Third International Conference on Sustainable Construction Materials and Technologies http://www.claisse.info/Proceedings.htm

The Case for Increased Wood Utilization in Urban Design toward Revitalization of Japan's Forest and Forestry

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ABSTRACT

66% of Japan is covered by forests, much of it made up of cedar and cypress plantations. Due to social transformations such as decreasing timber prices and declining workforce, an ever larger number of forest areas are however left to deteriorate, causing serious damage to their ecosystems. A fundamental solution for this problem would require, first and foremost, an understanding of the current situation of forest resources within the country, followed by an estimation and evaluation of future timber supply capabilities. An essential part of such an evaluation would be an assessment of the distribution of certain characteristics such as structural timber strength, so that a sustainable scenario could be developed for generating demand for domestic timber. Japan has been estimated to possess sufficient forest resources to eliminate the dependence on imported timber, which provides 80% of the current domestic demand. Unlike the conventional approach of human communities in which resources are being utilized in ways convenient to the rhythm and pace of economic activities, economic activities in future communities will have to adapt to the environmental rhythm of resources. In this regard, large-scale inputs of forest resources (timber) into urban areas will need to be taken into consideration for the foreseeable future. Urban areas that enjoy the multiple services provided by forests have an obligation to actively promote wood utilization in their design.

Keywords. Environmental Conservation, Ecological Material, Sustainable Development, Wood Utilization, Urban Design

INTRODUCTION

The latter half of the twentieth century, starting with the end of the World War II following the unconditional surrender of Japan, is characterized by the abandonment of military expansion and the pursuit of economic prosperity. "Engineering", which had held an important position in Japanese modernization since the late nineteenth century, made an unexpectedly significant contribution to this development by promoting the social infrastructure that provided the foundation of economic activities and providing a livelihood for large segments of the population. During this period, no one questioned the necessity of bureaucracy-led social infrastructure projects such as those for the construction of the Tokaido Shinkansen and the Meishin-Tomei Expressway.

At the beginning of the twenty-first century, many adverse effects of this development have however started to surface. The aggravation of environmental issues such as global warming, acid rain, deforestation, and desertification are increasingly being brought to the public's attention, raising awareness of environmental conservation issues at an accelerating pace. This sense of crisis is driving people to demand social mechanisms that allow us to live in harmony with the environment as well as the transition to a recycling-oriented society. The Kyoto Protocol adopted at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 3) held in Japan in 1997 sets specific targets for reducing emissions of greenhouse gases such as CO_2, while also providing a mechanism to measure CO_2 absorption by forests. This has helped to gradually increase public awareness of the positive environmental effects connected to forest and timber utilization, which include the fixation of CO_2 by forests, the storage of CO_2 by wooden structures, energy conservation through the utilization of timber, and energy substitution by the burning of timber. Legislation such as the Forest and Forestry Basic Act (revised in 2001) and Biomass Nippon Sogo Senryaku (Comprehensive Strategy for Utilization of Biomass) endorsed by the Cabinet in 2002 can also be considered to be based on a sense of urgency regarding the need to achieve these goals and to ensure a sustainable development of the country in the coming century.

CURRENT STATUS OF FORESTS IN JAPAN

Of the total land area of Japan, 66% (25 million of 38 million ha) is covered by forest, making Japan one of the most heavily forested countries in the world. Planted forest established under the forestry expansion policy implemented during the reconstruction period following World War II accounts for approximately 40% (10 million ha) (Figure 1). While forest expansion flourished until the 1970s, the number of related projects has decreased since then and has dwindled to almost nothing in recent years. Reforestation of cleared planted forest with conifers is also decreasing due to the forestry industry's prolonged recession. Although an age classification of Japanese planted forest displays a beautiful standard distribution curve (Figure 2), the lack of young forest can nevertheless pose a serious challenge, since this implies that harvestable planted forest will have disappeared within 50 years, rendering it impossible to maintain sustainable planted forest resources.

