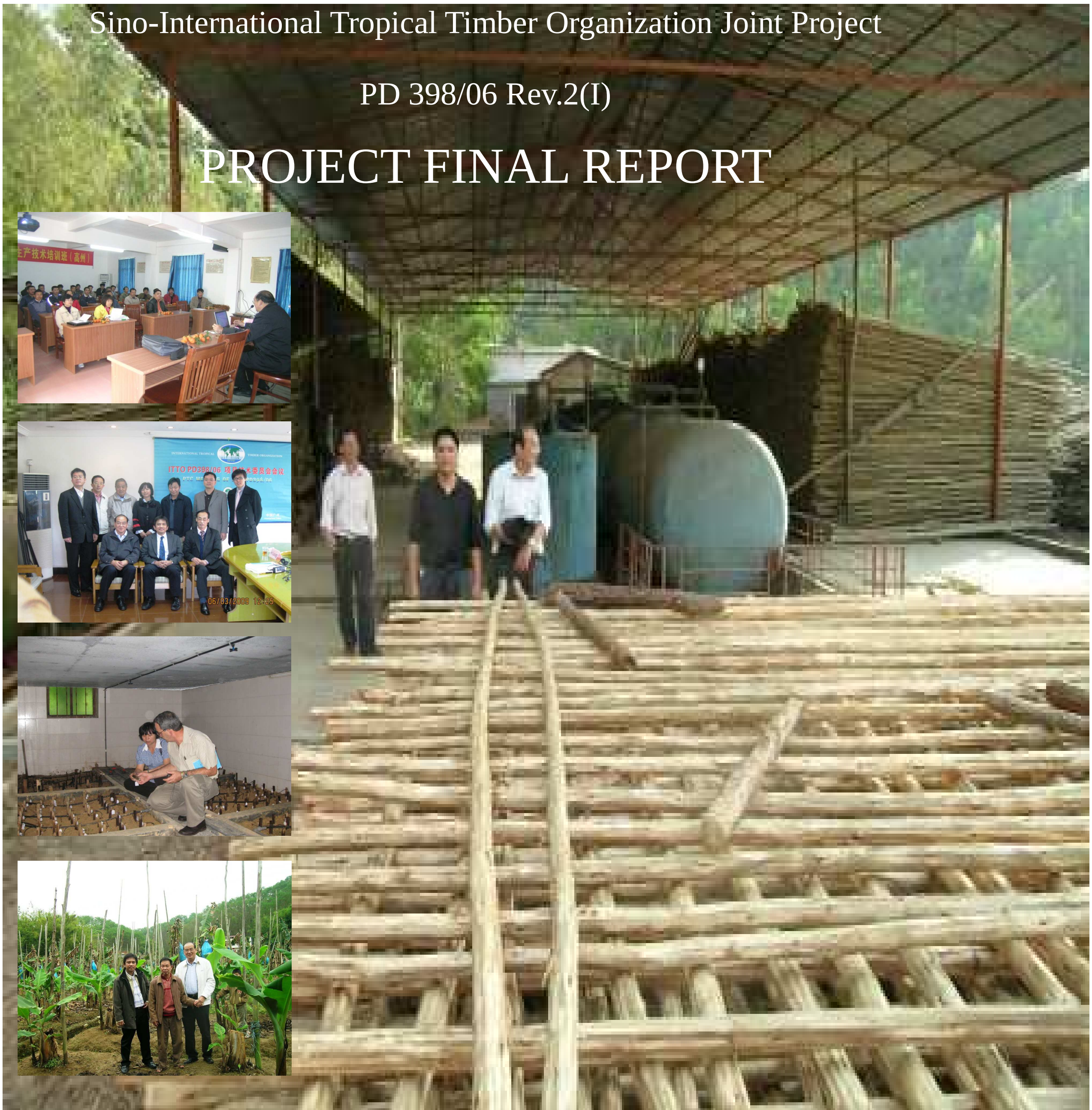
Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

Sino-International Tropical Timber Organization Joint Project

PD 398/06 Rev.2(I)

PROJECT FINAL REPORT



International Tropical Timber Organization

Guangdong Academy of Forestry

Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

Sino-International Tropical Timber Organization Joint Project
PD 398/06 Rev.2(I)

PROJECT FINAL REPORT

International Tropical Timber Organization

Guangdong Academy of Forestry

Project Final Report

P.R.China – ITTO Project on Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

2011 Guangdong Academy of Forestry, Guangzhou/ International Tropical Timber Organization (ITTO)

ACKNOWLEDGEMENTS

The project coordinator/leader would like to take this opportunity to thank the International Tropical Timber organization (ITTO), Director general of and members of the Project Technical and Steering Committees for their great support and guidance during the course of implementing the ITTO project PD 398/06 Rev.2(I). Particular gratitude goes to the following:

Mr. Jack Norton, the International consultant of the ITTO project, from DPI, Australia

Dr Jiang Mingliang, the national consultant of the ITTO project, from Research Institute of Wood Industry (China)

Mr. Li Qiang, the former Section Chief, Ministry of Commerce, P,R.China.

Mr. Zhang Zhongtian, Section Chief, State Forestry Administration, P.R.China.

Mr. Zhang Fangqiu, the Director General of Guangdong Academy of Forestry.

Mr. Li Zaobang, the project leader of the previous ITTO project PD 52/99 Rev. 2(I) and the previous Chief Engineer of Guangdong Academy of Forestry.

Mr. Zeng Linghai, the previous Deputy Director General of Guangdong Academy of Forestry.

Mr. Panwen, the deputy Director General of Guangdong Academy of Forestry.

The project coordinator/leader would also like to record his special appreciation and gratitude to the Executive Director of ITTO, Mr. Ze Meka, the present project manager for Forestry Industry Dr Yanuariadi Tetra and his predecessor, Dr. Hwan Ok Ma, for their overall support.

The active collaboration and cooperation of the sub-professional officer and field staffs from Maoming Forest Research Institute, Gaozhou Forest Research Institute and Boluo Forest Research Institute who were assigned to the project in successfully implementing the scheduled project activities certainly deserve the highest esteem of the Project Coordinator/leader.

ITTO Project Completion Report

Project Title: Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

Host Government: People's Republic of China

The executing Agency: Guangdong Academy of Forestry

Table of Contents

Lists of Tables

EXECUTIVE SUMMARY

1.0 Background and objectives

Project PD 398/06 Rev.2 (I) on "Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology" was proposed by Guangdong Academy of Forestry in December, 2005, and requested by the Government of P.R. China through the Forestry Department headquarters, and approved by the International tropical Timber Organization in May, 2006. The project was implemented during the period November 1, 2007 to October 31, 2010, with an extension period of 3 months beginning on November 1, 2010 to January 31, 2011.

PD 398/06 Rev.2(I) was the follow-up of the previous ITTO project PD 52/99 Rev. 2(I) on *"Development and Extension of Preservation Technology for Tropical Plantation Timber"*.

The previous project PD 52/99 Rev. 2(I) has proved to be successful and reached its original objectives and made the preservatives treated timber widely known by the society. Its outcomes had laid a preliminary foundation in terms of knowledge and technology for the development of the wood preservation industry in Southern China. Wood preservation has become a promising industry in the region. Over one hundred of treating plants have been set up all over the country ever since.

Project PD 398.06 Rev. 2 (I) has an overall development objective to further develop and extend environmentally sound preservation technology in order to promote the use of plantation timber resources, thus enhancing the sustainable development of plantation forest in the South China region.The specific objectives of the project are the following: To develop environmentally sound timber preservative technologies and establish treated timber products monitoring system to ensure the efficient use of the plantation timber resources, To continue and further expand the on-going demonstrations programs commenced in PD 52/99 Rev 2(I), and to establish a demonstration treating plant playing as a leading sample in products quality control, safety and environment protection.

2.0 Outputs and Achievements

The outputs and achievements are the following:

Output 1: A biological laboratory, a chemical analysis laboratory and 2 timber exposure yards, are set up and a treated timber product monitoring system is in operation

（1） **The establishment and improvement of the biological laboratory：** the original lab was enlarged, constructed and readjusted by purchasing more equipment, In addition, a soil-bed room with related facilities for accelerated field test, an insect rearing room with termite luring pond and termite rearing pond for termite or insect tests were added and approved by EA.

（2） **Study on the biological testing methods for wood preservation products：** At present, the biological laboratory has been established a relatively perfect biological testing system, which could meet the requirement for all biological tests on wood preservation products.

（3） **The establishment and improvement of the chemical laboratory:** The chemical analysis laboratory has established and improved greatly in its testing techniques and detecting functions, by constructing more wall bench, purchasing 3 advanced instruments including High performance liquid chromatography (HPLC), EDXRF Spetro Phoenix wood analyzer and timber digest facilitie, and relevant necessary accessories.

（4） **Study on the chemical testing methods for wood preservation products:** The testing techniques for the wood preservatives and wood preservatives treated products have been studied in order to strengthen the detectability and provide effective technical support for the wood preservation industry. EDTA standard solution titration method (EDTA) for detecting the active copper components in wood preservative ACQ, PLA-1 Refractometer for detecting the concentrtaion of wood preservatives, and HPLC for detecting the organic ingredients quaternary ammonium salt (BAC) and tebuconzole in wood preservatives ACQ and CuAz are 3 fast detecting methods developed in the period of the project.

（5） **The testing quality and capability of the laboratory have been improved and enhanced through Participating in testing intercomparisons between laboratories:** In 2008 the laboratory was authorized by Osmose (USA) Company as its one designated inspection agency in China for its product MicroPro, a micronized copper wood preservative, and MicroPro-treated timber products.

（6） **The establishment of 2 timber exposure yards:** Two exposure yards with area of about 3,000 m^2 have been established on the campus of GAF and Gaozhou, Guangdong province respectively. The one in Gaozhou was about 1,000 m^2 in which only earth-contact exposure test could be done. While in the one of GAF both the earth-contact exposure test and the non-earth contact exposure test could be done.

（7） **The establishment of laboratory management system:** In order to ensure the laboratory operate high efficiently, and promote the the standardization, institionalization and scientific management of laboratory, a complete and practical laboratory management system has been established.

（8） **The establishment of a website**: A website **(http://www.gdfri-wp.com)** for wood protection technology had been set up in 2008, which plays a very important role in the disseminating of the information of preservation treatment products and the establishment of the monitoring system for treated timber products. It has become an important information platform for the domestic and foreign counterparts communicating together and providing service for the industry.

（9） **The laboratory construction was supported and approved by the Chinese Government**:

In 2008, the laboratory was constructed and upgraded as the Guangdong Forestry Product Quality Supervision and Testing Station and the State Forest Products Quality Supervision and Testing Center (Guangzhou Branch), with the support and approval of Guangdong Government and the State Forestry Administration, which were mainly undertaken the testing on the wood protection products and relied on the supporting institution GAF.

（10） **13 technical Standards related to wood preservation have been drafted:** During the project period, 13 National or industrial standards on wood preservation have been drafted or co-drafted or co-revised by EA.These standards are the necessary component of the quality monitoring system.

（11） **The wood preservation products quality monitoring system has been established preliminarily:** The wood preservation products quality monitoring system has come into shape through setting up three quality inspection points including **Guangdong (South China)**, **Yangzhou (East China)** and **Sichuan (Southwest China)**, respectively. Through inspection points, the enterprises' products could be sampled and monitored regularly, which improve greatly the products quality and help enterprises cultivate good brand awareness**.**

<u>Output 2:</u> **The improved technologies, including new developed environmentally sound preservatives, are available and used in industry**

(1) **New wood preservatives of low toxicity have been developed and tested:** 3 formulations of low toxic wood preservatives including SGB borate concentrated solution for protection from termites and decay, and SBB and SLB boron -based flame retardants have been developed and used in the industries, and 3 relevant technical reports including "*Test on the effectiveness of concentrated borate wood preservative*", "*Study on the Flame-Retardant Properties of Treated Wood with SLB Flame- Retardant* ", "*Flame Retardant Performance of the Boron-Contained Wood Preservative SBB*" were seem by attachments. In addition, In addition, the experiment on the screening of water repels for LVL was carried out, and the relevant technical report "*Waterproof property of laminated veer lumber (LVL) made from poplar veneer treated with water repel*" is seen by attachment.

(2) **On-going tests maintain & data collection:** Some exposure tests carried out before and during the implementation of this project have been maintained and recorded data regularly, in order to accumulate valid long-term data and ensure the sustainable development of the project. Details about the exposure tests are seen by attachments

(3) **Demonstration of environmentally sound preserved product:** During the project period, ACQ and our newly developed products boron based wood preservative SGB have been used in agriculture and building and landscaping for demonstration. For example, integrating with TUAD program, 1 ha of banana plantation was used Eucalyptus supporting posts treated with ACQ preservative, and 1 ha of vegetables was used Bamboo supporting posts treated with ACQ. In addition, both ACQ and SGB treated timber have also been used in landscaping at public Parks and reconstruction of temples for demonstration.

<u>Output 3:</u> **The bamboo classification is established and some preserved treatment techniques**

are developed

(1) **The development of preservatives for bamboo:** According to the present application of wood preservatives, there was not a preservative developed for bamboo alone. But in order to study on the application of wood preservatives on bamboo, trials on the use of wood preservatives ACQ and CCA for treating bamboo have been carried out during the implementation of the project. The test results showed that bamboo could be treated with ACQ and CCA like wood, and the penetration of preservatives into bamboo was related to the structural properties of bamboo. In addition, the study on the new formulation of anti-mold agents for bamboo has been carried out, and 4 newly-formulated anti-mould agents were tested its efficacy on mould prevention of 3 bamboo species including *Bambusa eutuldoides*, *Phyllostachys pubescens* and *Arundinaria amabilis,* in comparison with commonly used anti-mould agent PCP-Na. The relevant technical report *"Study on the performance of treated bamboo with environmentally-friendly anti-mould agents"* is seen by attachment.

(2) **Treating experiment of bamboo:** At present the preservation processing of bamboo was mostly refered to that of wood. The tests on the treatability of *Phyllosrtachys heterocycla* and *Pseudosasa amabilis, Dendrocalamus bambusoides*, *Bambusa chungii* and *Dendrocalamus giganteus* were conducted during the implementation of the project, and wood preservatives CCA and ACQ were used for the pressure treatment. The results showed that wood preservatives could not be able to penetrate into bamboo culm if the internodes were not thirled and opened up.

(3) **Laboratory and field exposure tests of bamboo specie:** During the implementation of the project, 13 species of bamboos commonly used in Guangdong province were tested their natural decay resistance and natural durability by soil block tests and field exposure tests. 2 relevant technical reports "*Laboratory Exposure Tests on Bamboo Species*" and "*The natural durability and preservative treatability of 11 bamboo species*" are seen by attachments.

(4) **The classification of bamboo:** A grading method for assessing the performance of 18 common bamboo species was studied. The method was based on 4 grade levels with corresponding scores of 4 reference indexes of bamboos including culm diameter, culm-wall thickness, natural durabiliy and preservative treatability. In comparison with the traditional utlilization of bamboo, the grading results showed that this grading method was quite useful for evaluating the performance of bamboos. The relevant technical report "***Grading the performance of 18 common bamboo species***" is seen by attachment, and which had been submitted and presented at the 41th IRG meeting in France in May, 2010.

(5) **International consultancy & cooperation:** The international consultant Mr. Jack Norton has 3 visit trips for his consultancy missons to EA according to the project schedule. A number of recommendations given by him to EA during his visits were accepted by the project team and which were very helpful to EA for the improvement of the implementation of the project. His first consultancy report and final consultancy report were seen by attachments.

<u>Output 4:</u> **A demonstration treating plant is set up. Information can be accessed through seminars/workshops, training courses, publications and internet**

(1) **2 Demonstration treating plants were set up and related regulations were established：** 2 demonstration treating plants (see two sub-contracts by attachment) have been set up in Gaozhou and Guangzhou, Guangdong province respectively, and the treatment plant in Gaozhou is mainly provided the preservatives-treated timber for agricultural use, while the treating plant in Guangzhou is mainly provided the treated timber for building materials and gardening materials uses. The rules and a specified procedure for the safety production of timber preservation treatment plant was framed , and the relevant document ***"Operation Instructions for Timber preservation treatment plant"*** is seen by attachment. In addition, 2 regulations on the standardization of the safety operation of timber preservation treatment plant has been established.

(2) **3 Training courses has been hold for the wood treatment plant:** During the implementation of the project, integrating with the TUAD program and the demonstration program of treating plants, 3 technical training courses were designed and hold for the workers and administrative staffs of the treating plants,and let them understand the relevant terms of wood preservation, the basic requirement for the design and planning of the treating plant, the design of facility, the management of the leakage of the wood preservatives, the safety operation of workers, the contact and uses of wood preservatives, the equipment operation, the waste treatment and so on.

(3) **7 seminars/workshops related on wood preservation have been hold:** Integrating with the TUAD program, totally 7 seminars /workshops were organized by the project team, and there were more than 200 participants from every walks.

(4) **Attending national and international meetings related to wood protection:** The project team attended one national conference and 2 international meetings.

<u>Output 5:</u> **Treated-timber for uses in agriculture-region (TUAD) is established**

(1) **TUAD has been planned:** TUAD program has been planned in the first two months of the project period, and the proposal could be seen by attachment.

(2) **TUAD sites has been set up:** 20 ha of TUAD sites were set up as planned, distributed at 3 towns and 1 county in two cities in the province respectively, and in these sites treated Eucalyptus and bamboo poles were mainly used for supporting crops including banana, Chinese yam, Holand bean and bitter gourd. In addition, 3 dditional demonstration sites with an area of 2.5 ha has been set up in the project period, including one located at a State Forest Farm of Guangdong Province, in which treated pine poles wee used for supporting the fruit Pitaya; other two were set up in Hainan Island and Guangxi Zhuang Autonomous Region, respectively, in which only treated Eucalyptus poles were used for supporting banana, and collaborating with the local farmers and companies.

(3) Publicity materials on treated timber have been compiled and disseminated: During the implementation of the TUAD program, more than 1000 copies of standard document **"Preserved wood banana post"** and 1000 copies of the manual of using of Preserved wood banana post have been sent to the users of the preservatives treated products, including farmers and treating plants, and sellers of treated timber products.

(4) Holding workshops related on wood preservation: During the implementation of theTUAD program 4 workshops have been held by integrating with the the establishment of the demonstration plant program.

(5) Information related to wood preservation and the progress of ITTO project have been disseminated through public media, TV program, internet and brocasting.

3. Conclusion and Recommendations

In general, most activities of the project were well carried out according to the work plan and the guideline of ITTO, and the project was completed with all the specific objectives achieved, and it is concluded that:

(i) Progress has been made towards the promoting and extending the environmentally sound wood preservation technology for uses timber preservation industry in China. Relevant information is accessible for the potential investors and timber consumers, and the technologies derived from this project have been adopted by industry.

(ii) The demonstration sites, demonstration plants and website established by the project have been playing an important role in dissemination the knowledge of high value use of plantation timber. The provincial government has started to pay attention on the wood preservation industry, and more and more treated timber have been used in the construction of urban public facilities, and as well wood protection research has been considered in the Government's scientific research planning.

(iii) The total expenditure of the project was US$413,806.00 involved with a small amount of additional cost US$249.65. By the end of the project period, the realized cash received from ITTO's fund by EA was totally US$222,500.00, and the committed 6^{th} installment of US$20,000.00 has not received, and thus EA is in a debt of US$15,246.65 ITTO fund at the moment, it is expected that the 6^{th} installment will be arranged as soon as possible so that the project team could work on other projects smoothly.

The achievements previously mentioned and the experience gained during the period of the project enable the following recommendations:

(i) More international communication and information exchange with countries well developed in wood preservation and/or in tropical region would be significant to ITTO projects' activity.

(ii) It is strongly recommended that a training course or a workshop for the main project staffs on project execution and management is necessarily.

(iv) Study on bamboo preservation are not deep enough in this project, and the existing technology for bamboo preservation is still unable to meet the need of industrial production of treated bamboo, so further research on bamboo preservation will be needed in the future.

(v) Wood preservation industry is not well developed in tropical countries. It is suggested that ITTO continues to organize more projects to promote the better use of tropical timber. China needs to maintain the on-going activities, and extend achievements obtained from this project so that the timber preservation industry could be further developed sustainably.

Final Report on ITTO Project PD 398/06 Rev.2 (I) "Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology"

1. Project Identification

(i) Title: Promoting the Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology
(ii) Serial Number: PD 398/06 Rev.2 (I)
(iii) The Executing Agency: Guangdong Academy of Forestry (GAF)
(iv) Host Government: Government of the People's Republic of China
(v) Starting Date: November 19, 2007
(vi) Duration: 36 months (planned); 39 months (realized).
(vii) Project Cost (US$): 291,060.00 (planned); 286,306.65 (realized)

1.1 Contex

1.1.1 Economic Aspects

The timber from plantation is currently only in low value used such as for packaging, scaffolding in construction. The previous project PD 52/99 Rev.2(I) has proved that wood preservation treatment is an effective value-added timber processing, with a conclusion based on an economic evaluation on using treated banana supporting poles that "Comparing the use of treated and untreated banana posts, there is a maximum potential saving of up to RMB 749,000,000 over a six year period." This is only the direct benefit obtained by the banana farmers in Guangdong. If taking into into account of the increasing resource and producing more valuable treated timber products for construction and landscaping , it is no doubt that wood preservation treatment will increase in demand for timber and hence push forward the development of forest plantation, which will make significant contribution to the social economy by increasing GDP and employment.

1.1.2 Environmental Aspects

Better utilization of the potential plantation forest resource will ease the pressure from the demand for wood material and has positive affect to ecological environment. Tests in PD 52/99 Rev 2(I) and many countries revealed that no strong evidences indicated that the present commonly used CCA treated timbers really affected the environment and the human health. The improper use and deposition of treated timber are the most environmental concern, and researches on both more environmental friendly preservatives and better depositing method are taking progress to solve this problem.

1.1.3 Social Aspects

Demonstration program for using treated timber has proven in PD 52/99 to be a very effective mean to convince and a good approach of information for every aspect related. An integrated demonstration program, "Treated-timber Used in Agriculture Demonstration-region" (TUAD), in which preserved timber, from its production to the end-use, will be presented and producers and users are involved, is emphasized in this project. It is important to get support from local authorities and communities and industries during the implementation of the TUAD program. Since the potential positive affect of timber preservation to economy has been confirmed by the previous project, this project is expected to make contribution to the development of the local society.

1.1.4 Project location

Biological violation is the main factor caused the loss or failure of wood or wood-based materials.The project executing agency GAF located at tropical and subtropical region, with high temperature and high humidity, wood and wooden materials are easily subjected to biological attacks, and untreated timber suffers generally serious damages by decay fungi or insects within several months. A great quantity of bamboo or wood poles used to be consumed for supporting the crops like banana and Chinese yam, but it was costly due to the short service life of the poles without preservatives treatment. Therefore growers hoped urgently that the supporting wood/bamboo poles could be more durable and service longer.

1.1.5 Relevant National and Regional Policies and Programme

1.1.5.1 National and regional Policies

This project conforms to the Chinese policies about forestry and forestry products industry:

(i) The National Tenth-Five-Year Plan (2001-2005) for Forestry and the General Ideology of the Long-term planning to the Year 2010.

(ii) China's Agenda 21, Forestry Action Plan: Sustainable Development Policy of Forest Industry.

(iii) Six key forestry projects approved by the State Council. Among them one is construction of commercial forest bases by planting fast growing species.

(iv) Chinese Government's Policies and Measures: to Improve Wood Utilization Efficiency and Output Value of Forest Industry.

(v) Guangdong Province Forestry Development Plan (March 1998), to further develop plantation forests and to improve wood processing industry.

(vi) Act No 44, July 2000, Guangdong Government, To Improve the Afforestation and to increase the Efficiency of Forestry.

1.1.5.2 National and regional programme

Programs and Operational Activities:

(i) One of the China's national Six Key Forestry Programs, Establishment of the Fast-grow and High-Yield Forest Plantation Bases, launched in 2000.

(ii) Twice of national Timber Preservation Industry Development Conference held in 2002,2004.

(iii) Preparatory of the Chinese Timber Preservation Association began in 2002.

(iv) Two national standards, Timber Preservatives Standard and Classifications of Hazard Standard, was established in 2005.

(v) A provincial program of Guangdong, Agriculture Standardization Demonstration Region Program was launched in 2002, which covers forestry and forest products.

