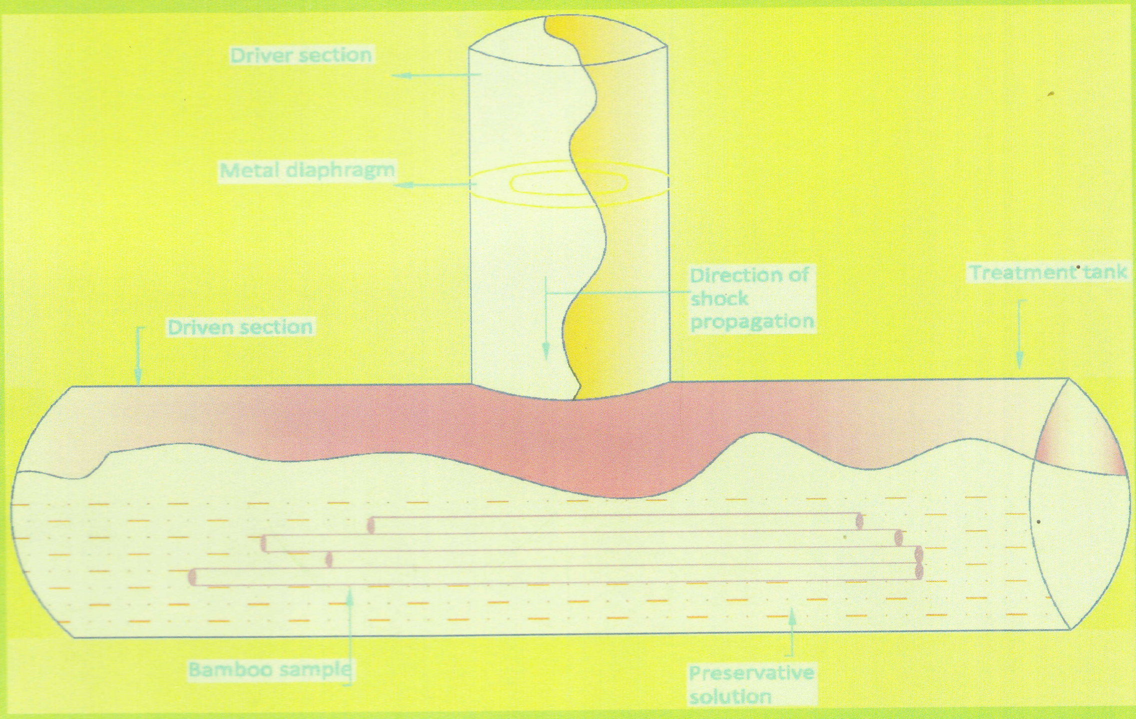
KFRI Research Report No. 346

ISSN: 0970-8103

SHOCKWAVE-ASSISTED PRESERVATIVE TREATMENT OF BAMBOO



T.K. Dhamodaran

R. Gnanaharan

Wood Science and Technology Division
Kerala Forest Research Institute
Peechi - 680 653, Thrissur, Kerala

August 2008

CONTENTS

OUTLINE OF THE PROJECT PROPOSAL

Project Number:	KFRI 485/'05
Title of Project:	Shockwave-assisted preservative treatment of bamboo
Principal Investigator:	Dr. T. K. Dhamodaran, (Wood Science & Technology)
Associate Investigator:	Dr. R. Gnanaharan, (Wood Science & Technology)
Objective:	Investigate the feasibility of employing shockwave for preservative treatment for bamboos
Programme Outline:	1. Investigate the effect of shockwave application on preservative retention and penetration of copper – chrome – boron (CCB) preservative, utilizing the shockwave facility available with Indian Institute of Science (IISc), Bangalore. 2. Investigate the effect of shockwave application on the physical properties of bamboo.
Funding Agency:	Kerala Forest Research Institute
Budget Outlay:	Rs. 15.5 Lakhs
Duration:	3 Years (April 2005-March 2008)

