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Comparison of CO_2 Fixation in Wood Used for Residence Houses in Japan and Korea

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In this study, we have estimated the amount of carbon (C) fixation in wooden materials used for residence house units in Japan and Korea. This type of C fixation might be helpful to prevent the global warming. In year 2000, the amount of C fixation in the wooden materials was approximately 7.3% (150 million C ton) of total forest C accumulation in Japan, whereas in Korea, it was 2.0% (4.3 million C ton) of the total forest C accumulation. The reason is that structural types of the house units on wood utilization in Japan and Korea are clearly different. Japanese have used 90% of wooden materials for their residence houses but Korean house units have built mostly using non-wooden materials such as concrete, bricks, and stones. It has resulted that the number of total houses in Japan is 5 times higher than that in Korea, whereas the amount of C fixed by the wood materials in Japanese house units is 35 times higher than in Korean's. Therefore, to improve C fixation, it might be necessary to increase wooden residence houses and use of the wooden interior or exterior materials in the residence houses, especially in Korea.

INTRODUCTION

The global warming that caused by increase of gas concentration with the greenhouse effect in the atmosphere has been seriously concerned during the last several years. Framework Convention on Climate Change was concluded to reduce and to control the gas concentration causing the global warming at the United Nations Conference on Environmental and Development, Rio de Janeiro, Brazil, in 1992 (Yorimitsu, 1999). However, increasing gas concentration that discharged by energy consumption can not be avoided in Japan and Korea because these countries need to continue the progresses of industrial and economic activities.

Nevertheless, at the 3rd Conference of the United Nations Framework Convention on Climate Change, Kyoto, Japan, on December, 1997, the forest was deeply considered as CO_2 absorption source. After cutting down trees from the forest, as long as it uses as wooden materials for residence house or others, CO_2 can not be discharged from the wooden materials. Therefore, the types of wood utilization become to be relocation of C storage from the forest to the cities (Mitsuhashi, 1997; Arima, 2002). The great potions of

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wood used are mostly for constructing residence houses using a quite amount of lumber and plywood except other uses, such as paper and pulp; thus, most of CO_2 stored in wooden materials is with construction field in the residence houses. However, the amounts of wood used are dependent upon various constructional types for the residence houses. Although the residence houses that constructed using non-wooden materials are continuously increased in Japan, the portion of wooden houses is still more than 60% of total residence houses, whereas the types of residence houses in Korea are mostly non-wooden structures. It results that the function of CO_2 fixation of the residence house is different between Japan and Korea (Choi and Sakai, 2002).

The objective of this study is to estimate the amount of CO_2 fixed in residence houses in Japan and Korea.

MATERIALS AND METHODS

1. Effect of CO_2 Fixation with Wood Utilization

Trees at young stage absorb and store CO_2 in the atmosphere with active growth, whereas at maturity stage, their growing activity is decreased and stopped as similar as its withering stage; however the amount of CO_2 fixed in the trees is not changed. At this stage, the trees can be CO_2 storage, but cannot be CO_2 absorption source because CO_2 absorption is almost equivalent with its discharge. Therefore, it is necessary to find a suitable time for cutting down the trees to be used as wooden materials. Also, then planting, proper management, and thinning for the forest are important factors to improve the activity of CO_2 absorption. These types of forest operation will give us great advantages to continuously use natural sources and to improve the CO_2 accumulation in trees and wooden materials (Nihon Ringyou Chosakai, 1998).

The forest supplies wood which is the most important product. The wood is a source of C storage because it keeps storing the amount of C fixed before cutting down from the forest and even after processing wooden materials for furniture and residence houses. Wood is an eco-material that being reproducible and environmentally safe resource because of as follows:

(1) It is an energy source that can be replaced for petroleum, coal, etc.; thus, after a period of time, the amount of CO_2 gas concentration will be increased.
(2) It is low energy consumption product to process a constructional material as comparing with other materials, such as aluminums and steels. For example, the energy consumption for the processed aluminum and steel materials is 179 and 191 times higher than that for the processed wooden material in 1.0 m^3, respectively (Okuma, 1998).
(3) Use of wooden materials for the residence house is very helpful to prevent the global warming because the wooden materials store C in long-term and save time until the trees at young stage in the forest are grown at maturity stage.
(4) Also, if the wooden materials are recycled, the storing periods of CO_2 in the wooden materials will be increased.