1.2 Origin and Problems

There is over 7 million hectares of commercial forests in Guangdong. Among them, 1.23 million hectares are fast-growing tropical species plantations for timber and 418 thousand hectares of bamboo plantation. The main species for plantation in Guangdong are Eucalyptus urophylla and its hybrids, Acacia magium, Pinus mansoniana, Pinus elliottii and Cunihemia lancialata etc. This is an increasing timber resource being available to meet the future growing demand. But one of the constraints to the further development of forest plantations is the low value of timber and limited use, which in some cases prevents the further investment from entering. Therefore the value-added timber processing technologies to enhance the efficiency of plantation is one of the effective approaches to solve the problems faced, while wood preservation technology could be the best of the value-added timber processing technologies.

Several factors contributing to the insufficiency uses of plantation timbers in Southern China have been identified. Among these factors are the following:

(i) lack of timber preservation knowledge & expertise in treating of plantation timber and bamboo;

(ii) better access of technology and information is required for both the treated timber producers and user;

(iii) lack of wood preservation standards and products specifications;

(iv) lack of laboratory that can undertake the monitoring duties;

(v) an impartial treated timber products market Is not available, quality was a worry;

(vi) CCA is still the main preservative in use and more environmentally sound preservatives are not accepted by many yet;

(vii) Environmentally sound preserving technology need to be developed for bamboo products;
(viii) Environment and safety problems are subject to occur in many treating plants.

The project PD 398/06 Rev.2(I) entitled "promoting the utilization of plantation timber resources by extending environmentally sound preservation technology"" was the follow-up of the previous project PD 52/99 Rev.2(1). It was proposed by GAF,China in December, 2005 and submitted to and approved by the International Tropical Timber Council (ITTC) at its 39th Session in May, 2006 in Yokohama, Japan. The project agreement was signed in August, 2007 by ITTO and Chinese Government. The total budget of the project is US$413,560.00. The awarded ITTO funding was US$291,060.00 and the Chinese Government counterpart fund was US$122,500.00.

The project was implemented for a total of 36 months beginning from November 19, 2007 and ending on October 31, 2010 with additional 3 months extension ending on January 31, 2011 with a small amount of additional cost involved (US$246.65).

2. Project Objectives and implementation strategy

The overall development objective of the project is to promote the use of plantation timber resources by further develop and extension of environmentally sound preservation technology to contribute to the sustainable development of plantation forest in the South China region.

2.1 Specific Objectives

(i) To develop environmentally sound timber preservative technologies and establish treated timber products monitoring system to ensure the efficient use of the plantation timber resources.

(ii) To continue and further expand the on-going demonstrations programs commenced in PD 52/99 Rev 2(I), and to establish a demonstration treating plant playing as a leading sample in products quality control, safety and environment protection.

2.2 Implementation Strategy

(i) To meet the requirement of technical support and good market environment for wood preservation industry in order to promote the development of the industry so that the plantation timber can be used more efficiently in Southern China.
(ii) Being as the currently only institution engaged in wood preservation in Southern China, GAF would further improve and extend the existed wood preservation technologies derived from the previous project PD 52/99 Rev.2(I) in order to play an important role in serving the industry technically through its D/R activities in wood/bamboo preservation and the execution of the project.
(iii) To establish an independent executive body of the products monitoring system for the wood preservation industry, taking GAF as the supporting institution and getting authorized and supported by the Government, in order to maintain an impartial and competitiive market through improving the research and testing facilities and enhancing testing technical levels.
(iii) As the member of Guangdong Forestry Industry Association (GFIA), GAF will strengthen the cooperation with GFIA and other members including preservation companies and forest

plantation owners, and dissemination of the knowledge and technologies derived from the project through implementing activities such as setting up of demonstration sites, seminars/workshops, training courses, informations booklets, TV program and internet website.

(iv) To strengthen the international cooperation and introduction of advanced foreign technologies and experience through hiring the international consultant, participating international academic meeting, study tour outside the country and communicating with foreign counterparts and so on.

3. Project Performance

3.1 The realized performance versus the planned performance

It can be seen from table 1 and table 2 that there were 4 added activities during the implementation of the project, but the planned specific objectives, main outputs and related activities were not changed, which were all basically competed, while 4 added activities made the main outputs showcase more perfect without extra budget from ITTO (Table 3).

From table 4 it can be seen that most of the activities were implemented according to the planned schedule or ahead of the schedule (e.g. Activity 1.1.4), while the 4 planned activities were lagged behind the schedule, such as Activity 1.3.1 6 months lagged behind the schedule with an extending period of 2 months due to more tests on bamboo; Activity 1.3.4 3 months lagged behind the schedule due to the readjustment visit schedule of the international consultant; Activity 1.3.5 3 months lagged behind the project period due to the readjustment of the target countries and the administrative step-by-step procedure for getting the passports.

Table 1 Planned activities

Specific objectives	Outputs	Related activities	Completion situation
(i) To develop environmentally sound timber preservative technologies and establish treated timber products monitoring system to ensure the efficient use of the plantation timber resources.	**Output1.1** A biological laboratory, a chemical analysis laboratory and 2 timber exposure yards are set up and a treated timber product monitoring system is in operation.	1.1.1 establishment of the biological room	completed
		1.1.2 establishment of chemical analysis laboratory	completed
		1.1.3 establishment of 2 timber exposure yards	completed
		1.1.4 establishment of monitoring system	Completed
	Output1.2 The improved technologies, including new developed environmentally sound preservatives，are available and used in industry	1.2.1 new preservatives development & tests	completed
		1.2.2 on-going tests maintain & data collection	completed
		1.2.3 demonstration of environ. sound preserved product	completed
	Output 1.3 The bamboo	1.3.1 development of	Basically completed

	classification is established and some preserved treatment techniques are developed.	preservatives for bamboo	
		1.3.2 treating experiment of bamboo	completed
		1.3.3 laboratory & exposure tests of bamboo species	completed
		1.3.4 international consultancy & cooperation	completed
		1.3.5 study tour outside the country**	completed
(ii) To continue and further expand the on-going demonstrations programs commenced in PD 52/99 Rev 2(I), and to establish a demonstration treating plant playing as a leading sample in products quality control, safety and environment protection.	**Output 2.1** A demonstration treating plant is set up. Information can be accessed through seminars/workshops, training courses, publications and internet	2.1.1 establishment of regulations for treatment plant	completed
		2.1.2 courses & training	completed
		2.1.3 seminar/workshop & attending international meeting	completed
	Output 2.2 TUAD is established	2.2.1 TUAD planning	completed
		2.2.2 organization of the implementing of TUAD	completed

Table 2 Unplanned Activities

Specific objectives	Outputs	Related activities	Completion situation
(i) To develop environmentally sound timber preservative technologies and establish treated timber products monitoring system to ensure the efficient use of the plantation timber resources.	**Output1.1** A biological laboratory, a chemical analysis laboratory and 2 timber exposure yards are set up and a treated timber product monitoring system is in operation.	1. study on the biological testing methods for treated timber products	completed
		2. Study on the chemical testing methods for treated timber products	Completed
		3. Participating in testing intercomparisons between laboratories.	completed

(ii) To continue and further expand the on-going demonstrations programs commenced in PD 52/99 Rev 2(I), and to establish a demonstration treating plant playing as a leading sample in products quality control, safety and environment protection.	**Output 2.2** TUAD is established	4. Setting up more demonstration sites	completed

Table 3 The Schedule and Outcomes for the Related Activities (the realized performance)

Related activities	Indicators/outcomes	Schedule	
		Planned completed date	Realized completed date
1.1.1 establishment of the biological room	a 3-room bio-lab, a soil-bed room, a termite luring room.	July 31, 2008	As planned
1.1.2 establishnment of chemical analysis laboratory	a 4-room chemical lab，4 capital items	December 31, 2008	As planned
1.1.3 establishment of 2 timber exposure yards	2 exposure yards, about 3,000m^2.	June 30, 2009	As planned
1.1.4 establishment of monitoring system	In operation, authorized certificates, website, 13 standards, lab. Management document	September 30, 2010	June 30, 2010
1.1.5 study on the biological testing methods for treated timber products	6 native isolates of wood rot fungi and mould; testing reports.	Not planned	October 31, 2010
1.1.6 Study on the chemical testing methods for treated timber products	Testing reports; 2 technical reports.	Not planned	October 31, 2010
1.1.7 Participating in testing intercomparisons between laboratories.	Osomse's authorized certificate; testing reports.	Not planned	October 31, 2008
1.2.1 new preservatives development & tests	4 preservatives, 4 technical reports.	June 30, 2010	As planned
1.2.2 on-going tests maintain & data collection	4 data collection sheets on treated timbers exposure tests	April 30, 2010	As planned
1.2.3 demonstration of environmentally sound preserved product	ACQ treated timbers demonstration in landscaping and agriculture, pictures.	September 30, 2009	As planned

1.3.1 development of preservatives for bamboo	ACQ treated bamboo for Demonstration, 1 technical report for anti-mould tests on bamboo	March 31, 2010	December 31, 2010
1.3.2 treating experiment of bamboo	1 IRG paper	November 30, 2009	As planned
1.3.3 laboratory & exposure tests of bamboo species	1 technical report, 1 IRG paper	January 31, 2008	As planned
1.3.4 international consultancy & cooperation	2 international consultancy reports, and pictures;	July 31, 2010	October 31, 2010
1.3.5 study tour outside the country**	Visit Indonesia, Pictures,	December 31,2010	January 31, 2011
2.1.1 establish. of regulations for treatment plant	2 demonstration treating plants, 2 sub-contracts, 3 management documents.	July 31,2009	As planned
2.1.2 courses & training	3 training courses, pictures	September 30, 2010	October 31, 2010
2.1.3 seminar/workshop & attending international meeting	7 workshops, 2 IRG meetings	October 31, 2010	As planned
2.2.1 TUAD planning	TUAD program plan	December 31, 2007	As planned
2.2.2 organization of the implementing of TUAD	4 demonstration sites, 20 ha, for banana, Chinese yam and vegetables	October 31, 2009	As planned
2.2.3 Setting up more demonstration sites	3 additional demonstration sites, 2.5 ha for banana and Pitaya.	Not planned	2009/2010

3.2 Inputs applied

The planned project duration is 36 months, while the realized project duration is 39 months. The total budget of the project is US$413,560.00, among US$291,060.00 was ITTO’s contribution, and US$122,500.00 was Chinese Government's contribution. It can be seen from the final financial auditing report attached as Appendix 1, the realized total amount of the project expenditure was US$413,806.65, among the total expenditure from ITTO's fund was US$286,306.65, and the remaining value was US$4753.35(see table 5); the total expenditure from Chinese Government's contribution was US$127,500.00, but it was overspent US$5,000.00 due to the extending project period (see table 6). Therefore the total project expenditure was US$413,806.00 involved with a small amount of additional cost US$246.65.

Among US$291,060.00 of ITTO's contribution, US$48,560.00 was retained by ITTO for its management fee, and the remaining US$242,500 was committed to go to EA by 6 installments. By the end of the project period, the realized cash received from ITTO's fund by EA was totally US$222,500.00, and the committed 6th installment of US$20,000.00 has not received, and thus EA is in a debt of US$15,246.65 (see table 4). While the whole project was overspent US$246.65, it is expected that the 6th installment will be arranged as soon as possible so that the project team could work on other projects smoothly.

It can be seen from table 7 that the biggest expense is the capital items, which costs totally US$10,1446.79, equal to more thanone third of the ITTO fund. The expense includes US$67946.79 of ITTO fund, and US$33,500 of Government counterpart's fund.

Table 4 Input Applied By Source

From Nov. 19, 2007 to Jan.31, 2011 (39months)

Budget Components		ITTO	Chinese Government
10	**Project Personnel**		
	11.National Experts		74,000.00
	12.National Consultants	12,025.32	
	13.Other Labor		15,000.00
	15..International Consultant	15,000.00	
	19.Component Total	27,025.32	89,000.00
20	**Sub-contracts**		
	21.Tteatimg Plant Demonstration	**35,000.00**	
	29.Component Total	**35,000.00**	
30	**Duty Travel**		
	31.Daily Subsistence Allowance	11,020.22	
	32.International Travel	5,875.80	
	33.Transport Costs	10,364.28	
	39.Component Total	27,260.30	
40	**Capital Items**		
	41.Premises		
	42.Land		
	43vehicles		
	44.Laboratory Equipment	67,946.79	**33,500.00**
	49.Component Total	**67,946.79**	**33,500.00**
50	**Consumable Items**		
	51.Raw Materials & Chemical	48,529.16	
	52.Spares	2,506.98	
	53. Fuel And Utilities	15,989.36	
	55.Office Supplies & Stationary	10,166.58	
	59.Component Total	77,192.08	
60	**Miscellaneous**		
	61.Sundry	3,322.16	**5,000.00**
	62.Auditing		
	69.Component Total	3,322.16	**5,000.00**
70	**Management**		
	79. Component Total		
	TOTAL	237,746.65	127,500.00
	Input up to now	222,500.00	127,500.00
	Remaining value	-15,246.65	**0.00**

Table 5 The Financial Situation of the project (The ITTO's Contribution, In US$)

From November 19, 2007 to Jan. 31, 2011(39 months)

Budget Components		Approved Total	Up-to date committed by E.A. but not spent	Up-to date spent	Spent +committed in period	Remaining Values	Explanation of Remaining Values
10	Project Personnel	27,000.00	0.00	27,025.32	27,025.32	-25.32	
20	Sub Contracts	35,000.00	0.00	35,000.00	35,000.00	0.00	
30	Duty Travel	29,500.00	0.00	27,260.30	27,260.30	2,239.70	*
40	Capital Items	73,000.00	0.00	67,946.79	67,946.79	5,053.21	**
50	Consumable Items	74,700.00	0.00	77,192.08	77,192.08	-2,492.08	***
60	Miscellaneous	3,300.00	0.00	3,322.16	3,322.16	-22.16	
70	Management	48,560.00	48,560.00	0.00	48,560.00	0.00	
100	SUBTOTAL	291,060.00	0.00	237,746.65	286306.65	4,753.35	

*****the remaining value was due to the international duty travel in one country in stead of two countries budgeted; ** the remaining value was due to the cheaper prices of the capital items than that budgeted; *** the remaining value was due to the extended project period.

Table 6 The Financial Situation of the Project (Govt. of Contribution, in US$)

From Nov.19, 2007 to Jan.31, 2011(39months)

Budget Components		Approved Total	Up-to date committed by E.A. but not spent	Up-to date spent	Spent +committed in period	Remaining Values	Explanation of Remaining Values
10	Project Personnel	85,000.00	0.00	89,000.00	89,000.00	-4,000.00	Extended project period
20	Sub Contracts	0.00	0.00	0.00	0.00	0.00	
30	Duty Travel	0.00	0.00	0.00	0.00	0.00	
40	Capital Items	33,500.00	0.00	33,500.00	33,500.00	0.00	
50	Consumable Items	0.00	0.00	0.00	0.00	0.00	
60	Miscellaneous	4,000.00	0.00	5,000.00	5,000.00	-1,000.00	Extended project period
70	Management	0.00	0.00	0.00	0.00	0.00	
100	SUBTOTAL	122,500.00		127,500.00	127,500.00	-5,000.00	

Table 7 List of Capital Items (US$)

No.	Item	Quantity	Unit cost	Total	
				ITTO	Chinese Gov.
1	High performance liquid Chromatography (HPLC)	1	29202.61	29202.61	
2	ASOMA X-Ray Fluoresence Spectroscopy Analyzer	1	38744.18	38744.18	
3	Timber digestion facilities	1	7,000.00		7,000.00
4	Temperature & Humidity Control System	1	26,500.00		26,500.00
	Total			67946.79	33,500.00
				10,1446.79	

4. Project Outcome, Target Beneficiaries Involvement

Main outputs :

(i) A biological laboratory, a chemical analysis laboratory and 2 timber exposure yards are set up and a treated timber product monitoring system is in operation.

(ii) The improved technologies, including new developed environmentally sound preservatives，are available and used in industry

(iii) The bamboo classification is established and some preserved treatment techniques are developed.

(iv) A demonstration treating plant is set up. Information can be accessed through seminars/workshops, training courses, publications and internet

(v) Treated-timber Used in Agriculture Demonstration-region (TUAD) is established

<u>4.1 Main Output 1:</u>

A biological laboratory, a chemical analysis laboratory and 2 timber exposure yards are set up and a treated timber product monitoring system is in operation

4.1.1 The establishment and improvement of the biological laboratory

The biological lab had been just set up with only 2 rooms and poorly equipped, and only soil-block test could be done before the execution of the project. In order to improve the condition of the laboratory so that it could play fully its functions, during the implementation the project, an additional room was approved by EA for enlarging the laboratory, and the original lab was readjusted and constructed by purchasing more equipment including air conditioners, refrigerators, biological incubators, luminar flow cabinet and so on. In addition, a soil-bed room with related facilities for accelerated field test, an insect rearing room with termite luring pond and termite rearing pond for termite or insect tests were added and approved by EA.

4.1.2 Study on the biological testing methods for wood preservation products

Since the wood preservation industry is still in its infancy in China, most of the national standards for biological testing were refer to other countries, and it was found in practice that some standards still have some shortages, and the biological test materials especially the standard strains of wood rot fungi and moulds were subject to degeneration due to improper maintaining, which lead to the poor test result.

Being located at the southernmost point of the Continental China, EA(GAF) is more advantageous in conducting biological tests than other regions in the country with its tropical and subtropical climates of high temperature and high humidity which is very suitable for the growth of many organisms.

Therefore it is very import for the project team to study on the biological testing methods, and related activities were carried out during the implementation of the project, including the rejuvenation and preservation of fungi strains, the isolation of native species of wood rot fungi and wood moulds, the rearing of termites and wood borers and testing on treated timbers and so on. About 6 strains of native wood rot fungi and moulds have been isolated and testing its efficacy of decay or molding on wood/bamboo, and testing results shown that these strains have stronger bioactivity than the standard strains showcasing their promising uses in the future. At present , the biological laboratory has been established a relatively perfect biological testing system, which could meet the requirement for all biological tests on wood preservation products.Testing services have been provided to more than 13 clients from universities, research institutes and companies, and more than 2000 treated or untreated wood samples have been tested.

4.1.3 The establishment and improvement of the chemical laboratory

The chemical analysis laboratory has established and improved greatly in its testing techniques and detecting functions, by constructing more wall bench, purchasing 3 advanced instruments including High performance liquid chromatography (HPLC), EDXRF Spetro Phoenix wood analyzer and timber digest facilitie, and relevant necessary accessories. These equipments were mainly used to analyse and detect the active components in the wood preservatives and treated timber products.

4.1.4 Study on the chemical testing methods for wood preservation products

The testing techniques for the wood preservatives and wood preservatives treated products have been studied in order to strengthen the detectability and provide effective technical support for the wood preservation industry.

4.1.4.1 A fast method (EDTA) for detecting the active copper components in wood preservative ACQ

A fast, handy and effective method for detecting the active copper components in wood preservative ACQ by application of EDTA standard solution titration method (EDTA) has been developed, in a synchronous comparison test with the atomic absorption spectroscopy method. The digesting pretreatment of ACQ treated wood samples will be omitted and the analysis time becomes shortened greatly if EDTA method is used to detect the active ingredient copper content in ACQ. In comparison with the atomic absorption spectroscopy method, it found that EDTA standard solution titration method is easy and convinent to manipulate, good in repeatability, highly accurate and precise, which will not be affected by the differences between regions. It is more practical for the analysis of the active copper component in a wider range of measurable concentrations of ACQ and could be settled for the production requirements of the industry. The technical report***"A Fast Test Method for Copper Active Component in ACQ Wood"*** is seen by attachment, and its Chinese version has been published in periodical.

4.1.4.2 A fast method (PLA-1 Refractometer) for detecting the concentrtaion of wood preservatives

A fast and handy method for measuring the concentration of wood preservatives working solution has been developed. This method was based on a refractometer to show the refractive index of an unidentified working solution of wood preservative, and then its relevant concentration could be calculated through a regression equation. According to the results on a series of concentrations of wood preservatives CCA-C and ACQ-C, and their relevant refractive index values measured by the refractometer PLA-1, a standard curve of the concentrations (y_i) of the working solution versus their relevant refractive indexes (x_i) measured by the refractometer PLA-1 was plotted, and the regress equation of y_i versus x_i was then fitted.

The refractomer PLA-1 is fast, highly accurate and precise, good in repeatability and repetition for detecting the concentration of wood preservative working solution. It is cheap, easy to handle and small and portable, and hence is particularly suitable for uses in those production enterprises with poor equipment conditions. The method could be used at any time for the quality control or long-distance quality monitoring in the production process of wood preservation, showcasing very good prospects for widely application. Technical report ***"Study on the Fast Test Methods For Wood Preservatives"*** is seen by attachment, and its Chinese version has been published in periodical.

4.1.4.3 A fast method (HPLC) for detecting the organic ingredients quaternary ammonium salt (BAC) and tebuconzole in wood preservatives ACQ and CuAz

The high performance liquid chromatography (HPLC) is a high-speed, high-efficiency, high-delicacy and highly automatic instrumental analysis method, which is also the widely used chemical separation and analysis method at present. Both ACQ and CuAz are the most cpmmonly used environmentally sound wood preservatives now. However, there is no conventional analysis method for the determination of the active ingredient tebuconzole in CuAz, and it is not so accurate in the deternmintation of the active ingredient BAC in ACQ with the conventional chemical analysis method.

Therefore during the implementaion of the project, the study on the performance conditions of HPLC for the determination of BAC and tebuconzole in ACQ and CuAz was carried out in order to provide a fast, highly efficient and higly acurate and advanced analysis method for detecting the two ingredients.

The study showed that HPLC could be a fast and accurate detecting method for determination of quaternary ammonium salt (BAC) and tebuconzole in environmentally-sound preservatives ACQ and CuAz and treated wood. The best condition with HPLC for detecting the two components (BAC & tebuconzole) in ACQ and CuAz wood preservatives has been set up respectively, including the type and ratio of flow phases, the flow speed and the standard curve between retention time and peak area of the flow phase.

4.1.4.4 Participating in testing intercomparisons between laboratories

To carry out the study on the intercomparisions between laboratories can promote effectively the progress of the wood preservation in China and enhance the overall testing level of the industry. Through the intercomparisions between laboratories, the laboratory itself could be evaluated its testing quality and capability, found the possible problems and relevent methods and measures for their improvement and correction, and as well increase trust sense of clients on the testing results provided by th elaboratory. In addition, it could be found out the discrepancies between laboratories, strengthen the technical exchanges between laboratories, and together enhance the testing capability of the wood preservation industry.

In 2008, a testing intercomparision was carried out between NewYork Industrial Technical Research Division of Osmose Company (Osmose), China Federation of Logistics and Purchasing Wood Protection Quality Supervision and Test Center (CFLP-WPQ-STC) and our laboratory (GAF), and totally 12 items were intercompared, including 2 wood preservatives and 4 different treated timber specimens. The intercomparision testing results were shown in table 8.

Table 8 The intercomparision testing results of wood preservatives MCQ

Specimen	Testing result of GAF	Testing result of CFLP-WPQ-STC	Testing result of Osmose	R1	R2
Treated-timber A	1.777	1.916	1.766	0.011	0.150
Treated-timber B	1.125	1.342	1.171	-0.046	0.171
Treated-timber C	0.906	1.012	0.902	0.004	0.110
Treated-timber D	0.529	0.598	0.506	0.023	0.092
Wood-preservative solution A	1.410	1.578	1.491	-0.081	0.087
Wood -preservative solution B	0.713	0.784	0.741	-0.028	0.043

Notes: R1- is the deviation value of the detecting results between GAF and Osmose; R2-is the deviation value of the detecting results between CFLP-WPQ-STC and Osmose.

It can be seen from the intercomparison testing results (Table 8) that our testing result is very colsed to that of NewYork Industrial Technical Research Division of Osmose Company in both good repeatability and consistency, and the maximal and minimal deviations are 0.081% and 0.004% respectively. Therefore, in 2008 the laboratory was authorized by Osmose (USA) Company as its one designated inspection agency in China for its product MicroPro, a micronized copper wood preservative, and MicroPro-treated timber products.The following picture is the authorization letter from Osmose.

In 2010, a testing intercomparision activity between laboratories was again organized by the **Wood Preservation Committee of China Wood and Wooden Products Circulation Association**. Totally 6 laboratories participated in the activity, and 10 items and 2 wood preservatives CCA and ACQ were tested. Our laboratory (GAF) involved in the testing intercomparision activity and the testing was satisfied. The test results showed that 5 of 9 valid items tested by our laboratory were completely consistent with the median value, and other 4 items were also basically consistent with the median value. Thus once again the testing capability of our laboratory is proven to be in the leading position in China.

