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PRESERVATIVE TREATMENT METHODS FOR BAMBOO : A REVEIW

PART-II OF BAMBOO SHELTER : A DEMONSTRATION OF BEST CONSTRUCTION PRACTICE

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ABSTRACT

Bamboo, in general, is not durable. It should be treated with preservative chemicals, especially when it is to be used as an engineering material in structures. Treatment methods reported in the literature have been critically reviewed and evaluated in this report. The advantages and disadvantages of each method have been highlighted. Suitable methods, depending on the material (green or dry: round or split), end-use (outdoor or indoor: ground contact or non-ground contact) and availability of infrastructure, have been suggested for treating bamboo. Also, the report lists the existing research gaps.

Keywords: bamboo. treatment, methods, preservatives.

INTRODUCTION

Bamboo has unique features: presence of node, cavity between nodes, reduction' of diameter and wall thickness from bottom to top, reduction of density from outer periphery to inner wall, etc. Because of these features, strength properties vary along the length of the culm as well as across the culm wall. In spite of all these bvariations, bamboo has excellent strength properties. Some bamboos are reported to be stronger than structural timbers.

From time immemorial, man has used bamboo for construction purposes (poles, rafters, trusses, purlins), fence, scaffolding, woven products (mats, baskets), agricultural implements, ladders, props, etc. As bamboo was cheaper than expensive construction materials like timber, steel, etc., it was referred as 'poor man's timber'. Now, efforts are being made to bring out a bamboo building code so as to promote bamboo as an engineering material.

Natural durability

Bamboo, in general, is not durable. Unlike durable timbers, it does not possess toxic extractives to impart natural durability. It is highly prone to attack by biological organisms. Results from the graveyard test conducted by the Forest Research Institute, Dehradun show that the average life of untreated bamboos is less than two years (Kumar et al, 1994). Among different species, there is little variation in durability, even though some species have shown to be more resistant than others. Round bamboo is more resistant than split bamboo. Outer part of the culm is more resistant than the inner part.

Depending on the end-use, the service life of bamboo will vary. For example, when used under cover and out of ground contact, bamboo will last longer, up to 5 years or more. Generally the attack by biological organisms is severer in tropical regions than in temperate regions. For structural uses, whether indoor or outdoor, whether in tropical or temperate region, bamboo should be treated with preservative chemicals to provide adequate service life. For outdoor applications, bamboo should be treated with fixed-type preservative chemicals which are resistant to leaching.

Treatability

In general, the treatability of bamboo is poor mainly because of its anatomical structure. Unlike wood, bamboo has vascular bundles (vessels and thick-walled fibres) which are not uniformly distributed. Smaller but numerous bundles are present in the outer part of the culm while larger but fewer bundles are present in the inner part of the culm. This means that the outer periphery has mostly fibres and the inner part has parenchyma and vessels. Bamboo has no ray cells for taking the preservative across the culm wall. Also, the outer wall is siliceous and hard and is less permeable than the inner layer. Accordingly, the treatability of bamboo varies along the height of the culm and across the culm wall thickness.

According to Liese (1985), as the vessels occupy only 5-10% of the cross-section, the preservatives should have good diffusive properties so as to diffuse from the vessels into the surrounding fibres and parenchyma tissues to ensure satisfactory treatment of the culm. This could be ensured, to a great extent, in a green bamboo. In dried bamboo, the entrapped air in various tissues increases the interfacial tension restricting the flow of fluids (Kumar et al, 1994).

The treatability of bamboo can be significantly improved by ponding. This is mainly because soluble sugars present in the parenchyma cells get leached out or degraded by bacteria.

Literature survey

Different method3 and preservatives for the treatment of bamboo have been suggested in the literature. Purushotham et a1 (1953), for the first time, recommended different preservatives, their concentration and absorption for treating bamboo for various applications. However, nothing was mentioned about treatment method and the recommendations were mostly what were applicable to timber. Narayanamurti and Mohan, in their report brought out by the United Nations, included a table recommending different preservatives for treating green or dry bamboo for indoor or outdoor applications (UN, 1972). The Bureau of Indian Standards brought out a Code of Practice for preservation of bamboo for structural purposes (ISI, 1979). Tewari and Singh (1979) summarized the results of different treatment methods they had carried out for treating bamboo with different preservative chemicals. Practical problems faced in carrying out some of the treatment methods have been highlighted by Liese (1980). Besides these, there have been general articles on bamboo preservation by Casin and Mosteiro (1970), George (1985). Jayanetti (1975). Kumar and Dobriyal (1990). Laxamana (1970). Martawidjaja (1964). Tewari (1981). Wang (1989), etc. Recently, bamboo preservation techniques were reviewed by Kumar et al (1994).