Therefore, use of wood and wooden materials decreases the CO_2 discharge or helps the gas fixation in the atmosphere.

2. Amount of Wood Used for Residence Houses

Physical unit (m^3/m^2) of wood utilization and total amount of wood used based on the constructional methods and the structures of Japanese residence houses are presented in Table 1. According to the results, Wooden Frame Work Construction System (WFWCS) is 0.179 m^3/m^2, Two by Four System (TFS) is 0.169 m^3/m^2 as similar as WFWCS, and followed by Wood-Base Prefabricated House (WBPH). If it becomes non-wooden residence house using concrete, RS & SRC, or S structures, the unit of wood utilization will be significantly decreased (Table 1).

Table 1. Physical unit of wood utilization by housing structure in Japan.

Structure	Construction method		Physical unit of wood utilization (m^3/m^2)	Floor area (1,000 m^2)	Amount of wood utilization (1,000 m^3)	Composition ratio (%)
Wooden	Frame work construction	Single house	0.179	57,433	10,281	74.0
		Apartment	0.126	4,415	556	4.0
	Two by four	Single house	0.169	3,909	661	4.8
		Apartment	0.163	407	66	0.5
	Prefabricated house	Single house	0.103	2,579	266	1.9
		Apartment	0.129	327	42	0.3
Steel	Prefabricated house	Single house	0.062	8,121	504	3.6
		Apartment	0.053	3,940	209	1.5
Concrete	Prefabricated house	Single house	0.048	449	22	0.2
		Apartment	0.033	975	32	0.2
RC & SRC	Conventional construction	Single house	0.032	3,492	112	0.8
		Apartment	0.022	13,080	288	2.1
		Rented apartment	0.014	20,037	281	2.0
S	Conventional construction	Single house	0.045	5,863	281	2.0
		Apartment	0.038	7,825	297	2.1
Total					13,897	100.0

Source: Morita, M. 1994 Forest products economics. Buneido Publishing Co., Ltd, pp. 16–18.

As estimating the portion of total amount of wood used depending on the wooden constructional methods, WFWCS is 78% and TFS including WBPH is 85%. On the other hands, the most portions, 87%, of wooden materials are used with single house units including non-wooden houses (Morita, 1994).

The methods for estimating the physical unit of wood utilization for wooden and non-wooden residence houses based on different housing structures are described as follows: Most of wooden residence houses are single house units, and those houses have been mostly built using WFWCS and TFS. Therefore, the mean value of the physical unit of wood utilization for WFWCS and TFS is 0.174 m^3/m^2 that assumed as the physical unit

of wood utilization for wooden residence houses. For the non–wooden residence houses, such as the single house units and apartments built using concrete, RS & SRC, or S structure, the different residence units are almost similar in the rate; thus, the mean value for the different constructional methods is 0.039 m^3/m^2 that assumed as the physical unit of wood utilization for non–wooden residence houses. However, other values, 0.2 and 0.04 m^3/m^2, are sometimes assumed as the physical units of wood utilization for wooden and non–wooden residence houses, respectively (Arima, 1991; Tonosaki, 1999).

In Korea, there is any specific physical unit of wood utilization for different constructional types of non–wooden residence houses, except for wooden resistance houses. Korean house units have been constructed with steel–concrete structures, which indicated that amount of wood used per floor area in the house unit are very low. The physical units of wood utilization for multistoried apartment, single house unit, townhouse (apartment unit in a private house), and row house that classified in Korean housing statistics are shown in Table 2 (NSO, 2002). Based on the statistical analysis, the single house units without temporary work timber, multistoried apartment, and townhouse are 0.028, 0.016, and 0.008 m^3/m^2, respectively (Table 2) (Kim *et al.*, 2000). The values are assumed as the physical units of wood utilization.

Table 2. A Physical unit of wood utilization by housing structure in Korea

Structure	Physical unit of wood utilization	Total	Finish work timber			Temporary work timber		
			Sub–total	Door & window	Ceiling & Others	Sub–total	Square timber	Plywood
Single house	m^3/m^2	0.074	0.028	0.014	0.014	0.046	0.025	0.021
	(%)	100.0	37.8	19.1	18.7	62.2	33.8	28.4
Apartment	m^3/m^2	0.041	0.016	0.005	0.011	0.025	0.014	0.012
	(%)	100.0	38.7	11.3	27.4	61.3	33.1	28.2
Town house	m^3/m^2	0.046	0.008	0.004	0.004	0.038	0.025	0.013
	(%)	100.0	38.2	14.1	24.1	62.4	44.7	17.7

Source: Kim *et al.* 2000 The collecting system for enhancement of wastewood recycling, Korea Forest Research Institute, pp. 58–63.