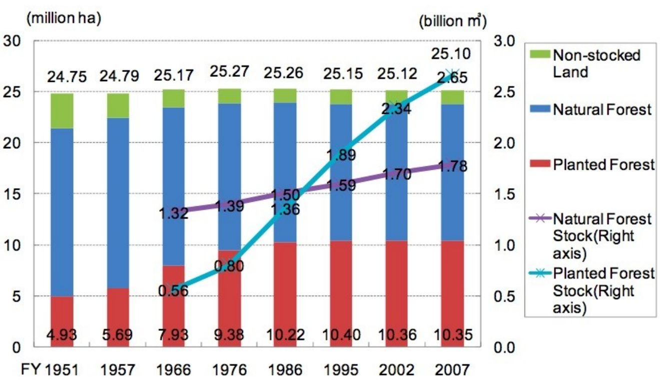

Figure 1. Planted forest area and natural forest area in Japan (Source: Forestry Agency)

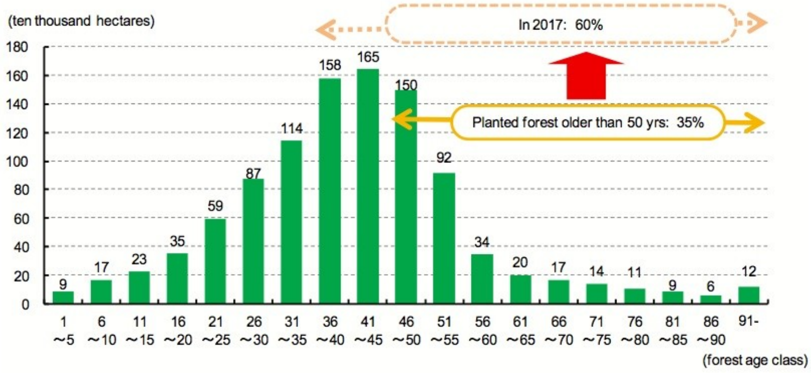

Figure 2. Distribution of planted forest area by forest age class (Source: Forestry Agency)

The extent of forested areas in Japan has not changed between 1951 and 2007 (Figure 1). Planted forest area has also remained almost the same since the end of forestry expansion. The amount of accumulated forest resources, on the other hand, has increased five-fold from 500 million m^3 in 1960 to 2.5 billion m^3 in 2007 (Figure 3). The degree of timber self-sufficiency in Japan, however, has remained almost unchanged (20%) since 1995. While there are some indications that this value may increase to 30%, this is solely due to a recent decrease in the total supply, which is demonstrated by the fact that the supply of domestic timber has remained constant at around 20 million m^3 since 1997 (Figure 4).

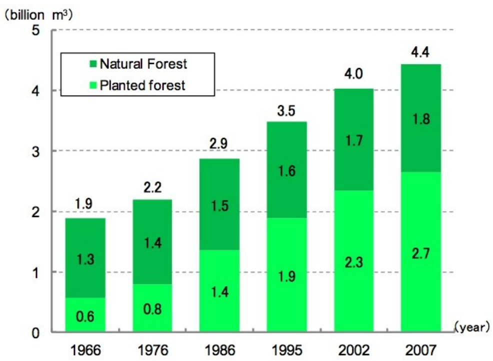

Figure 3. Forest resources in Japan (Source: Forestry Agency)

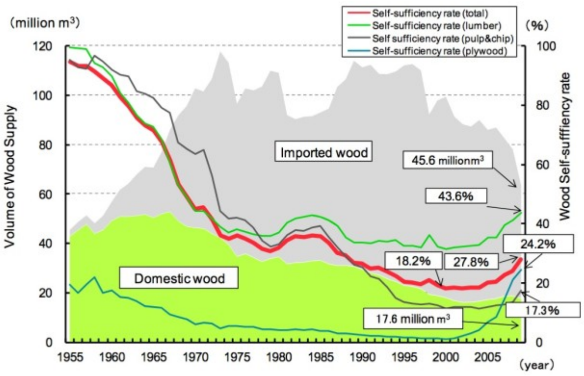

Figure 4. Supply of domestic wood and wood self-sufficiency rate in Japan (Source: Forestry Agency)

