in impermeable spaces. Although the interaction between the phenomena and urban biodiversity has not yet been proven in detail, it is likely that even microclimate change will disturb urban biodiversity. Moreover, it is already very uncomfortable for urban dwellers to live under the phenomena in summer. Hence the reduction of the consumption of air-conditioners is quite important as well as greenways for urban biodiversity.

This chapter aims to encompass the technologies in each of the chapter and make a proposal to the future urban planning toward sustainable city.

5.2 Methods

5.2.1 Simulation Site

Kitakyushu City in Fukuoka Prefecture is situated latitude $33^\circ 53' 00''$N and longitude $130^\circ 53' 00''$E. The city's twentieth century began with the opening the Yahata Steel Works, which was just the first of many major metals and chemical manufacturing plants in the city, and heavy industry soon became the backbone of the local economy (Kitakyushu City 2004). Despite deteriorating natural environment, steel production expanded dramatically through the first half of the century fuelled by the demands of a rapidly growing national infrastructure and two world wars (Kitakyushu City 2004). At last, in the 1950s, the city was faced with pollution-related health crises like the world-famous Minamata mercury poisoning (Kitakyushu City 2004). Just like Minamata City, Kitakyushu City produced metals and chemicals in large quantities, and even had a polluted bay, which was known as the 'Sea of Death' (Kitakyushu City 2004). Afterward, in the 1970s, pollution regulations were strengthened, so air and water qualities in Kitakyushu City were improved step by step. Nowadays the city has garnered international awards, the U.N. Global 500 and U.N. Sustainable Development Award reflecting the efforts made in promoting various environmental issues since the past environmental pollutions. Naturally, the city has been preserving and restoring green areas. It is argued that the city is one of the cities with the highest motivation for addressing various environmental issues in Japan.

In this chapter, Shimoitozu area ($54ha$) in Kitakyushu City was defined as a simulation site (Fig.5-1). A GIS data of 2007 was analysed by use of ArcGIS 8.1. In order to avoid complexities of the simulation, each of the green area within the site was regarded as a brownfield site, and each of the building except buildings of more than $0.1ha$ was regarded as dwellings and 7-meter-tall.

5.2.2 Identification of Green Space Networks based on Graph Theory and Gravity Modeling

In recent years, graph theory has established itself as an important mathematical tool in a wide variety of subjects, ranging from operational research and chemistry to genetics and linguistics, and from computer science and geography to sociology and architecture (Wilson 2010). The advantage of a graph theory approach over other modeling techniques is that it is a heuristic framework which can be applied with very little data and improved from the initial results (Bunn et al. 2000). In graph theory, the degree to which all nodes in a system are linked is known as network connectivity (Linehan et al. 1995). The parameters that determine network connectivity are (a) the number of separate networks within the region, (b) the number of links within the network, and (c) the number of nodes within the network (Linehan et al. 1995).

A widely used way to measure interaction between nodes is based on the gravity model (derived from the law of gravity in physics). It may be written (in a modified form)

$$l_{ij} = \mathrm{K}\frac{P_i \times P_j}{d^2}$$

to describe the amount of interaction (l) between nodes i and j, where P_i is the population size or amount of objects at node i, P_j is the population size or amount of objects at node j, and d is the distance between the two nodes. K is simply a constant to relate the equation to the particular objects being studied, such as heat energy, water molecules, or aardvarks (Forman &

Gordon 1986). In this chapter, it is defined that P is the area of node, and K is *1.0*.

5.2.3 Evaluation of Green Space Networks

The gamma index of network connectivity is the ratio of the number of links in a network to the maximum possible number of links in that network. The number of links present is counted directly. The maximum possible number of links can be determined by counting the number of nodes present. With three nodes present, only three links are possible, but with four nodes present, three additional links are possible, making a total of six. Assuming no new intersections are found, the maximum number of links rises by three each time a node is added. Thus, we have the gamma index for connectivity

$$\gamma(raw) = \frac{L}{L_{max}} = \frac{L}{3(V-2)}$$

where L is the number of links, L_{max} is the maximum possible number of links, and V is the number of nodes. The gamma index varies from zero, indicating that none of the nodes is linked, to *1.0*, indicating that every node is linked to every other possible node (Forman & Gordon 1986).