3. Estimation of Amount of CO_2 Fixed in House Units

1) Amount of CO_2 fixed in Japanese housing units

The amount of CO_2 fixed in the residence houses in Japan was estimated from Year 2000 data of total number of house units, average floor area per unit, amount of wood used in the house units.

The data for total number of Japanese house units are adopted from those of "the statistical investigation for residence house and land use" that conducted in every 5 years (Statistics Bureau, 2002). The data have showed that the residence houses differentiated by residential or nonresident household and by constructional structures in the number of total house units. However, there is no differentiation with the constructional structures for the house units nonresident household; thus the wooden and non–wooden house units was assumed as equal in ratio. According to the results, total number of houses in Year

1998 was 50,246×1,000 units that can be separated between 32,332×1,000 units of wooden houses and 17,924×1,000 units of non-wooden houses (Table 3).

Table 3. Housing present status in Japan, 1968~1998 (1,000 households)

Year	Average floor area (m^2)	Total	Nonresident household	Residential household		
				Sub-total	Wooden house	Non-wooden house
1968	73.86	25,519	1,393	24,198	22,151	2,047
1973	77.14	31,059	2,328	28,731	24,776	3,954
1978	80.28	35,451	3,262	32,189	26,287	5,901
1983	85.92	38,607	3,902	34,705	26,871	7,834
1988	89.29	42,007	4,594	37,413	27,314	10,100
1993	91.92	45,849	5,106	40,773	27,787	12,987
1998	92.43	50,246	6,324	43,922	28,275	15,647

Source: Statistics Bureau, Japan 2002 [Online] http://www.stat.go.jp

In Year 2000, the number of total houses was 52,151×1,000 units, which also distinguished between 33,097×1,000 units (63%) of wooden houses and 19,054×1,000 units (37%) of non-wooden houses. The year 2000 data for the residence house units has been calculated using the total number of house units in 1998 and the net numbers of house units between the numbers of house newly built and destructed from Year 1999 to 2000. The average floor area per a house unit might be increased about 93 m^2 as comparing with Year 1998 data;

Thus, total floor area: 52,151×1,000×93 m^2=4,850,043×1,000 m^2

1) Floor area for wooden houses: 33,097×1,000×93 m^2=3,078,021×1,000 m^2

2) Floor area for non-wooden houses: 19,054×1,000×93 m^2=1,772,022×1,000 m^2

Amount of wood used in the residence houses has been estimated by use of the amount of wood used per 1.0 m^2 of floor area in wooden and non-wooden houses with the data for physical unit of wood utilization shown in the previous section. The physical units of wood utilization for wooden and non-wooden houses were 0.174 and 0.039 m^3/m^2, respectively, and those values will be multiplied with values for floor area, then the amount (m^3) of wood used can be calculated as follows:

1) Wooden materials used in wooden houses: 3,078,021×1,000 m^2×0.174 m^3/m^2
=535,576×1,000 m^3

2) Wooden materials used in non-wooden houses: 1,772,022×1,000 m^2
×0.0385 m^3/m^2=69,109×1,000 m^3

The amount of carbon in wood used for the residence houses can be estimated using the results presented above because the amount of C in 1.0 m^3 of wood was 500 kg after removing water contents, and then 1.0 kg of wood contained 0.5 kg of C. Therefore, the amounts of C fixed in the house units are as follows (Okazaki and Okuma, 1998; Nihon Ringyou Chosakai, 1998):

1) C fixed in wooden houses: 535,576×1,000 m^3×0.5 ton/m^3×0.5
=133,894×1,000 ton (A)

2) C fixed in non-wooden houses: 69,109×1,000 m³×0.5 ton/m³×0.5
=17,277×1,000 ton (B)

3) C fixed in the total residence houses: (A)+(B)=151,171×1,000 ton

Those results indicated that total amount of C fixation in wooden materials used for Japanese residence houses in 2000 was 150 million C ton that fixed mostly in wooden residence houses. In addition, as the amount of C fixed in the forest is approximately 1,100 million C ton, the amount of C fixed in wooden materials for houses was 7.3% of total forest C accumulation. Also, the amount of C fixed in residence houses has been continuously increased, which is that 80 million C ton in 1968, 110 million C ton in 1978, 130 million C ton in 1988, and 150 million C ton in 1988; thus the C fixation influenced 70 million ton of CO_2 reduction in the atmosphere during the last 32 years (Fig. 1).

