The Use of Woody Constructions for Strip Roads Based on the Durability of Used Woods

O. Iwakawa[1]
Shizuoka University
Shizuoka City, Japan

ABSTRACT

This research discusses the possibility of using woody constructions, for example retaining walls, based on the durability of used wood for strip roads under long-term use. Used woods having a reliable record were adopted as samples. Their durability was compared with that of fresh wood (as standard samples) by means of Brinnel hardness, compression strength and bending strength. Visually, three layers were seen from the dug-out roundwood cross-section: a decayed sapwood, discoloured sapwood and sound heartwood. From the results of three tests it was confirmed that the heartwood was still sound in spite of 17 years of use.

Keywords: *strip road, retaining wall, woody constructions, utilization of thinning trees, durability of used wood.*

INTRODUCTION

Japan now has a lot of man-made forest, about 10 million hectares, mainly consisting of Japanese Hinoki (Chamaecyparis Obtusa) and Japanese Sugi (Cryptomeria Japonica D.Don), so that effectively utilizing the thinning trees produced on site is very important to Japanese forestry.

This paper discusses only the use of Japanese Hinoki. In building a lot of strip roads, the use of wood materials, especially thinning trees, for road construction would decrease the building costs, because the earth moving volume decreases markedly by this method. As a result, the forest environment would be well maintained.

In order to recommend foresters to adopt this method, however, the durability of used wood materials has to be confirmed. Unfortunately, the author could not find useful data determining the aging of wood from past literature.

Since the research samples which have a reliable record were fortunately obtained from the very old woody retaining walls at site, this research was started for the following two purposes: first, to know the possibility of woody constructions based on the durability of used wood; and second, to use a lot of thinning trees as materials for road constructions.

The durability of used wood was compared with that of fresh wood as standard samples. Discussion is focused on the durability of used wood by means of Brinnel hardness value, Young's modulus in compression perpendicular to the grain of wood, and bending strength, Young's modulus.

EXPERIMENTAL METHODS

For the purpose of this test, 22 roundwoods were dug out from the woody retaining walls or sheathing works built in 1971. Those timbers were from thinning trees cut while building the strip road. The appearance of the wood before digging out from retaining walls at site is shown in Photo 1. The author considered the following conditions while digging out roundwoods: difference in moisture at places where retaining walls were located and depth from the ground surface as seen in Table 1, because it was assumed that the degree of deterioration of wood materials was due to these conditions.

Many samples were made from the dug out roundwood in lengths of about 1 metre. First, boards were cut into a thickness of 2.5 cm including the pith of roundwoods. Second, boards were placed in an artificial drying room in order to obtain a constant moisture condition, 9% for both used wood and fresh wood. Third, final test pieces were cut into sizes according to the following three test methods: Brinnel hardness test; compression test; and bending test. The method of making test pieces is shown in Figure 1. The Brinnel hardness test was done at points having symbols of X as seen on a 10 cm board in Figure 1.

The size of test pieces was 2x2x4 cm for the compression test and 2x2x28 cm for the bending test. Regarding the compression test, the load condition

[1]*The author is a Professor, Department of Forest Resources Science, Faculty of Agriculture.*

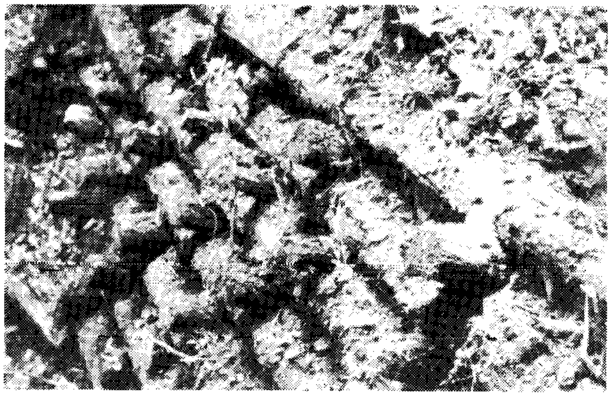

Photo 1. An example of retaining wall built for protecting roadsides 17 years ago.

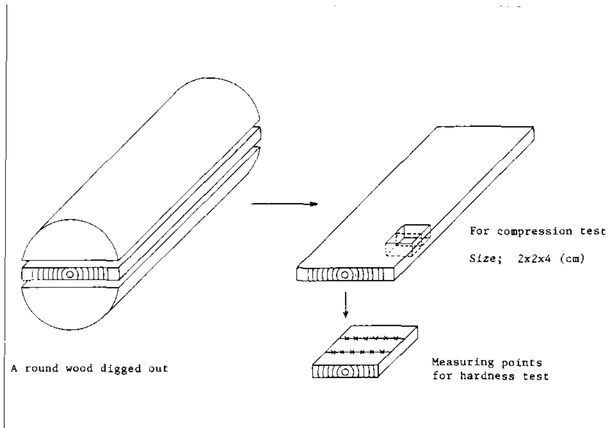

Figure 1. Test pieces prepared.