The basic principle is that harvesting must not exceed annual forest growth volume to ensure the sustainability of forest resources. Excessive harvesting refers to the removal of forest resources exceeding the annual growth volume. Is it likely that the self-sufficiency target of 50% set by the Forest and Forestry Revitalization Plan will lead to excessive harvesting? Annual growth volume of planted forest has steadily increased until 1986 and has remained in the vicinity of 60 million m^3 since that time. On the other hand, annual timber harvest has gradually decreased until 2002, remaining in the vicinity of 20 million m^3 since then. Although it might seem as if excessive harvesting has happened before 1976, this is because the harvest from natural forest is also included in the annual harvest. The annual growth volume of planted forest in 2007 was 62.7 million m^3, which is almost equivalent to the same year's timber supply (63.2 million m^3). This indicates that a self-sufficiency rate as high as 90% (59.9 million m^3) is achievable at the current state. Even if the demand for timber should increase in the future, an annual production of 56 million m^3, which is equivalent to 50% of the total timber supply in 1995 when it peaked at 112 million m^3, is still fully achievable. The self-sufficiency target of 50% set by the Forest and Forestry Revitalization Plan should therefore not encourage excessive harvesting even if the current timber supply doubles.

Despite these abundant forest resources that have accumulated within the country, Japan depends on imported products for 80% of its timber demand, making it the second largest importer of timber after China.

TIMBER AS AN ECOLOGICAL MATERIAL

The term "sustainable development" describes a kind of development that does not destroy future possibilities. The materials that support our lives need to be considered within this context of sustainability and harmony with the global environment. The idea of "ecological materials" or "environmentally harmonious materials" has emerged from this thinking process. The characteristics of an ecological material should include (1) small energy input required for production and processing, (2) no environmental pollution is generated during production processes, (3) it can be recycled, (4) waste materials produced by usage or disposal can be recycled, (5) no environmental pollution is produced during final disposal of waste materials, and (6) it can be manufactured sustainably.

Timber has the potential to meet these requirements. Trees in forests absorb atmospheric CO_2 and fix carbon through photosynthesis. Carbon fixed and stored in a tree remains even after the tree is processed as timber. Civil and architectural structures using timber therefore also serve as carbon storage tanks. New trees planted in cleared areas will also absorb carbon as they grow. Although timber will eventually release carbon back into the air through combustion and decay after several cycles of re-use, this does not necessarily have a net negative effect on the environment, since merely the carbon that had previously been absorbed as a tree is returned into the air. This is the rationale for the concept of "carbon neutral".

The Amount of Energy Used to Manufacture Different Types of Materials. Timber and wooden materials require less energy in processing than do other materials. Table 1 shows the amount of energy entailed in manufacturing different types of materials along with the associated carbon emissions (Buchanann, 1990; Nakajima, 1991). The production of aluminum is known to require a significant amount of electricity; the amount of energy is considerably larger than for other materials, followed by steel and paper (Table 1). The same holds true for the amount of carbon released in production. By replacing aluminum and steel with timber, it is possible to considerably reduce the carbon emissions in production, thus contributing significantly to the reduction of the environmental impact.

The right-hand column of Table 1 shows the difference between the amount of carbon fixed and stored in timber (which is equivalent to the amount of carbon absorbed from the air during growth) and the amount of carbon released in production. In Table 2, timber and steel beams are compared by applying this calculation to the actual use of materials in a structure (Buchanann, 1990; Nakajima, 1991). Steel members having the same (or equivalent) performance to large cross-section laminated timber beams require 3.2 times more energy in production than laminated timber and release 2.7 times more carbon (28 kg) into the air during their production: in addition, timber beams will retain 8 kg of carbon that was previously absorbed during tree growth. The difference in carbon release between equivalent steel and timber beams amounts to 36 kg, indicating that by replacing 1 kg of steel beams with timber beams, it is possible to reduce carbon emissions by 0.9 kg.

Table 1. The Amount of Energy Consumed to Manufacture Different Types of Materials with Associated Carbon Emissions

Type of Material	Amount of fossil fuel energy consumed		Amount of carbon released in production		Amount of carbon stored in manufactured product	± Amount of carbon
	MJ/kg	MJ/m^3	kg/t	kg/m^3	kg/m^3	kg/m^3
Air dried lumber (specific weight: 0.50)	1.5	750	30 (32)	15 (16)	250 *1	-235 -234
Kiln dried lumber (specific weight: 0.50)	2.8	1,390	56 (201)	28 (100)	250 *1	-222 -150
Laminated wood (specific weight: 0.55)	12	6,000	218 (283)	120 (156)	248 *2	-128 -92
Particle board (specific weight: 0.65)	20	10,000	308 (345)	200 (224)	260 *3	-60 -36
Steel	35	266,000	700	5,320	0	5,320
Aluminium	435	1,100,000	8,700	22,000	0	22,000
Concrete	2.0	4,800	50	120	0	120
Papter	26	18,000		360		

Figures in brackets ( ) include the amount of carbon released through the use of heat energy by burning waste

*1, *2, *3 :Calculated with a carbon content of 50, 45, and 40%, respectively.