ACKNOWLEDGEMENTS

Sincere thanks are due to Dr. J. K. Sharma, Former Director, Kerala Forest Research Institute for granting this research project with financial support from the KFRI Plan Funds, without which this project could not have been taken up. We thank Dr. G. Jagadeesh, Department of Aerospace Engineering, Indian Institute of Science, Bangalore for facilitating the use their shockwave generation facility in the present project. The service of Mr. S. Babu, Senior Project Fellow (Wood Science & Technology Division, KFRI) is acknowledged. The services of Engr. K. N. Arun Raj, (Research Fellow, Wood Science & Technology Division, KFRI) for the drawings are also acknowledged. Acknowledgements are also to Dr. K.V. Bhat, Dr. S. Sankar and Dr. K.K. Seethalakshmi for editorial services.

PREFACE

Apart from being a livelihood material to the poor traditional artisan community, bamboos are an excellent industrial raw material too. Being a perishable material, when utilized for permanent structures, bamboos need to be preservative treated conforming to standards. Due to its structural and anatomical differences from timber, effective treatment of bamboos conforming to standards is still a challenge. It is in this context, Dr. T. K. Dhamodaran and Dr. R. Gnanaharan started working to explore the possibility of utilizing shockwaves for preservative impregnation treatment of bamboos, a novel concept, but still in infancy. The system is found capable to treat bamboos quickly achieving complete penetration of the preservative chemical. The present detailed work is the first of its kind in the country and the success in effective shockwave-assisted preservative treatment in bamboos points out the need for further work for developing the innovative technology for industrial applications. As at present shockwave generators are designed for confined use in aerospace engineering fields, and as the system showed its potential for use in otherwise difficult to treat bamboos within short time, KFRI is looking for collaborative research efforts for availability the equipment for its application in bamboo processing industry.

I expect the present report will motivate researchers and organizations concerned with bamboo, specifically in the field of preservative treatment of bamboos for large scale utilization such as for construction purposes and for industries.

Dr. K. V. Sankaran

DIRECTOR
KFRI

ABSTRACT

Bamboo, being a perishable material, needs to be properly treated with preservative chemicals before putting into use. Because of its structural and anatomical differences from timber, effective preservative treatment of bamboos, especially in bulk quantities within short time, conforming to standards remains a challenge. A novel concept expected to be capable to overcoming the problems in treating bamboos, the shockwave-assisted preservative impregnation, is attempted in the present study. Shockwaves are strong perturbations (during explosions, lightening shocks and contact surfaces in laboratory devices) in aerodynamics that propagates at supersonic speeds independent of the wave amplitude.

The shockwave generator available with the Aerospace Engineering Department of the Indian Institute of Science, Bangalore was employed to treat round and half-split *Bambusa bambos* in green as well as air dry condition with copper – chrome – boric (CCB) preservative formulation. Even though the dry salt retention (DSR) of the preservative chemical obtained in the treated bamboo employing a 4% CCB formulation in the present study was low (1.5-3.0 kg/m^3), excellent through-and – through penetration was observed, which was seldom obtainable in the conventional bamboo treatment methods such as the dip diffusion and vacuum – pressure impregnation (VPI) treatments. As the access to equipment facility was not available for continued studies, it was not possible to repeat the study with higher concentrations and to investigate the effect of other parameters. However, extrapolated calculations on DSR showed that adequate retention is possible with the use of higher concentrations. The results of the present preliminary study showed the promising potential of shockwave-assisted preservative impregnation for bamboo treatment. Further systematic studies coupled with developing improved equipmental facilities are warranted for standardizing the technology for industrial applications. Application of shockwaves for preservative treatment is found not causing any visual physical damage or defect to wood and bamboo samples. Wood density was not found adversely affected due to shockwave application for the preservative treatment.