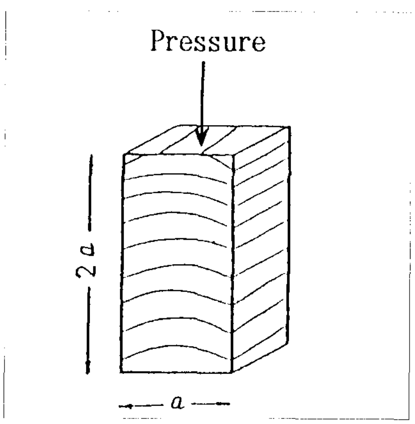

Figure 2. The relation between the inclination of annual rings and load direction in compression test.

to annual rings is shown in Figure 2, since the compression strength perpendicular to the grain was important for the purpose of retaining walls.

The Young's modulus in the proportional limit was used to evaluate compression strength and bending respectively. It is true that the compression strength is important, but the strength of the compression perpendicular to the grain is impossible to measure due to the unlimited deformation of materials toward power direction.

The Young's modulus was adopted due to this fact. All values of the three test methods were calculated from the generally used formula.

RESULTS AND DISCUSSIONS

1. Results of Tested Roundwoods

Twenty-two roundwood samples, cut in lengths of about 1 metre, were used, and consequently all of them were clear enough to distinguish between heartwood and sapwood through their cross-sections. In addition, they still contained a strong perfume, or smell characterized by Japanese Hinoki. Most of the sapwood exposed to the air during 17 years of use were observed to decay. On the other hand, the sapwood from the buried roundwood was considerably stable. However, in the case of heartwood, both exposed and buried were stable. Photo 2 shows an exposed wood (A_1) and buried woods (A_2, A_3) dug-out at site, and Photo 3 a used roundwood, B_3 laid at about 70 cm below ground surface. Three visual layers were particularly seen in the roundwood cross-section: a stable heartwood,

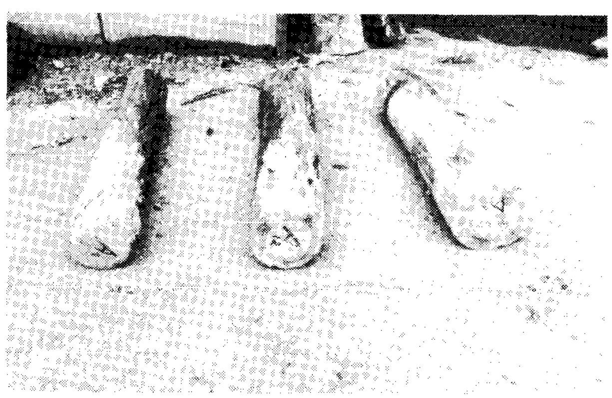

Photo 2. Samples of A_1, A_2 and A_3 dug-out at wet place.

Table 1. Factors and their levels to analyze the Brinnel hardness value.

Factors	Factor's level		
Collected place and moisture condition (X_i)	X_1 : A	wet place	retaining wall
	X_2 : B	wet place	"
	X_3 : C	dried place	"
	X_4 : D	dried place	"
	X_5 : E	wet place	"
	X_6 : F	dried place	"
Situations of roundwood (Y_i)	Y_1 :	wood exposed to the air	
	Y_2 :	wood buried into the ground	
Part of wood (Z_i)	Z_1 :	heartwood	
	Z_2 :	sapwood	

Note: For example, A is divided into A_1, A_2 and A_3. Regarding the depth from surface, A_1 = 0 cm, A_2 = 40-50 cm, A_3 = 80-100 cm.

Table 2. Results of variances analysis regarding the Brinnel hardness value.

Factors	df	ss	ms	F_0		*P*
X	5	1.99	0.40			(%)
Y	1	0.23	0.23			
Z	1	3.73	3.73	16.22	**	26.0
X•Y	5	1.27	0.25			
X•Z	5	0.86	0.17			
Y•Z	1	0.25	0.25			
e	29	4.97	0.17			
é	42	13.30	0.23			
T	**47**	**13.30**				

Note: The symbol ** is significant for 99% confidence limit.