± Amount of carbon: The amount of carbon released in production minus the amount of carbon stored in production

Table 2. Amount of carbon consumed in production with associated carbon emissions compared between timber and steel beams

	Large cross-section beam (values per square meter)	
	Steel 31 OUB 40	Laminated timber 550 x 135 mm
Weight (kg)	40	37
Energy per unit weight (MJ/kg)	35	12
Production energy (MJ)	1,400	444
Carbon release (kg)	28	10.5
Carbon storage (kg)	0	18.5
Carbon release - carbon storage (kg)	28	-8
Difference in carbon release (kg)	36	
Reduction in carbon release by replacing steel with timber (kg)	0.9	

As a more specific example, this approach can be applied to a wooden road bridge over the Mur River in Steiermark, Austria (Figure 5). This 85-meter, three-hinged arch bridge is the largest wooden bridge in Europe. Although the design itself might seem relatively ordinary, the fact that it is constructed of timber rather than steel or concrete makes it a significant engineering achievement. The main structure of the bridge was built using 300 m^3 (210 tons) of laminated timber. The additional amount of carbon released by constructing the same bridge using 227 tons of steel is estimated at 204 tons (227 x 0.9). Although this is just a rough calculation, it can be argued that the release of a comparable amount of carbon was avoided by the choice of building material. Replacing steel and concrete with timber opens up possibilities for contributing to the overall reduction of environmental impacts.

Figure 5. Murbrücke, a wooden bridge in Steiermark, Austria

DIFFERENT FUNCTIONS OF FOREST AND BENEFITS PROVIDED BY HARVESTING TIMBER

It is sometimes argued that wood utilization creates a dual environmental impact by cutting down trees that would otherwise absorb CO_2 from the air as well as by releasing more CO_2 during further use. Such practices are labeled as environmentally destructive. This argument is, however, incorrect. Logging and harvesting of trees can ensure a permanent cycle of resources if new trees are successively planted in cleared areas to rejuvenate the stands.

Forests provide a wide range of services such as water and soil conservation, watershed protection, ecosystem maintenance, timber production, and landscape and environmental conservation. While some types of forest should be preserved for ecological functions, others need however to be logged and harvested to ensure a resource production cycle, and these two types of forest must coexist. From a perspective of CO_2 absorption and oxygen generation, natural forest with older age classes is less significant than planted forest with young trees that tend to carry out photosynthesis more actively. Actively logging and harvesting those trees that have reached the appropriate age, followed by replanting of the cleared areas, can therefore reduce the amount of atmospheric CO_2 while allowing timber utilization. In other words, depending on the balance between the amount of CO_2 eventually returned to the air (e.g., through burning) and the amount of CO_2 absorbed by the tree during its growth, it could be possible to reduce the amount of atmospheric CO_2 through the utilization of timber. Long-term uses of timber in particular can have significant effects on the reduction of environmental impacts by delaying the release of CO_2 for considerable periods. For example, Horyuji Temple in Nara has stored carbon for the last 1300 years, helping CO_2 levels in the air to stabilize (Kawai, 1993; Tadaki, 1993).

Forests and their ecosystem functions, as well as timber produced from forests, constitute an enormous resource recycling mechanism, providing significant benefits to humans and other organisms. Humanity should appreciate the value of such a mechanism. Issues such as forest conservation, restoration and rebuilding of forestry, and the need to ensure a more efficient use of timber are likely to increase in importance, requiring new social structures and policies based on the concept of resource recycling. In addition, it would be desirable to ensure more long-term use of timber (products and structures), as well as a mechanism to manage the entire cycle of production, utilization and disposal.