Key words: *Preservative treatment; Bambusa bambos; copper – chrome – boron (CCB) preservative; shockwave-assisted preservative treatment.*

INTRODUCTION

Bamboo, apart from being a livelihood material to the socially and economically backward rural communities, is a good structural material for cost effective housing and furniture. With the development of modern mechanical processing technologies, bamboo is now accepted by the industries as a promising raw material. Further, the country is rich in bamboo resources; it has the second place in the world in the bamboo resources next to China. The significance of bamboo in the national economy is revealed from the annual production of about 3.2 million tonnes from an area of around 9.0 million hectares. The major limitation in the utilization of bamboo is its non-durable nature. Unlike durable timbers, it does not contain toxic extractives to impart natural durability. It is found susceptible to attack from biological organisms such as fungi, insect borers, termites, etc. Wherever an enhanced durability is desired, whether indoor or outdoor, bamboo should be preservative treated.

Preservative treatment of bamboo is a challenge, as its treatablity is poor because of its peculiar morphological and anatomical structure. The siliceous and hard outer wall and the nodal septa make it less permeable. The unevenly distributed vascular bundles (vessels and thick-walled fibres) and absence of ray cells make the material difficult to treat, especially in the round form. Even though various treatment methods such as the butt treatment boucherie methods, steeping, steaming and quenching, hot & cold method and the conventional vacuum – pressure impregnation (VPI) are suggested (Gnanaharan, 2000; Kumar *et al.*, 1994), are all tedious and cumbersome. All the methods have limitations for quick treatment of large quantities in truckloads desired for industrial scale processing. In brief, unlike wood, bamboo is a problematic material as far as its large-scale treatment for industrial processing is concerned.

A revolutionary concept capable of overcoming the problems in treating huge quantities of bamboo, green or dry, within short time is suggested by Jagadeesh *et al.*, (2005) by utilizing the shock tube and shockwave generating facility, Bangalore, India. This involves the shockwave assisted impregnation of preservatives using various methods such as laser focusing, instantaneous pressure energy release in a shock tube, electric discharge in water and simultaneous actuation of piezo-electric crystals.

Shockwaves are strong perturbations in aerodynamics that propagate at supersonic speeds independent of the wave amplitude. Shockwaves of any requisite strength can be generated in controlled fashion. While substantial progress has been made in research related to medicinal (Delius, 1994), biological (Jagadeesh and Takayama, 2002) and micro-electronics (Takayama *et al.*, 2003) industrial applications of shockwaves, no work has been reported, except the one by Jagadeesh *et al.,* (2005) on the possible use of shockwaves in the area of wood preservation. They have achieved substantial increase in the copper, chromium and arsenic retention in the shockwave assisted CCA preservative treatment of round bamboos when compared with the conventional VPI and hot & cold methods of treatment. The amount of time involved in the treatment was only about ten minutes including the manual operations whereas the time involved was up to 3 hours in the conventional treatment systems. As shockwaves are compressive in nature, the chances of enhanced permeability due to repeated shock propagation resulted in penetration through the outer hard skin thereby facilitating better penetration and retention of the chemical after the treatment.

As the method of treatment, penetration, distribution and retention of chemicals is much faster compared to the conventional methods, further systematic studies are necessary to clearly understand the basic physical principles associated with preservative injection through shockwave loading. Standardizing the system, optimizing the treatment conditions, designing, developing and fabricating a modal pilot-scale shockwave impregnation system are the further steps needed for up-scaling its industrial potential. It is with this view the present project was formulated with the preliminary objective of testing the feasibility of shockwave-assisted copper – chrome – boric (CCB) preservative (the traditional commercial wood preservative chemical used for the protection of structural timbers) impregnation in the Kerala grown bamboo, *Bambusa bambos*.

REVIEW OF LITERATURE

The bamboo preservation compendium by Liese and Kumar (2003) along with the reviews on the same subject by Gnanaharan (2000) and Kumar *et al.*, (1994) clearly show that bamboo is a perishable, but difficult to treat material compared to wood due to its inherent peculiar physical and anatomical features. Due to the same reason, even now, use of adequately treated bamboos having dry salt retention (DSR) conforming to published standards are seldom practiced. The above reviews describe the various methods and chemicals to use for bamboo treatment depending upon the exposure conditions, etc. The Indian Standards IS 9096 IS 1902 and IS 401 (BIS 1979, 1993 and 2001) the code of practice for preservation of bamboos ant timber for structural and non-structural purposes. Depending upon the end use, desired dry salt retention (DSR,) levels of CCB in bamboos ranges from 4.8 - 8.0 kg/m^3. The same standards describe the formulation and specifications of the commercial grade copper – chrome – boric (CCB) preservative.