4.1.5 The establishment of 2 timber exposure yards

Two exposure yards with area of about 3,000 m^2 have been established on the campus of GAF and Gaozhou, Guangdong province respectively. The one in Gaozhou was about 1,000 m^2 in which only earth-contact exposure test could be done. While in the one of GAF both the earth-contact exposure test and the non-earth contact exposure test could be done, and it was established by enlarging the original one for about 2,000 m^2 and including newly set-up one section for non-earth contact exposure test. Now there are more than 3000 m^2 timber samples treated or untreated with preservatives for testing in the yard, from GAF, Universities, research institutes, companies at home and abroad.

4.1.6 The establishment of forest products quality monitoring system

4.1.6.1 The establishment of laboratory management system

In order to ensure the laboratory operate high efficiently, and promote the the standardization, institionalization and scientific management of laboratory, a complete and practical laboratory management system has been established, and please see the attachment ***"Laboratory Management Documents"***, which includes mainly the following 12 sections:

(i) Public Statement
(ii) A Statement from the Laboratory Director
(iii) Guidelines for Employees
(iv) Policies, Objectives and Commitments to Quality
(v) Personnel and Responsibility System
(vi) Instrument Allocation and Personnel
(vii) Management System for Testing Facilities and Environment
(viii) The Testing Procedure Management System and the Procedural Flow-Chart
(ix) Quality Assurance (QA) Management System
(x) Management of Testing Traceability

(xi) Administration Regulations on Internal Affairs Such as Safety and Sanitation Practices in the Laboratory

(xii) Laboratory Waste Disposing System

4.1.6.2 The establishment of a website

A website **(http://www.gdfri-wp.com)** for wood protection technology had been set up in 2008, which plays a very important role in the disseminating of the information of preservation treatment products and the establishment of the monitoring system for treated timber products. It has become an important information platform for the domestic and foreign counterparts communicating together and providing service for the industry. The website was designed four columns including:

(i) Wood Protection Research Team Column, from which information about the introduction of the research team, including the research activities and achievements of the research team could be accessible.

(ii) Guangdong Provincial forest Products Quality inspection Station Column, from which information about the introduction of the station, the inspection services, the sampling inspection bulletin and other documents related the quality inspection of forest products, could be accessible.

(iii) International Tropical Timber Organization (ITTO) Column, from which information about the progress and related activities of the IITO project could be released.

(iv) Guangdong Linke Technology Development Ltd. Column, from which information about the introduction to wood preservatives developed by the company and new products of wood preservatives developed at home and abroad could be accessible.

4.1.6.3 The laboratory construction was supported and approved by the Chinese Government

In 2008, the laboratory was constructed and upgraded as the Guangdong Forestry Product Quality Supervision and Testing Station and the State Forest Products Quality Supervision and Testing Center (Guangzhou Branch), with the support and approval of Guangdong Government and the State Forestry Administration, which were mainly undertaken the testing on the wood protection products and relied on the supporting institution GAF.

In Feburary 3, 2008, Guangdong Forestry Product Quality Supervision and Testing Station obtained the 《Aptitude Authorized Certificate》, and allowed to use CAL Logo and certificate number (2008)(Yue) Qualitative Inspect to Read No.003 (see the following pictures).

In addition, the《Aptitude Metrology Authentication Certificate》 was also got and CMA Logo and certificate number 2008190485Z was allowed to use. In March 17, 2008, the State Forest Products Quality Supervision and Testing Center (Guangzhou Branch) was set up and approved by the State Forestry Administration, with the《Administrative Licensing Decisions》, the 《certificate of authority》 and its number Linke Permission [2008]No.07.

Through measurement authentication, the testing station/center has basic conditions and ability specified by relevant state laws and administrative regulations, and it can open to the society and issues data and results of proof role, which will play an important role in boosting the establishent of quality monitoring and control system of wood protection.

4.1.6.4 13 technical Standards related to wood preservation have been drafted

During the project period, 13 National or industrial standards on wood preservation have been drafted or co-drafted or co-revised by EA.These standards are also the necessary component of the monitoring system, and they are summarized as follows:

Table 9 List of standards drafted or co-drafted by the project team

No.	Types	Titles	Completion situation	Roles
1	National (GB/T--)	Methods for analysis of waterborne wood preservatives	Standard draft has been approved GB/T 23229-2009	Second presider
2	National (GB/T--)	Methods for analysis of quaternary ammonium compounds in preservative-treated wood by 2-Phase Titration	Standard draft for approval	presider
3	National (GB/T--)	Methods of pretreatment for chemical analysis of preservative-treated wood	Standard draft for approval	presider
4	National (GB/T--)	Preservative-treated pole for supporting use in agriculture	Standard draft for approval	presider
5	National (GB/T--)	Safety code for wood preservation plant Part1:Plant design	Standard draft for approval	presider
6	National (GB/T--)	Safety code for wood preservation plant Part2:Operation	Standard draft for approval	presider
7	National (GB/T--)	Wood preservatives	Standard draft for approval	Second presider
8	National (GB/T--)	Use category and specification for preservative-treated wood	Standard draft for approval	Second presider
9	Industrial (LY/T--)	sawn timber of rubber wood	Standard draft for approval	presider
10	National (GB/T--)	Standard Method of Evaluating Wood Preservatives in a Soil Bed	Standard draft for approval	presider
11	National (GB/T--)	Method of Testing Water-Repellency Efficiency of Water Repellent	Standard draft for approval	presider
12	National (GB/T--)	Field test for evaluation of wood preservatives by ground proximity decay method	Standard draft for approval	presider
13	Industrial (LY/T--)	Method of laboratory test for toxicity of Wood reservatives to decay fungi	Standard draft for approval	presider

4.1.6.5 The wood preservation products quality monitoring system has been established preliminarily

The wood preservation products quality monitoring system has come into shape through setting up three quality inspection points including Guangdong (South China), Yangzhou (East China) and Sichuan (Southwest China), respectively. Through inspection points, the enterprises' products could be sampled and monitored regularly, which improve greatly the products quality and help enterprises cultivate good brand awareness.

As the members of the Guangdong Forestry Industry Association (GFIA) which will be in charge of the monitoring system, and the runners of the laboratories (Biological Lab & Chemical Lab) which will act as a key entity technically supporting the monitoring system, the project team will try to cooperate with GFIA and promote the operation of the monitoring system at the end of the project (see Figure 1 below):

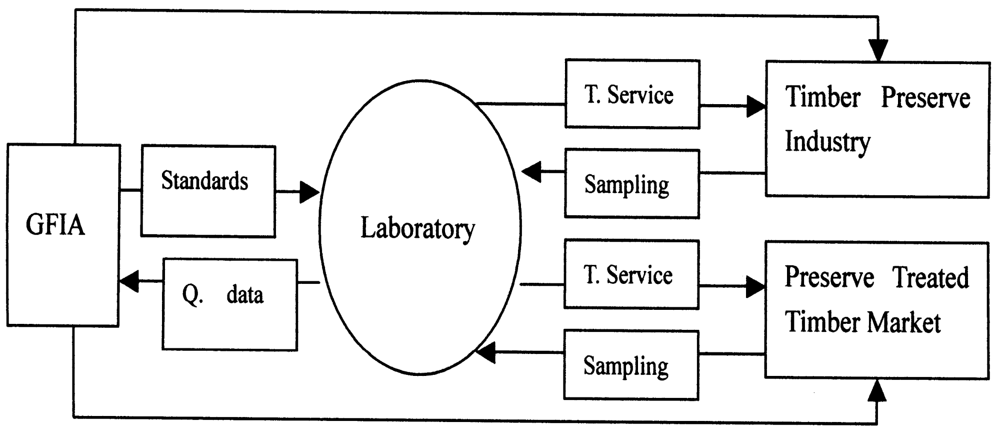


Fig.1 the operation of the monitoring system

4.2 Main output 2:

The improved technologies, including new developed environmentally sound preservatives are available and used in industry

4.2.1 New wood preservatives of low toxicity have been developed and tested

3 formulations of low toxic wood preservatives including SGB borate concentrated solution for protection from termites and decay, and SBB and SLB boron -based flame retardants have been developed and used in the industries.

The biological tests on SGB and its treated wood showed that wood (*Pinus massoniana*) brushed with a mixture of SGB preservative and water (1:1 and 1:2, mass ratio respectively) was very resistant to termites, and wood (*Eucalyptus urophylla*) treated with SGB at a retention level more than 3.119

Kg/m^3 by non-pressure treating could be highly resistant to decay fungi, and the acute oral toxicity of SGB to mammal belonged to low grade. Relevant technical report "***Test on the effectiveness of concentrated borate wood preservative***" is seen by attachment and which was submitted and presented at 40th Annual Meeting of the International Research Group on Wood Protection (IRG) in May, 2009.

Study on the Flame-Retardant Properties of Treated Wood (*Pinus massoniana* and *Albizzia falcate*) with SLB showed that when the wood retention was more than 40kg/m^3, the fire-retardant properties of the treated wood was comforming to corresponding standards, and better fire-retardant properties of treated wood was got with the increase of SLB retention in wood. At a similar retention, the fire-retardant properties of treated *A. falcate* wood were better than that of treated *P. massoniana* wood. Relevant technical report "***Study on the Flame-Retardant Properties of Treated Wood with SLB Flame Retardant*** " is seen as attachment and which has been published in periodical.

Study on Flame Retardant Performance of SBB and (NH4) 2HPO4 showed that the flame retardant performance of treated wood (*Pinus massoniana*) with $(NH_4)_2HPO$ or SBB was enhanced with the retention increased. The flame retardant effect of SBB is a little worse than that of $(NH_4)_2HPO_4$, but when both agents were mixed together a synergistic effect would play a role in improving the flame retardant performance of wood. Wood treated with a mixture of $(NH_4)_2HPO_4$ and SBB in a ratio of 1:3 and its 10% mass concentration working solution had the best flame retarding performance, and the mass loss rate of combustion is 5.19%, and the average flame combustion time is 0. Relevant technical report "***Flame Retardant Performance of the Boron-Contained Wood Preservative SBB***" was seen as attachment and which has been published in periodical.

In addition, the experiment on the screening of water repels for LVL was carried out. The test result showed that LVL treated with 20% paraffin emulsion could improve its waterproof property, and the water-repellent efficient (WRE) of LVL was significantly decreased. Relevant technical report "***Waterproof property of laminated veer lumber (LVL) made from poplar veneer treated with water repel***" is seen as attachment.

4.2.2 On-going tests maintain & data collection

Some exposure tests carried out before and during the implementation of this project have been maintained and recorded data regularly, in order to accumulate valid long-term data and ensure the sustainable development of the project. Details about the exposure tests are seen as attachments and summarized as follows:

(i) The field exposure tests on three species of wood *(Pinus masson. Pinus elliotti, Populus tomentosa*) treated with 6 wood preservatives including CCA, ACQ-B, ACQ-C, ACQ-Z, CC and CTL-oil were carried out in 2003, and one year interval for a check and data recording, and it has lasted about 8 years now.

(ii) In 2009, 4 pine woods (*Pinus masson, Pinus contorta, Pinus sylvestinis var. mongolica and larix gmelinii*) were treated with high temperature heat treatment (220-230^{o}c) and carried out the field exposure tests, and 3 months or 6 months interval for a check and date recording.

(iii) In 2009, 4 wood preservatives (ACQ-D, MCQ2:1, MCQ1:1, and MCA) treated pine wood with 4 retentions were exposed in the GAF exposure yard , 3 or 6 months interval for a check and data recording . The recorded data showed that after one year, most of the control samples were failure while most of the treated samples were still intact or being attacked by decay or termites lightly.

(iv) In 2009, 3 wood preservatives (CCA, ACQ and CuAz) treated small diameter of Eucalyptus wood with different retentions were conducted a comparative field exposure and soil-bed exposure tests at the same time, and checked once per year. The exposure tests were set up and done according to the suggested testing plan made by the international consultant Mr. jack Norton in his first consultancy report in 2008.

(v) In 2009, about 160 sample of small diameter of 8 species of Eucalyptus woods were carried out the field exposure test on the natural durability.

4.2.3 Demonstration of environmentally sound preserved product

ACQ (alkaline copper quaternary) is one of the water-borne wood preservatives widely used in the world for its efficient in wood preservation, insect prevention and termite resistance. It is an environmentally sound wood preservative free of toxic arsenic element unlike CCA which is most commonly used wood preservative contained toxic arsenic element. During the project period, ACQ and our newly developed products boron based wood preservative SGB have been used in agriculture and building and landscaping for demonstration. For example, integrating with TUAD program, 1 ha of banana plantation was used Eucalyptus supporting posts treated with ACQ preservative, and 1 ha of vegetables was used Bamboo supporting posts treated with ACQ. In addition, both ACQ and SGB treated timber have also been used in landscaping at public Parks and reconstruction of temples for demonstration.

4.3 Main Output 3:

The bamboo classification is established and some preserved treatment techniques are developed.

4.3.1 The development of preservatives for bamboo

According to the present application of wood preservatives, there was not a preservative developed for bamboo alone. But in order to study on the application of wood preservatives on bamboo, trials on the use of wood preservatives ACQ and CCA for treating bamboo have been carried out during the implementation of the project. The test results showed that bamboo could be treated with ACQ and CCA like wood, and the penetration of preservatives into bamboo was related to the structural properties of bamboo. The treatment results were shown in the following table 10.

In addition, the study on the new formulation of anti-mold agents for bamboo has been carried out, and 4 newly-formulated anti-mould agents were tested its efficacy on mould prevention of 3 bamboo species including *Bambusa eutuldoides*, *Phyllostachys pubescens* and *Arundinaria amabilis,* in comparison with commonly used anti-mould agent PCP-Na. Results showed that bamboo sample treated with higher concentration of anti-mould agents, got higher retention and better anti-mould effect. One newly-formulated anti-mould agent SMR has similar mould prevention effect to that of PCP-Na, and its treated bamboo was still in good performance against mould after 6 months exposure. The relevant technical report **"Study on the performance of treated bamboo with environmentally-friendly anti-mould agents"** is seen by attachment.

Table 10 The weight gain of bamboo after treated with wood preservatives

Bamboo species	Weight gain of bamboo (%, w/w)			Density (g/cm^3)
	ACQ (0.5%)	ACQ (1%)	CCA (2.5%)	
(Phyllostachys heterocycla x D.latiflorus) No.1	78.00	76.32	85.40	0.42
(Bambusa pervariabilis×D. latiflorus）No.7	69.56	66.09	78.04	0.45
Bambusa sinospinosa	59.35	66.80	74.97	0.57
[Bambusa pervariabilis×(D.latiflorus+B. textilis)] No.1	51.18	45.32	54.14	0.62
Dendrocala mus giganterus	60.16	59.65	65.37	0.62
Dendrocalamus brandisii	57.87	53.51	58.81	0.72
Phyllostachys glauca var. variabilis	35.69	36.21	47.43	0.81
Dendrocalamus bambusoides	21.94	27.05	27.36	0.84

4.3.2 Treating experiment of bamboo

At present the preservation processing of bamboo was mostly refered to that of wood. However, unlike wood, bamboo is amlost composed of axial tubulous cells and wood perservative penetrates into bamboo mainly through tracheas, sieve tubes and intercellular spaces in vescular bundles, and hence treating bamboo with wood preservatives could not be refered completely to the processing method of wood. In comparison with wood, bamboo has no radial parenchyma cells and ray cells, and its internodal cell tissues are all arranged vertically, and hence wood preservative is not able to penetrate into along the radial direction, and as well the hard and thin layer being rich in wax and silicon covered on the surface of bamboo also makes wood preservative penetrate difficultly into bamboo from radial direction. Besides, sedimentary colloidal material and thyloses in bamboo lead to the loss of transverse permeability of tracheas and sieve tubes inside bamboo. Therefore, bamboo is more difficult to be treated with wood preservatives than wood.

The tests on the treatability of *Phyllosrtachys heterocycla* and *Pseudosasa amabilis*, *Dendrocalamus bambusoides*, *Bambusa chungii* and *Dendrocalamus giganteus* were conducted during the implementation of the project, and wood preservatives CCA and ACQ were used for the pressure treatment. The results showed that wood preservatives could not be able to penetrate into bamboo culm if the internodes were not thirled and opened up, this happened especially in the case of *Phyllosrtachys heterocycla*. In the process of pressure treatment of bamboo, *Phyllosrtachys heterocycla* culm without oppening up the internodes cracked severely when a pressure of 0.9 Mpa was used, while *Pseudosasa amabilis* culm with smaller diameter did not crack under a presure of 1.4 Mpa. There was a linear relationship between the retention by mass in bamboo and its density, and in generally the weight gain of preservative treated bamboo decreased with the increase of bamboo density

4.3.3 Laboratory and field exposure tests of bamboo species

Bamboo is commonly used outdoor in Guangdong province, but the warm and humidity climate throughout the year makes preservatives or antimould agents untreated bamboos being easily attacked and damaged by decay or termites. To study on the natural decay resistance of bamboo, some of its characteristics could be understood and hence provides direct guidance for the rational utilization of the bamboo. During the implementation of the project, 13 species of bamboos commonly used in guangdong province were tested their natural decay resistance and natural durability by soil block tests and field exposure tests. The soil block test results showed that that among 13 bamboos tested, except 2 species (*B.pervariabilis×D.latiflorus No.7, and Dendrocalamus giganteus*) which belonged to light decay resistance rating, other 11 species belonged to decay resistance rating. Relevant technical report **"*Laboratory Exposure Tests on Bamboo Species*"** is seen by attachment.

Field exposure test results showed that the natural durability of bamboos were varied among 11 species tested, for example, *Thyrsostachys siamensis* and *D. bambusoides* had 21 average months of natural durability, while *Gigantochloa levis×D.latiflorus No.1* and *B.pervariabilis×D.latiflorus No.7* had only 9 average months of natural durability. Therefore, the natural durability of bamboo itself should be considered when it is selected to be used as untreated structural material. The rating of natural durability of bamboo is different from that of wood, since wood is uniform in three-dimensional structure while the structure of the outer green layer and the inner layer of bamboo is quite different which makes bamboo to be estimated difficultly its decay degree. In this test, the time lasted till more than 60% of bamboo samples was decayed or damaged was taken as the natural durable average month of bamboo.

It was reported that there was a linear relation between density of mature wood and its' natural durability, but the test result showed that the natural durability of bamboo was not related closely to its density, which was quite different from wood. The result of bamboo may be related to the effect of bamboo's chemical components, and abundant nutritive materials in bamboo make it being more susceptible to decay and termites, and the impact of these factors was more than that of the density on the natural durability of bamboo. Relevant technical report **"*The natural durability and preservative treatability of 11 bamboo species*"** is seen by attachment and which had been also submitted and presented in 41st IRG meeting in France in May, 2010.

4.3.4 The classification of bamboo

A grading method for assessing the performance of 18 common bamboo species was studied. The method was based on 4 grade levels with corresponding scores of 4 reference indexes of bamboos including culm diameter, culm-wall thickness, natural durabiliy and preservative treatability. In comparison with the traditional utlilization of bamboo, the grading results showed that this grading method was quite useful for evaluating the performance of bamboos, and bamboo species with higher grade level and higher score was more suitable to be used as timber. The relevant technical report "***Grading the performance of 18 common bamboo species***" is seen as attachment, and which had been submitted and presented at the 41th IRG meeting in France in May, 2010.

4.3.5 International consultancy & cooperation

The international consultant Mr. Jack Norton has 3 visit trips for his consultancy missons to EA according to the project schedule. The three visits were made on on 31 March 2008, 19 to 22 May 2009, and 16 to 23 October 2010 respectively. A number of recommendations given by him to EA during his visits were accepted by the project team and which were very helpful to EA for the improvement of the implementation of the project.

During each visit to EA, Mr. Jack gave an academic presentation about the wood preservation technology and wood science in Australia and in the world. The introduction to the preservative treated products quality monitoring system used in Australia by Mr. Jack was very helpful for EA in the establishment of the monitoring system for the treated timber products in China. His first consultancy report and final consultancy report were seen by attachment.

The project team had not only improved the project implementation according to his recommendations, but also carried out an experimental plan **"Evaluation of the environmentally friendly wood preservatives alkaline copper quaternary (ACQ) and copper azole (CuAz)"** and a research project "**Evaluating the impact of debarking before preservative treatment**" proposed and designed by him.

In his final consultancy report, Mr Jack Norton concluded that the team at GAF has successfully achieved the objectives of the project’s activities. Indeed the members are to be congratulated on their efforts.

4.3.6 Report on study tour to Indonesia

As part of the training program for the project, one visit to Indonesia was arranged for the project staffs. The visit took place from 11 to 16 January, 2011, the schedule and activities for the visit in Indonesia are seen in Table 11. The objective of the visit was to know better about the situation of the development of wood/bamboo preservation in the target country and to enlarge the visual field of the project team in order to improve the future research of the project team.

On the day visited the Forest Products Research and Development Center (FORDA) in Bogor, the visitors were warmly welcomed by the deputy director, professor Agus Djoko ismanto, and his colleagues including the administrative staffs and technical staffs and experts in the fields of wood processing, wood engineering, wood drying, wood chemistry, wood physics and mechanical, wood anotomy and identification, wood preservation and wood composites. The visitors had an academic exchange meeting with the FORDA staffs, and shared with the host their achievements and experience of executing ITTO projects by giving a presentation "Introduction to the wood preservation in China" and the meeting was active and firendly. After the exchange meeting, the visitor had the opportunity to be showed around different divisions of FORDA and relevant laboratories including the insturments laboratory, entomology and mycology laboratory, wood drying facility, wood preservation pilot plant, wood processing workshop, wood/bamboo composites products, wood specimen collection room and so on.

The visitors also visited the Bogor Agricultural University (BAU) and received the hospitality of the head of the Department of Forest Products, Dr. Wayan Darmawan and the head of the Division of Bio-Composite, Dr. Yusuf Sudo Hadi. A short exchange meeting was also held for the visitors and some staffs of the Department of Forest Products. The visitors then had the opportunity to visit Bogor Botanical Garden and Bamboo Collection Garden of BAU guiding by Dr. Yusuf Sudo Hadi and his colleagues. Wood/bamboo preservation and utilization in Indonesia were introduced to the visitors aslo during the visit.

One mission of the study tour in Indonesia is to visit bamboo preservation treatment plants and invesigate the bamboo preservation and utilization in Indonesia, so the visitors were arranged to visit the Environmental Bamboo Fountation (EBF) in Bali, an non-profit organization, which used to work on bamboo preservation in collaboration with the world leading expert in bamboo processing in using Boucherie Bamboo Preservation, and now mainly work on the Green Tourism Villa, with pure bamboo buildings and structures and bamboo garden. By the head of EBF, the visitors were introduced to PT Bamboo Pure Ltd, a bamboo preservation treatment plant, which was an overseas-funded enterprise, bamboo culms were mainly treated with boron-based wood preservatives by non-pressure method—hot and cold bath treatment. The PT Bamboo Pure Ltd processes the treated bamboo into different finished products for the buildings and structural construction for selling. Its Green villa under construction with pure treated bamboo was also introduced to the visitors.

Table 11 The schedule and activities for visit in Indonesia

Day	Activities
Day 1	11 Jan. 2011, Tuesday, Arrival in Jakarta Bandara Soekarno Hatta Airport from Guangzhou Baiyun International Airport and accommodated at Shantika Hotel Bogor.
Day 2	12 Jan. 2011, Wednesday, 09:00-11:00, visit Forest Products Research and Development Center; 13:00 – 15:00, visit Bogor Agriculture University; 15:00 – 17:00, visit Botanical garden in Bogor.
Day 3	13 Jan. 2011, Thursday, 09 - 10:30, visit bamboo collection garden of Bogor Agricultural University; 11:00 – 15:00, visit bamboo handicrafts and products markets in Bogor; 19:20, leave Jakarta for Bali; 21:30 arrived in Bali and accomodated at Kuta Station Hotel Bali.Ngurah Rai Airport.
Day 4	14 Jan., 2011, Friday, visit wood curvings plant and shops and bamboo products factory markets in Bali in the morning; visit Environmental Bamboo Foundation, Bali, in the afternoon.
Day 5	15 Jan., 2011, Saturday, visit bamboo preservation treatment plant in Bali---PT Bamboo Pure Ltd. and Green Village.
Day 6	16 Jan., 2011, Sunday, 06:00, departure from Bali for Guangzhou with a stopover in Jakarta.

The following project staffs participated in the visit:

1. Mrs. Zhang Yanjun: professor, speciality in chemical analysis, and assist project leader and Chief supervisor of laboratory and monitoring system - Guangdong Academy of Forestry (GAF)
2. Mrs. He Xuexiang: associate professor, speciality in biological tests, and assist project leader and chief supervisor of external communication and coordination with ITTO - GAF.
3. Mrs. Chen Lifang: associate professor, speciality in chemical analysis, assist chief supervisor of laboratory and monitoring system - GAF.
4. Mr. Xie Guijun: assistant professor, speciality in wood modification, assist chief supervisor of laboratory and monitoring system - GAF.