NAGOYA UNIVERSITY'S INCREASED WOOD UTILIZATION IN URBAN DESIGN PROJECT

The Ise Bay Bioregion, where Nagoya University is located, features vast areas of planted cedar and cypress forest. Due to social transformations such as decreasing timber prices and declining workforce, more and more forest areas are however left to deteriorate, causing serious damage to their ecosystems. A fundamental solution for this problem would require, first and foremost, an understanding of the current situation of forest resources within the region, followed by an estimation and evaluation of future timber supply capabilities. An essential part of such an evaluation would be an assessment of the distribution of certain characteristics such as structural timber strength, so that a sustainable scenario could be developed for generating demand in urban areas for timber produced in this region. According to an estimate, Japan has sufficient forest resources to eliminate dependence on the imported timber that supplies 80% of current domestic demand (Takagi, 2009). Unlike the conventional approach of human communities in which resources are being utilized in ways convenient to the rhythm and pace of economic activities, economic activities in future communities will have to adapt to the environmental rhythm of resources. In this regard, large-scale inputs of forest resources (timber) into urban areas will need to be taken into consideration for the foreseeable future - urban areas that enjoy the multiple services provided by forests have the obligation to actively promote wood utilization in their design. To help fulfill this obligation, Nagoya University has launched a research group called "Increased Wood Utilization in Urban Design Project" in collaboration with government officials in the fields of forestry, timber, energy, architecture and urban design. Its purpose is to engage in cross-sectional collaboration toward a fundamental solution to the problems faced by the forestry and timber industries. In the following, we discuss the project's ambit and the problems that may be faced in the effort to revitalize forest and forestry.

Research Objectives. The project has identified the following four challenges as requiring immediate attention:

1) Development of a plan to forecast demand for a required quality of timber: Identify the appropriate proportion of plantations based on the demand forecast and the forestry data of the region, and evaluate the potential for timber utilization.
2) Case study on timber utilization: Obtain logs from the local forestry cooperative, establish problems likely to be encountered in their use, extrapolate from these, and share the solutions.
3) Cooperation between rural and urban areas: Deepen the understanding between producers and users (i.e., builders) to establish a mutual framework and develop human resources.
4) Identify a fair timber price: Identify a fair price for timber to enable sustainable forestry.

For objectives (1) and (2), we used 45-year-old cedar logs harvested from a typical cedar plantation in Toyota City (Figure 6). As the objective was to promote the efficient use of forest resources, we did not pick a specific sample of trees and also included possibly lower-quality logs of class IV and V in the survey. A total of 507 logs was surveyed, consisting of 268 logs of classes I–III (top end diameter 217.7 ± 42.2 mm) and 239 logs of classes III–V (top end diameter 137.9 ± 14.3 mm). Logs were classified based on personal information from the forestry cooperative. To evaluate their quality, we measured stress wave velocity, diameter at top and bottom ends, surface moisture content and ring width. As an example of the findings the distribution of stress wave velocity is shown in Figure 7. While stress waves travelled faster in logs of classes I–III than in those of classes III–V, no correlation was found between stress wave velocity and top end diameter. Based on the results of this evaluation, we estimated the distribution of Young's modulus of materials provided by suppliers, using a simulation method. Material input per product unit (m^3/m^2) of different houses (based on information provided by four house builders) was calculated to estimate Young's modulus of timber used in house construction, following JAS standards and existing databases of structural strength. The comparison of material quality between supply and user side indicated a gap between the performance required by house builders and the quality of materials provided by suppliers. This underlines the importance of finding an appropriate balance between forest management and timber utilization, by generating a forecasting simulation of both the quantity and quality of future timber production, based on the estimated number of houses to be constructed and the predicted growth rate of forest resources.