Table 3. Main efficiencies of both factors, sapwood and heartwood.

Factors		Brinnel hardness value
Part of wood	Heartwood	1.30 ± 0.20 (kg•f/mm^2)
	Sapwood	0.73 ± 0.20
Standard wood	Heartwood	1.99 ± 0.20
	Sapwood	0.90 ± 0.20

Note: Standard woods are fresh woods of Japanese Hinoki, (d = 16 cm, 22 cm)

The standard wood was selected from the fresh wood of Japanese Hinoki cut in the same area, because we could not get a standard from the same wood of round one buried 17 years ago.

Photo 3. A used roundwood, B_3 laid at about 70 cm below ground surface. It was with water and visually sound.

a discoloured sapwood and a decayed sapwood. Therefore, the test of wood deterioration was conducted between the stable heartwood and discoloured sapwood.

The decision as to whether the board is stable was based on the process standard that it was possible to make samples with the board. In addition, when showing a stable ratio SR = (width of stable wood/roundwood diameter) X 100, the SR, on average, was 86% for whole roundwoods.

Consequently, it was judged from visual results that all whole heartwood was sound. However, since this judgement is based on unscientific results, the author wants to discuss the durability of used wood from the results of next three test methods in order to confirmthis fact more scientifically.

2. Deterioration of Brinnel Hardness Value

To carry out the Brinnel hardness test, the next experimental designs were formed. The relation between the analysing factors and their levels is shown in Table 1. The measuring points 7 to 9 were placed on each board, and numbers of samples, (n = 181,) were used to analyse the wood hardness.

A final target of this research was to determine also the conditions under which wood constructions could maintain life at site as long as possible. This is the reason why the author included the analysis between factors into the design.

A result as to analysis of variance is shown in Table 2. Furthermore, Table 3 indicates a result regarding a significant factor, heartwood and sapwood. Consequently, the relationship between heartwood and sapwood was significant. On the basis of this result, Brinnel hardness values were shown by comparing used woods with those of standard wood in Figure 3. And besides, Figure 4 shows a result of each level based on the factor Y. It was concluded from this result that buried woods into the ground or in water were much more sound, but the aging of sapwood was in progress at each site. Photo 4 shows a board from buried roundwood.

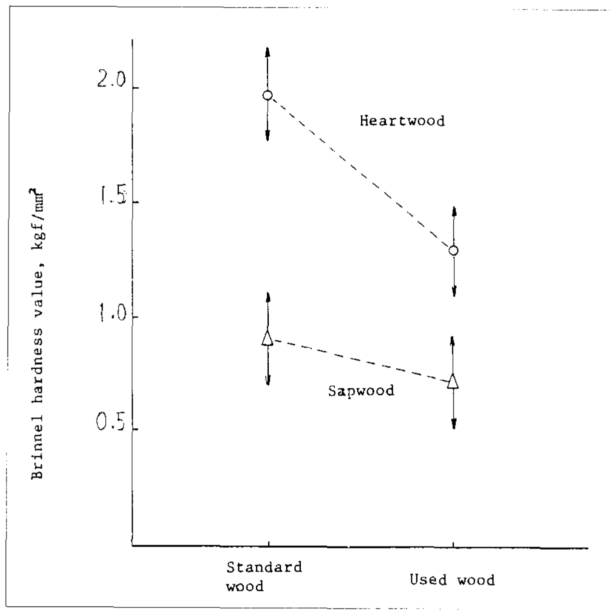

Figure 3. Difference of the Brinnel hardness value between sapwood and heartwood.

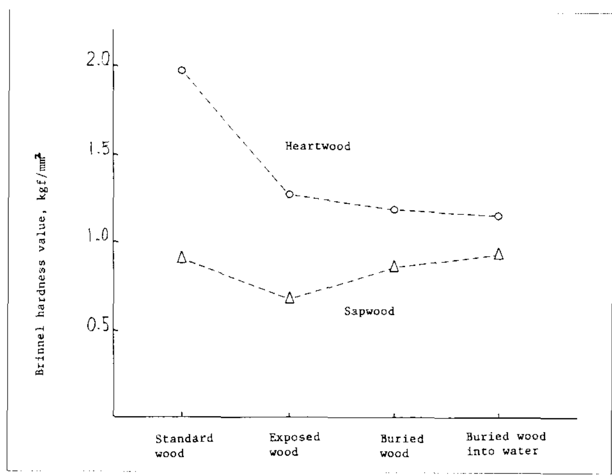

Figure 4. Difference of the Brinnel hardness value between sapwood and heartwood.

Table 4. A result of variances analysis regarding the compression perpendicular to the grain of wood materials.