4.4 Main output 4:

A demonstration treating plant is set up. Information can be accessed through seminars/workshops, training courses, publications and internet

4.4.1 2 Demonstration treating plants were set up and related regulations were established

2 demonstration treating plants (see two sub-contracts by attachment) have been set up in Gaozhou and Guangzhou, Guangdong province respectively, and the treatment plant in Gaozhou is mainly provided the preservatives-treated timber for agricultural use, while the treating plant in Guangzhou is mainly provided the treated timber for building materials and gardening materials uses.

The rules and a specified procedure for the safety production of timber preservation treatment plant was framed, and the relevant document ***"Operation Instructions for Timber preservation treatment plant"*** is seen by attachment.

In addition, 2 regulations on the standardization of the safety operation of timber preservation treatment plant has been established, including ***"Safety code for wood preservation plant Part1:Plant design"*** and ***"Safety code for wood preservation plant Part2:Operation"***, both have been approved by the Chinese Standard Commission as the national standards. The two demonstration treatment plants were constructed according to the two standards and specified procedure and meet standard requirements for the management, quality control and the safety of production.

4.4.2 3 Training courses has been hold for the wood treatment plant

During the implementation of the project, integrating with the TUAD program and the demonstration program of treating plants, 3 technical training courses were designed and hold for the workers and administrative staffs of the treating plants, and let them understand the relevant terms of wood preservation, the basic requirement for the design and planning of the treating plant, the design of facility, the management of the leakage of the wood preservatives, the safety operation of workers, the contact and uses of wood preservatives, the equipment operation, the waste treatment and so on.

Table 12 The schedule of the training courses for treatment plants

Date	Location	Number of participants	Training contents
January 8, 2009	Guangzhou	12	The basic knowledge of wood preservation
January 13, 2009	Gaozhou	37	The basic knowledge of wood preservation
October , 2010	Gaozhou	18	The safety and standardization production of treatment plant.

4.4.3 7 seminars/workshops related on wood preservation have been hold

Integrating with the TUAD program, totally 7 seminars /workshops were organized by the project team, and there were more than 200 participants from every walks. Details about each seminar /workshop organized by the project team were summarized as follows:

(i) On March 1, 2008, the first seminar was held in the campus of EA, Guangzhou, after the ITTO project on-line monitoring system training workshop, Dr. YS Hadi from the Bogor Agriculture University, Indonesia and Dr Tan Ye from The Forest Research Institute of Malaysia (FRIM), Malaysia, were invited to have an academy exchange with the project team, both of them gave the presentation about the situation of treated preservation industry in Malaysia and Indonesia respectively, and the project team gave the talk on about the wood preservation development in China and introduction to wood protection research group, the project team. There were about 25 participants from universities, institutes and enterprises.

(ii) On March 31, 2008, the 2nd seminar was held in the campus of EA during the first consultancy mission of the international consultant Mr. Jack Norton. Mr Jack Norton gave the presentation about the situation of wood preservation industry in Australia and gave suggestions related to how to establish the monitoring system for treated timber products in China. 25 participants were from universities, institutes and enterprises. Extensive discussion was launched to the issue about the unfair competition and variable products quality of wood preservation market due to the lack of standardization and quality monitoring of wood preservation production in China at the seminar.

(iii) On January 17, the 3rd seminar was held in the campus of Gaozhou Forest research Institute, the project leader Mr Su Haitao gave the talk mainly about technical requirements for the application of preservatives treated timber for supporting poles for crops such as banana, melon, fruits , vegetables and so on. 37 Participants mainly came from local forestry administrative institutions, research institutes and farmer representatives.

(iv) On March 11, 2009, the fourth workshop was held in Chengdu, Sichuan province, there were about 18 participants including administrators and sales representatives from the wood preservation treatment plants. The project leader Mr. Su Haitao gave the presentation about the wood preservation technology, key technical requirements in wood preservation production, safety production and standardization operation rules and basic knowledge for identifying the quality of preservatives treated timber. He emphasized the importance of producing treated products in good quality for the reputation of the industry. Discussion was also opened out on the situation and problems existed in the wood preservation industry in China during the workshop.

(v) On May 20, 2009, the 5th seminar was held in the campus of GAF, the Australian expert on wood preservation, Mr Jack Norton, dring his 2nd mission of international consultancy of the project, Professor Gao Zhenzhong from South-China Agricultural University, and the project staff Mrs. He Xuexiang gave the presentation at the seminar, respectively, including topics ***"The Situation of Wood Preservation Technology Development in Australia and Other Countries in the World"***, ***"The Development of the Flame Retardant and Wood Modification Technology in China"*** and ***"Introduction to the ITTO Project PD 398/06 Rev.2 (I) 'Promoting the Utilization of Plantation Resources by Extending Environmentally Sound Wood Preservation Technology '"***. Broad and in-depth discussion was also opened up especially on monitoring and detecting techniques for the wood preservation at the seminar. Participants were mainly from 12 organizations including universities, research institutes, Guangdong Forestry Administration Department and wood enterprises.

(vi) On November 16-19, 2009, the sixth workshop, **the Seventh Symposium on Chinese Wood Protection and the 25th Anniversary Celebration of the Establishment of Wood Protection Research Group of Wood Industry Association of Chinese Society of Forestry,** was held in Guangzhou. It was organized by the project team with the assistance of Chinese Research Institute of Wood Industry. The theme of the symposium was "**The Development of Wood Protection Technology and Quality Control of Treated Wood Products**". 45 papers were received and 101 participants were from 55 institutions including research institutes, universities, enterprises, testing institutions and media agencies. The project leader Mr Su Haitao gave the presentation ***"Strengthen the quality monitoring of wood preservation products" ,*** and he put forward the ideas of the establishment of quality monitoring system of wood preservation products in China.

(vii) On October 21, 2010, the 7th seminar was held in the campus of EA during the 3rd consultancy mission of the international consultant Mr. Jack Norton. Mr Jack Norton, the executive director of the International Research Group on Wood Protection (IRG), professor Wei Xiang from Central-South China Forestry Technical University, associate professor Tu Dengyun from South China Agricultural University and Mr Xie Guijun , a project staff, gave the presentations respectively, including topics ***"Recent advances in the development of timber treatment technology in Australia"***, ***"Study on the moisture content of wood in the process of high temperature treatment "***, ***"The application of techniques for ultra-temperature treatment of wood"*** and "***Study on the heat treatment of wood"*** respectively.

4.4.4 Attending national and international meetings related to wood protection

The project team attended one national conference and 2 international meetings, details about the meetins is the following:

(i) On November, 17-19, 2010, attending the Fifth Symposium on Chinese Wood protection held in Kunming. 190 Participants came from institutions related to wood protection, including enterprises, research institutes, universities, governnment departments and news media. At the symposium, the project leader Mr Su Haitao gave presentation on the relevant quality problems in the process of wood preservation production, and the project staff Zhang Yanjun gave the talk on strengthening the quality control of wood preservation products.

(ii) On May 24 - 28, 2009, attending the 40^{th} Annual Meeting of the International Research Group on Wood Protection (IRG), in Beijing, China, and submitted one paper "**Test on the effectiveness of concentrated borate wood preservative**" （IRG/WP 09-30500) which was given the oral presentation by one project staff Mrs. He Xuexiang.

(iii) On May 9-13, 2010, the 41th Annual Meeting of the International Wood Protection Research Group (IRG) was held in Biarritz, France, the project team submitted 2 papers **"The natural durability and preservative treatability of 11 bamboo species"** (IRG/WP 10-10708) and **" Grading the Performance of 18 Common Bamboo Species" (IRG/WP-10-10723)** and authorized the new executive Director of IRG, Mr Jack Norton, the international consultant of the project presented the papers for us at the meeting.

4.5 Main output 5:

Treated-timber for Uses in agriculture emonstration-region (TUAD) is Established

4.5.1 TUAD has been planned

TUAD program has been planned in the first two months of the project period, and the proposal could be seen as attachment. The content of the demonstration including the following elements:

(i) Setting up 20 hectares of preservative treated timber utilization site for demonstration

(ii) Disseminating standard of 《Preserved wood banana post》for 1,000 copies at least

(iii) Compiling and disseminating the Manual on using of preserved wood banana post for 1,000 Copies at least

(iv) Holding workshops

(v) Disseminating Information via media

4.5.2 TUAD sites has been set up

20 ha of TUAD sites were set up as planned, distributed at 3 towns and 1 county in two cities in the province respectively, and in these sites treated Eucalyptus and bamboo poles were mainly used for supporting crops including banana, Chinese yam, Holand bean and bitter gourd. In addition, 3 dditional

demonstration sites with an area of 2.5 ha has been set up in the project period, including one located at a State Forest Farm of Guangdong Province, in which treated pine poles wee used for supporting the fruit Pitaya; other two were set up in Hainan Island and Guangxi Zhuang Autonomous Region, respectively, in which only treated Eucalyptus poles were used for the supporting banana, and collaborating with the local farmers and companies. The detail information for the distribution of demonstration site is as follows:

Table 13 Details of TUDA sites

No.	Region/province	Detailed site	Area (hectares)
1	Gaozhou, Guangdong	Changpo town	6
2	Gaozhou, Guangdong	Changpo town	8
3	Gaozhou, Guangdong	Mukeng town	4
4	Huizhou, Guangdong	Bolo county	2
5	Zhaoqing, Guangdong	DaNanshan state forestry farm	0.5
6	Chongzuo, Guangxi	Jiangzhou town	1
7	Chengmai, Hainan Island	Agricultural Limited Company	1
	Total		22.5

4.5.3 Publicity materials on treated timber have been compiled and disseminated

During the implementation of the TUAD program, more than1000 copies of standard document **"Preserved wood banana post"** and 1000 copies of the manual of using of Preserved wood banana post have been sent to the users of the preservatives treated products, including farmers and treating plants, and sellers of treated timber products.

4.5.4 Holding workshops related on wood preservation

During the implementation of the TUAD program 4 workshops have been held by integrating with the the establishment of the demonstration plant program, and detail about the workshops was seen in Main output 4.4.

4.5.5 Information related to wood preservation and the progress of ITTO project have been disseminated through public media, TV program, internet and brocasting

(i) On August 29, 2008, a paper titled "The most long-lived 'Wooden-chair Grandpa' could live for more than 40 years" was reported by Guangzhou Daily Newspaper for introducing the wood preservation technology, which can be seen by opening website : http://gzdaily.dayoo.com/html/2008-08/29/content_302843.htm. In addition, the Guangdong Southern TV introduced also wood technology by having an interview with the project leader Mr Su Haitao.

(ii) Integrating with the program for establishing the monitoring system, we set up a website (http://www.gdfri-wp.com) called Wood ProtectionTechnology Website, and timely renew the information of the website, which has become a main window for counterparts at home and abroad to understand the progress of the ITTO project and information on wood preservation. Details of the website could be known more in Main output 4.4.

4.6 Contribution to the achievement of the development objective

(i) The prospect in extending advanced wood preservation technology is rather optimistic. In recent years, wood preservation industry develops rapidly, and more than 400 processing factories have been set up successively, and the annual output of treated timber is up to 1.5 million m^3, which will be expected up to 8 million m^3 to 12 million m^3 by 2020. Treated timber has been widely used in landscaping and buildings, and as well as involved in the national key projects like the Olympics, the World Expo and the Asian Games. It is predicted that the demanding for preservative treated timer will continue to grow rapidly in the future years.

(ii) The the environmentally sound wood preservation demonstration sites set up during the impelmenttaion of this project will guide the industry toward a sound and healthy development direction, and which is no doubt to promote the further development of the environmentally sound wood preservstion technology. At present, the environmentally sound wood preservation products acccount for only 15% to 20%, and which will be expected to account for more than 80% by 2020.

(iii) The fast testing techniques for wood preservation products produced in this project have been applied in the process of wood preservatives production and wood preservation processing by many enterprises, and which has made the production process including production cost and products quality be controlled and monitored effectively, and hence created good social benefits.

(iv) The quality monitoring system of wood preservation products has been established preliminarily, and which has strengthened the quality monitoring of the wood preservation products and is helpful for standardizing the wood preservation market, protecting environment and promoting the orderly and healthy development of wood preservation industry.

4.7 Target Beneficiaries Involvement

(i) The wood processing industry who obtaining the new technology is the direct beneficial owner, and as well many other potential clients who got aware of the new technology by participating in the seminars/workshops, observing the demonstration plants and TUAD sites or through public media like website, newspapers and television. They will be also benefited from a more regular market environment due to the facilitation of the monitoring system established by the project.

(ii) The consumers of the treated timber products, including farmers and landscape builders, know how to use the treated timber products with different retentions under different environment, and how to distinguish what is qualified products by participating in the quality monitoring system established. They can aslo save a lot of money annually by using the durable treated timber products instead of the untreated ones.

(iii) The suppliers of the treated timber products, especially the forest plantation growers, are also one of the main beneficiaries. Wood preservation technology not only increases the added-value of the timber products but also promoting the consumption of plantation timber.

(iv) The public is also one of the main beneficiaries. More and more treated timber with environmentally sound preservatives are used in the urban construction projects including public facilities, landscape building and the playgrounds where children often reach and touch, which create more and more safe and comfortable environment for the community.

4.8 The situation existing at project completion as compared to the pre-project situation

(i) The executive agency, with the improved laboratory and RD resources, is ready to service the industry, playing as the regional technical center in terms of technology and information by means of demonstration, training, seminar/workshop, publications and internet etc.

(ii) A products quality monitoring system for industry is established and in functioning. A framework between the government and industry sector is in operation to supervise and coordinate the quality of products in the market and the treating plants' operation.

(iii) Wood preservation has been expanded from less 100 enterprises to more than 400 enterprises in China and become a vigorous industry, which has promoted the rational utilization of plantation timber by producing good value products.

(iv) Technologies derived from this project such as environmental sound preservatives (e.g. ACQ, boron- based preservatives) and fast testing methods for wood preservatives or treated timber, for example, have been disseminated into industry.

(v) The laboratory established in this project has been authorized by the authority, which is not only the main component body of the product monitoring system but also becomes a R/D center focusing on tropical plantation timber utilization in the South China area.

(vi) The demonstration elements, including the treating plants and TUAD sites, have been evolved into a permanent wood preservation technological extension base, which will continue to play a role in promoting the development of wood preservation industry.

(vii) Wood preservation has attracted great attention of government departments.

4.9 The expectation of project sustainability after project completion

(i) The project team has done a lot of works on the wood preservation since the implementation of the ITTO project, including the application and extension of CCA preservatives in agricultural uses, the development of new environmentally sound preservatives, the drafting of standards, the establishment of the monitoring system etc. It could be said that the project team has played a very important role in promoting the development of wood preservation industry in China. To ensure the sustainable development of the project, the outputs of the project, for instance the application technology of the preservatives will be used in the first extension program of GAF and be extended at national level. As the increase in demanding of environmentally sound preservatives and preservation technology, the extension of these technologies will be the key element in the future work.

(ii) The project has been got great support from EA. It is expected that EA will continuously give support to the project team to ensure the sustainable extension of the project by ways including to make sure personnel and facilities available for the project team, and to encourage and assist the project team to apply more research projects funded by state or local, and provincial governments, especially the extension projects, in order to make sure sufficient fund for the further research and enlarge the influence of the project team on wood preservation industry.

(iii) The provincial government has accepted two suggestions proposed from the representatives of the Provincial People's Congress "the suggestion on the extending uses of treated timber in the construction of urban public facilities" and "the suggestion on the strengthening investment in the wood protection research", and this is very important to maintain the sustainable development of the project. In fact, more treated timber has been used in the public facilities construction and wood protection has been considered more in the Governmental Scientific Research planning recent years.

5. Assessment and analysis

(i) The specific objectives planned in this project have been successfully realized.

(ii) The main outputs of the project planned have been also achieved with some additional outcomes made them more perfect than the original plan.

(iii) On the whole, the project was implelmented according to the schedule planned. The actual duration of the project was extended for 3 months because 2 activities planned had to be delayed due to irresistible reasons.

(iv) The total expenditure of the project was US$413,806.00 involved with a small amount of additional cost US$249.65, among the ITTO fund was remained US$4753.35, while the government counterpart’s fund was overspent US$5000.00 according to the final financial auditing report. By the end of the project period, the realized cash received from ITTO's fund by EA was totally US$222,500.00, and the committed 6th installment of US$20,000.00 has not received, and thus EA is in a debt of US$15,246.65 ITTO fund at the moment. While the whole project was overspent US$246.65, it is expected that the 6th installment will be arranged as soon as possible so that the on going work could be carried on smoothly.

(v) To further strengthen and disseminate the results obtained rather than to have another project in the same region is recommended. But a replication in other countries with similar conditions may be feasible.

(vi) The wood preservation in China is still in its infancy, so to further strengthen and disseminate the achievements of R/D obtained to promote the development of industry, a follow-up project on training and demonstration program is essential. In addition, to run legally and fairly the quality monitoring system of wood preservation production set up with the support of local government is important for ensuring the development of a sound and healthy wood production industry, so a follow-up collaboration project with other countries with a well- established quality monitoring system of wood preservation production as well as a follow-up action for cooperation with local government and industries are essential.

(vii) The website for wood protection technology has been set up and is accessible, through which outputs of the project and information can be disseminated easily to people who require.

(viii) The international consultant has had great contribution to the project, his comments and advices raised during three consultancy missions were very helpful for the improvement of the technical level of the outputs and sufficiently completion of the objective of this project.

(ix) Timber treated with environmentally sound preservatives (ACQ/CC) is still limited used due to their costly production and products. But with the raise of the people's living standards, environmentally-sound treated timber will be accepted by more people in future.

(x) The monitoring system of the wood preservatives and treated products has been set up and put into operation. But it would be an arduous work to keep the system performs its function continuously. The coordination and active participation of enterprises, customers, Government Departments and publics in the system is important but it is a time-taking issue too.

(xi) Study on bamboo preservation was not deep enough in this project and further research is needed.

6. Lessons Learned

6.1 Development lessons

6.1.1 The design of the project proposal is the main factor to determinate the success or failure of the developmental goal

(i) The developmental objective of the project is consistent with the national policy related, 《General Office of the State Council forwarding the notification from National Development and Reform Commission "About the work opinion for the speeding up of the saving of timber and using of timber substitutes"》（the State Council Document No.(2005〕58.）. In addition, this is the follow-up project of the previous project PD 52/99.Rev.2(I), which had achieved its anticipated target, and made wood preservation and treated timber known by many, and as well provided technical and congnitive groundwork for the development of wood preservation industry in southern China. Wood preservation industry has been regarded as a promising industry in Southern China.

(ii) The project positioning is to provide a sound R/D groundwork and technical support for the industry. The outputs and activities of the project, for example, the environmentally sound wood preservation treatment technology, the products quality monitoring system, and the demonstration use of environmentally sound wood preservatives treated timber products are all considered further development in the future.

(iii) At the present stage, the utilization of environmentally sound wood preservation products is still very limited, and it is crucial for the project team to get further support to extend the utilization of technology and products quality monitoring techniques. Therefore a follow-up project along this direction especially in the field of bamboo wood preservation treatment technology is essential.

(iv) To continue to call on the Government to support the construction of wood preservation products quality system, and make sampling testing become a routine inspection.

(v) With the facilities and resources set up by the project, the project team is now carrying out some experiments and testing for domestic and foreign enterprises on the preservation products and as well collaborating in the development of products with the enterprises.

(vi) The laboratory and demonstration treatment plants and sites have been opening to industry, research and education. It is important for more and more people to receive the technical training in the future.

(vii) With the help of public media like network platform, the knowledge of environmentally sound wood preservation was introduced, which let more and more people know about the latest related information. This has given a good education to the public.

6.1.2 Factors which will most likely affect project sustainability after completion

(i) Financial supports available to further improve and maintain the on-going long term activities started during the two ITTO projects.
(ii) A well trained technical team maintained
(iii) Government and related policies supports.
(iv) A follow-up ITTO or Government project will be a crucial factor.

6.2 Operational lessons

6.2.1 Project organization and management

(i) It has been proved to be a right decision to emphasize on some forward-looking activities such as the development of environmentally sound wood preservation technology, the quality monitoring system establishment and demonstration programs because the timber preservation industry is till in its infancy in China.
(ii) The international consultant, Mr. Jack Norton, has played an important role in the project implementation. He is an Australian scientist with rich experience in wood preservation production industry. He made many comments and recommendations which were not only helpful to the project executive but strengthened the international exchange.

(iii) The field exposure yards set up by the project have been well used through the collaboration with universities, research institutes and production enterprises, domestic and international as well. The project team has also improved its ability and got public awareness in the interactivities.

6.2.2 Project documentation

ITTO has an adequate guidance for project documentation and an ITTO On-line Project Monitoring System Training Workshop was held in Guangzhou in Feburary, 2008, which were great assistant for documenting.

6.2.3 Monitoring and evaluation, quality of project planning

(i) It is necessary for national and international experts with rich experience and expertise in the field involved in the project monitoring system and evaluation, especially the international consultant of the project has had great help to the project execution.

(ii) Three ITTO Project Technical Committee (PTC) meetings, held in Feburary, 2008, Feburary, 2009, and March, 2010 respectively, provided very timely and effective guidance to the progress of the project, which also ensured the project going on track.

(iii) The Government officials related inspected the project many times and gave concern to its progress, and as well the coordination and informationa exchanges between ITTO and local Government in the monitoring have contributed greatly to the project implementation.

6.2.4 Definition of the roles and responsibilities of the institution involved in the project implementation

Roles and responsibilities defined on subcontract basis is proved a good way for implementation and management in a project. Sub-contracts agreements were signed between the Subproject Executors and the Project Executive Agency in this project, and the implementation of the subcontracts, particularly the subcontract for employing international consultant ended well with outcomes expected. In this project, the construction of demonstration plants and TUAD program were all implemented and managed on subcontract basis and defined the roles and responsibilities of both sides.

6.2.5 Actions to be taken to avoid variation between planned and actual implementation

Variation is sometimes unpredictable so that adjustment is necessary. Main changes in the implementation of this project were as follows:

(i) In order to extend the influence of the TUAD program and as well at the customers' request, 2 more demonstration (TUAD) sites were set up outside the Guangdong province and one more in the province. But the planned activities were not affected and no additional cost incurred.

(ii) Study tour outside the country was organized only one trip with more trainees rather than once trip per year with fewer trainees, and which is the main factor leading to additional 3 months extension of the project due to inevitable reasons.

(iii) Developing preservation technology for bamboo is the key research activity of this project, since bamboo is quite different from wood in structural properties, and bamboo preservation treatment is much harder than wood. Therefore more tests on bamboo preservation were reasonally forseen and hence incurred the delay of plan for 2 months, which is also another main reason for the extension of the project.

7. Conclusions and Recommendations

7.1 Conclusions:

In general, most activities of the project were well carried out according to the work plan and the guideline of ITTO, and the project was completed with all the specific objectives achieved.

(i) Progress has been made towards the promoting and extending the environmentally sound wood preservation technology for uses timber preservation industry in China. Relevant information is accessible for the potential investors and timber consumers, and the technologies derived from this project have been adopted by industry.

(ii) The demonstration sites, demonstration plants and website established by the project have been playing an important role in dissemination the knowledge of high value use of plantation timber. The provincial government has started to pay attention on the wood preservation industry, and more and more treated timber have been used in the construction of urban public facilities, and as well wood protection research has been considered in the Government's scientific research planning.

(iii) The total expenditure of the project was US$413,806.00 involved with a small amount of additional cost US$249.65. By the end of the project period, the realized cash received from ITTO's fund by EA was totally US$222,500.00, and the committed 6th installment of US$20,000.00 has not received, and thus EA is in a debt of US$15,246.65 ITTO fund at the moment, it is expected that the 6th installment will be arranged as soon as possible so that the project team could work on other projects smoothly.

7.2 Recommendations:

(i) More international communication and information exchange with countries well developed in wood preservation and/or in tropical region would be significant to ITTO projects' activity. (It is helpful to go to the advanced countries for academic visit and and experience with other ITTO projects staffs. In this project, due to limited fund, we only had a 6 days study tour in Indonesia and had academic exchange with them , and shared with them our experience and achievements of the ITTO projects.)

(ii) It is strongly recommended that a training course or a workshop for the main project staffs on project execution and management is necessarily.

(iv) Study on bamboo preservation are not deep enough in this project, and the existing technology for bamboo preservation is still unable to meet the need of industrial production of treated bamboo, so further research on bamboo preservation will be needed in the future.

(v) Wood preservation industry is not well developed in tropical countries. It is suggested that ITTO continue to organize more projects to promote the better use of tropical timber. China needs to maintain the on-going activities, and extend achievements obtained from this project so that the timber preservation industry could be further developed sustainably.