Figure 6. Japanese cedar logs (507 logs, 58 m^3)

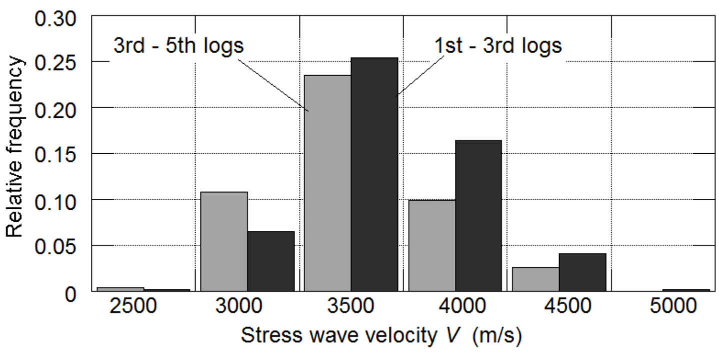

Figure 7. Stress wave velocity in Japanese cedar logs

In the case study on timber utilization, we selected the following four uses among those suggested in the project to investigate possible emergent problems, extrapolated from these, and then shared the solutions:

a) Use as an exterior material in houses in residential areas
b) Use in the renewal conversion of existing houses
c) Construction of the roofed bicycle shelters next to the E&S Building at Nagoya University
d) Flooring of the E&S Building at Nagoya University

Figure 8 shows the flooring and bicycle shelters built using the logs shown in Figure 6. Twelve bicycle shelters of the design shown were built. The flooring was laid in the postgraduate office of the Department of Environmental Engineering and Architecture, where architectural students (future timber users) engage in their research. Prior to the construction, which coincided with the completion of the E&S building, we had to make our case to the parties involved and arrive at an understanding about the use of the timber. Fortunately, we have so far received a reasonable number of positive responses from the users of these facilities, showing that this kind of timber use can be accepted by a wider public. The bicycle shelters in particular have attracted a lot of interest from various sectors and show potential for future development; their use in public facilities as well as in combination with solar panels has been suggested. Follow-up studies are to be scheduled for these four case studies, to clarify a broad range of factors such as problems relating to maintenance and user preferences.

Figure 8. Wood utilization on Nagoya University campus (Cedar flooring and bicycle parking)

To explore the possibilities for enhancing the cooperation between rural and urban areas, we organized a seminar (attended by 120 people) and a forest tour (in Kashimo, Nakatsugawa, Gifu Prefecture; attended by 20 people) from November 31 to December 1 2010 with the aim of discussing a new model of direct cooperation between forestry/lumber/house construction industries. The seminar brought together interested parties in the fields of forestry, lumber manufacturing, construction, public administration, and research, as well as those representing the general public, to discuss such issues as the revitalization of the forestry industry and the need to encourage timber utilization in urban design. While the need to enhance the cooperation between forested and urban areas was expressed by many participants, all agreed that no such opportunities were presently available, and many recognized the importance of ensuring that such opportunities could exist on an ongoing basis. In addition, we proposed a renovation plan for the Chojamachi development based on timber utilization. This was done at a workshop (Figure 9) held in collaboration with the

"Nishiki 2-Chome Community Revitalization Master Plan Organizing Committee" in Sakae, Nagoya, at which 63 participants including forestry/lumber industry representatives, local residents, businessmen, government officials, and researchers gathered to exchange cross-sectoral links and ideas and to visit various people in key positions in Chojamachi, Sakae, Nagoya. Increased wood utilization in roads and the roofs and walls of buildings is expected to improve the atmosphere of the city, while contributing to the ecological and economical health of the timber source. For this reason, the organizing committee has incorporated our "Increased Wood Utilization in Urban Design Project" into their community revitalization program, which has been compiled and distributed as a booklet. As the first step under the theme of "Revitalization of Forest and Reduction of Global Warming through Increased Wood Utilization in Chojamachi", the program aims to renovate the city by laying wood decking on one lane of some roads that are unnecessarily wide by today's standards. This is achieved through productive discussions on cascade utilization and reevaluation of wooden materials between all stakeholders, including representatives from rural areas, forestry industry, construction industry, local communities, and public administration (Figure 10).

Figure 9. Workshop for wood utilization in urban design

Figure 10. Wood material flow in wood utilization in urban design

Emerging Problems. Since the launch of this project about two years ago, our efforts to increase wood utilization in urban design have faced various problems such as legal and operational obstructions and contradictions and a lack of understanding of timber as a material, which are summarized below.