Factors	df	ss	ms	F_0		*P*
X	3	104.06	34.689	22.303	**	39.4%
Y	1	29.15	29.155	18.749	**	10.9
Z	1	41.04	41.042	26.394	**	15.7
X • Y	3	5.50	1.834			
X • Z	3	17.25	5.751	3.698	*	5.0
Y • Z	1	0.39	0.399			
e	35	54.73	1.564			
é	39	60.63	1.555			29.0
T	47	252.15				100.00

Note: This analyses were done regarding 4 levels, A, B, C, D, in factors X.
The symbol * is significant for 95% confidence limit.

Table 5. Main efficiencies of the Young's modulus in the compression perpendicular to the grain regarding each factor aand level.

Factors		The Young's Modulus
Collected places	A	3.94 ± 0.73 tf/cm^2
(moisture condition)	B	2.93 ± 0.73
	C	6.72 ± 0.73
	D	3.38 ± 0.73
	(S)	5.87 ± 0.47
Situation	Y_1: exposed wood	3.46 ± 0.51
	Y_2: buried wood	5.02 ± 0.51
Part of wood	Z_1: heartwood	5.17 ± 0.51
	Z_2: sapwood	3.32 ± 0.51
	(S) Z_1: heartwood	5.82 ± 0.44
	(S) Z_2: sapwood	5.82 ± 0.98
(Place) x (Part of wood)	A heartwood	4.33 ± 1.03
	A sapwood	3.64 ± 1.03
	B heartwood	4.70 ± 1.03
	B sapwood	1.11 ± 1.03
	C heartwood	7.28 ± 1.03
	C sapwood	6.17 ± 1.03
	D heartwood	4.41 ± 1.03
	D sapwood	2.35 ± 1.03

Notes: (S) is a symbol of standard wood.

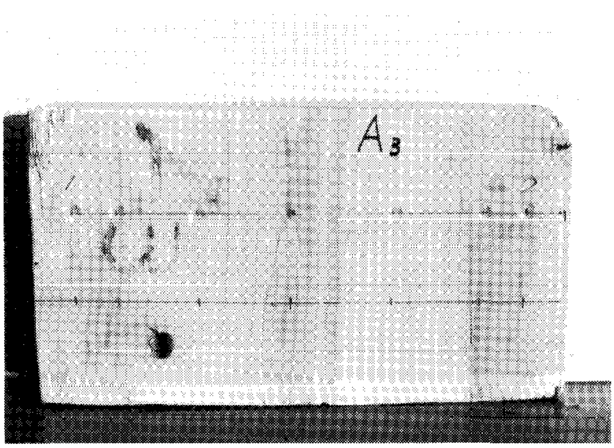

Photo 4. A board, A_3 got from the buried wood.

Judging from the very limited data published in the past by which the Brinnel hardness value for fresh woods of Japanese Hinoki was 1.2 kgf/mm. in average and 0.7 kgf/mm. in minimum [3], we can recognize a fact that these used woods have still maintained the high level of wood hardness in spite of 17 years of use [1].

3. Deterioration of Compression Strength

The measurements were carried out with a lot of test pieces (n = 240) based on the JIS, Z2111. The test pieces (n = 48) which the pressure gets perpendicular to the grain as seen in Figure 2 were used for analysing between factors because the larger the inclination to the grain, the smaller the compression strength.

Table 4 is a result of variances analyses for the compression test. Table 5 shows main efficiencies at each level based on each factor. From the analysis of factor X, an interesting fact was drawn: the Young's modulus was smaller at wet places than in dry places, and B place was the smallest. This result agrees with those of Brinnel hardness value [1]. Comparing woods exposed to the air with woods buried in the ground, the variation of Young's modulus was smaller on the latter, under a condition including whole samples of sapwood and heartwood.

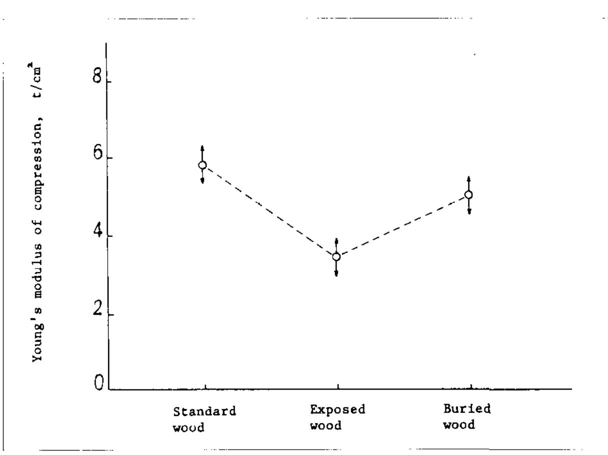

Figure 5. Differences of the Young's modulus in compression perpendicular to the grain of wood.