Responsible for the Report

Name: (type and sign) **Position held: Su Haitao**

Date: May 18, 2011

Annex 1 Project financial statement

PROJECT FINANCIAL STATEMENT(in US Dollar)

for ITTO Funding

Project/Pre-Project No. PD 398/06Rev.2(I)

Period ending on: **January 31, 2011**

Project/Pre-Project Title: Promoting The Utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

Component			Original Amount (A)	Expenditures To-date Accrued (B) a/	Expended (C)	Total (D) { B + C }	Available Funds (E) { A - D }
I.	Funds managed by Executing Agency						
10.	Project/Pre-Project Personnel						
	11.	National Experts (long term)	0	0			
		11.1 Project Coordinator					
		11.2 Forester 1					
		11.3 Forester 2, etc.					
		11.4 Administrator					
	12.	Other Personnel	0				
		12.1 Assistant 1					
		12.2 Assistant 2					
		12.3 Other labor	0				
	13.	National Consultant(s) (short term)	12,000.00	0	12,025.32	12,025.32	-25.32
		13.1 Consultant 1					
		13.2 Consultant 2					
		13.3 Consultant 3					
	14.	International Consultant(s)	15,000.00	0	15,000.00	15,000.00	0.00
		14.1 Forest Inventory Expert					
		14.2 Consultant 2					
	15.	Fellowships and Training					
		15.1 Training 1 (specify beneficiaries)					
		15.2 Training 2					
		15.3 Training 3					
	19.	Component Total:	27,000.00	0	27,025.32	27,025.32	-25.32
20.	Sub-contracts						
	21.	Sub-contract	35,000.00	0	35,000.00	35,000.00	0.00

	22.	Sub-contract (Topic 2)					
	29.	Component Total:	35,000.00	0	35,000.00	35,000.00	0.00
30.	Travel						
	31.	Daily Subsistence Allowance 31.1 National Expert(s)/Consultant(s) 31.2 International Consultant(s) 31.3 Others	11,000.00	0	11,020.22	11,020.22	-20.22
	32.	International Travel 32.1 National Expert(s)/Consultant(s) 32.2 International Consultant(s) 32.3 Others	8,500.00	0	5,875.80	5,875.80	2,624.20
	33.	Local Transport Costs 33.1 National Expert(s)/Consultant(s) 33.2 International Consultant(s) 33.3 Others	10,000.00	0	10,364.28	10,364.28	-364.28
	39.	Component Total:	29,500.00	0	27,260.30	27,260.30	2,239.70
40.	Capital Items						
	41.	Premises					
	42.	Land					
	43.	Vehicle(s)					
	44.	Capital Equipment 44.1 Computer Equipment (specify) 44.2 Forestry Equipment (specify) 44.3 Others	73,000.00	0	67,946.79	67,946.79	5,053.21
	49.	Component Total:	73,000.00	0	67,946.79	67,946.79	5,053.21
50.	Consumable Items						
	51.	Raw Materials	47,700.00	0	48,529.16	48,529.16	-829.16
	52.	Spares	2,500.00	0	2,506.98	2,506.98	-6.98
	53.	Utilities	14,500.00	0	15,989.36	15,989.36	-1,489.36
	54.	Office Supplies	10,000.00	0	10,166.58	10,166.58	-166.58
	59.	Component Total:	74,700.00	0	77,192.08	77,192.08	-2,492.08
60.	Miscellaneous						
	61.	Sundry	3,300.00	0	3,322.16	3,322.16	-22.16
	62.	Audit Costs					

63. Contingencies					
69. Component Total:	3,300.00	0	3,322.16	3,322.16	-22.16
70. National Management Costs					
71. Executing Agency Management Costs					
72. Focal Point Monitoring					
79. Component Total:	0			0	
Sub-Total:	242,500.00	0	237,746.65	237,746.65	4,753.35
80. Project Monitoring & Administration					b/
81. ITTO Monitoring and Review					
82. ITTO Mid-term and Ex-post Evaluation					
83. ITTO Programme Support Costs					
83. Donor Monitoring Costs					
89. Component Total:					
90. Refund of Pre-Project Costs (Pre-Project Budget)					b/
Sub-Total:		-	-	-	b/
100. GRAND TOTAL:	242,500.00	0	237,746.65	237,746.65	4,753.35

Note: Budget Components are those detailed in the Project/Pre-Project Document.

a/ Accrued expenditure: expenditures committed/accrued as at the end of the reporting date, but not yet settled.

b/ Funds retained and accounted for by ITTO - details not available with Executing Agency.

Annex 2 Project cash flow statement

PROJECT/PRE-PROJECT CASH FLOW STATEMENT

For ITTO fund

Project No. PD 398/06Rev.2(I) Period ending on: **January 31, 2011**

Project Title: Promoting The utilization of Plantation Timber Resources by Extending Environmentally Sound Preservation Technology

Component			Reference	Date	Amount	
					in US$	Local Currency
A.	**<u>Funds received from ITTO:</u>**					
	1.	First instalment	Agreement	Dec 07	60,000.00	443,784.00
	2.	Second Instalment	Agreement	May 08	60,000.00	418,128.00
	3.	Third instalment	Agreement	Nov 08	40,000.00	272,604.00
	4.	Fourth instalment	Agreement	May 09	40,000.00	272,632.00
	5.	Fifth. instalment	Agreement	June 10	22,500.00	152,536.50
		Total Funds Received:			222,500.00	1,559,684.50
B.	**<u>Expenditures by Executing Agency:</u>**					
10.	Project/Pre-Project Personnel					
	11.	National Experts (long term)			12,025.32	85,500.00
		11.1 Project Coordinator				
		11.2 Forester 1				
		11.3 Forester 2, etc.				
		11.4 Administrator				
	12.	Other Personnel				
		12.1 Assistant 1				
		12.1 Assistant 2				
		12.2 Other labour				
	13.	National Consultant(s) (short term)				
		13.1 Consultant 1				
		13.2 Consultant 2				
		13.3 Consultant 3				
	14.	International Consultant(s)			15,000.00	102,610.84
		14.1 Forest Inventory Expert				
		14.2 Consultant 2				
	15.	Fellowships and Training				
		15.1 Training 1 (specify beneficiaries)				

	15.2 Training 2 15.3 Training 3				
19.	Component Total:			27,025.32	188,110.84
20.	Sub-contracts				
21.	Sub-contract (Topic e.g. mapping, etc.))			35,000.00	238,000.00
22.	Sub-contract (Topic 2)				
29.	Component Total:			35,000.00	238,000.00
30.	Travel				
31.	Daily Subsistence Allowance			11,020.22	77,141.50
	31.1 National Expert(s)/Consultant(s)				
	31.2 International Consultant(s)				
	31.3 Others				
32.	International Travel			5,875.80	41,130.59
	32.1 National Expert(s)/Consultant(s)				
	32.2 International Consultant(s)				
	32.3 Others				
33.	Local Transport Costs			10,364.28	72,549.99
	33.1 National Expert(s)/Consultant(s)				
	33.2 International Consultant(s)				
	33.3 Others				
39.	Component Total:			27,260.30	190,822.08
40.	Capital Items				
41.	Premises				
42.	Land				
43.	Vehicle(s)				
44.	Capital Equipment			67,946.79	479,024.84
	44.1 Computer Equipment (specify)				
	44.2 Forestry Equipment (specify)				
	44.3 Others				
49.	Component Total:			67,946.79	479,024.84

50. Consumable Items				
51. Raw materials			48,529.16	339,704.12
52. Spares			2,506.98	17,649.10
53. Utilities			15,989.36	111,925.50
54. Office Supplies			10,166.58	71,166.09
59. Component Total:			77,192.08	540,444.81
60. Miscellaneous				
61. Sundry			3,322.16	23,255.10
62. Audit costs				
63. Contingencies				
69. Component Total:			3,322.16	23,255.10
70. National Management Costs				
71. Executing Agency Management Costs				
72. Focal Point Monitoring				
79. Component Total:			0	0
Total Expenditures To-date:			237,746.65	1,659,657.67
Remaining Balance of Funds (A-B):			-15,246.65	-99,973.17

Notes: (1) Amounts in U.S. dollars are converted using the average rate of exchange when funds were received by the Executing Agency

(2) Total Expenditures To-date (in local currency) should be the same as amount shown in Sub-Total of column (C) of the Financial Statement.

Project number: PD 398/06 Rev.2 (I)
Starting date of the Project: 19 November 2007

Duration of the Project (month): 36 months

Project costs (US $): 291,060.00

The type of the report: the project completion report

Project technical and scientific staffs :

Mr. Su Haitao: Project coordinator/leader, Guangdong Academy of Forestry(GAF), 233 Guangshan 1st Road, Tianhe District, Guangzhou 510520, P.R. China;Tel: 86-20-87028275 Fax: 86-20-87035975; E-mail: haitaosu2002@163.com

Mrs. Zhang Yanjun: Assistant project leader and Chief supervisor of laboratory and monitoring system, GAF; Tel: 86-20-87030010 ; Fax: 86-20-87035975 ; E-mail: zhangyanjun82@yahoo.com.cn

Mrs.He Xuexiang: Assist project leader and chief supervisor of external communication and coordination with ITTO, GAF; E-mail: lhshan92@yahoo.com.cn.

Mrs.Chen Lifang: Assist chief supervisor of laboratory and monitoring system, GAF; E-mail: chenlf2000@126.com

Mr. Xie Guijun: Assist chief supervisor of laboratory and monitoring system, GAF; E-mail: xgj80@126.com.

Mr.Pang Weifeng: Chief supervisor of TUDA**,** Maoming Forestry Research Institute

Mr. Zeng Wu: Assist chief supervisor of TUDA, Gaozhou Forestry Research Institute

Dr. Ma Hongxia: Assist chief supervisor of laboratory and monitoring system, GAF; E-mail: lkymhx@hotmail.com

Mr Wang Jianqing: Assist chief supervisor of laboratory and monitoring system, GAF.

Dr Jack Norton: International consultant, Queensland Department of Employment, Economic Development&Innovation (DEEDI), Australia. Jack..Norton@deedi.qld.gov.au

Dr Jiang Mingliang: National consultant**,** Research Institute of Wood Industry, Chinese Academy of Forestry (CAF), E-mail: jiangml@caf.ac.cn

Implementing institutions: Guangdong Academy of Forestry (GAF)

Address: 233 Guangshan 1st Road, Longdong,Tianhe , Guangzhou 510520, P.R. China, Tel: 86-20-87035975 Fax: 86-20-87035975; E-mail: lhshan92@yahoo.com.cn

The place and date the report was issued: Guangzhou, P.R.China.

Technical Reports

Attachment 1

A Fast Test Method for Copper Active Component in ACQ Wood Preservative

Zhang Yanjun, Chen Lifang, Su Haitao, Xie Guijun, He Xuexiang, Ma Hongxia
(Guangdong Academy of Forestry，Guangzhou，501520)

Abstract: This article was based on the comparison tests on the active copper component in ACQ wood preservatives with EDTA complexometric titration and on those in ACQ-treated wood samples with atomic absorption spectrometry．The test results showed that EDTA complexometric titration was easy to operate and accurate enough to determine the active copper component in ACQ wood preservative，and it is a fast test method suitable for the quality control of ACQ wood preservative production in industries.
Key words: ACQ wood preservative，copper，EDTA complexometric titration

ACQ (alkaline copper quaternary) is one of the water-borne wood preservatives widely used in the world for its efficient in wood preservation, insect prevention and termite resistance[1-2]. The concentration of most ACQ preservatives sold on the market is 15% and its active components are copper and quaternary ammonium salt (DDAC or BAC). There are four ACQ formulas classified according to the ratio of cupric oxide (CuO) to quaternary ammonium salt (DDAC or BAC). The standard ratio of these two components in different ACQ formulas was stipulated in Standard LY/T 1635-2005. Therefore the content of CuO is an important index to evaluate the quality of a specified ACQ formula, and study on a fast, convenient and acurate method for detecting the copper content is a very important approach for the quality monitoring of the preservative production.

At present three methods are commonly used to detect the copper content in ACQ wood preservative in China, including chemical analysis method according to Chinese Standard SB/T 10404-2006 Determination of Active Components in waterborne preservatives and Fire-retardants----Determination of Copper Content in Copper-based Preservatives; the atomic absorption spectroscopy according to American Standard AWPA 2006 A11-93, and x-ray spectroscopy according to American Standard AWPA 2009 A09-08. The first method is a conventional chemical analysis method which is inconvenient for manipulating and a pretreatment of samples is needed, while other two methods are instrumental analysis methods which are costly and highly demanding for the facility though they are easy to handle, fast and highly accurate[3].

This study was used EDTA standard solution to test the copper content in ACQ wood preservative in comparison with the atomic absorption spectroscopy. The result showed that EDTA standard solution is a fast method with good repeatability, high accuracy and precision for detecting the active copper component in ACQ wood preservative. It is also easy to manipulate and free from the regional difference, and therefore it could be used for the quality control of the industrial production of ACQ wood preservatives[4].

1 Materials and Method

1.1 Materials and equipments

ACQ wood preservative provided by Guangdong forestry Science & Technology Development Co., Ltd.; Reagents, AR; distilled water; 4510 atomic absorption spectrophotometer; electronic balance.

1.2 Test method

1.2.1 Basic chemical reaction principle

EDTA is an organic complexing agent, which can react with Cu^{2+} ion to form a 1:1 type stable chelate.

Cu^{2+}+EDTA=Cu-EDTA.

1.2.2 Test procedure

First certain amount of ACQ wood preservative was weighed (correct to 0.001g) and put into a 250mL erlenmeyer flask before adding 40mL distilled water, 3mL 10% acetic acid and1mL 0.1% methylthymol blue solution in succession to mix with . Then the mixed solution was titrated slowly with 0.05mol/L EDTA standard solution (calibrated by high purity copper) until its color changed from blue to light green, and record the consumed volume of EDTA standard solution . Repeated the above procedure more than 2 times and calculate the average consumed volume of EDTA standard solution.

1.2.3 Calculation of copper concent

The copper content (CuO by percent) was calculated according to the following formula:

$$w_{CuO}(\%)=(V\times m\times 7.96)/C \qquad (1)$$

wherein, V was the consumed volume of EDTA, mL;

C was the molar concentration of EDTA, mol/L;

m was the mass of ACQ wood preservative, g;

w_{CuO} was the mass fraction of CuO in tested sample, %.

2 Results and analysis

2.1The accuracy of EDTA test

The test results of copper content in ACQ wood preservative tested by EDTA and atomic absorption spectroscopy were shown in table 1 respectively. Each result was the average value of 5 repetitions.

From table 1, it can be seen that the result obtained by EDTA test method was close to that obtained by atomic absorption spectroscopy method. This indicated that the EDTA titration method was highly acurate and in accordance with the requirement for macro analysis, and as well as the method could meet the requirement for the quality control of ACQ wood preservative production in factories.

Table 1 Copper content (CuO%) in ACQ preservative tested by two test methods

Sample	$\bar{w}_{CuO}$ by EDTA method	$\bar{x}_{CuO}$ by atomic absorption spectroscopy method	Relative deviation
1	10.40	10.43	0.29
2	4.86	4.99	2.61
3	3.94	3.97	0.76
4	2.04	1.97	3.55
5	1.03	1.03	0.00

Note: $r = \frac{|\bar{x}_{CuO} - \bar{w}_{CuO}|}{\bar{x}_{CuO}} \times 100\%$

2.2 The precision of EDTA test

Coper content in ACQ wood preservatives with different concentrations were tested by EDTA method and the result was shown in table 2.

From table 2, it could be seen that the standard deviations of the copper contents tested by EDTA in five concentrations of ACQ were 0.0207%, 0.00035%, 0.00447%, 0.00837% and 0 respectively, and the relative standard deviations were 0.199%, 0.0072%, 0.113%, 0.410% and 0 respectively. All of the standard deviations were lower than 0.02%, which showed that EDTA method had good repetition and high precision and could meet the requirements for routine chemical analysis [5-6].

Table 2 Copper content (CuO%) in ACQ wood preservatives tested by EDTA method

Sample	$\bar{w}_{CuO}$	Average	Standard deviation	relative standard deviation
1	10.42, 10.37, 10.40, 10.41, 10.42	10.40	0.02070	0.1990
2	4.88, 4.85, 4.85, 4.84, 4.88	4.86	0.00035	0.0072
3	3.94, 3.94, 3.94,3.93,3.94	3.94	0.00447	0.1130
4	2.05, 2.04, 2.04,2.03, 2.03	2.04	0.00837	0.4100
5	1.03, 1.03, 1.03, 1.03, 1.03	1.03	0	0

Note: $S = [\sum_{i=1}^{n} w_{CuO} - \bar{w}_{CuO} / (n-1)]^{1/2}$; $RSD = S / \bar{w}_{CuO} \times 100\%$

3 Conclusions

3.1 EDTA test method for copper content in ACQ wood preservative had high accuracy and precision.Compared with atomic absorption spectroscopy method, the result got by EDTA method had low deviation and high accuracy and precision, and can meet the test requirements.

3.2 EDTA test method is a practical method for detecting the copper content in ACQ preservative in a wode range of concentrations. EDTA test method can directly detect the copper content in any concentration of ACQ preservative from concentrate solution to working solution. Its detection range of concentration is wider relatively than that of atomic absorption spectroscopy method, and as well as it is more practical due to its free from the regional differences.

3.3 EDTA test method is easy and simple to handle and highly efficient for detecting the copper content in ACQ preservative. With present standard testing methods, all ACQ samples should be pretreated for digesting the organic matters befoe being tested the copper content in it due to its containing of quaternary ammonium salt, while the pretreatment is very fussy. However, with EDTA method, the pretreatment of ACQ samples was not needed since the organic matters make no difference of the test result. With EDTA method for detecting the copper conten t in ACQ preservative, without the pretreatment which could cause the system error during the digestion and dilution processes, the testing time, the testing cost and the testing cycle would be reduced, and therefore the testing efficiency will be enhanced greatly.

Reference:

[1] Jin Zhongwei, Shi Zhenhua and Zhang Zuxiong. ACQ Preservative and Preservative-treated Wood [J]. CHINA WOOD INDUSTRY, 2004 (18): 34-36.

[2] Timber Value Promotion and Substitution Administration Center. SB/T 10404-2006 Determination of active components in waterborne preservatives and fire-retardants[S]. STANDARDS PRESS OF CHINA, 2006.

[3] National Bureau of Quality and Technical Supervision. JJF1059-1999 Evaluation of Uncertainty in Detection. Beijing: CHINA METROLOGY PUBLISHING HOUSE (CHINA) SCIENCE PRESS, 1999.

[4] Wang Qingyu and Han Xiuxian. Evaluation of the uncertainty of measurement in the determination of soybean oil acid value. JOURNAL OF JILIN GRAIN COLLEGE, 2004, 19(2): 10-14.

Attachment 2

Study on the Fast Test Methods For Wood Preservatives

Zhang Yanjun, Chen Lifang, Su Haitao, Xie Guijun, He Xuexiang, Ma Hongxia
Guangdong Academy of Forestry, Guangzhou, 501520

Abstract: Abstract: By testing on the concentration of working solution of wood preservatives, the quality and the cost of preservatives-treated timber products could be controlled. Refractive index of wood preservatives treating solution was measured by Refractometer and the results showed the refractive index of treating solutions had a linear relation with the concentration of wood treating solution, and the correlation coefficient r surpasses 0.999, which confirms the reliability of this method in running fast tests on the concentration of working solutions. This method was based on a refractometer to show the refractive index of an unkown solution, and then used a standard regression equation between the refractive index and concentration to calculate the preservative concentration. The method is simple, fast, and accurate, and which could be recommended for application in wood preservation industires.
Key words: fast test, Refractometer, Concentration ,Wood Preservatives

In wood preservation production, the concentration of wood preservative working solution determines the preservative retention in treated wood which affects direclty the quality of treated timber and its preformance. Therefore controling the concentration of wood preservative working solution is an effective approach for the product quality control of wood preservation factories.

Conventional chemical analysis method and instrumental analysisl method are commonly used for the determination of the concentration of wood preservative. Both methods have their own advantages and disadvantages, and all have their limits for using in the industries. For chemical analytical method, it is easy and cheap but needs professional workers and time consuming to work with, while for instrumental analytical method it is fast and highly acurate but costly to operate such HLPC[1]. In China, most wood preservation factories ignore the quality monitoring in the production process, which leading to the production of unqualified treated timber products with low preservative retention due to undetecting the working solution in storage tank after treating a large quantities of timber or keeping storage for a long time. [2].

A new fast-testing method was studied using a PLA-1 refractometer. Based on a series of concentrations and refractive indexes of the working solutions of standard wood preservatives products CCA and ACQ were detected by chemical analysis and refractometer, respectively, the relative curve of the concentration versus refractive index was plotted and the regression equation was fitted. With the refractive index x of an unknown working solution detected by refractometer, the concentration y of it can be quickly calculated by the regression equation[3-4].

1 Materials and methods

1.1 Apparatus and reagent

Apparatus: PLA-1 refractometer(Japan),4510 atomic absorption spectrophotometer(China) and electronic balance(China).

Reagents:CCA-C wood preservative, ACQ-C wood preservative provided by Guangdong forestry Science & Technology Development Co., Ltd.

1.2 Working principle of refractometer

The working fo refractometer was based on the light reflaction in the liquid to detect the concentration of a liquid. It has been known that a liquid with different concentrations has different light refractivity, and there is a positive correlation between the concentration of a liquid and its refractive index. Therefore the concentration of an unknown wood preservative solution could be conversed by the correlation of its refractive index read by refratometer to the concentration.

1.3 Testing methods

1.3.1 Determining the concentration of working solution

CCA-C and ACQ-C wood preservatives were diluted into working solutions in a range of concentrations commonly used for timber treatment. Their active components were detected according to SB/T10404-2006 *Determination of active components in waterborne preservatives and fire-retardants*. The total content of the active components by mass percentage was taken as the concentration of the working solution, denoted by y.

1.3.2 Detecting the refractive index of the treating solutions

The refractometer PLA-1was used and standardized first by dropping a drop of purified water on onto the prism before pressing the start button, and the refractive index will be displayed in 3s. following by pressing the reset button to finish the standardization procedure. Second, drop a drop of working solution onto the prism, pressed the *start* button, and read the refractive index shown by the refractometer, denoted by x.

1.4 Data processing

The data of the concentrations of working solution and the refractive indexes were processed with Microsoft Excel, and the correlation diagram of refractive index vs. concentration of working solution was plotted and correlative regression equation was fitted.

2 Results and analysis

2.1 Correlation between refractive index and the concentration of working solution

Refractive indexes (x_i) of identified CCA-C and ACQ-C working solutions with different concentrations (y_i) were meadured by refractometer and listed in table 1. Based on data in table 1 the correlation curves of refractive index (xi) vs. concentration (y_i) of treating solutions were plotted, and correlative regression equations was fitted (figure 1 and figure 2). The concentration of treating solution $\hat{y}$ was calculated according to the regression equations shown in table 1.

Table 1. Correlation between concentration and refractive index of working solution

Sample	CCA-C			ACQ-C		
	Refractive index x_i（%）	Concentration y_i（%）	Concentration calculated $\hat{y}_i$（%）	Refractive index x_i（%）	Concentration y_i（%）	Concentration calculated $\hat{y}_i$（%）
1	4.9	3.687	3.660	11.2	3.607	3.595
2	4.7	3.508	3.512	10.8	3.449	3.464
3	4.4	3.308	3.290	10.0	3.169	3.201
4	4.1	3.020	3.068	9.7	3.106	3.102
5	3.7	2.769	2.771	9.4	3.006	3.004
6	3.5	2.664	2.623	8.7	2.777	2.774
7	3.2	2.385	2.401	8.1	2.585	2.576
8	2.9	2.208	2.179	7.5	2.373	2.379
9	2.7	2.027	2.031	6.9	2.161	2.182
10	2.5	1.894	1.883	6.4	2.032	2.018
11	2.2	1.628	1.661	6.2	1.960	1.952
12	2.0	1.480	1.513	5.6	1.763	1.755
13	1.8	1.374	0.365	5.0	1.541	1.558
14	1.7	1.250	1.291	4.4	1.357	1.360
15	1.3	1.030	0.995	3.7	1.136	1.130
16	1.0	0.802	0.773	3.4	1.032	1.032

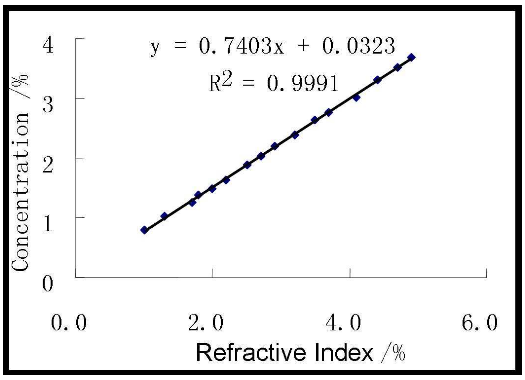


Fig. 1 Correlation between concentration and refractive index of CCA-C working solution

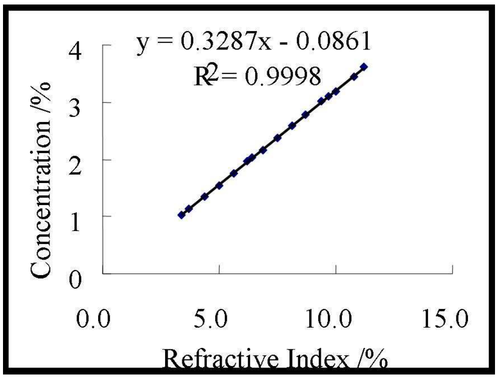


Fig. 2 Correlation curve between concentration and refractive index of ACQ-C treating solution

Results showed that there was a significant linear relationship between the refractive index x and the concentration of the treating solution y. The calculated value $\hat{y}$ was close to the experimental date y. The sum of the deviations y_{CCA} and y_{ACQ}, calculated according to $y=\sum_{1}^{16}(y_i-\hat{y}_i)$, was 0.01 and 0 respectively. And the determination confidence R^2_{CCA} and R^2_{ACQ}, was 0.9991 and 0.9998 respectively.