The novel concept of application of shockwaves in wood preservation was first suggested by Jagadeesh *et al.,* (2005). Shockwaves appear in nature whenever the different elements in a fluid approach one another with a velocity larger than the local speed of sound (Griffith, 1981). Physically, the presence of shockwave is always associated in sudden non-linear jumps in pressure, temperature, and density behind the wave. Shockwaves of required strength can be generated in the laboratory by laser focusing, instantaneous pressure energy release in a shock tube, electric discharge in water and simultaneous actuation of piezo-electric crystals. No earlier reports are available on the application of shockwaves for wood preservation. More information on the applicability of shockwaves in wood preservation is scanty.

MATERIALS AND METHODS

A pilot scale wood preservative impregnation system that has been developed for utilizing the non-linear pressure spike behind a propagating shockwave in a vertical shock tube in the shockwave generating facility available at the Aerospace Engineering Laboratory of the Indian Institute of Science, Bangalore has been employed for the present study. The stainless steel vertical shock tube is partitioned into a driver and driven sections separated by a metallic diaphragm made with aluminium (Fig. 1).

Samples of *Bambusa bambos* were cut from the basal portion of individual culms. For convenience, air dry round and half-split samples of length 500 mm and green round samples of 1500 mm length were subjected to shockwave-assisted preservative impregnation. As making small holes in every node was effective in getting better absorption of preservative in the conventional treatment of round bamboos, trials were conducted in round green bamboos after drilling holes to compare the results with undrilled specimens.

Round, air dry bamboo (*Bambusa bambos*) samples of length 500 mm were fixed both vertically and horizontally in the sample carrier tray placed just below the driver section of the shock tube, in the treatment tank for subjecting them to shockwave in the treatment chemical solution.. Half-split air dry bamboo samples of length 500 mm fixed horizontally were also exposed to shockwaves in the same solution. To understand the effect of moisture content and length of the samples on retention of preservative in the treated bamboos, round green bamboo samples (with and without holes made in the nodes) of length1500 mm were fixed horizontally for subjecting to shockwaves in solution as earlier.

An aqueous solution of commercially available copper – chrome – boric (CCB) preservative formulation of 4% concentration was flooded into the horizontal treatment cylinder in which weighed bamboo samples of known moisture content were placed just below the driven section, till the samples were submerged in the solution.

Helium was used as the driver gas in the shock tube separated between the driver and driven sections by a 1.5 mm thick aluminium diaphragm and shockwave was generated by employing a maximum overpressure of about 30 bars for about 300 microseconds. The samples submerged in solution were subjected to the shockwave generated by the automatic rupture of the diaphragm. Each sample was subjected to three repeated shots of shockwave loading. After the treatment, solution was pumped back to the storage tank and samples were removed and weighed. From the difference in weight and volume of samples solution pick up was calculated. Dry salt retention (DSR) was calculated by multiplying the solution pick up with concentration. The metallic diaphragm was changed after every trail. Air dry round bamboo samples (500 mm long) were also directly subjected to shockwave in the absence of preservative solution, in order to check whether shockwave cause any visual damage to the samples.

Moisture content was determined by oven drying and density by water displacement method. Penetration of preservative in the treated material was tested as per Indian Standard (BIS, 2001). The method essentially consisted of applying a 0.5% chrome azurol -S solution in 5% sodium acetate in the cut or half split faces of treated bamboos. Development of deep blue colour indicated the extent of penetration of the preservative.

