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Bioresidue Boards Produced from Agricultural Residues and Weeds

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Abstract

This study was undertaken to determine the technical feasibility of fabricating boards from agricultural fibres and weeds. Our investigations revealed that without using synthetic adhesives, very satisfactory results could be obtained. The physical properties of seitaka awadachiso (*Solidogo altissima*), were very outstanding among the weeds under investigation. This weed entered Japan from North America during the Meiji era and has already spread to many parts of the country. Among the agricultural residues investigated, the physical properties of cornstalk were the most promising, with an internal bond strength value exceeding MDF type 5 boards and a low thickness swelling value of 1.4%.

Key words: Bioresidue boards, agricultural residue, weeds, highly pressurized steam, physical characteristics

1. INTRODUCTION

Large volumes of weeded material along roads or riverbanks and agricultural residue are usually generated on a daily basis in many countries and their means of disposal usually poses a threat to the environment. In the Chubu region of Japan, about 80% of weeds cleared along roads and riverbanks (roughly 19,000 t/yr and covering an area of about 39 square kilometers) are burnt to waste. Burning also seems to be a common disposal option for most agricultural residues such as rice straw, rice husk, corn stalk, etc. With recent global concerns on greenhouse gas emissions, many industries are now compelled to pursue ecologically acceptable disposal options such as carbon credit schemes. As a contribution to ease the burden on the environment, our laboratory has been assessing the possibility of fabricating biomass boards mainly from agricultural residue and weeds by means of the high-pressure steam treatment [1, 2, 3] without the use of synthetic adhesives. This paper describes the fabrication process for homogeneous single-layer bioresidue boards manufactured from agricultural residue, namely cornstalk, corn corncob, rice straw, rice husk as well as Seitaka awadachiso (*Solidogo altissima*) and Susuki (*Miscanthus sinensis*), which are two common weeds found along rivers and roads in Japan. The physical characteristics of these bioresidue boards are also analyzed while a further discussion is made on the various practical uses of the bioresidue boards including their use as moisture-retention materials or erosion control structures. The basic fabrication processes are illustrated in Fig I.

2. MATERIALS AND METHODS

2.1 Board preparation

The agricultural residues (rice straw, rice husk, cornstalk and corncob) were all collected from the Gifu University farm while the two weed types (Susuki and Seitaka awadachiso) were slashed along the downstream banks of the Nagara River. Seitaka awadachiso samples were separated into an upper green stem and leaves and a lower brown stem. After oven drying at 105℃ for 3 hours, each residue was milled into smaller particles and sieved through a 2-mm screen. An amount of 600g of the milled material (about 10% moisture content) were placed inside metallic frames lined with Teflon sheets *for fabrication*. The High-pressure steam apparatus

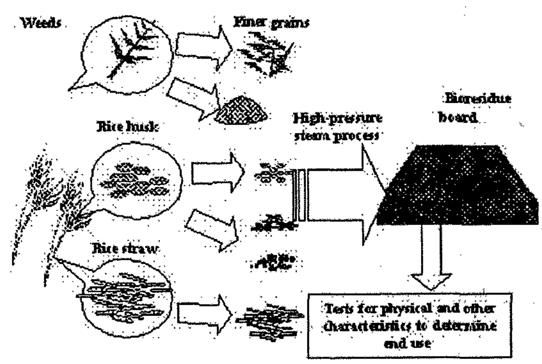

Fig. I Illustration of the fabrication process

	Bioresidue	Density (g/cm^3)	TS (%)
Agricultural Residues	Rice straw	0.83	12.17
	Rice husk	0.79	5.56
	Cornstalk	0.83	1.40
	Corncob	0.90	5.54
Weeds	Upper seitaka	1.10	7.83
	Lower seitaka	0.85	9.20
	Susuki	0.83	11.03

Table I Target densities and Thickness swelling (TS) values for the various boards