2.2 The confidence range of slope b and intercept a of the regression equations

The regression equation was tested its reliability by caculating the confidence range of slope b and intercept a . From table 2 it can be seen that the confidence range of slop b of the correlative regression equation for CCA-C and ACQ-C working solutions was 0.7274~0.7532 and 0.3257~0.3317 respectively, and the intercept a was -0.0110~0.0756 and -0.1093~-0.0629 respectively.

Table 2. The confidence range of slope b, intercept a and the regression equations

	Calculation Formula	t（0.05,14）	Result	
			CCA-C	ACQ-C
Standard Deviation of the Regression Equation $s_{y/x}$	$\sqrt{\frac{\sum_i (y_i-\hat{y}_i)^2}{N-2}}$		$=\sqrt{\frac{0.0111}{16-2}}$ =0.0282	$=\sqrt{\frac{0.026}{16-2}}$ =0.0136
Standard Deviation of Slope b S_b	$\frac{s_{y/x}}{\{\sum_i (x_i-\overline{x})^2\}^{\frac{1}{2}}}$		$=\frac{0.0282}{4.72}$ =0.0060	$=\frac{0.0136}{9.72}$ =0.0014
Standard Deviation of intercept a S_a	$S_{y/x}\{\frac{\sum_i x_i^2}{N\sum_i (x_i-\overline{x})^2}$		$=0.0282\times\sqrt{\frac{158.06}{16\times 22.34}}$ =0.0188	$=0.0136\times\sqrt{\frac{950.06}{16\times 94.50}}$ =0.0108
The concentration range of slope b	$b\pm t_a\ s_b$	2.145	=0.7403±2.145×0.0060 =0.7403±0.0129 =0.7274～0.7532	=0.3287±2.145×0.0014 =0.3287±0.0030 =0.3257～0.3317
The concentration range of intercept a	$a\pm t_a\ s_a$	2.145	=0.0323±2.145×0.0188 =0.0323±0.0433 =-0.0110～0.0756	=-0.0861±2.145×0.0108 =-0.0861±0.0232 = -0.1093～-0.0629

2.3 Repeatability of refratometer test method

The concentrations of ACQ and CCA working solutions were tested by conventional chemical analysis method and refractometer method based on 5 repetitive parallel tests, and the results were shown in Table 3, wherein the concentration y were tested by conventional chemical analysis method, and the concentration y’ was calculated by refractometer method .

Table 3. Repeatability of the refractormeter measuring method

Sample	Concentration tested y（%）	Concentration calculated $\hat{y}$（%）	Refractive index X(%）	Average $\bar{x}$（%）	Standard deviations（%）
ACQ1	2.789	2.785	8.7,8.7,8.7,8.7,8.7	8.7	0.00
ACQ2	2.189	2.191	6.9,6.9,6.9,6.9,6.9	6.9	0.00
ACQ3	1.755	1.763	5.6,5.6,5.6,5.6,5.6	5.6	0.00
ACQ4	1.176	1.170	3.8,3.8,3.8,3.8	3.8	0.00
CCA1	2.599	2.614	3.5, 3.5,3.5,3.5,3.5	3.5	0.00
CCA2	2.068	2.031	2.7,2.7,2.7,2.7,2.7	2.7	0.00
CCA3	1.494	1.521	2.0,2.0,2.0,2.0,2.0	2.0	0.00
CCA4	1.016	1.011	1.3,1.3,1.3,1.3,1.3	1.3	0.00

From table 3, it can be seen that the refractormeter had good repeatability to measure the refractive index of working solution. Compared with the conventional chemical analysis method, the refractormeter was not only accurate but also precise.

2.4 Repeatability of the regression equation

Studies showed that the regression equation may fluctuate with different batches of products, especially with the raw materials and formula of wood preservatives which were once changed or precipitation in products, and accordingly the refractive index of the working solution may also change. The regression equations of CCA-C and ACQ-C were $\hat{y}_{(CCA)}=0.7286x+0.0638$, $r=0.9991$ and $\hat{y}_{(ACQ)}=0.3295x+0.0821$, $r=0.9995$ were fitted based on data in table 3, but wherein the slope *b* and intercept *a* were still in the confidence range.

3 Conclusions

3.1 The refractive indexes of CCA-C and ACQ-C working solutions measured by refractometer had good correlation with the concentration tested by standard chemical analysis method. The correlation coefficient r exceeded 0.999. The concentration of wood preservatives calculated by the regression equation was very close to that tested by the standard chemical analysis method.

3.2 The regression equation of CCA-C working solution was $\hat{y}$ =0.7403x+0.0323, the confidence range of b and a was 0.72743～0.7532 and -0.011～0.0756, respectively.

3.3 The regression equation of ACQ-C treating solution was $\hat{y}$ =0.3287x-0.0861, the confidence range of b and a was 0.3257～0.3317 and -0.1093～-0.0629, respectively.

3.4 The refractometer with small volume and low price, was easy to operate accurately and precisely. The highest measurable concentration was up to 38.5% for CCA-C and 15% for ACQ-C. It is especially suitable for use in factories with poor facilities to monitor and control the quality of of wood preservation production.

3.5 The standard regression equation and its coefficient r, slope b and intercept a may be changed with different product batches of wood preservatives products. Therefore the suppliers of wood preservatives are recommended to provide the matching standard regression equation for every batch of preducts.

Reference:

[1] Zhang Yanjun and Chen Lifang. A Brief Introduction on the Method for Determination of Active Components in CCA Wood Preservatives. Forestry Science and Technology of Guangdong Province. 2006: 22(4): 56-58.

[2] Su Haitao, Zhang Yanjun and Liu Lei. Wood Preservation Plants in China: Problems and Suggestions. China Wood Industry. 2007, 21(6):31-33.

[3]Qi Deyao, Xiao Mingyao and Wu Xinxin. Physical and Chomical Analysisa Data HandlingHandbook. Beijing，Chinese Mensuration Press，1991.

[4]Li Yunyan and Hu Chuanrong. Experiment Design and Data Processing. Beijing, Chemical Industry Press, 2008.

Attachment 3

IRG/WP 09-30500

THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION

Section3
Wood Protecting Chemicals

Tests on the effectiveness of concentrated borate wood preservative

Su Haitao Zhang Yanjun Xie Guijun Chen Lifang He Xuexiang
Forestry Industry Division, Guangdong Academy of Forestry, 233 Guangshan 1st Road, Longdong 510520， Guangzhou, China

Paper prepared for the 40th Annual Meeting

Beijing, China

24-28 May 2009

IRG SECRETARIAT

Box 5609

SE-114 86 Stockholm

Sweden

www.irg-wp.com

Tests on the effectiveness of concentrated borate wood preservative

Su Haitao[1], Zhang Yanjun[1], Xie Guijun[1], Chen Lifang[1], He Xuexiang[1]
Forestry Industry Division, Guangdong Academy of Forestry,
233 Guangshan 1st Road, Longdong 510520, Guangzhou, China.
Tel: 86-20-87030010 Fax: 86-20-87035975 E-mail: Haitaosu2002@126.com

ABSTRACT
Tests were carried out to examine the toxicity of concentrated borate wood preservative to termites, fungi and mammals. The results showed that the preservative treated timber had high resistance to termite or decay and its acute oral toxicity belonged to low grade. The research shows that concentrated borate solution is an environmentally sound preservative and can be used in non-pressure treating.

Key words: concentrated borate solution, wood preservative, toxicity

1. INTRODUCTION

Recent study on wood preservatives in China was mostly focused on vacuum/pressure treatment, such as Copper Chrome Arsenate (CCA), and new generation preservatives like Alkaline Copper Quaternary (ACQ), Copper Azole (CuAz), copper naphthenate, and so on. Whilst Vacuum/pressure processes have high production efficiency, industrial production needs large equipment, and makes strict demands on tree species and reagents. It isn't appropriate when wood is difficult to penetrate, contains high moisture content or a low level of protection is required.

Brushing or dipping is the simplest method of wood preservative treatment and is used on a large scale on many occasions due to its simplicity and rapid treatment time. The preservative in non-pressure treating, in general, consists of borate and phosphate mixture (called BP mixture for short), organophosphate, synthetic pyrethroid quaternary ammonium salt and boron preservative. BP mixture containing pentachlorophenol is banned. The application of organic preservatives is limited due to their high price, single-spectrum and low solubility.

Boron preservative has been paid a lot of attention owing to their advantages such as low price, high permeability, no colour, no odour and high resistance to insects and fungi. Boron preservative solution with low boron content can not be used for brushing at present. In order to meet domestic needs, recently the authors started to develop a concentrated borate solution as a wood preservative, and which is called as SGB preservative for short. Laboratory tests on the toxicity of SGB preservative to termites, fungi, and mammals have been carried out and the results are reported in this paper.

2. MATERIALS AND METHODS

2.1 Preparation of SGB preservative

The SGB preservative is a concentrated borate solution. Its basic physical and chemical properties are presented in Table 1

Table 1: Physical and chemical properties of SGB

H_3BO_3[%]	42.4%
Specific gravity*25.2	1.296
Color	Light yellow
pH	7 – 8
Solubility in Water	Mixable with water
Viscosity	Slightly sticky

2.2 Toxicity test on to termites

2.2.1 Test materials

Wood sample: *Pinus massoniana* Lamb, dimension: 25×25×6mm^3

Termite: *Coptotermes formosanus*

Reagent: A series of diluted solutions of SGB preservative were prepared by mixing SGB preservative with water in a dilution ratio of 1:1, 1:2, 1:3, 1:4 and 1:5 (m/m), respectively.

2.2.2 Test methods

The experiments were carried out by following American Wood Preservers' Association Standard AWPA EI-97, Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites. Wood samples were treated with preservative by brush treatment twice, and then air dried before being testing.

2.3 Toxicity test on fungus

2.3.1 Test materials

Wood sample: (*Eucalyptus urophylla*) sap wood, dimension: 20×20×10mm3

Fungus: *Coriolus versicolor*

Reagent: A series of diluted water solutions of SGB preservative were prepared. The concentration of SGB in these solutions included 0.125%, 0.25%, 0.5%, 1.0% and 2.0%, respectively.

2.3.2 Test methods

The test was done by following the method described in Chinese Standard LY/T 1283-1998, Standard Method for Laboratory Evaluation to Determine Resistance to decay fungus.

2.4 Toxicity test on mammal

2.4.1 Test materials

Mammal: SPF grade SD mice were supplied by Medical Experimental Animal Centre of Guangdong Province, healthy and weighing180~220g, total 10 mice including 5 males and 5 females, and randomized grouping test.

2.4.2 Test methods

The test was carried out by following the method described in Chinese Standard GB15670-1995, Toxicological Testing Methods for Pesticide Registration. After being fasted (not cut-off water) for 12h, the animals were given test substance with a dose of 10ml/kg body weight by intra-gastric administration and observed for 14days.

3. Results and discussion

3.1 Toxicity test on termite

The results of termite feeding can be seen in Table 2. At the end of experiments, Termite Resistance Grade of control samples was zero, and most of timberworks (e.g. frame houses) were damaged. With the decrease of concentration of SGB in the treating solution, retention of SGB and B_2O_3 content in treated wood decreased accordingly. When wood samples measuring 25mm × 25mm × 6mm were brushed with a 1:1 mixture of SGB to water, the preservative retention of SGB attained 75.55Kg/m3 and the B_2O_3 content was 16.62 Kg/m3. All the treated wood samples suffered a significant decrease in termites' feeding compared to the controls. Wood treated with a 1:1 and 1:2 SGB at a dilution ratio were strongly resistant to termite attack with a termite resistance grade of 10, i.e. no termite feeding on the treated wood. Wood treated with 1:3, 1:4, and 1:5 solutions of SGB in water were not very resistant to termites. The average termite grade for these samples was 7.

Table2: The resistance of wood treated with SGB solutions to termite

SGB: water (mass ratio)	Retention [kg/m^3]	B_2O_3content [kg/m^3]	Termite resistance grade
1:1	75.55	16.62	10
1:2	57.93	12.74	10
1:3	34.84	7.67	7
1:4	23.72	5.22	7
1:5	22.13	4.87	7
0:1	0	0	0

According to the Chinese Industry Standard LY1636-2005 *Classification and Requirements of Preservative-Treated Wood*, 4.5 Kg/m^3 B_2O_3 content in treated wood for Commodity class C2 (indoor, resistant to termites) is required. In this experiment, B_2O_3 content used for treating wood samples were all above 4.5 Kg/m3, therefore, the treated wood was highly resistant to termites. B_2O_3 content in SGB can reach above 22%, so adequate retention in wood could be obtained easily when brushing treatment is applied.

3.2 Toxicity tests on fungus

It can been seen from Figure 1 that the weight loss of the control wood is 52%, while the weight loss of all SGB treated wood is less than 10%. The results indicate that SGB preservative can enhance the resistance of wood to fungus. It can be seen also from Figure 1 that the retention level of treated wood increased with the increasing concentration of SGB water solution, but the weight loss decreased accordingly. When wood was treated with 0.5% SGB water solution, at a retention level below 3.119 Kg/m^3, the weight loss was still less than 3%. So the lethal dose of SGB preservative to fungus is the retention level 3.119 Kg/m^3.

The lethal concentration of SGB to fungus is far lower than it is to termites, and therefore wood treated with non-pressure treating of SGB preservative could have greatly enhanced resistance to fungus.

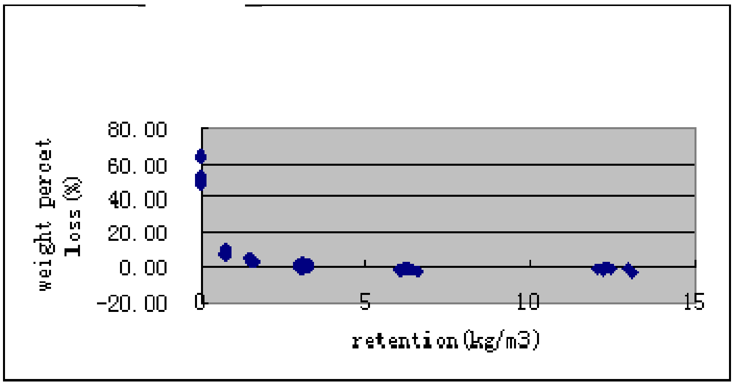


Figure 1: Relationship between weight percent loss and retention

3.3 Toxicity tests on mammal

The results of acute oral toxicity tests on mammal are listed in Table 3. It can be seen from Table 3 that the animals appeared spiritless with less activity after being exposed to SGB for 5 hours. Animals were still spiritless 4days later whilst the male was lost weight. The heart rate of the animal was approximately normal 7days later and all the tested animals survived at dose of 5050 mg/kg of SGB fed after 14 days at the end of the test. According to Chinese national standard GB15760-1995 *Acute Oral Toxicity of Pesticide Classification Standards*, if a dose of more than 5,000 mg/kg was applied in acute oral toxic tests and none of animals was dead, then it is not necessary to try to use a higher dose any more. The dose of SGB used in this acute oral test on SD mice is higher than 5050 mg/kg and did not cause death of the animal, so the acute oral toxicity of SGB belongs to ‘low grade’ according to standard GB15760-1995.

This study demonstrated that SGB has high toxicity to termite and fungus, but its toxicity on mammals is very low. Therefore, SGB is an environmentally sound preservative and less harmful than other commonly used wood preservatives.

Table3: Rat body weight changed after being exposure to SGB preservative

Dose[mg/kg]	Sex	Day o weight	Day 4 weight	Day 7 weight	Day 14 weight	Death number
5050	Female	**211.8±6.4(5)**	**216.4±12.1(5)**	**219.8±13.4(5)**	**235.6±13.4(5)**	**0**
	male	**205.0±5.4(5)**	**192.2±20.0(5)**	**192.4±17.0(5)**	**217.4±10.6(5)**	**0**

4. CONCLUSION

(1) When wood was brushed with a mixture of SGB preservative and water (1:1 and 1:2, mass ratio respectively), it was very resistant to termites.
(2) Wood treated with SGB preservative at a retention level more than 3.119 Kg/m^3 by non-pressure treating could be highly resistant to decay fungi.
(3) Acute oral toxicity of SGB wood preservative to mammal belongs to low grade.
(4) SGB preservative used by non-pressure treating is an environmentally friendly preservative.

Reference:

[1] American Wood Preservers' Association. E1 - 97: Standard Method for Laboratory Evaluation to Determine Resistance to Subterranean Termites [S]. American Wood Preservers' Association. American Wood Preservers' Association standards, 2004: 381-383.
[2] State Forestry Administration. LY/T 1283-1998: *Method of laboratory test for toxicity of wood preservatives to decay fungi* [S]. Beijing, Standards Press of China, 1999:6.
[3] State Bureau of Quality and Technical Supervision. GB 15670-1995: *Toxicological test methods of pesticides for registration*[S]. Beijing, Standards Press of China, 1999:38.
[4] State Forestry Administration. LY/T 1636-2005: *Use category and specification for preservative-treated wood*[S]. Beijing, Standards Press of China, 2005:6.
[5] Quarles. W. Borates provide least toxic wood protection [J]. The IPM Practitioner, 1992, 14 (10): 1-11.

Attachment 4

Study on the Flame-Retardation Properties ofTreated Wood with Fire Retardant SLB

Chen Lifang, Su Haitao, Zhang Yanjun, Xie Guijun
(Guangdong Academy of Forestry, Guangzhou, 510520)

Abstract: *Pinus massoniana* and *Albizzia falcate* were treated by a new wood fire retardant SLB, and the flame retardant properties of these two treated wood were tested. The results showed that more than 40kg/m^3 of SLB retention in treated wood could guarantee the fire-retardant properties of the treated wood reach the specified standards, and the flame resistance of treated wood became stronger with the increase of SLB retention in treated wood. With a similar retention, treated wood *A. falcate* had better the flame retardation performance than treated wood *P. massoniana*.
Key words: SLB fire-retardant, *Pinus massoniana*, *Albizzia falcate*, Fire-retardant property

There are numerous flame retardants for wood fire retardancy. Most of them are composites, in which different components form synergistic effect, improving the flame retardant properties of flame retardants. As the development of flame retardancy technology, flame retardants with low cost, halogen free, nontoxicity and smoke inhibition properties are much more competitive, especially the boron-based composites which posses low toxicity, good penetration into wood, little effect on the mechanical and physical properties of wooden materials as well as their good ability for flame retardancy, preservation and insect prevention [1-3].

Most flame retardants share common elements such as boron, phosphorus, nitrogen. Under hot conditions, phosphorus can produce dehydrating agents which lead to dehydration and carbonization of cellulous and semi-cellulose of wood. The carbonized layer has low heat conduction rate, thus can prevent the thermal decomposition of inner wood. Boron melts and covers on the surface of wood under flame temperature. The boron coverage inhibits the flame spread on wood surface, at the same time absorbs heat and inhibits smoke production [4-6]. Through the interaction and synergistic effect of these compounds, the flame retardant can reach a good flame retardant effect. SLB is a new developed boron-based fire retardant by Guangdong Academy of Forestry. In order to understand its effect on flame retardancy, the flame retardant performance of SLB treated wood was studied [7].

1 Materials and Methods

1.1 Materials

1.1.1 SLB wood flame retardant

SLB was made by wood protection research group of Guangdong Academy of Forestry. Its main ingredient was boron composed with phosphorus and nitrogen. Its solubility was more than 20g and the concentration of boron trioxide in it was more than 50%.

1.1.2 Sample preparation [8]

Wood species used in this experiment were *Pinus massoniana* and *Albizzia falcate*. Experimental samples with two dimensions were prepared, 13mmX13mmX76mm and 4mmX6.5mmX150mm. The repeated number of sample was prepared according to the wood crib method and oxygen index method.

1.2 Treating method

Wood samples were treated by SLB solution with vacuum pressure treatment. The concentration of treatment solutions were 5%, 10% and 15%. The detailed treatment process was as follows: samples were loaded into the treatment vessel; a vacuum of -0.08MPa was drawn over the wood for 30min; then the preservative was slowly drawn into the vessel without losing the vacuum; the pressure increased to 1.30MPa and held for 40min; At the end of the cycle, the pressure was slowly released and samples were removed, air dried and weighted.

The untreated samples were taken as control samples.

1.3 Flame retardant performance tests of wood

The oxygen indexs of treated *P. massoniana* and *A. falcate* wood samples were tested with JF-3-type oxygen index tester, according to GB/T 2406-1993 *Plastics—Determination of fammability by oxygen index* [9]. The loss rate of quality of wood samples treated different SLB concentrations were also tested according to GA/T 42.1-92 *Testing method of burning property of flame-retardant wood-method of wood stack* [10].

2. Results and analysis

2.1 The estimation of flame retardant performance of SLB-treated wood by oxygen index method

The oxygen index could be used to estimate the inflammability of the material and its possibility for fire fighting. A material with high oxygen index means that it need much oxygen for being set on fire, which belongs to fire resistant one. Otherwise, a material with low oxygen index is easy to be burned. Usually, a material with oxygen index lower than 22 belongs to fire inflammable one, between 22~27 belongs to combustible one and higher than 27 belongs to nonflammable material [11]. In this experiment, the oxygen index values of SLB-treated wood samples tested by JF-3 type oxygen indexer were shown in table 1.

Table 1. Test result of flame retardant performance of treated wood by oxygen index method

Samples	Concentration of SLB w/%	Retention/(kg.m^{-3})		Oxygen index/%		Relative difference of oxygen index/%	
		P. massoniana	*A. falcate*	*P. massoniana*	*A. falcate*	*P. massoniana*	*A. falcate*
Control	0	0	0	18.2	21.0	0	0
1	5	23.43	28.53	26.9	38.0	47.8	81.0

2	10	44.60	65.14	32.0	50.2	75.8	139.0
3	15	66.84	90.69	41.7	62.8	129.1	199.0

It can be seen from table 1 that the retention of SLB in two species of treated timber increased with the increase in the concentration of SLB working solution, and the oxygen index of wood samples increased correspondingly. The retention of SLB in *P. massoniana* increased from 23.34 kg/m^3 to 66.48 kg/m^3, and its oxygen index increased from 18.2% to 41.7%; the retention of SLB in *A. falcate* increased from 28.53 kg/m^3 to 90.69 kg/m^3, and its oxygen index increased from 21.0% to62.8%. The relative difference value betweeen both oxygen index of treated timber and that of untreated timber also increased as the increase of the SLB retention in treated timber, and as well as the performance of the treated timber was better on flame retarding.

Under the same experimental condition, the retention of SLB in *A. Falcate* was more than that in *P. massoniana*, which indicated that SLB was more easier to permeate into the former than into the latter. Higher oxygen index of *A. Falcate* than that of *P. massoniana* may be due to the existence of some combustibles like resin in *P. massoniana* itself. At similar retention level, the oxygen index of *A. Falcate* was 6 percent to 8.5 percent higher than that of *P. massoniana*, thus *A. Falcate* had better flame retardant performance than *P. massoniana.*

From table 1, it can be seen that the flame retarding properties of both two species of timber treated with 10% SLB met the specified standard for the retardants of first class according to the Japanese standard JISD 1322-77 [12-14]. The oxygen index of *P. massoniana* treated with 10% SLB was 32%, 75.8% higher than that of the control; and the oxygen index of *A. Falcate* treated with 5% SLB was up to 38%, 81% higher than that of the control samples. Therefore, in order to meet the flame retardancy requirements, different wood species should be treated with different concentration of SLB.