As there is confusion in the names used in the literature for different treatment methods, attempt has been made to standardize the names in the report.

Objectives

The objectives of this report are to evaluate the different methods available for treating bamboo for structural uses and to suggest suitable methods depending on the material (green or dry; round or split), end-use or indoor; ground contact or non-ground contact) and availability of infrastructure (with or without equipment).

METHODS FOR TREATING GREEN BAMBOO

Tree methods based on sap displacement (butt treatment with branches and leaves: butt treatment without branches and leaves, and modified Boucherie) and three methods based on flow of preservatives through diffusion (steeping, double steeping and, steaming and quenching) are evaluated here.

Butt treatment (with branches and leaves)

This method involves keeping the freshly felled culms along with branches and leaves in a standing position in a preservative solution. The butt end, up to 0.25 m, is kept immersed in the preservative solution. As the leaves transpire, the preservative solution is picked up. The preservative solution in the container is made up to maintain the initial level. The treatment normally takes 7 to 14 days. Singh and Tewari (1980) carried out systematic experiments to treat 9.5 m long green culms of Bambusa *polymorpha* and *Dendrocalamus strictus*. They tried copper sulphate and zinc chloride, whereas Jayanetti (1975) tried .copper-chrome-arsenate (CCA) on Bambusa *bambos* and B. vulgaris.

Advantages

Short length bamboo culms can be treated satisfactorily. This method does not call for any expensive equipment and technical Singh and Tewari (1980) reported an even distribution of preservative throughout the wall one month after treatment and also, adequate amount of preservative at the top end.

Disadvantages

Freshly felled bamboo with high moisture content can only be treated. It is a cumbersome method. It is not suitable for species with unwieldy branches or culms which are not straight. There will be loss of preservatives due to absorption in branches and leaves. Liese (1980) reported that in most bamboos the vessels would not take up enough liquid to preserve the surrounding fibres and parenchyma. This method cannot be carried out in a commercial scale.

Butt treatment (without branches and leaves)

This method is similar to the above method. The only difference is that the bamboo culms are cut to right lengths after removing the branches and leaves. Also, this method can be employed to treat split bamboo. The preservative solution rises by wick action as the sap is sucked up. Singh and Tewari (1980) treated 1.85 m long specimens (both round and split) of *Bambusa polymorpha* and *Dendrocalamus strictus* with various preservative chemicals like copper sulphate, arsenic pentoxide, sodium dichromate, zinc chloride, boric acid-borax, ACC and CCA.

Advantages

It is a simple and economical method. No special skill is required. It can be carried out even in a rural set up. The treatment can be completed in about 3 to 6 days. This method is suitable for treating bamboo with unisalt preservatives like copper sulphate and boron. Singh and Tewari (1980) reported uniform distribution of the preservatives.

Disadvantages

This method is not suitable for treating bamboo with multisalt preservatives like CCA. In the case of CCA, it was reported by Singh and Tewari (1980) that only selective absorption of different elements in the preservatives took place. Slob et al (1987) noticed poor longitudinal distribution of CCA, although retention at the butt end was sufficient. Laxamana (1970) reported that bamboo treated for 48 hours in boric acid failed to prevent beetle infestation. (However, no information is provided on the absorption of boric acid to be able to make an objective judgement.) What is the maximum length that can be treated by this method is not known. The bamboo should be fresh with high moisture content.