1) Timing of timber supply: Identifying necessary timing and volumes of harvesting in relation to demand has proved difficult, underlining the difference of timber from other industrial products.
2) Issues of cost: Due to deflation in the construction industry, cost considerations tend to be prioritized over other factors such as personal preference and environmental value. A lack of information on maintenance costs also inhibits the utilization of wood.
3) Lack of understanding of cedar as a timber material: A general lack of knowledge about the performance and maintenance of timber is present, together with unrealistic quality expectations regarding natural imperfections and maintenance-free timber products.
4) Lack of an information network linking forest to construction site representatives (such as architects and owners).
5) The need to examine maintenance approaches (in relation to coating and inspection methods): Initial processing, frequency and methods of maintenance, and economic efficiency, among other areas, need to be optimized.

In this project, we have addressed the problems faced by forestry and lumber industries in the Ise Bay Bioregion and Japan in general, through a cross-sectoral collaboration. We hope that increased utilization of domestic timber in urban design will lead to a return of workforce to the forest industry, providing solutions to such issues as livelihood stabilization, revitalization of forests and forestry, and environmental conservation. Sustainable production and utilization of timber resources that would allow future generations to do the same is the obligation of anyone living in an urban setting. Increased wood utilization in urban design is essential for the revitalization of forests as well as for maintaining the sustainability of urban environments. It is hoped that this project will contribute to the solution of these issues by encouraging stakeholders to respect each other's roles while fulfilling their own, thus enabling coexistence and co-prosperity of all citizens.

CONCLUSION - ENVIRONMENTAL CONSERVATION AND TIMBER UTILIZATION

Forestry and timber industries cannot be measured with the same yardstick as other industries, as common values based on economy and efficiency do not really apply to them. This is because forests, as well as the timber harvested from them, constitute a natural capital that is formed over a long period of time. To be able to establish a recycling-oriented society rather than just precipitate another environmental resource boom, current values based on intensive energy consumption and pursuing profit maximization must be reexamined and permanently replaced by a new set of values. As an example, Germany, one of the world's most advanced countries in the fields of greenhouse gas reduction and renewable energy, has been placing increasing importance on environmental conservation despite high unemployment rates and unfavorable economic conditions.

Structural design techniques used in timber architecture have gradually disappeared in Japan since the 1950s, due to a significant decline in timber construction. Education and research in this area have long since ceased to exist in this country, until recently compelling us to rely on overseas case studies. Thanks to dedicated efforts by those concerned, large-scale timber architecture has however made a comeback since the 1980s. The cedars and cypresses that form the greater part of Japanese forests have lower strength performance compared to imported timber. To utilize lower-strength timber, simple but technologically highly advanced wooden structures (timber architecture) that are both energy- and cost-efficient and sustainable need to be developed. Improved and increased utilization of lower-quality timber will be the key in this regard, given the current situation of forest resources in Japan. Instead of building the entire structure from timber, hybrid structures combining steel or concrete frames with wooden panels or the use of skeleton-infill units should be considered.

Timber harvested from forests is a natural material that has been employed for a wide range of purposes for as long as soil and stones have been utilized. However, its value as a material has been underestimated due to its ready availability. Unlike other industrial materials manufactured for a specific performance and in uniform qualities, timber varies in quality and requires specific wisdom and knowledge for its full utilization, placing it outside the field of conventional high-tech materials. However, timber structures, which store but do not produce CO_2, are a kind of structure that can exist in harmony with the global environment. We hope that increased timber utilization will promote the establishment of a recycling-oriented society, leading to the revitalization of both forest and forestry.

REFERENCES

Buchanan, A. H. (1990). "Timber engineering and the greenhouse effect." *Proceedings of 1990 International Timber Engineering Conference*, pp931-937

Kawai, S. (1993). "Energy consumption and environmental pollution in timber processing" *The Japan Wood Research Society*, pp. 41-51

Nakajima, S., and Okuma, T. (1991). "Increased timber utilization as a preventative measure against global warming." *Mokuzai Kogyo (Wood Industry)*, Vol. 46, No. 3, pp.127-131

Nishiki 2-Chome Community Revitalization Master Plan Organizing Committee. (2011). "Toward the mixed community (2011-2030)"

Tadaki, Y. (1993). "Global forest ecosystems as material and environmental resources." *The Japan Wood Research Society*, pp. 1-11

Takagi, K., and Sasaki, Y. (2009). "Environmental analysis and timber utilization in the forestry scene of Aichi Prefecture." *Nagoya University Forestry Science*, Vol. 27, pp. 1-18