The index ranges from zero, for a network with no circuits, to *1.0* for a network with the maximum possible number of loops present (Forman & Gordon 1986). Furthermore, the adjusted gamma is defined as follows (Linehan et al. 1995):

$$\gamma(\text{adjusted}) = \frac{\gamma}{\gamma_{max}}$$

The cost ratio index is calculated by dividing the number of links in the network by their total distance, resulting in a value per total distance (Linehan et al. 1995).

$$\text{Cost Ratio} = 1 - \left(\frac{\text{no. of links}}{\text{distance of links}}\right)$$

The beta index represents the number of links divided by the number of node:

$$\beta = \frac{\text{no. of links}}{\text{no. of nodes}} = \frac{L}{V}$$

If $\beta < 1$, a dendrogram occurs; if $\beta = 1$, there is a single circuit; if $\beta > 1$, more complex levels of connectivity exist (Linehan et al. 1995).

5.2.4 Evaluation of Shikkui's Potential for Cooling

In *Chapter 4*, the heat release characteristic from Shikkui cube was 4.8×10^4 J as a result of calculating it with the use of the mean temperature difference between Shikkui and Siding cube. The total area of the three Shikkui walls on the cube was 18.75m^2, thus the heat release characteristic from Shikkui per square meter was $4.2 \times 10^5 \text{J}/m^2$. Lastly, the obtained value multiplied the total area of the buildings walls under 0.1ha within the simulation site, and the calculated value means the Shikkui's potential for cooling.

Fig.5-1 Location of the Simulation Site

5.3 Results & Discussion

5.3.1 Effective Installment of Brown/Biodiverse Roof

First, using ArcGIS fourteen brownfields were identified within the simulation site (see table 1), and there were thirty-nine linkages among the brownfields (see table 2 & 3). Fig.5-2 visualises the thirty-nine linkages.

Second, two brown/biodiverse roofs on building areas were installed in order to enhance weak linkage points (see table 1). As a result, the number of linkages was improved to fifty-five linkages (see table 2 & 3). Fig.5-3 visualises the improved linkages. Of course, the installment of brown/biodiverse roofs was able to improve not only linkage but also other indices, γ (Raw & adjusted), β and Cost ratio. Notably, the ratio of installed brown/biodiverse roofs was 2.4 % of the total. That means even if the amount of brown/biodiverse roofs is small compared to some total preservation area, it would be very effective for improvement of connectivity.

Even so brown/biodiverse roof is slightly more inexpensive than green roof, it would not be good idea that urban planners install brown/biodiverse roof without strategies. Creating corridors using the connectivity analysis is much more effective than randomly selecting links, and randomly selected networks may not be as effective at protecting and enhancing biodiversity (Ruud et al. 2002). For instance, if brown/biodiverse roof is installed beside some brownfields, it will be not effective. It is quite important to keep an appropriate distance between a brown/biodiverse roof and brownfields by means of some evaluation indices like this chapter' method.

The presence of brownfields within the urban landscape should be seen as a compliment and enhancement of the urban quality of life

(Robinson & Lundholm (2012). Younger, earlier successional brownfield sites seem to support a greater diversity and abundance of plant and invertebrate species (Robinson & Lundholm 2012). This proposed method would be one of the beneficial planning ways to enhance urban biodiversity by use of brown/biodiverse roof.

5.3.2 Shikkui's Potential for Cooling

Table 5-4 shows the result of the simulation about Shikkui's potential for cooling. The calculated $6.9{\times}10^{10}\,J$ means a Shikkui's potential for cooling inside during daytime hours, compared to the current siding wall. The $6.9{\times}10^{10}\,J$, however, is released to outside, so the amount of both inside and outside heat would be same.

In other words, it can be safely said that Shikkui can decrease electricity consumptions to release an accumulated inside heat to outside. In spite of the fact that Shikkui room is cooler than siding room, Shikkui room would also require small electricity consumptions in order to release accumulated inside moistures to outside when natural ventilation is not enough.