Modified boucherie method

Freshly felled green bamboo culms can be treated by this method. In the Boucherie method, the sap is displaced by preservative chemicals by gravity. The culm is connected to a container of preservative solution kept at a higher level. In the modified Boucherie method (Purushotham et al, 1953), pressure is applied in the range of 100-140 kPa. Even a simple hand pump can be used for the purpose or a centrifugal pump for commercial scale operation. Also, the bamboo culm can be with or without branches and leaves. The water-transporting part of the culm can be penetrated completely by this method. At the beginning of the treatment, the solution dripping from the top end will be mainly sap and subsequently the preservative. This can be collected, filtered and mixed with fresh preservative for reuse. The treatment is said to be completed when the concentration of the solution at the dripping end is almost equal to that of the preservative solution. Purushotham et al (1953) treated *Bambusa nutans, B. polymorpha* and *Dendrocalamus strictus* with different types of preservatives (zinc chloride, 'Boliden' salts, CCA, copper-chrome-boric acid (CCB), chromated zinc chloride and a fireproof-cum-antiseptic composition). Slob et al (1987) treated 4 m long *Arundinaria alpina* with CCA by gravity pressure method. Gonzalez and Gutierrez (1996) treated about 3 m long *Guadua atlantico* with boron preservative. They reported that culms stored in water for one day before treatment were more permeable than fresh culms.

Advantages

The equipment used for this method is simple, low-cost and can be built anywhere with easily available materials. Furthermore, it can be built in different scales, from a portable equipment to treat a few culms to a large scale, permanent plant to treat hundreds of culms per day (Gonzalez and Gutierrez, 1996). In terms of penetration, distribution and retention of preservatives, this method is one of the best. Laxamana (1970) found the modified Boucherie method, among the different methods investigated, the most effective.

Disadvantages

Liese (1980) pointed a number of areas which merit attention. A low initial moisture content will result in a higher osmotic pressure of the parenchyma cells surrounding the vessels. Thus the water will be withdrawn from the preservative solution inside the vessels and precipitation will occur blocking the vessels. Failures may occur during the dry season. Preservatives with quick precipitation and fixation generally will stop flowing through the culm in a relatively short time, thus blocking the vessels. Also, this method is not applicable for all bamboo species, for example *Bambusa bambos.* Purushotham et al (1953) reported that in some bamboos the treatment was very poor due to resistance to the flow of preservative. Slob et al (1987) experienced high leaching rates of the toxic compounds of CCA. Even though good fixation could be obtained by using CCA of higher concentration (10%), use of a 10% solution led to rapid blocking of the vessels.

Steeping

It is a simple method to carry out. It involves keeping the green bamboo completely submerged in the preservative solution. Laxamana (1970) treated Philippine bamboo (details not available) with different preservatives like zinc chloride, copper sulphate, CCA, boric acid-borax. Singh and Tewari (1981a) treated *Dendrocalamus strictus* in copper sulphate, acid-cupric-chromate (ACC), zinc chloride, boric acid-borax, chromated zinc chloride and sodium dichromate. The treatment specimens, however, were only 0.5 m long, each containing two nodes. The specimens were kept submerged in water for about a week before treatment. Both round and half-split specimens were treated for a period of up to 50 days.

Singh and Tewari (1978) studied the effect of ponding on the preservative retention of bamboo. They treated round and split specimens of *Dendrocalamus strictus,* 0.9 m long with three nodes, kept stored in water for various periods like 1,2,3 or 4 months. The preservative they tried was ACC. Although ammonia based preservative like ammoniacal copper arsenate (ACA) can diffuse faster, and also can be heated to get better penetration and loading (Dev et al, 1991). no one has tried ACA for treating green bamboo. As diffusion of preservative is better from the inner wall than from the outer wall, the septa should be punctured or small notches made near the nodes to facilitate free access of the preservative solution to the inner wall.

Advantages

This method can be carried out even in a rural set up. This does not require any electricity. Depending on the scale of operation, treatment tanks of appropriate sizes can be made. Laxamana (1970) reported that immersing split and round specimens in 20% boric acid-borax solution for 24 and 48 hours respectively, prevented beetle infestation. Singh and Tewari (1981a) obtained complete penetration of boric acid by keeping round bamboo in 5% boric acid equivalent (BAE) solution for 30 days. Singh and Tewari (1978) reported that ponding even for a month prior to treatment with ACC increased the dry salt retention of the preservative three fold.

Disadvantages

This method is not suitable for treating bamboo with multisalt preservatives like CCA, ACC, etc. as there was selective absorption of different elements (Singh and Tewari, 1981a). Liese (1980) claimed that penetration and absorption of water-soluble preservatives were lower in freshly felled culms than in air-dried material. According to Slob et al (1987), the steeping method gave satisfactory salt retention (5 kg/m^3) of CCA. but radial distribution was very poor. Also, they felt that the main disadvantage of the steeping method was the crystallization of the salt on the inner and outer culm wall, giving rise to health hazards during handling and storage.