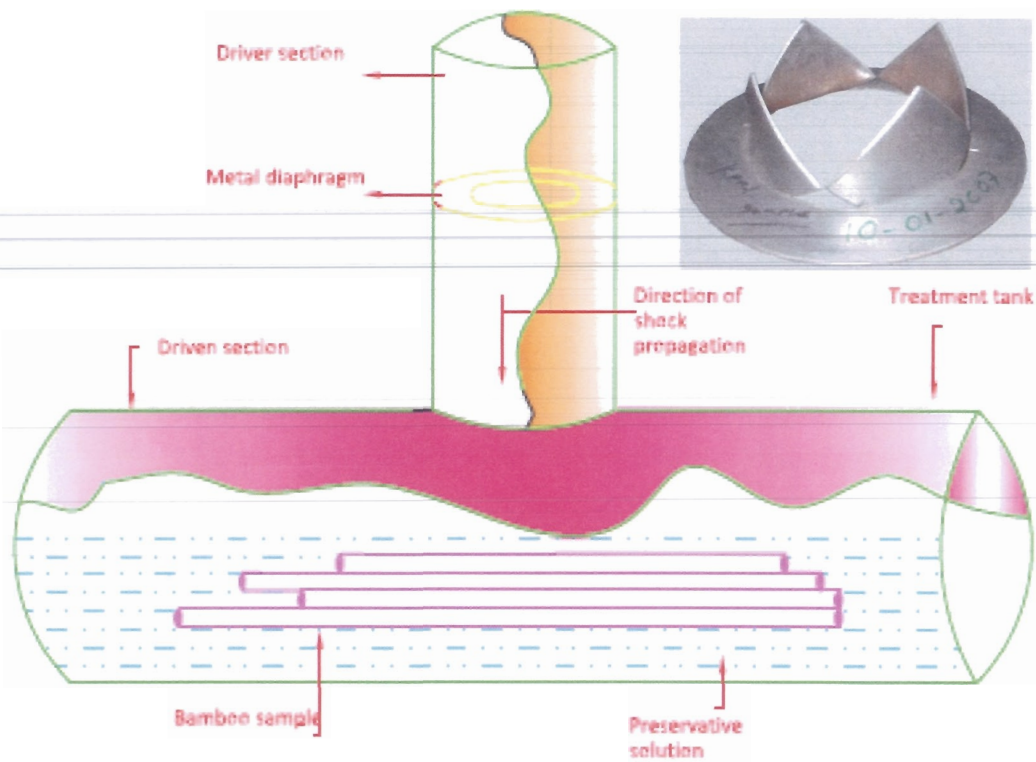


Fig. 1. Schematic diagram of the IISc shock tube used for preservative impregnation (Insert photograph shows the broken diaphragm)

RESULTS AND DISCUSSION

The physical properties (moisture content and density) of the samples in test condition are given in Table 2. Mean air dry moisture content of bamboo samples was 20%. Green bamboo for test was having a mean moisture content of 65%. The density of bamboo samples was in the range of 600-740 kg/m^3 with a pooled mean value of 670 kg/m^3 (Table 1).

Table 1. Moisture content and density of test samples (CV% values are given in brackets)

Species & Moisture condition	Mean Moisture content (%)	Mean Density (kg/m^3)
Bambusa bambos, air dry	20 (10.8)	740 (6.3)
Bambusa bambos, green	65 (17.5)	600 (10.8)

n = 5

Air dry round bamboo samples placed in both horizontal and vertical ways were first subjected to shockwave in 4% CCB solution. Only low retention was achieved in both ways of sample placing (mean DSR of 2.2 kg/m^3 in horizontal and 3.9 kg/m^3 in vertical placing) (Table 2) which is not the desired range as per Indian Standards (4.8 to 8.0 kg/m^3; BIS 1979, 1993). The same was the result for horizontally placed half-split air dry bamboos (mean DSR of 2.5 kg/m^3) (Table 3). Table 1 showed a increased loading in vertically placed samples; but vertical placing of bamboos in the treatment chamber is not practical while doing commercial scale treatments. Treatment of green bamboos of length 1.5 metres, placed horizontally in the treatment cylinder also gave poor retention (mean DSR of 2.3 kg/m^3) (Table 4). All these results showed the need for increasing the concentration of treatment solution.