2.2 Flame retarding performance of SLB treated wood tested by wood stack method

Oxygen index method has some limitation to indicate the flame retarding property of material in practice, for the oxygen concentration can not be changed in the environment. In order to understand the flame retardency of wood under combustion state, the combustion properties of the treated wood samples were tested according to GA/T 42.1-92. The test result showed in table 2.

Table 2 Test result of flame retardancy of treated wood by wood stack method

Samples	Concentration of SLB w/%	Retention/(kg.m^{-3})		The average mass loss of combustion %		Flaming combustion time/min	
		M. pine	*A. Falcate*	M. pine	*A. Falcate*	M. pine	*A. Falcate*
Control	0	0	0	89.98	86.65	5.65	6.75
1	5	20.12	19.10	66.51	71.40	5.02	3.66
2	10	40.16	40.13	20.56	14.05	4.05	2.94
3	15	65.23	63.05	5.11	5.00	0	0

It can be seen from table 2 that the retention of SLB in both wood species increased as the increase of the concentration of SLB treating solution. The retention of SLB in *P. massoniana* increased from 20.12kg/m^3 to 65.23kg/m^3; and the retention of SLB in *A. Falcate* increased from 19.10 kg/m^3 to 63.05kg/m^3. Both wood species, when treated with the same concentration of SLB working solution, obtained similar retention in this experiment due to different moisture contents in wood before treated.

The results also showed that SLB had good flame retardancy, and its effect increased as the increase of the retention of SLB in samples. The mass loss of combustion of the control wood was much more than that of the treated one. The mass loss of combustion of untreated *P. massoniana* and *A. falcate* was 89.98% and 86.65%, respectively. The average mass loss of combustion and flaming combustion time of wood samples decreased with the increase of concentration of working solution. The average flaming combustion time was 0 min when wood samples were treated with 15% SLB. Both the mass loss of combustion and flaming combustion time of treated *A. Falcate* were lower than those of *P. massoniana*, thus the flame retardancy property of *A. falcate* was better than that of *P. massoniana*, and the result was consistent with that tested by oxygen index method.

It can be seen also from table 2, the mass losses of combustion of *P. massoniana* and *A. Falcate* treated with 10% SGB were 20.56% and 14.05% respectively, and their flaming combustion times were 4.05min and 2.94min respectively. These values were far lower than the specified standard for the mass loss of combustion (60%) and flaming combustion time (6 min) according to stamdard GA/T 42.1-92 [6-7,15]. Therefore it could be concluded that wood treated with a concentration of more than 10% SLB had good flame retardancy.

3 Conclusion

3.1 The flame retarding performance of SLB treated wood is closely related to the retention in wood. The flame retardancy of treated wood increased with the increase of SLB retention, which increased also with the increasing in the concentration of working solution. With a concentration of more than 10% SLB, treated wood demonstrated good flame retardancy. With the retention of 65 kg/m^3 , the relative differences of oxygen index of treated *P. massoniana* was up to 129.1% while that of treated *A. falcate* was up to 139%, compared with the control.

3.2 The flame retarding performance of *A. falcate* is better than that of *P. massoniana*, and that may be due to the existence of resin with it. Resin is easy to combustion and makes *P. massoniana* easier to combustion. But the presumption needs to be verified by future experiment.

3.3 Different wood species have different flame retardancy performance, even under the same treating conditions. Therefore, we should consider the attributes of wood species before determine the treating process. In this experiment, *P. massoniana* and *A. falcate* treated with a retention of more than 40kg/m^3 could meet the retaled standard for good flame retardant performance.

Reference:

[1] Liu Yanji. Fire Retardancy Treatment For Wooden Material-Combustion And Fire Retardancy of Wooden Material [J]. CHINA WOOD INDUSTRY. 1997, 11(1): 41-42.
[2] Yang Wenbin, Wu Chunchu and Gu Lianbai. Review and Prospect of Wood Fire-retardant[J]. FORESTRY MACHINERY & WOODWORKING EQUIPMENT. 2000, (4):4-6.
[3] Liu Qimei, Peng Wanxi, Zhang Minglong et. al. Review of Research on Fire-Retartant Technique of Woody Materials [J]. WORLD FORESTRY RESEARCH. 2006, 19(1): 42-46.
[4] Li Shujun, Wang Qingwen and Hou Jianmin. Comparison of the Effects of Three Wood Fire-retardants on Wood Hygroscopicity and Dimensional Stability [J]. JOURNAL OF NORTHEAST FORESTRY UNIVERSITY. 1999, 27(6): 34-37.
[5]Liao Hongxia, Liu Lei, Xie Guijun et. al. Flame Retardant Performance of the Boron Contained Wood Preservative SBB [J]. JOURNAL OF SOUTH CHINA AGRICULTURAL UNIVERSITY. 2008, 29(1): 120-123.
[6] Wu Yuzhang and Toshiro Harada. The Burning Behaviour of Plantation Wood Treated with Ammonium Phosphate [J]. SCIENTIA SILVAE SINICAE. 2005, 41(2): 112-116.
[7] Yin Ning. Study on the Fire Retardancy in Aqueous Multitreat Agent with Treated Wood [J]. JOURNALOF BELLING FORESTRY UNIVERSITY. 1998, 20(5): 28-32.
[8] Collection of Chinese forestry standard [G]. STANDARD PRESS OF CHINA.1998:84-148.
[9] Qiu Lixia. GB/T 2406-1993 Plastics—Determination of fammability by oxygen index [S]. BEIJING STANDARD PRESS. Beijing, 1994.
[10] Su Yun and Lu Guojian. GA/T 42.1-92 *Testing method of burning property of flame-retardant wood-method of wood stack* [S]. NATIONAL PUBLIC SAFETY INDUSTRY STANDARD. Beijing, 1992.
[11] Li Guohua and Wang Linjing. Grade Evaluation of combustibility by Oxygen Index [J]. Shandong Fire. 1998, (12):41-41.
[12] Luo Jieyu and Miao Guoping. Zinc Borate and Its Effect on The Flame Retardancy of Wood. [J]. JOURNAL OF FLAME RETARDANT MATERIAL AND TECHNOLOGY. 1992, (1): 5-9.
[13] Luo Jieyu. A General Discussion on Flame Retardant Treatment of Wood [J]. CHINA FOREST PRODUCTS INDUSTRY. 2000, 27(2): 7-9.
[14] Liu Yanji. Related Test methods and Rules for Combustion of Wooden Material [J]. CHINA WOOD INDUSTRY. 1997, 11(3): 33-36.
[15] Li Shujun, Wang Qingwen and Hou Qingmin. Comparison of the Effects of Three Wood Fire-retardants on Wood Hygroscopicity and Dimensional Stability [J]. JOURNAL OF NORTHEAST FORESTRY UNIVERSITY. 1999, 27(6):34-37.

Attachment 5

Flame Retardant Performance of the Boron-Contained Wood Preservative SBB

Liao Hongxia[1], Liu Lei[2] , Xie Guijun[2] , Yun Hong[1], Deng Tianhua[1]
(1 College of Forestry, South China AgriculturalUniversity, Guangzhou 510642, China;
2 Guangdong Academy of Forestry, Guangzhou 510520, China)

Abstract: Flame retardant performance of high boron-contained wood preservative SBB and its mixtures with (NH4) 2HPO4 in different ratios were evaluated. The results showed that the fire retardant performance of (NH4) 2HPO4 was better than that of SBB preservative when single agent was used alone, while a synergetic effect played a role in enhancing the fire retardant performance when both agents used by mixing together. The treatment with 10% mass concentration of the mixture of (NH4) 2HPO4 and SBB in 1:3 ratio was the best choice.
Key words: Boron fire retardant preservative; SBB preservative; (NH4) 2HPO4

With the rapid development of new types of flame redartants in recent years, the environmental problems with the flame retardants themselves and their application come into notice gradually. The development of fire retardants of low cost, halogen-free, nontoxicity, composite and smoke suppression has become an growing trend [1-4]. Boron-contained composite is a kind of inorganic flame retardant commonly used, and it can improve significantly the fire resistance performance of its treated materials[5-7]. China is rich of boron resource, and has advantage to develop boron-contained fire retardants. In recent years, the authors have developed SBB wood preservative, which has multi- protecting effects on wood against decay, insects, moulds and flame. In this paper the flame retardant performance of SBB was mainly studied.

1 Materials and methods

1.1 Materials

SBB, a boron-based wood preservative made by authors at laboratory, with 67.% mass percentage of B_2O_3 (w) and the solubility of 221g/L.

$(NH_4)_2HPO_4$, an industrial product, bought from Market.

Wood sample, Masson pine (*Pinus massoniana*), cut into 13mm×13mm×76mm(longitudinal direction)[8].

1.2Treatment tests with single agent

Wood sample was treated with $(NH_4)_2HPO_4$ and SBB, respectively. The concentrations of both treating solution were 5%, 7.5%, 10%, 12.5% and 15%. A vacuum-pressure treatment was employed. The detailed process was as follows: samples were loaded into the treatment vessel before opened the vacuum pump to a vacuum of -0.08MPa and kept for 30min, then closed the vacuum pump and the preservative was slowly drawn into the vessel without losing the vacuum and a pressure of 1.30MPa was imported slowly and kept for 40min, and finally sampes were taken out of the vessel after released the pressure and drained the working solution.Samples were air dried and weighed before treated with different mass concentrations of 2 flame retardants. The flame retardant performance of treated wood was tested by wood stack method, according to GA/T 42.1-92 *Testing method of burning property of flame-retardant wood-method of wood stack* [9], and 3 replicates for each treatment condition.

1.3 Treatment tests with mixtures of $(NH_4)_2HPO_4$ and SBB in different ratios

$(NH_4)_2HPO_4$ and SBB were mixed with ratios of 1:1, 1:2, 1:3, 1:4 and 1:5, then diluted into 10% mass concentration of working solutions with water. Air dried wood samples were treated with these working solutions and the treating method was as the same as that in 1.2. The untreated wood samples were taken as control samples.

2 Results

2.1 The comparision of the flame retardant performance of treated wood with $(NH_4)_2HPO_4$ and SBB

Results in table 1 showed that with the increase of the concentration of $(NH_4)_2HPO_4$ and SBB treating solution, the retention of flame retardants in wood increased. The retention of $(NH_4)_2HPO_4$ in wood samples increased from 21.35% to 68.19%, while the retention of SBB in wood samples increased from 23.31% to 66.91%. With the same concentration of working solution, the retention of SBB-treated wood was slightly lower than that of $(NH_4)_2HPO_4$ treated wood, while the average mass loss of combustion and average flaming combustion time of the former were higher than that of the latter, in addition, the flame retardant performance of SBB treated wood is slightly poorer than that of $(NH_4)_2HPO_4$ treated wood.

Table 1 the comparison of flame retardant efficacy of two chemicals

w_A/%	Retention/%		Average loss rate of combustion/%		Average flaming combustion time/min	
	$(NH_4)_2HPO_4$	SBB	$(NH_4)_2HPO_4$	SBB	$(NH_4)_2HPO_4$	SBB
5.0	21.35	23.31	66.53	70.69	5.02	7.56
7.5	32.56	33.64	33.56	28.72	3.13	5.15
10.0	42.75	43.02	34.43	54.00	4.26	5.19
12.5	55.68	56.00	19.80	54.05	2.10	5.06
15.0	68.19	66.91	13.32	19.95	0.54	2.20

2.2 The effect of mixtures of $(NH_4)_2HPO_4$ and SBB in different ratios on the flame retardant performance of wood

It can be seen from table 2 that the retention in different treated samples was in a range of 48.3%~68.7%, each of them was higher than that specified in the related standard(≥30%) [9]. The control samples had the highest mass loss rate of combustion, followed by the samples treated with a mixture of $(NH_4)_2HPO_4$ and SBB in a ratio of 1:1, and the samples treated with the mixing ratio of 1:3 had the lowest mass loss rate of combustion (5.19%). The result indicated that SBB could effectively improve the flame retardant performance of wood. Compared the result in table 1 with that in table2, it can be seen that except the samples treated with mixture ratio of 1:1, the mass loss rate of combustion of samples treated with other mixing ratios were lower than 20%, far lower than that of single agent under the same treating condition(w=10%). In addition, the flaming combustion time of samples treated with mixtures was also shorter than that of samples treated with single agent without exception, and thus the flame retardant performance of wood treated with mixtures of $(NH_4)_2HPO_4$ and SBB was far more better than that with one agent alone.

Table 2. Comparison of flame retardant efficacy between treated samples and untreated samples

m [(NH4) 2HPO4] ∶ *m* (SBB)	Retention/%	Average mass loss rate of combustion /%	Average flaming combustion time/min
0	0	90.33	1.24
1:1	54.9	63.50	2.02
1:2	53.2	15.49	1.09
1:3	50.2	5.19	0
1:4	48.3	13.23	0.01
1:5	68.7	18.54	0.32

3 Discussion and conclusion

There was not a big difference between the retentions of treated wood with $(NH_4)_2HPO_4$ and SBB when both were used alone, since both agents were inorganic and the same treating process was employed. The flame retardant mechanism of $(NH_4)_2HPO_4$ is that it can accelerate the dehydration and carbonization of wood, and inhibit wood combustion and decrease heat release rate through the non flammable gasses like water vapor and ammonia decomposed by $(NH_4)_2HPO_4$ itself [6-7]. SBB is a kind of compound with low melting point and when being heated its surface was formed a layer of glassy film which played a role in heat insulation and oxygen barrier[6-7]. But SBB was weaker than $(NH_4)_2HPO_4$ in suppression of ignition and heat release, therefore SBB treated wood had higher mass loss rate of combustion and flame combustion time than $(NH_4)_2HPO_4$ treated wood.

When both $(NH_4)_2HPO_4$ and SBB were used together, the mixsture was rich of phosphorus and boron elements, and phosphate flame retardant when being heated transformed into polyphosphoric acid, which is a strong dehydrating agent making cellulose and hemicellulose dehydrated and wood surface carbonized. The heat transfer rate of the carbonized wood surface was very low and as a result inhibited the thermal decompositon of the inner part of wood. Meanwhile, SBB was melted down at flame temperature and covered on wood surface, and as a result the oxygen supply was cut off and the fire catching and flaming spreading on wood were inhibited [10-12] and therefore enhanced the flame retarding efficacy. The test results also indicated that a flame retardant system with synergistic effects was established when both $(NH_4)_2HPO_4$ and SBB were used together and the best mixing ratio of m $[(NH_4)_2HPO_4]$: m [SBB] is 1:3.

In conclusion, the flame retardant performance of treated wood with $(NH_4)_2HPO$ or SBB was enhanced with the retention increased. The flame retardant effect of SBB is a little worse than that of $(NH_4)_2HPO_4$, but when both agents were mixed together a synergistic effect would play a role in improving the flame retardant performance of wood. Wood Treated with a mixture of $(NH_4)_2HPO_4$ and SBB in a ratio of 1:3 and its 10% mass concentration workinging solution had the best flame retarding performance, and the mass loss rate of combustion is 5.19%, and the average flame combustion time is 0.

Reference:

[1] Li Zhijuan, Li Qingshan and Yang Dezhi. New Century New Flame Retardant Approach[J]. CHEMICAL ENGINEER. 2001, (4): 36-36.

[2] Yang Wenbin, Wu Chuchun, Gu Lianbai. Review and Prospect of Wood Fire-retardant[J]. FORESTRY MACHINERY & WOODWORKING EQUIPMENT. 2000,(4): 4-6.

[3] Liu Qimei, Peng Wanxi, Zhang Minglong, et al. Review of Research on Fire-Retartant Technique of Woody Materials [J]. WORLD FORESTRY RESEARCH. 2006, 19(1):42-46.

[4] Oloyede A, Groombr Idge P. The Influence of Microwave Heating on the Mechanical Properties of Wood [J]. MATERIALS PROCESSING TECHNOLOGY, 2002 (100) : 67-73.

[5] Garaba B. Effective of Zinc Borate as Flame Retardant Formulation on Some Tropical Woods [J]. POLYMER DEGRADATION AND STABILITY, 1999 (64): 517-522.

[6] Luo Jieyu and Miao Guoping. Zinc Borate and Its Effect on The Flame Retardancy of Wood. [J]. JOURNAL OF FLAME RETARDANT MATERIAL AND TECHNOLOGY. 1992, (1): 5-9.

[7] Luo Jieyu. A General Discussion on Flame Retardant Treatment of Wood [J]. CHINA FOREST PRODUCTS INDUSTRY. 2000, 27(2): 7-9.

[8] Collection of Chinese forestry standard [G]. STANDARD PRESS OF CHINA.1998:84-148.

[9] Liu Yanji. Related Test methods and Rules for Combustion of Wooden Material [J]. CHINA WOOD INDUSTRY. 1997, 11(3): 33-36.

[10] Li Shujun, Wang Qingwen and Hou Jianmin. Comparison of the Effects of Three Wood Fire-retardants on Wood Hygroscopicity and Dimensional Stability [J]. JOURNAL OF NORTHEAST FORESTRY UNIVERSITY. 1999, 27(6): 34-37.

[11] Wu Yuzhang and Toshiro Harada. The Burning Behaviour of Plantation Wood Treated with Ammonium Phosphate [J]. SCIENTIA SILVAE SINICAE. 2005, 41(2): 112-116.

[12] Yin Ning. Study on the Fire Retardancy in Aqueous Multitreat Agent with Treated Wood [J]. JOURNALOF BELLING FORESTRY UNIVERSITY. 1998, 20(5): 28-32.

Attachment 6

Waterproof property of laminated veer lumber (LVL) made from poplar veneer treated with water repel

Xie Guijun, He Xuexiang Ma Hongxia Zhang Yanjun Chen Lifang
（Guangdong Forestry Academy, Guangzhou, 510520）

1 Experimental Purpose

Study the effect of 20% paraffin emulsion on the waterproof property of LVL made from poplar veneer.

2 Test Time

From April 15, 2009 to April 28, 2009.

3 Test Method

Test method was according to ASTM D 5401- standard test method for evaluating clear water repellent coatings on wood.

3.1 Material preparation

(iv) 5 specimens cut from paraffin emulsion treated LVL for testing and 5 for untreated control set. Sample dimension was 50×40×50mm.

(v) Weighed each specimen to 0.1g, and calculated the mean weight. Weight deviation of each specimen must be in10% from the mean.

(vi) Stored the treated specimens in a conditioning chamber along with five untreated specimens for at least 7days at 23±2℃ and relative humidity of 50±5%. A raised screen was used to provide ventilation around each specimen. After they reached constant weight, recorded their weight to 0.1g.

3.2 Test procedure

(vii) The specimens were placed in a container of water at 23±2℃, floating for 15min. Then turn them over and let them float for another 15min to give a total floating time of 30 min.

(viii) Removed the specimens from the water and drained briefly, wiped the specimens with a slightly dampened cloth to remove excess water, reweighed and recorded weight to 0.1g. Calculated the water repellent efficiency (WRE, in percent) for each specimen.

(ix) Water immersion ageing treatment: Specimens were placed into boiled water for 4h, then oven dried at 63℃ for 20h, after that boiled for 4h and dried at 63℃ for 17h. Specimens were then cooled to room temperature in desiccators and weighed to 0.1g. Repeated the first and the second test procedures, calculated WRE of each specimen.

3.3 Calculation formula

(x) Calculated the water repellent efficiency (WRE, in percent) as follows:

$$WRE=100[(A-B)-(C-D)]/(A-B)$$

A = weight of untreated sample after water floating treatment (g)

B = weight of untreated sample before water floating treatment (g)

C = weight of treated sample after water floating treatment (g)

D = weight of treated sample before water floating treatment (g)

4 Experimental Results

The results of testing on the waterproof effectiveness of LVL treated with 20% paraffin emulsion with/without water immersion aging treatment were showed in Table 1 and Table 2. It can be seen from Table 1 and Table 2 that the laminated veer lumber (LVL) treated with 20% paraffin emulsion could be enhanced its waterproofing, and its WRE value averaged 51.06% without water immersion aging treatment while 37.85% with water immersion aging treatment. The test result also showed that the water immersion aging pre-treatment could reduce the water repellent efficiency of the treated LVL.

Table 1 The waterproof effectiveness of LVL treated with paraffin emulsion without water imersion aging treatment

Treatment	replicate	Weight of sample before water floating (g)	Weight of sample after water floating (g)	Water absorption of sample (g)	WRE (%)
CK	1	56.63	68.14	11.51	
	2	48.11	57.25	9.14	
	3	49.27	60.49	11.22	
	4	50.79	61.87	11.08	
	5	50.56	60.67	10.11	
20% paraffin emulsion	1	52.41	56.15	3.74	67.51
	2	51	57.11	6.11	33.15
	3	48.63	53.24	4.61	58.91
	4	49.36	54.83	5.47	50.63
	5	50.94	56.49	5.55	45.10
	Average				51.06

Table 2 The waterproof effectiveness of LVL treated with paraffin emulsion with water imersion aging treatment

Treatment	replicate	Weight of sample before water floating (g)	Weight of sample after water floating (g)	Water absorption of sample (g)	WRE (%)
CK	1	52.49	72.3	19.81	
	2	44.13	60.53	16.4	
	3	45.41	67.42	22.01	
	4	46.59	62.58	15.99	

	5	46.72	61.82	15.1	
20% paraffin emulsion	1	48.16	57.57	9.41	52.49
	2	46.09	57.07	10.98	33.05
	3	44.47	54.38	9.91	54.98
	4	45.23	59.33	14.1	11.82
	5	46.1	55.63	9.53	36.88
	Average				37.85

5. Conclusion

The laminated veer lumber (LVL) made from poplar veneer used for container flooring can improve the added-value of poplar wood, but its poor waterproof property was a worry for its in-service performance. The experiment on the screening of water repels for LVL was carried out. The test result showed that LVL treated with 20% paraffin emulsion could improve its waterproof property, and the water-repellent efficient (WRE) of LVL was significantly decreased. So paraffin emulsion could be used as water repel for LVL.

Attachment 7

Study on the performance of treated bamboo with environmental-friendly anti-mould agents

Chen Lifang, Zhang yanjun, Xie Guijun, Ma Hongxia, He Xuexiang
(Guangdong Academy of Forestry, Guangzhou510520)

Abstract: Effect of five anti-mould agents(GM, DCM, MSR and PCP-Na) on mould prevention of 3 bamboo species (*Bambusa eutuldoides* Mcclure, *Phyllostachys pubescens* Mazel ex H. de Leh. and *Arundinaria amabilis* Mcclure) was tested. Results showed that bamboo sample treated with higher concentration of anti-mould agents, got higher retention and better anti-mould effect. The anti-mould effect of treaed *A. amabilis* was the best, followed by *Ph. Pubescens* and *B. eutuldoides.* The anti-mould effect of SMR, UD and PCP-Na treated bamboo was better than that of DCM and GM treated bamboo after 12 weeks exposure. But after 6 months exposure, the test result showed that the mould prevention effect of chemicals was decreased with the lapse of time. The environmental-friendly anti-mould chemical SMR has similar mould prevention effect to that of PCP-Na.
Key words: Bamboo, Anti-mould chemical, Mould prevention effect.

Bamboo, as a biological material, is easy to be attacked by mould. And the traditional anti-mould chemical PCP-Na was forbidden for its high toxicity to human beings and environment. Environmental-friendly anti-mould chemical is becoming a developing trend. In this study 3 anti-mould agents for bamboo were developed and tested their performance on mildew prevention in comparision with the traditional mildew-proof agent PCP-Na and another anti-mould agent purchased from the market.

1 Material and method

1.1 Material

1.1.1 Bamboo samples

3-year old *Bambusa eutuldoides* Mcclure, *Phyllostachys pubescens* Mazel ex H. de Leh. and *Arundinaria amabilis* Mcclure, were used in this experiment. The dimension of samples of *B. eutuldoides* and *Ph. pubescens* was 200mm×20mm×thickness (bamboo culm) and the sample of *A. amabilis* was cut into two parts from longitudinal direction and the length was 200mm. All samples were taken from the bamboo culm 1 meter higher from the ground.

1.1.2 Anti-mould chemicals

UD, developed by wood protection team themselves, the main component was DDAC;

GM, purchased from the market, the main component was 2-(Thiocyanatomethylthio) benzothiazole;

PCP-Na, traditional anti-mould agent, being forbidden to use;

DCM, developed by wood protection team themselves, the main component was Isothiazolinones;

SMR, developed by wood protection team themselves.

1.2 Test method

Sample preparation, treatment and anti-mould test procedure were conducted according to standard GB/T 18261—2000 *Testing method for anti-mould chemicals in controlling mould and blue stain fungi on wood*.