Double steeping

This method is an extension of the previous method. As single steeping of bamboo in multisalt preservative results in selective absorption of different elements, this method is suggested. Singh and Tewari (1981b) steeped *Dendrocalamus strictus* first in 20% copper sulphate or 20% zinc chloride for 48 or 96 hours and then in 20% sodium dichromate for 48 or 96 hours, respectively. The treated specimens were close stacked for a month under cover.

Advantages

This method results in even distribution of the preservative. The depth of penetration and absorption of preservatives can be controlled by varying the steeping period.

Disadvantages

This method involves double handling of the material. This can also result in spillage of chemicals. In round bamboo, the penetration of copper sulphate-sodium dichromate preservative was only about 40 percent.

Steaming and quenching

This method involves first steaming the green bamboo at about 100°C for 1 to 2 hours and then quenching in a water-borne preservative for about 2 days and then storing for a month. There could be variation in the schedule. Singh and Tewari (198lb) and Younus-uzzaman (1994) carried out laboratory study with very small specimens. While the former treated *Dendrocalamus strictus*, the latter treated *Arundinaria falconeri*

Advantages

This method results in almost complete penetration with a high loading of the preservative. Steaming for 2.5 hours and quenching for 48 hours resulted in a dry salt retention of 18 kg/m³ of CCA (Singh and Tewari, 1981b). If septa could be punctured or small notches or holes could be made, this treatment should be applicable to any species to obtain better penetration and higher loading. Bamboo can be treated in a large scale.

Disadvantages

This method is not suitable for rural set up or where the required skill is not available.

METHODS FOR TREATING DRY BAMBOO

Steeping

This method is similar to that of the method for treating green bamboo. The bamboo is kept completely immersed in the preservative solution. Here, the preservative solution is absorbed by capillary action while in the case of green bamboo by diffusion. Laxamana (1970) treated round and split bamboo in boron solution for 1 to 3 weeks. Singh and Tewari (1979) treated *Bambusa polymorpha* and *Dendrocalamus strictus* in CCA. The specimens were only 0.5 m long. Dev et a1 (1993) treated *D. strictus* with ACA, a diffusible preservative and CCA. Here also, the specimens were small (with two nodes and one internode or with two internodes and one node).

Advantages

As green bamboos may not always be available, this is a simple method that can be employed even in a rural set-up to treat dry bamboo. Penetration of preservative by capillary action in a dry bamboo is higher than by diffusion action in green bamboo (Singh and Tewari, 1979). *D.* strictus had a dry salt retention (DSR) of about 10 kg/m3 CCA in round specimens in 6 days. Dev et a1 (1993) obtained good penetration and absorption with ACA.

Disadvantages

Dev et a1 (1993) reported that even though there was adequate DSR in bamboo treated with CCA, spot test showed negative for copper. So, this method may not be suitable for all preservatives.

Hot and cold method

This method is suitable for treating bamboo with creosote preservative. The method involves keeping the bamboo in a tank fitted with heating arrangement, filling with creosote-fuel oil mixture, heating it to about 90°C. maintaining the heat for about 3-6 hours and cooling the preservative. To facilitate higher loading, the septa should be punctured or small holes should be drilled near the nodes. Singh and Tewari (1979) treated 0.9 m long samples of *Bambusa polymorpha* and *Dendrocalamus strictus* in both round and split

Advantages

If creosote is the only preservative available and if the bamboo is to be used outdoors, this is a simple method which could be employed.

Disadvantages

This method is not economical. Singh and Tewari (1979) found that dry bamboo was quite refractory to this treatment.

Vacuum pressure method

Like timber, bamboo also can be treated with preservative chemicals by vacuum pressure method. However, culms with thin walls tend to crack even when treated under low pressure (500-700 kPa) (Singh and Tewari, 1979). However, Sonti (1990) suggested drilling holes or notches between septa and claimed that it eliminated cracking and did not reduce the strength of bamboo.

Advantages

This method is suitable for treating bamboo in a commercial scale. If holes are drilled or notches are made between septa, uniform penetration of preservative from outer wall and inner wall can be ensured.

The initial investment for the treatment plant is high. Dry bamboo is quite refractory to pressure treatment. If cracks develop during treatment, it will reduce the strength of bamboo.