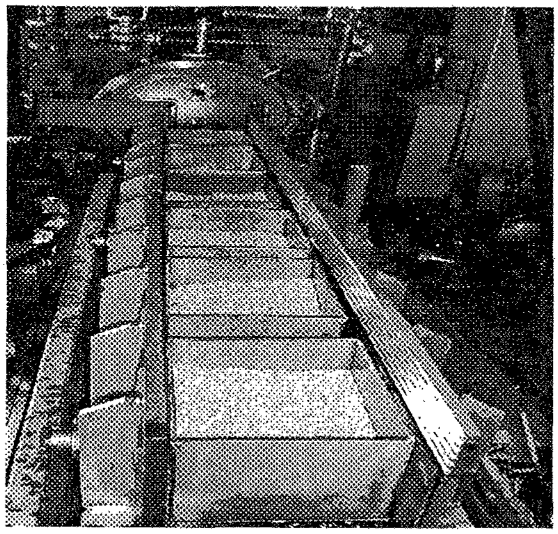

Fig.II. Samples ready to be fed into the high-pressure steam apparatus

(Hisaka made HTP-60/250) with an internal diameter of 60 cm and a depth of 250 cm, a compressor, an intake valve and an exhaust valve (Fig. II). The fabrication processes involved are briefly introduced in the following stages:
Softening stage: Hot steam is initially injected into the chamber to drive away air for 5 minutes. More steam is injected while the temperature gradually rises to 120℃ in 5 minutes. The temperature is then held constant for 10 more minutes with the purpose of softening the mat.
Compressing stage: The softened mats are compressed to a capacity of 1.5MPa resulting in a target density of about 1 g/cm^3.
Fixation stage: In this compressed stage, more steam is injected while the temperature gradually rises to 180℃ within a 10-minute duration and maintained for a further 10 minutes.
The fabricated homogeneous single-layer boards were of dimensions 200×300 mm and 10 mm thick.

2.2 Sample preparation and testing
All boards were trimmed and cut to various specifications for testing. Physical properties such as modulus of elasticity and modulus of rupture, internal bond strength, thickness swelling, and surface hardness in accordance with JIS A 5908-1994. Samples were also prepared for the determination of total carbon and nitrogen contents of the raw materials and boards to see if there had been significant changes arising from the fabrication process.

3. RESULTS AND DISCUSSION

3.1 Board appearance

Each type of board had a peculiar smell and all had different colours from their original materials. Removal from the metallic frames was relatively easier due to the Teflon linings. Boards made from fibres treated under severe steam-explosion usually have a smell, which is an indication of a high degree of hydrolysis or modification of the chemical components during steaming [4].

3.2 Mean density and thickness swelling (TS)
Mean densities for all the various board species are shown in Table 1. Of all the board densities, only that of lower seitaka awadachiso exceeded the target density of 1 g/cm^3 possibly due to the fact that the lower portion is almost a woody material. Results of the percentage increases in thickness (thickness swelling) when samples were immersed in cold water for 24 hours are also shown in Table I. Almost all the boards satisfied the JIS specification of below 12% for all MDF types. In our previous report on boards fabricated from agricultural residues, TS values of 56.93% and 46.98% were obtained for rice husk and straw respectively [5]. Larger particle size boards have a porous structure, which may allow a quicker water uptake and in turn cause the boards to swell.

3.3 Modulus of elasticity (MOE), modulus of rupture (MOR), internal bond strength (IB) and surface hardness (SH)
Table II gives the values of the basic physical characteristics of the boards. As no adhesives and clean fibres were used in the fabrication process, the boards were not expected to exhibit any extreme qualities in bending strength. Nevertheless, the MOE, MOR and IB strength values for the lower portion of seitaka awadachiso were the highest and exceeded the specified JIS values of 0.8 GPa, 5.0 MPa and 196 KPa respectively for MDF type 5 boards. The internal bond strength for the upper portion of seitaka awadachiso was the highest, exceeding the JIS standards for all the MDF board types. Of the agricultural residue boards, the IB value for cornstalk was also very satisfactory. In the determination of internal bond strength, failure occurred in the core of most of the samples, indicating that the particles were more loosely packed in the core than areas near the surface.
Results of the surface hardness test indicates that the SH values were generally low, considering the nature of the original materials. As expected, SH values were highest for upper seitaka and closely followed by lower seitaka. In our previous wok on boards fabricated from

Table II Physical characteristics of the boards

	MOR MPa	MOE GPa	IB KPa	SH MPa
Rice straw	1.19	0.19	27.91	1.34
Rice husk	0.46	0.05	14.16	1.62
Cornstalk	1.67	0.20	299.08	2.26
Corncob	0.26	0.03	157.16	1.61
Upper seitaka	3.27	0.58	526.66	4.47
Lower seitaka	6.57	1.23	340.82	4.52
Susuki	2.07	0.37	57.71	2.85

dried rice husk and straw, SH values of 1.23 MPa and 0.28 MPa respectively were obtained [5]. Tests were performed on both surfaces (top and bottom) of all the samples. During the compression phase of the fabrication process, many finer particles escaped to the bottom, thus resulting in a higher concentration of finer particles and hence a higher top SH values than the corresponding bottom values. This was quite visible when longitudinal sections were made through the samples.