Table 5-1 Profile of Brownfields and Brown Roofs at the Simulation Site

	Area (㎡)	Status	Ratio (%)
1	2889.5	Brown fileld	19.5
2	2411.5	Brown fileld	16.2
3	321.3	Brown fileld	2.2
4	451.8	Brown fileld	3.0
5	1268.5	Brown fileld	8.5
6	126.0	Brown fileld	0.8
7	368.2	Brown fileld	2.5
8	127.8	Brown fileld	0.9
9	342.5	Brown fileld	2.3
10	1465.1	Brown fileld	9.9
11	200.8	Brown fileld	1.4
12	3755.1	Brown fileld	25.3
13	243.8	Brown fileld	1.6
14	522.8	Brown fileld	3.5
15	117.4	Brown roof	0.8
16	237.1	Brown roof	1.6
total	14849.2	−	100

Table 5-2 Result of Calculating Linkages among Brownfields and Brown Roofs (Coloured values means connected condition)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1		1.29	2.80	13.31	2.40	0.46	0.87	0.22	0.24	0.44	0.45	1.01	0.81	0.31	0.26	0.53
2			4.94	1.12	2.37	7.83	10.62	0.86	0.84	1.22	2.42	0.83	18.73	0.74	1.30	3.22
3				2.05	2.41	1.03	3.02	0.30	0.32	0.67	0.91	0.95	2.93	0.43	0.43	0.88
4					4.14	0.40	0.65	0.19	0.21	0.31	0.33	0.55	0.63	0.22	0.21	0.53
5						0.82	0.98	0.38	0.40	0.40	0.48	0.48	1.04	0.28	0.34	1.56
6							3.09	1.10	1.00	0.85	1.86	0.39	4.13	0.52	1.87	2.60
7								0.50	0.50	1.79	5.15	0.96	89.18	0.96	1.20	1.05
8									57.90	0.39	0.48	0.19	0.52	0.28	1.03	1.25
9										0.42	0.49	0.21	0.52	0.31	1.01	1.19
10											5.04	1.16	1.40	27.24	1.49	0.43
11												0.75	3.81	2.04	2.38	0.62
12													0.77	0.88	0.33	0.29
13														0.78	1.17	1.23
14															0.93	0.29
15																0.66
16																

Table 5-3 Evaluation of Connectivity among Brownfields and Brown Roofs

	No. of nodes	No. of links	γ		β	Cost ratio
			Raw	Adjusted		
Theory max	14	91	1.00	N/A	6.5	N/A
Before	14	39	0.43	0.71	2.79	0.99
After	16	55	0.60	1.00	3.44	0.83

Fig.5-2 Visualised Linkages before Installing Brownroofs

Fig.5-3 Visualised Linkages after Installing Brownroofs

Table 5-4 Result of the Simulation about Shikkui's Potential for Cooling Effect

No. of buidlings under 0.1ha	Hypothetical total wall area (㎡)	Hypothetical amout of heat release from Shikkui walls (J)
310	163604.49	6.9 x 10^{10}

5.4 Conclusion

Globally, the world's population is expected to increase from the present 6 billion people to 10 billion by the year 2050, mostly in urban areas (Rudd et al. 2002). Urban environmental issues will become more important agenda.

We should abandon the common belief that each landscape is associated with a certain connectivity value. It is not. Connectivity has two dimensions: landscape and the organism considered. Only a combination of these two will yield a meaningful value of connectivity. Thus, different landscapes may have different degrees of connectivity for the same species, and the same landscape may have different degrees of connectivity for different species or even for the same species at different times. Landscape connectivity also changes with the choice of measures. For example, connectivity measures based on distances may be appropriate for birds as the matrix and corridors may not be of great importance in this case. Measures based on the amount of corridors in the landscape may be appropriate for small mammals (e.g., carabid beetles) whose movement is affected by matrix permeability. Furthermore, road and railway lines are considered to be barriers against the movement of animals moving on the ground (Kamada 2005). Evidently, each of these measures will give us a different connectivity for the same landscape (Kindlmann & Burel 2008). Another very important component of network planning is the consideration of private and unprotected areas (e.g., brownfield). Those habitats can be an invaluable food and habitat source for a wide range of urban species and are essential in developing the matrix that supports the large numbers of corridors required for connectivity. Public education on gardening with native plants and providing proper habitats is another tool to enhance the connectivity of the region and improve the viability of the corridors. This is crucial in urban areas because of existing development and lack of green space (Rudd et al. 2002). Conservation managers should be concerned with how to invest resources wisely to realise the greatest return, in terms of protected or enhanced biodiversity (Kadoya 2009).