However, the most striking feature observed was the uniform and through and through penetration of the preservative in all the samples treated, even in the round form, irrespective of the moisture condition (air dry and green) of the samples and DSR levels achieved (Fig 2 and 3). Thus, the achievement of uniform and through and through penetration of preservative chemical in the treated material can be taken as the characteristic feature of shockwave-assisted preservative treatment and indicates the potential of effective protection even in low retention levels achieved.

Table.2. Treatment of 0.5 m long air dried (MC 20%) *Bambusa bambos* in round form, with 4% CCB solution.

Parameters	**Horizontally placed**	**Vertically placed**
Solution pick up (kg/m^3)	70.8	158.8
	66.9	122.2
	39.0	81.4
	29.4	63.4
	65.0	58.8
Mean	**54.2**	**96.9**
DSR (kg/m^3)	2.8	6.3
	2.7	4.9
	1.6	3.3
	1.2	2.5
	2.6	2.4
Mean	**2.2**	**3.9**

Table 3. Treatment of 0.5 m long air dried (MC 20%) *Bambusa bambos* in half-split form placed horizontally, with 4% CCB solution.

Parameters	**Value**
Solution pick up (kg/m^3)	74.5
	44.5
	55.6
	70.7
	65.4
Mean	**62.1**
DSR (kg/m^3)	3.0
	1.8
	2.2
	2.8
	2.6
Mean	**2.5**

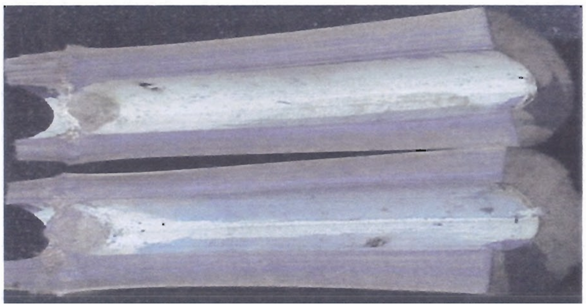
Table 4. Treatment of 1.5 m long green (MC 65%) *Bambusa bambos* in round form, placed horizontally, with 4% CCB solution.

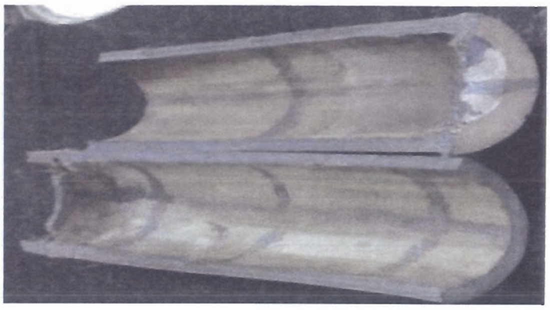
Parameters	Value
Solution pick up (kg/m^3)	51.5 59.8 50.5 54.9 69.4
Mean CV (%)	**57.2**
DSR (kg/m^3)	2.1 2.4 2.0 2.2 2.8
Mean	**2.3**

In the traditional vacuum – pressure treatment of round bamboos drilling of small holes in the nodel region is reported to be helping the achievement of desired loading of chemicals (Gnanaharan, 2000). In order to assess the effect of drilled holes the shockwave-assisted treatment, an experiment was conducted on limited number of samples (n=2 only) of round green bamboos of 1.5 m length exposed to shockwave in 2.5% CCB solution indicated an increased level of DSR achievement (0.9 $kg.m^3$) in such material compared to bamboos without holes drilled (0.6 $kg.m^3$). However, between these samples there was no significant difference in the extent of penetration, as observed by the intensity of colour developed in the visual colour tests employed for testing of penetration of preservative in the treated samples. In the shockwave-assisted treatment also, drilling of small holes in the nodal region was advantageous for achieving better retention.