3.5 Total carbon and total nitrogen

The total nitrogen and carbon contents of the boards before and after fabrication were analysed to see if any changes had occurred. As shown in Table III, it can be clearly seen that with the exception of susuki, no significant changes had occurred in both total nitrogen and total carbon for all the materials. While the total nitrogen increased by 26.47%, the total carbon had increased by 45.68%. Apart from this anomaly in the results of susuki, the overall effect of the fabrication process was that of slight decreases in both total nitrogen and total carbon. The upper portion of seitaka awadachiso had the highest content of total nitrogen and a corresponding least C/N ratio.

Table III Total nitrogen and total carbon contents of the materials before and after fabrication

Board type	Total Nitrogen (%)	Total Carbon (%)	C/N ratio
Rice straw	0.53	39.26	74.7
〃 Board	0.47	34.94	73.9
Rice husk	0.40	43.64	110.6
〃 Board	0.35	36.12	104.8
Cornstalk	0.98	46.14	47.2
〃 Board	0.86	42.08	49.7
Corncob	0.38	41.65	110.5
〃 Board	0.30	36.28	120.3
Upper seita	1.38	46.58	33.9
〃 Board	1.14	46.46	41.1
Lower seita	0.25	47.90	190.2
〃 Board	0.23	45.16	192.8
Susuki	0.75	0.75	47.66
〃 Board	1.02	64.73	63.64

4. CONCLUSION

The fabrication of bioresidue boards outlined in this paper was successfully used in producing boards with satisfactory physical characteristics. By using this processing technique, agricultural residue and weeds can be effectively utilized instead of burning. Among the agricultural residue boards, the physical characteristics of cornstalk were the most satisfactory. In a previous work on composites derived from maize fibers and polypropylene, Chow et al, they reported that cornstalk, in particular the outer sections, possesses fiber dimension properties comparable to wood [6,7]. Unlike sawdust, the nitrogen content of boards made from agricultural fibers and weeds are relatively higher. The use of mulches and other materials to suppress weeds that is gaining popularity in recent years is one area where the bioresidue boards may be used. One main disadvantage with the boards is the strong distinctive smell, which usually reduces with the passage of time. As a recommendation, a further analysis of other biomaterials should be explored.

REFERENCES

[1] Ito, Y., Tanahashi, M., Shigematsu, M., and Shinoda, Y., Compressive-molding of wood by high-pressure steam treatment: Part1. Development of compressively molded squares from thinnings., Holzforschung. 52, 211-216 (1998)

[2] Ito, Y., Tanahashi, M., Shigematsu, M., and Shinoda, Y., Compressive-molding of wood by high-pressure steam treatment: Part2. Development of compressively molded squares from thinnings., Holzforschung. 52, 217-221 (1998)

[3] M. Tanahashi, K. Kyomori, Y. Natsume, S. Okawa, S.Onwona-Agyeman, M. Shigematsu, Development of aggregated-wood and assembled-wood by compressive molding process from small logs under high-pressure steam with and without any adhesives., Proc. Of the 5th Pacific Rim Bio-Based Composites Symposium, pp.456-462 (2000)

[4] Laemsak, N. and Okuma, M. 2000. Development of boards made from oil palm frond II: properties of binderless boards from steam-exploded fibers of oil palm frond. J. Wood Sci 46: 322-326.

[5] Onwona-Agyeman, S., Tanahashi, M., Shigematsu, M., Sugi, S. and Itoh, H., Adhesive-free biomass boards fabricated by the high-pressure steam process., Proc. Of the 5th Pacific Rim Bio-Based Composites Symposium, pp.448-455 (2000)

[6] P. Chow, C. T. Bowers, J. A. Youngquist, N. M. Stark, J. H. Muehl and A. M. Kryzysik, Injection-molded plastic composites from maize fibers and polypropylene. Proc. Of the 5th Pacific Rim Bio-Based Composites Symposium, 10-13 Dec, Canberra, pp.638-643 (2000)

[7] R. M. Rowell, R. A. Young, J. K. Rowell (ed). 1997. Paper composites from Agro-based resources. CRC Lewis Publishers pp 446.

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