SUITABLE METHODS

Even though many methods are available for treating bamboo, not all are suitable for treating bamboo for structural uses. For bamboo to be used outdoors and that too in ground contact, choosing the right treatment method and preservative chemicals is essential. Treatment methods which could ensure even distribution of chemicals among vessels and fibres and preservative chemicals which have good diffusing properties should be identified. The right methods for treating green bamboo and dry bamboo should be identified. Methods which are suitable for round culms will be normally suitable for split culms also, As bamboo may have to be treated in a rural set up where facilities like electricity, skill, infrastructure, etc. may not always be available, treatment methods suitable for such conditions should also be identified.

As the information available in literature is mostly based on laboratory scale trials, one has to be extra cautious in selecting the suitable methods for treating bamboo for structural uses. Also, as no field performance data are readily available for different bamboo species treated by these methods, with regard to retention, one has to still rely on retention figures for timber for similar applications. As bamboo is anatomically different from timber (vessels are only 5-10% in bamboo), extra loading of preservative may be required. Other than for butt treatment and modified Boucherie method, when bamboo is to be treated in round form, septa should be punctured or holes should be drilled near the nodes or notches should be made between septa.

After evaluating the different methods objectively, the following methods and preservative chemicals could be recommended confidently. Treatment schedules will have to be worked out for different species depending on concentration of the treatment solution.

Location	Form	Condition	Treatment method	Preservation chemicals	Remarks
Ground contact	round; split	green	Ponding and steeping	CCA CCB	Septa punctured or holes/ notches
			Steaming and quenching	CCA: CCB	1-month storage after treatment
		dry	Vacuum and pressure	CCA; CCB	septa punctured or holes/notches
Out-of-ground contact			Steeping	ACA .	
Out-of-ground contact	round	green	Modified Boucherie	Boron	1-day ponding before treatment
	round: split		Butt treatment	Boron	
ground contact	round	green	Butt treatment	CUSO,	
		dry	Steeping	CCA; CCB; ACA	Septa punctured or notches

Research gaps

Even after so many years of research on bamboo preservation, many gaps are still there. The following gaps are listed.

- ➢ Information on distribution of preservatives in different tissues of bamboo treated by different methods.
- ➢ Species specificity of different treatment methods.
- ➢ Information on field performance of bamboo treated by different preservatives.
- > Data on the effect of ponding on strength of bamboo.
- > Data on the effect of steaming (duration) on strength of bamboo.
- > Information on the effect of moisture content of bamboo on the preservative retention and penetration in the steeping method.
- > Information on the treatability of green bamboo with diffusible preservatives by vacuum-pressure method.

CONCLUSIONS

Based on available information in the literature, different treatment methods for bamboo preservation were evaluated. Depending on the end-use (outdoor or indoor) and material (green or dry bamboo: round or split), suitable treatment methods and preservative chemicals have been suggested for treating bamboo for structural uses. To ensure effective treatment, the following points should be kept in mind.

- While treating round bamboo by a method other than one of the sap displacement methods, septa should be punctured or holes/notches. made near the nodes to facilitate absorption of preservative from the inner wall also.
- Preservatives which have good diffusing properties should be chosen to ensure even penetration and distribution.
- Information on dry salt retention alone is not sufficient to understand the efficacy of the treatment; information on penetration and distribution of preservatives in the different tissues is required.
- Large-scale treatment will reduce the cost.
- Danger of pollution due to spillage of preservatives should be borne in mind.

LITERATURE CITED

Casin, R.F. and Mosteiro, A.P. 1970. Utilization and preservation of bamboo. Wood Preservation Report 5(6):86-92.

Dev, I., Chand, P. and Pant, S.C. 1993. A note on the treatment of dry solid bamboos with ACA. Journal of Timber Development Association of India 39(1):24-28.

Dev, I., Pant, S.C., Chand, P. and Kumar, S. 1991. Ammoniacal copper ansenite: A diffusible wood preservative for refractory timber species like *Eucalyptus*. Journal of Timber Development Association of India 37(3):12-15.

George, J. 1985. Preservative treatment of bamboo, rubber wood and coconut palm: Simple methods for treating building timbers. Part 1. Preservative treatment of bamboo. In W.P.K. Findlay (Ed) Preservation of Timber in the Tropics. Martinus Nijhoff/Dr W. Junk Publishers, Dordrecht, The Netherlands: 233-247.