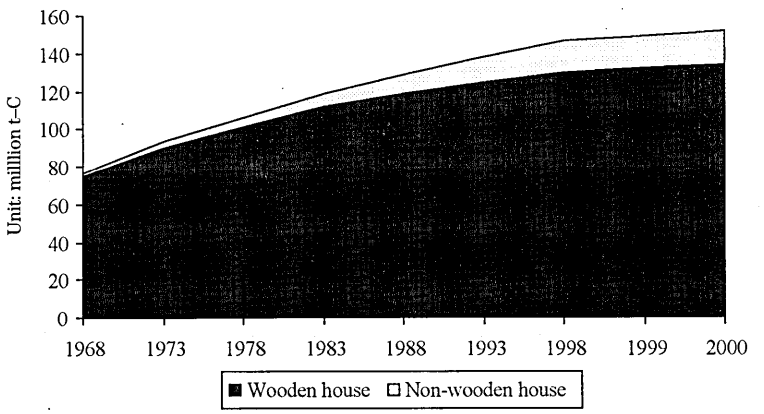

Fig. 1. Amount of CO_2 fixed in Japanese housing units, 1968~2000.

2) Amount of CO_2 fixed in Korean house units

The number of total house units in Korea is different as comparing with that in Japan; thus there is no statistical data based on the structures of residence houses. Therefore, we have used the data obtaining from "Housing Statistics in Population" that investigated in every 5 years (NSO, 2002). The data contained the number of housing units in details, such as single house unit, multistoried apartment, and townhouse in different housing types. The numbers of total housing units in Korea based on Year 2000 data are 10,959×1,000 units, and average floor area per a housing unit was 81.57 m² (Table 4). The potions of different types of houses were 37% with single house units, 48% with multistoried apartments, and 15% with townhouses. Therefore, total floor area was 10,959×1,000×81.57 m²=93, 926×1,000 m². The floor area depending on different types of housing units is as follows:

1) Floor areas for single house units: 4,069×1,000×81.57 m²=331,908×1,000 m²

2) Floor areas for multistoried apartments: 5,231×1,000×81.57 m²
=426,693×1,000 m²

Table 4. Housing present status in Korea, 1970~2000 (1,000 households)

Year	Average floor area (m^2)	Total	Housing structure		
			Single house	Apartment	Town house
1970	65.54	4,359	4,155	33	171
1975	66.38	4,734	4,382	89	263
1980	74.64	5,319	4,652	374	293
1985	75.63	6,104	4,719	822	563
1990	84.21	7,160	4,727	1,628	805
1995	80.58	9,205	4,337	3,455	1,413
2000	81.57	10,959	4,069	5,231	1,659

Source: National Statistical Office, Korea 2002 [Online] http://www.nso.go.kr

3) Floor areas for townhouses: $1,659 \times 1,000 \times 81.57\ m^2 = 135,325 \times 1,000\ m^2$

The amounts of wood utilization per $1.0\ m^2$ of floor area are $0.028\ m^3/m^2$ for single house unit, $0.016\ m^3/m^2$ for multistoried apartment, and $0.008\ m^3/m^2$ for townhouse. The amounts of wood used in the different types of house units were estimated as follows:

1) Wood used in single house units: $331,908 \times 1,000\ m^2 \times 0.028\ m^3/m^2$
$= 9,293 \times 1,000\ m^3$

2) Wood used in multistoried apartments: $426,693 \times 1,000\ m^2 \times 0.016\ m^3/m^2$
$= 6,827 \times 1,000\ m^3$

3) Wood used in townhouses: $135,325 \times 1,000\ m^2 \times 0.008\ m^3/m^2$
$= 1,083 \times 1,000\ m^3$

The amounts of C fixed in the different types of house units were estimated as follows:

1) C fixed in single house units: $9,293 \times 1,000\ m^3 \times 0.5\ ton/m^3 \times 0.5$
$= 2,323 \times 1,000$ ton (A)

2) C fixed in multistoried apartments: $6,827 \times 1,000\ m^3 \times 0.5\ ton/m^3 \times 0.5$
$= 1,707 \times 1,000$ ton (B)

3) C fixed in townhouses: $1,083 \times 1000\ m^3 \times 0.5\ ton/m^3 \times 0.5 = 271 \times 1,000$ ton (C)

4) C fixed in total residence houses: (A)+(B)+(C)$= 4,301 \times 1,000$ ton

According to the results shown above, total amount of C fixation in wooden materials used for Korean residence houses in 2000 was 4.3 million C ton that associated 54% with single house units, 40% with multistoried apartments, and 6% with townhouses. The amount of C fixed in wooden materials for residence houses was 2.0% of total forest C accumulation that was approximately 201 million C ton. Also, the amount of C fixed in residence houses has been continuously increased from 1.9 million C ton in 1970 to 4.3 million C ton in 2000 with increasing housing units such as multistoried apartments and townhouses (Fig. 2). This result indicated that the C fixation affected 2.4 million ton of CO_2 reduction in the atmosphere during the last 30 years.

RESULTS

According to this study, we found that the amount of C fixed in residence houses in

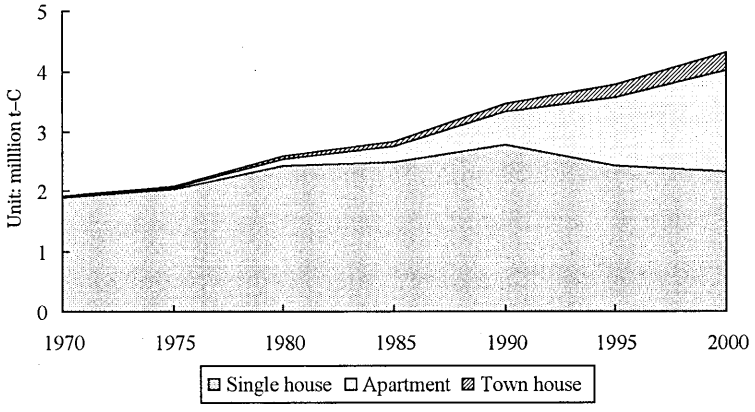

Fig. 2. Amount of CO_2 fixed in Korean housing units, 1970~2000.

Japan was approximately 7.3% of total C fixed in the forest. Ninety percent (90%) of C fixed in the residence houses were mostly with wooden house units; thus the wooden house units can be called as storage of CO_2. However, in Korea, there are mostly non-wooden residence house units that accumulate less C than wooden houses do. Nonetheless, the amount of C fixed in the house units in Korea was 4.3 million C ton that is 2.0% of the total forest C accumulation. In particular, the amount of C fixed in multi-storied apartment units has been remarkably increased because the apartment units were conspicuously increased in Korea since the mid or end of 1980s. Although the structures of housing units functioned as C fixation are clearly different between Japan and Korea, use of wooden materials in the housing constructional field is very helpful to prevent the global warming because it is a source of CO_2 fixation.

On the other hand, the number of house units has been affected by population and economical activities of people involved. If the population is decreased or there is in economic slump, the supply of residence house will be decreased. According to the announcement of "National Institution of Population and Social Security Research" in 1997, Japanese population will be the highest in 2007, and then it will be decreased (The Tokyo Foundation, 2001). In Korea, the rate of house supply reached 100% in 2002, which mean is that a group of family household statistically owned a house (SERI, 2000). Therefore, there will be no more remarkable increases of house units unlike it happened in previous years. Because of this reason, we cannot expect marked increase of the C fixation by use of wooden materials in the housing constructional field.

Therefore, the possible way to increase the C fixation in houses is with increase of the amount of wood utilization in new house units built in every year. With this possible method, wood stocks in house units will be continuously increased. There are two possible solutions in the method: 1) wooden houses that contain woods, such as pillar and post, as much as possible are needed to be built; 2) wooden materials for wall, interior or exterior materials, and others in the house units are need to be used to increase the

amount of wooden materials used per floor area. These possible solutions are important to efficiently increase the C fixation in house units; especially, the latter is very efficient solution in Korea because there are mostly non-wooden houses using steel and concrete structures.

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