As trials with treatment solutions of higher concentrations could not be conducted due to non-availability of the shockwave application system for further work, calculation of the DSR that can be achieved by the use of a 15% solution from the solution pick up data (assuming that the solution pick up will not vary much due to increase in concentration up to a level of 15%) by multiplying it with concentration showed that the desired range of DSR as per Indian Standards (8.0 kg/m^3 for structural purposes) could be achieved by the use of 15% CCB solution.

Bamboo samples subjected to shockwaves in the absence of preservative solution as well as with preservative solution were checked for any visual damages. None of the samples showed signs of any types of damages or defects. Also it was shown that there was absolutely no weight loss due to shockwave application in the absence of preservative solution. The density of samples also showed no significant change. This conclusively proved that shockwave-assisted preservative treatment in bamboos no way adversely affects the wood quality as far its utilization is concerned.





(A)

(B)

Fig. 2. Excellent penetration of preservative in 4% CCB treated round (A) and half-split (B) air dry bamboo samples.

Fig. 3. Excellent penetration in round green bamboo sample of length 1500 mm treated with 4% CCB.

CONCLUSION

Shockwave-assisted preservative impregnation is found to have the potential for achieving uniform and through and through penetration of preservative even in round green bamboos in short time. However, the required dry salt retention (DSR) specifications could be achieved only by employing treatment solution of high concentration (in the range of 15% weight/volume copper – chrome – boric, CCB). Application of shockwaves was found not causing any visual damage or defect to bamboo samples. Desired chemical loading and extent of penetration of preservative could be achieved within short time (say, 5-10 minutes). These results indicate the potential of the applicability of the novel concept of shockwave-assisted preservative treatment in bamboos and the need for further systematic studies for standardizing or optimizing the technology. Studies are also warranted for designing an appropriate plant suitable and capable for the commercial scale treatment of bamboos in full length and in different forms (round, split, slats and slivers).

REFERENCES

Bureau of Indian Standards (BIS). 1979. Code of practice for preservation of bamboos for structural purposes. IS 9096. Bureau of Indian Standards, New Delhi. 5p.

Bureau of Indian Standards (BIS). 1993. Preservation of bamboo and cane for non-structural purposes – Code of Practice. IS 1902. Bureau of Indian Standards, New Delhi. 8p.

Bureau of Indian Standards (BIS). 2001. Code of practice for preservation of timber. IS: 401. Bureau of Indian Standards, New Delhi. 23p.

Delius, M. 1994. Medical applications and bio-effects of extracorporeal shock waves. *Shock Waves*.4: 55-72.

Gnanaharan, R. 2000. Preservative Treatment Methods for Bamboo: A Review. Part – II of Bamboo Shelter: A Demonstration of Best Construction Practice. *KFRI Research Report No. 177* (II). Kerala Forest Research Institute, Peechi – 680 653, Kerala, India. 19 p

Griffith, W. C. 1981. Shockwaves. *Journal of Fluid Mechanics*. 106: 81-101.

Jagadeesh G. and Takayama K. 2002. Novel applications of micro-shockwaves in biological sciences. *Journal of Indian Institute of Science* 82: 49-57.

Jagadeesh, G., Lal, R., Ravikumar, G. and Rao, K. S. 2005. Shockwaves in wood preservation. *International Research Group on Wood Protection Document No. IRG/WP* 05-40308. 7p.

Kumar, S., Shukla, K. S., Dev, I. and Dobriyal, P. B. 1994. Bamboo Preservation Techniques: A Review. *INBAR Technical Report No.* 3. International Network for Bamboo & Rattan (INBAR), New Delhi. 59p.

Liese, W. and Kumar, S. 2003. Bamboo preservation compendium. CIBART, International Network for Bamboo and Rattan (INBAR), Beijing, China. 229p.

Takayama, K. Jagadeesh, G. and Shibasaki, S. 2003. High-speed rotor device for removal of particles from solid surfaces using shockwaves. *Japanese Patent No. 3445982.*