Gonzalez, G. and Gutierrez, J.A. 1996. Bamboo preservation at the Costa Rican National Bamboo Project. *In* P.M. Ganapathy, J.A. Janssen and C.B. Sastry (Eds) Bamboo, People and the Environment. Volume 3: Engineering and Utilization. INBAR, New Delhi: 121-129.

Indian Standards Institution (ISI) 1979. Code of Practice for Preservation of Bamboos for Structural Purposes. IS: 9096-1979. New Delhi, India.

Jayanetti, D.L. 1975. Some methods of preservative treatment of bamboo. Sri Lanka Forester 12(2): 101-103.

Kumar, S. and Dobriyal, P.B. 1990. Preservative treatment of bamboo for structural uses. *In* I.V. Ramanuja Rao, R. Gnanaharan and C.B. Sastry (Eds) Bamboos: Current Research. KFRI, India and IDRC, Canada:199-206.

Kumar, S. Shukla, K.S. Dev, I. and Dobriyal, P.B. 1994. Bamboo Preservation Techniques: A Review. INBAR Technical Report No.3. INBAR, New Delhi and ICFRE, Dehradun. 59 pp.

Laxamana, M.G. 1970. The preservation of bamboo. Wood Preservation Report 5(6):92-94.

Liese,W. 1980. Preservation of bamboos. *In* G. Lessard and A. Chouinard (Eds) Bamboo Research in Asia. IDRC, Canada: 165-172.

Liese, W. 1985. Bamboos - Biology, Silvics. Properties and Utilization. GTZ, Eschborn, Germany. 132 p.

Martawidjaja, A. 1964. Preservative treatment of bamboo in Indonesia. Rimba Indonesia 9(1):66-76.

Purushotham, A., Sudan, S.K. and Sagar, V. 1953. Preservative treatment of green bamboos under low pneumatic pressures. Indian Forester 79: 652-672.

Singh, B. and Tewari, M.C. 1978. Studies on the effect of ponding on the preservative treatment of bamboos by pressure and diffusion processes. Journal of Indian Academy of Wood Science 9: 46-49.

Singh, B. and Tewari, M.C. 1979. Studies on the treatment of bamboos by steeping, open tank and pressure processes. Journal of Indian Academy of Wood Science 10: 68-71.

Singh, B. and Tewari, M.C. 1980. Studies on the treatment of green bamboos by stepping and sap-displacement methods. Journal of Indian Academy of Wood Science 11: 21-27.

Singh, B. and Tewari, M.C. 1981a. Studies on the treatment of green bamboos by different diffusion processes. Part I - Dip diffusion and Osmose process. Journal of Timber Development Association of India 27(1):38-44.

Singh, B. and Tewari, M.C. 1981b. Studies on the treatment of green bamboos by different diffusion processes. Part II - Steaming and quenching and double diffusion. Journal of Timber Development Association of India 27(2): 38-46.

Slob, J.W., Nangawe, P.F., deLeer, E. and Donker, J. 1987. CCA impregnation of bamboo - leaching and fixation characteristics. In A.N. Rao, G. Dhanarajan and C.B.Sastry (Eds) Recent Research on Bamboos. CAF, China and IDRC, Canada: 321-336.

Sonti, V.R. 1990. A workable solution for preserving round bamboo with Ascu (CCA type salts). In I.V. Ramanuja Rao, R. Gnanaharan and C.B. Sastry (Eds) Bamboos: Current Research. KFRI, India and IDRC, Canada: 207-208.

Tewari, M.C. 1981. Recent studies on the protection of bamboos against deterioration. *In* Proc. Bamboo Production and Utilization. Group 5.03. IUFRO World Congress, Kyota, Japan. Japan Society of Bamboo Development and Protection.

Tewari, M.C. and Singh, B. 1979. Bamboos – Their utilisation and protection against biodeterioration. Journal of Timber Development Association of India 25(4): 12-23.

United Nations (UN) 1972. The use of bamboo and reeds in building construction. Department of Economic and Social Affairs, United Nations, New York. Document No.ST/SOA/ 113. 95 p.

Wang, C.L. 1989. A review of studies on the preservation of bamboo in Taiwan. Forest Products Industries 8(3): 79-85.

Younus-uzzaman, M. 1994. Preservative treatment of two bamboo species by steaming and quenching and pressure impregnation methods. Bangladesh. Journal of Forest Science 23(2): 79-85.