This relation is clearly seen in Figure 5, but this fact teaches us that the method to isolate wood materials from the air would be practically effective in protecting woody constructions.

This probably depends on the variation of surrounding conditions, that is, temperature, moisture, fresh air, etc. Consequently, it is considered that the buried roundwood has hardly been influenced by the above-mentioned conditions during long-term use.

There are very few reports regarding the compression perpendicular to the grain of wood, especially in used wood. The author could only find Fukuhara's report only on the fresh roundwood, Japanese Hinoki, but it did not include any data of Young's modulus in the proportional limit [4]. However, according to the data about fresh wood, Japanese Sugi, though it is generally inferior to the Hinoki in strength, the value was 6.0 t/cm² while

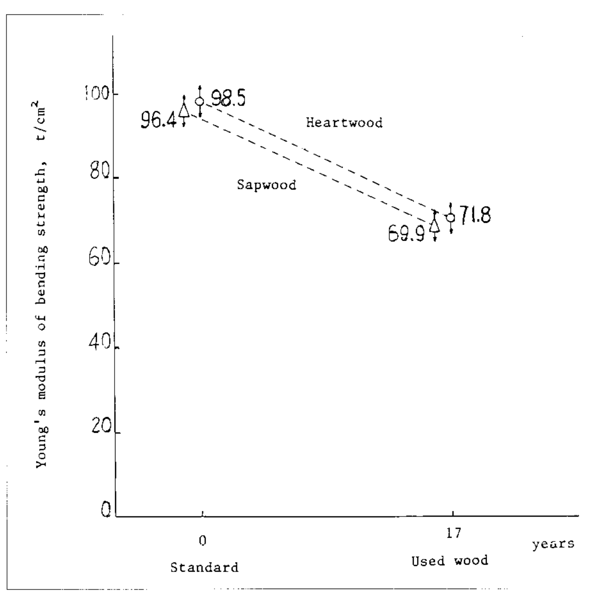

Figure 6. Relation of the bending strength between the stable sapwood and heartwood.

being perpendicular to an annual ring, and 3.0 t/cm^2 at 45° inclination angle [3]. Therefore, it was concluded that these used woods have maintained the high level of Young's modulus.

If roundwoods are used under the condition to be isolated from the air, that is, covered with soil, a retaining wall with roundwood will be good for building the low-cost strip roadas well as from the point of view of protecting wood deterioration [2].

4. Deterioration of Bending Strength

Bending tests were carried out with a lot of samples on the above-mentioned design. Their results were given by Young's modulus after the compression strength as seen in Figure 6.

There was little difference between sapwood and heartwood, and as a whole roundwood it was confirmed that the used woods have maintained the high level of bending strength in spite of long-term use.

CONCLUSIONS

From the aging of wood during 17 years of use, the following conclusions were made: (1) Using the wood materials containing a high percent of heartwood is effective for retaining walls. (2) To protect against the aging of wood, we should adopt a method of construction that exposes wood materials to the air as little as possible. (3) Wood from Japanese Hinoki thinnings are suited to the construction of retaining walls.

If a retaining wall built in siteis well kept and fills its role in excess of 10 years of use, it is expected that banked areas of strip roads will be stabilized both naturally during long terms, and also with sprouting vegetation, over the long term. From this point of view, this result is satisfactory with regards the durability of wood constructions.

SUMMARY

This paper is a discussion on the durability of used roundwoods and the possibility of woody retaining walls based on its result. From experiments, the following conclusions were drawn: (1) The relationship between sapwood and heartwood with test pieces was significant regarding the Brinnel hardness value. From the analysis of the factor X, the Brinnel hardness value in wet places was smaller than in dry place. (2) The Young's modulus of the compression perpendicular to the grain did not significantly decrease in the case of heartwood. According to the result comparing the wood exposed to the air with buried wood, the variation of Young's modulus was smaller by far on the latter. Therefore, it was seen that it is practical to bury wood in the ground as an effective way of delaying the aging of wood materials for the construction of forest and strip roads. (3) The heartwood maintains the high level of bending strength in spite of 17 years of use when compared with the average of fresh wood in Japanese Hinoki, wood.

Judging from the wood subjected to 17 years of use, it was concluded that thinning timbers, made from Japanese Hinoki, were suitable as a material for the construction of strip roads.

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