This chapter suggests that rooftop space can contribute to enhance urban biodiversity. If possible, however, to create habitats on the ground is more preferable than on the rooftop due to accessibility. Moreover, if impervious spaces (e.g., concrete and asphalt) are replaced with pervious spaces (e.g., green area and brownfield), it is significant for not only urban biodiversity but also Urban Heat Island. Especially, the heating and cooling loads are more balanced, and a reduced heating load deeper within the Urban Heat Island is matched by an increased cooling load (Kolokotroni et al. 2007). The collaboration between Shikkui and increase in pervious space might be able to push our life to sustainable society.

Even so, the character of habits in urban areas desired for biodiversity is not completely compatible with the needs for a secure human environment (e.g., sexual assault on women). As a consequence, the directives in management plans aim to remove potentially dangerous places (e.g., shrubs in urban green spaces). Another conflict between biodiversity and people is the risk of falling trees or branches from large old trees, and accordingly insurance implications that can force the removal of standing dead wood. To deal with the planning dilemma between social security and biodiversity maintenance, one solution may be small-scale zoning planning in parks to create vegetated zones with different characteristics in urban green spaces (Sandström et al. 2006). Understanding the ecological interactions between built and natural areas within cities can help us manage and plan urban environments to promote diversity and ecological function (Newbound et al. 2010).

Chapter 6

Overall Conclusion & Future Prospects

Social demand for conservation of biodiversity and restoration of degraded ecosystems has increased year on year as a result of widespread recognition of the biodiversity crisis. The Convention on Biological Diversity was signed at the United Nations Conference on Environment and Development, the so-called Rio Summit, held in 1992, and the protection of biological diversity and restoration of degraded ecosystems have been accepted as one of the most important environmental issues in Japan (Kamada 2005). One important aspect in dealing with biodiversity is that not all species are equal. Species vary in size, shape, abundance, distribution, trophic position, ecological function, feeding habits and desirability (Savard et al. 2000). In addition, conservation planning requires the identification of conservation priorities and invariably involves compromises with other socioeconomic objectives (Rhodes et al. 2006). Methods to establish a clear target image of the restored ecosystem and to design the restoration work should be established for each individual site (Kamada 2005). Some species may play important roles in the community, so their absence would significantly affect several other species (Savard et al. 2000). For example, insect pollination is a vital ecosystem function in terrestrial systems (Robinson & Lundholm 2012). In addition, Dragonflies (Odonata) are one of the commonest indicator species because of being major predators in terrestrial and aquatic ecosystems (Bernåth et al. 2002, Kadoya et al. 2008, Kadoya et al. 2004, Purse et al. 2003, Samways & Steyrler 1996, Soluk et al. 2011).

Fungi (Newbound et al. 2010) and Birds (Pellissier et al. 2012) are also good indicators.

At the same time, we have to discuss the quality of urban habitats with their aesthetic value. For example, Öckinger et al. (2009) found that traditional parks had the lowest number of butterfly species because traditional parks usually lack most of the features that constitute suitable butterfly habitat. Typically, they have short grass turf that is cut regularly, low numbers of native plant species and a low structural diversity. On the other hand, Öckinger et al. (2009) also found that brownfields had a high value for urban biodiversity and it may be more beneficial to leave brownfields unmanaged than to try to manage urban and suburban parks for biodiversity. Which site is preferred by urban dwellers? As mentioned in the Chapter 6, additionally, the connectivity among habitats has to be considered.

Furthermore, Urban Heat Island linked to Climate Change would threaten urban biodiversity. It is not, however, easy to solve those issues because we have to change our lifestyle or values. It can be safely said that to review traditional lifestyle is significant due to the fact that they could optimise ecosystem service without any electricity consumption. Moreover, each of the vernacular architecture has much knowledge to adjust local climate.

To conclude, there have been many studies to dig into just one topic as of today, and they have greatly contributed to buildup of the contemporary civilisation. However, such a traditional approach will not resolve urban environmental issues. We have to encompass distributed technologies and findings regardless of age or background. If can resolve urban environmental issue, we can also resolve global environmental issue. Everything on the earth may link each other at the core.

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