1.2.1 Sample treatment

Samples were weighed before treated, then immersed into anti-mould chemicals for 24hrs. three concentrations were made up for each chemical to treat bamboo samples and 20 replicates of bamboo samples for each concentration. After treatment, lightly wiped the chemicals on the surface of samples with filter paper and weighed immediately. The retention of chemical in sample was calculated as follows:

$$R_w = \frac{(m_2 - m_1)\times c}{m_1}\times 1000 \qquad (1)$$

wherein R_w was mass retention of chemical in samples, ‰; m_1 was the weight of sample before treated, g; m_2 was the weight of sample after treated, g; C was the concentration by mass percentage of the anti-mould chemical, %.

1.2.2 Assessment of the effectiveness

Control and treated samples were exposed under the environment of 25℃-30℃ and RH 65%-75%。The degree of mildew growth on the surface of sample was checked each four weeks. The anti-mould effect of chemicals was assessed by the infection value which was classified according to table 1. The prevention efficiency was calculated according to the following formula (2):

$$E = (1 - \frac{D_t}{D_0})\times 100 \qquad (2)$$

wherein, E was the prevention efficiency of anti-mould chemical，%；D_t was the average infection value of treated sample; D_0 was the average infection value of untreated sample.

Table 1. The infection value of sample

Infection value	The area of infected mould on surface of sample
0	Infected area is less than 5%, no mycelium can be seen the surface of sample
1	Infected area is between 5% and 25%
2	Infected area is between 25% and 50%
3	Infected area is between 50% and 75%
4	Infected area is larger than 75%

2 Results and analysis

2.1 The retention of chemicals on samples

Three concentrations of each anti-mould chemical were set according to the specification of the chemicals. The retention of chemical in bamboo sample was shown in table 2.

Table 2 Retention of anti-mould chemical in sample

Anti-mould chemical	Concentration of chemical/%	Retention of chemicals in B. *eutuldoides* /‰	Retention of chemicals in *Ph. pubescens* /‰	Retention of chemicals in *A. amabilis* /‰
UD	1	3.15	1.07	2.37
	2	6.40	2.33	4.00
	3	9.87	2.55	6.74
GM	3	9.18	3.04	5.97
	5	15.12	5.10	9.48
	7	20.96	8.55	14.04
PCP-Na	1	3.13	1.26	2.15
	2	6.29	2.82	4.10
	3	8.09	4.09	6.52
DCM	1	2.73	1.34	2.35
	2	5.81	2.48	4.22
	3	8.14	2.62	5.78
SMR	1	3.2	0.7	2.8
	2	6.4	2.7	5.3
	3	10.9	4.1	10.7

It can be seen from table 2 that the retention of chemicals on the surface of bamboo increased as the increase of concentration of working solution. However it differed in different bamboo species. *Ph. Pubescens* had the highest retention, followed by *A. amabilis* and B. *eutuldoides*. This may be related to the structure difference of bamboo species.

2.2 The performance of anti-mould chemical treated bamboo

The experimental result was shown in table 3.

Table 3 The prevention efficiency of anti-mould chemical treated bamboo after 3 months exposure

Anti-mould chemical	Concentration of chemical/%	Prevention effect of treated B. *eutuldoides* /%			Prevention effect of treated *Ph. pubescens* /%			Prevention effect of treated *A. amabilis* /%		
		4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks	4 weeks	8 weeks	12 weeks
UD	1	100	100	70	100	83.8	52.5	100	100	71.3
	2	100	100	75	100	97.5	70	100	100	100
	3	100	100	56.3	100	98.8	53.8	100	100	100
GM	3	87.5	47.5	27.5	100	56.3	21.3	100	76.3	68.8
	5	100	33.8	30	100	82.5	51.3	100	87.5	68.8
	7	100	51.3	38.8	100	95	73.8	100	71.3	70
PCP-Na	1	83.8	58.8	65	100	73.8	85	86.3	47.5	35
	2	92.5	68.8	50	100	100	83.8	100	82.5	100

	3	95	77.5	70	100	97.5	80	100	93.8	100
DCM	1	46.3	40	0	77.5	15	0	77.5	50	0
	2	82.5	62.5	55	100	78.8	55	100	85	60
	3	91.3	82.5	46.3	100	78.8	70	100	56.3	31.3
SMR	1	65	46.3	95	88.8	93.8	80	100	100	70
	2	75	62.5	95	97.5	93.8	90	100	100	75
	3	81.3	66.3	85	100	97.5	98.8	100	100	76.3

Note: The untreated bamboo sample was completely got mold after 4 weeks exposure, and the infection value was 4.

It can be seen from table 3 that the mould prevention efficiency of treated bamboo increased as the concentration of working solution increased.

2.2.1 The effectiveness of anti-mould chemicals

Five different anti-mould chemicals had different effect on different bamboo species. The mould prevention effects of chemicals with 3% concentration on bamboo samples was compared with, and the results (figure 1-3) showed that after 4 weeks exposure , all the anti-mould chemicals had good effect on mould prevention and there was no significant difference between them. The anti-mould effect of treated *Ph. Pubescens* and *A. amabilis* was similar, and B. *eutuldoides* was little weaker. After 8 weeks exposure, the anti-mould effect of DM and GCM decreased and after 12 weeks exposure, the anti-mould effect of most chemicals decreased significantly . Except *A. amabilis*, the anti-mould effect of *Ph. Pubescens* and B. *eutuldoides* treated with UD was poor.

From the experimental result, the anti-mould effect of SMR and PCP-Na were similar and were better than the other three ones. Mold resistance varied significantly among treated bamboo species, and treated *A. amabilis* had the best mould prevention efficiency, followed by *Ph. Pubescens* and B. *eutuldoides.*

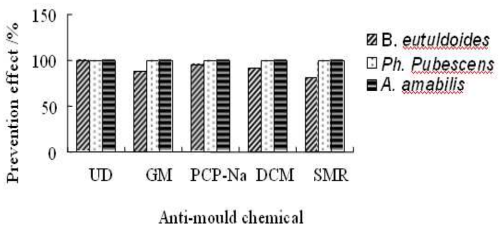


Figure 1. The prevention effect of 3% anti-mould chemical on bamboo after 4 weeks exposure

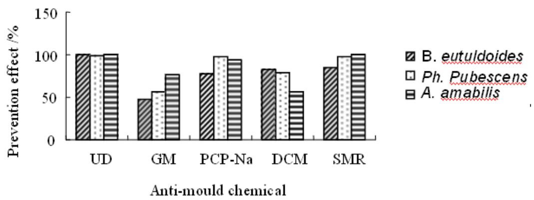


Figure 2. The prevention effect of 3% anti-mould chemical on bamboo after 8 weeks exposure

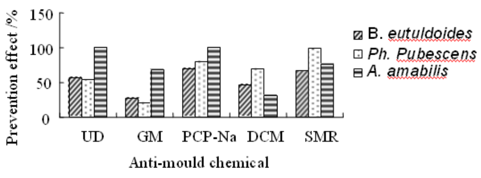


Figure 3. The prevention effect of 3% anti-mould chemical on bamboo after 12 weeks exposure

2.3 The long-term effect of anti-mould agents

In order to understand the long-term effect of anti-mould agents, the mould degree of bamboo samples was checked after 6 months exposure. There were no mould on samples which had good anti-mould effect and full of mould or totally blue stain on samples which had poor anti-mould effect. The long-term effect of bamboo samples were classified by the infection value. Samples with infection value≤2, had good long-term effect, and samples with infection value ≥ 4, had poor long-term effect. The result (table 4) indicated that PCP-Na and SMR had the best anti-mould effect. If NCP-Na treated bamboo samples got mildewed, only the outers (bamboo green) were seen mould growth, because the outer was hardly penetrated by chemicals due to its smooth surface and compact structure. Other chemicals such as UD, GM and DCM treated samples were fully grown mould on the surface of both the outer and inner parts. Some of them were also attacked by beetles. The anti-mould effect of UD treated sample was good after 8 weeks exposure and then decreased after 12 weeks exposure, and finally it hardly acted against mould and fungi after 6 months exposure.

Table 4 The mould degree of samples after 6 months exposure

Anti-mould chemical	Concentration of chemical/%	Infection value ≤2						Infection value a≥4					
		B. eutuldoides		*Ph. pubescens*		*A. amabilis*		*B. eutuldoides*		*Ph. pubescens*		*A. amabilis*	
		number	Ratio/%	number	Ratio/%	number	Ratio/%	number	Ratio/%	number	Ratio/%	number	Ratio/%
UD	1	0	0	0	0	0	0	20	100	20	100	20	100
	2	0	0	0	0	0	0	20	100	20	100	20	100
	3	0	0	0	0	0	0	20	100	20	100	20	100
GM	3	0	0	0	0	0	0	20	100	20	100	20	100
	5	0	0	0	0	0	0	20	100	20	100	20	100
	7	0	0	0	0	0	0	20	100	20	100	20	100
PCP-Na	1	6	30	10	50	2	10	14	70	10	50	18	90
	2	8	40	15	75	15	75	12	60	5	25	5	25
	3	15	75	20	100	19	95	5	25	0	0	1	5
DCM	1	0	0	0	0	6	30	20	100	20	100	14	70
	2	0	0	4	20	10	50	20	100	16	80	10	50
	3	0	0	10	50	15	75	20	100	10	50	5	25
SMR	1	5	25	8	40	12	60	15	75	12	60	8	40
	2	4	20	12	60	15	75	16	80	8	40	5	25
	3	0	0	20	100	17	85	20	100	0	0	3	15

3. Conclusion

The anti-mould chemicals treated bamboos have obvious effect on mould prevention, compared to the untreated control samples. But the effect decreases as the lapse of exposure time. Untreated bamboo samples were totally mildewed while all of the treated bamboo samples demonstrated good anti-mould effect after 4 weeks exposure. After 8 weeks exposure, the anti-mould effect of SMR, UD and PCP-Na treated bamboo samples was better than that of DCM and GM treated samples. Among three bamboo species treated, *A. amabilis* performed best against mould, followed by *Ph. Pubescens* and *B. eutuldoides.*

Among 4 newly-developed anti-mould agents, SMR is the best in long-lasting and anti-mould efficiency, which is similar to that of PCP-Na. SMR treated bamboo was still in good performance against mould after 6 months exposure, and hence it will be applied extensively and prospectively as an environment-friendly anti-mould chemical. The performance of PCP-Na treated bamboo infered that the treating process is also important for bamboo mould prevention. Because chemical is hard to penetrate into the smooth outer of bamboo, to improve the penetration properties of bamboo should be considered in future study.

Attachment 8

Laboratory Exposure Tests on Bamboo Species

Xie Guijun He Xuexiang Su Haitao Chen Lifang Zhang Yanjun
（Guangdong Forest Research Institute，Guangzhou，510520）

Abstract There are 500hm^2 of bamboo forest in Southern China and the output of bamboo volume is as high as 1800 tons every year. Different species of bamboo varies in their resistance to wood decay fungi. The antiseptic performance of different species of bamboo should be determined by laboratory exposure tests in order to determine and extend the application scope and scales of bamboo species.
Key words bamboo species, toxicity, laboratory exposure test

It is well known that indigenous forest resources is not able to meet the future growing demand in wood in China, especially lacking of excellent quality woods. To solve the problem, it is necessary to use other renewable and substituted resources for wood like using bamboo and plantation timbers. Bamboo is one of the most important plantation resources in Southern China. Bamboo can cost less time to be mature than other wood species, with some advantages such as excellent strength, high elastic behavior and difficult to abrade. However, bamboo has been limited in use because it contains high content of carbohydrates which make it being so susceptible to insect and fungi. To extend the application scope of bamboo, it is important to develop the preservation technology of bamboo. It is essential to understand the natural durability of different species of bamboo before it is treated with preservative. Therefore, the test on bamboo species resistant to wood decay fungi has been conducted, and the test result is summarized as follows.

5. Materials and methods

1.1 Test materials

1.1.1 Test bamboo

13 bamboo species which can be easily found in southern China were selected for the test, including: *Gigantochloa levis×D.latiflorus Munro No.1*, *Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1, B.chungii McClure, Gigantochloa.atter, Gigantochloa apus, B.sinospinosa McClure, B.textilis McClure, Fargesia dracocephala, Thyrsostachys siamensis(kurz ex Munro)Gamble, D.bambusoides Hsueh et Yi, Dendrocalamus brandisii*, *B.pervariabilis×D.latiflorus No.7* and *Dendrocalamus giganteus Munro.*

1.1.2 Test fungi

Coriolus versioolor (CV) and *Gloeophyllum trabeum* (GTR)

1.2 Test methods

The test was carried out by following the soil block test method introduced in Chinese Standard, GB/T13942.1-92.

1.2.1 The culture of fungi

Test culture medium, maltose-agar medium, was prepared, including the following ingredients: (1) Maltose, 2g; (2) Agar, 2g; (3) Distilled water，100ml?.

The above 3 components were put in 500ml Erlenmeyer flask and sterilized at 121^{o}C for 30min. The sterilized medium was poured into sterilized Petri dishes when it is cooled at about 60-70^{o}C. The test fungi were then inoculated on the medium in Petri dished after it is cooled completely and cultured in the incubator at about 25^{o}C for 7-10 days before they are used for the test.

6. Preparation of feeding samples

Feeding samples：pine wood or poplar wood，hart wood was cut into 20x20x10mm in size， the same size as test samples.

1.2.3 Preparation of soil matrix

The soil matrix was prepared, including components: (1) clean and dried sand sieved through 20-30 mesh, 20-30g; (2) Masson pine sapwood powder sieved through 20-30 mesh, 20-30g; (3) corn flour, 8.5g; (4) brown sugar, 1g. (5) 2% maltose solution 100ml.

Firstly, the components (1) to (4) were mixed equably and put into the 500ml Erlenmeyer flask to be the soil matrix for the soil block test, then 3 feeding wood samples were put on the surface of the soil matrix, and then the component (5) was added slowly into the flask, and finally the flask sealed with cotton plug was autoclaved for 1 hr before it is used for the test.

1.2.4 Inoculation of the test fungi

7-10 days old of test fungi culture on plate was inoculated on the centre of soil matrix in the flask, and then the flask was kept in the incubator with temperature of 28±2℃, and relative moisture of 75-85%.

1.2.5 The preparation of test samples

At least 12 test samples for each species of bamboo with serial number were selected and cut into about 20x20x10mm in size. Each test sample was labeled and weighted after being dried at 100±5℃ to a constant weight. Then test samples were autoclaved for about 30 min by being packed with several layer of cloth or paper to get 40 to 60 percent of moisture content before being used.

1.2.6 The inoculation of the test samples

The sterilized test bamboo sample with about 40-60% moisture content was inoculated on the top of the feeding sample which was infested and covered fully with the test fungus culture on its surface, when the surface of soil matrix was full of the growing fungus in the flask.

The flask with the test bamboo sample was kept in the incubator (28±2℃,75-80%RH) for at least 3 months before the end of the test.

1.2.6 The evaluation of the test result

In the end of the test, all test samples were taken out from the flasks and cleared away the soil matrix and fungus culture with brush, and dried at 100±5℃ to a constant temperature before they were weighted separately. Then the natural decay resistance for each bamboo species was classified based on the weight loss for each. (re. GB/T 13942.1-92)

2 Results and Discussion

The result of the laboratory exposure test is listed in Table 1. It can be seen from Table 1 that the weight loss of most species of bamboo (totaled 11 species) is less than 25% caused by brown rot fungus GTR or white rot fungus CV, and these bamboo species are belonged to decay resistance class (GB/T 13942.1-92). Only two species of bamboo, including *B.pervariabilis×D.latiflorus No.7* and *Dendrocalamus giganteus Munro*, were caused 27% to 30% of weight loss by the two test fungi and classified into little decay resistance class (GB/T 13942.1-92).

The test bamboo did not have much change in color when it was infested by the white rot fungus CV, while it became darkening when infested by the brown rot fungus GTR. It seems as if the white rot fungus CV caused a relative higher weight loss than the brown rot fungus GTR in this test, for example, the weight loss of bamboo *Dendrocalamus brandisii* caused by CV is 10% more than that of the same bamboo species caused by GTR.

Table 1 Weight percent loss of bamboo by decay fungi

Serial Number	Name	Weight Percent Loss by Decay Fungi		Evaluation of decay resistant
		GTR	CV	
A	*Gigantochloa levis×D.latiflorus Munro No.1*	17	19	Decay resistant
B	*Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1*	18	20	Decay resistant
E	*B.pervariabilis×D.latiflorus No.7*	27	28	Little decay resistant
F	*B.chungii McClure*	21	25	Decay resistant
G	*Gigantochloa.atter*	15	16	Decay resistant
I	*Gigantochloa apus*	14	16	Decay resistant
J	*B.sinospinosa McClure*	13	17	Decay resistant
L	*Dendrocalamus giganteus Munro*	27	30	Little decay resistant
Q	*B.textilis McClure*	17	18	Decay resistant
S	*Fargesia dracocephala*	13	19	Decay resistant
T	*Thyrsostachys siamensis(kurz ex Munro)Gamble*	12	18	Decay resistant
X	*D.bambusoides Hsueh et Yi*	15	20	Decay resistant

Y	*Dendrocalamus brandisii*	12	22	Decay resistant

6 Conclusion

According to the classification method of natural decay resistant of wood introduced in Chinese Standard GB/T 13942.1-92, which based on the weight loss, the test bamboo species were classified into two different groups. Among 13 test bamboo species, 11 species were belonged to decay resistance, which included *G. levis×D.latiflorus No.1*, *B.pervariabilis×(D.latiflorus+B.textiles) No.1*, *B.chungii* , *G.atter, G.apus, B.sinospinosa, B.textilis, F.dracocephala, T.siamensis, D.bambusoides* and *D.brandisii*, the other two species including *B.pervariabilis×D.latiflorus No.7* and *D.giganteus* were belonged to little decay resistance.

Attachment 9

IRG/WP 10-10708

THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION

Section 1
Biology

The natural durability and preservative treatability of 11 bamboo species

Chen Lifang, Su Haitao, Zhang Yanjun, Wang Yuxia, He Xuexiang,
Ma Hongxia, Xie Guijun
Forestry Industry Division, Guangdong Academy of Forestry, 233 Guangshan 1st Road, Longdong 510520， Guangzhou, China

Paper prepared for the 41st Annual Meeting

Biarritz, France

9-13 May 2010

IRG SECRETARIAT

Box 5609

SE-114 86 Stockholm

Sweden

www.irg-wp.com

The natural durability and preservative treatability of 11 bamboo species

Chen Lifang, Su Haitao, Zhang Yanjun, Wang Yuxia, He Xuexiang,
Ma Hongxia, Xie Guijun
Forestry Industry Division, Guangdong Academy of Forestry,
233 Guangshan 1st Road, Longdong 510520，Guangzhou, China.
Tel: 86-20-87030010 Fax: 86-20-87035975 E-mail: Haitaosu2002@126.com

ABSTRACT

Tests on the natural durability and preservative treatability of 11 common bamboo species were conducted. The results showed that there was a linear relation between bamboo density and its preservative retention by mass, and the preservative retention of bamboo reduced while its density increased. The test also showed that there were significant differences in the natural durability of bamboos, but the natural durability of bamboo was not related closely to its density, and 11 bamboos were all belonged to non-durable grade, lasting less than 2 years in filed exposure.

Keywords: Bamboo culm, Preservative treatability, Retention, Natural durability.

1. INTRODUCTION

The bamboo planting area accounts for 1/4 of the world's total and it is considered as the most potential substitute material for wood. Now bamboo is widely used in the industries of paper making, building, furniture, panel board and so on. The use of bamboo is limited due to its short service life caused by decay, mildewing and worm-eaten. Most untreated bamboos as structural materials can service only for 2~3 years. Therefore it is necessary to study on bamboo preservation in order to improve its' service life. This study is to test and evaluate on the natural durability and treatability of 11 bamboo species commonly used in China for providing the guideline in bamboo preservation.

2. MATERIALS AND METHODS

2.1 Sample preparation:

11 bamboo species: *Gigantochloa levis×Dendrocalamus latiflorus Munro* No.1*; Bambusa pervarilis×D.latiflorus*nNo.7*;B.sinospinosa*McClure*;B.pervariabilis×(D.latiflorus+B.textiles)* No.1*;B.chungii* McC1;*Dendrocalamus giganteus* Munro; *D.*brandisii*; Thyrsostachys siam ensis(*Kurz ex Munro*)* Gamble*; B. textiles* McClure*; Bamlousa culgaris;D.bambusoides* Hsueh et D. ZLi;

All species of bamboo are 3 years old, being cut from Guangdong academy of forestry.

2.2 Experimental method:

2.2.1 Field test

The test on the natural durability of bamboo samples was based on the field test method according to GB/T13944.2-92[5], and samples were cut into 50cm in longitudinal direction. The decay degree of sample was checked every 3 months.

2.2.2 Density measurement

Samples of 20mm×20mm×thickness were prepared for density measurement. Samples should be dried in an oven at 103±2℃ unto constant weight, then weighted. Sample volumes were measured by putting each sample into a measuring cylinder containing liquid paraffin. Bamboo Density was determined by the following formula:

$$D= W_1/(V_2 - V_1)$$

D---- the density of sample (g/m^3);

W_1 ---- the weight of sample (g);

V_2 ---- the reading value of measuring cylinder with sample (m^3);

V_1 ---- the reading value of measuring cylinder without sample (m^3)

2.2.3 Treating method

Bamboo was cut into 500mm long, air-dried, and then cleaved into four parts as samples for treatment. All samples were treated with 2.5% CCA preservative through the vacuum-pressure impregnation procedure at the vacuum degree of 0.08MPa and the pressure of 1.6MPa, and the whole procedure took 2.5h.

2.2.4 Retention analysis

Every sample was weighed before and after treatment, and labeled as W_0 and W_1 respectively. Ten samples from each treated species were tested for preservative retention (W/%) calculated by the following formula:

$$W/\% = (W_1 - W_0)/W_0 \times 100$$

3 Results

3.1 Treatability of bamboos

The preservative retentions of different bamboo species showed in Table 1. It can be seen that from Table 1 the retention of CCA treated bamboo was different between bamboo species, which was affected by the bamboo density. A close relationship exists between preservative retention and bamboo density, and the preservative retention of bamboo declined as the increase of bamboo density (see Fig.1), and a regression equation was set up as follows:

$$y = -129.1x+140.6, R=0.9147$$

y---- the preservative retention;

x -----the bamboo density

Table 1 The average density and preservative retention of samples

Species	Preservative Retention（%）	Average Density (g.cm^{-3})
Gigantochloa levis×Dendrocalamus latiflorus Munro No.1	85.40	0.42
Bambusa pervarilis×D. latiflorus No.7	78.04	0.43
B. sinospinosa McClure,	74.97	0.57
*B.pervariabilis×(D. latiflorus+B.textiles)*No.1	54.14	0.61
B.chungii McC1	69.05	0.62
Dendrocalamus giganteus Munro	65.37	0.65
*D.*brandisii	51.79	0.68
*Thyrsostachys siam ensis(*Kurz ex Munro*)* Gamble	42.09	0.71
B. textiles McClure	32.74	0.75
Bamlousa culgaris	47.43	0.81
D.bambusoides Hsueh et D. ZLi	27.36	0.84

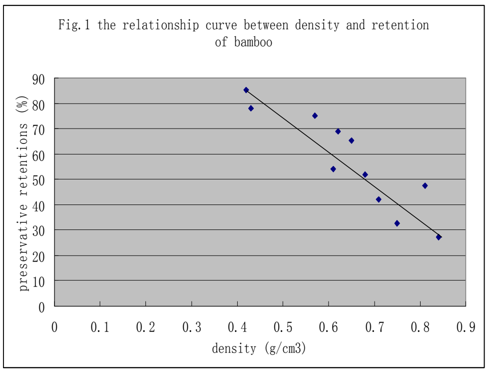


Fig.1 the relationship curve between density and retention of bamboo

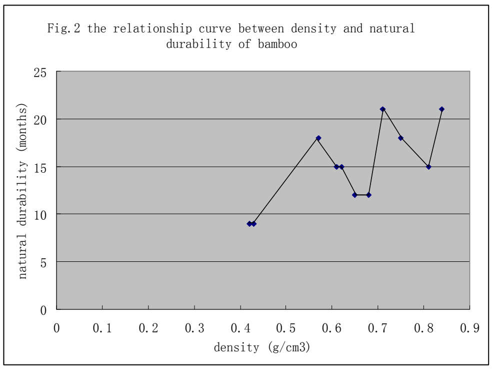


Fig.2 the relationship curve between density and natural durability of bamboo

3.2 Natural durability of bamboos

It was hard to determine the rotten degree of bamboo based on the surface rotting rating method according to the related standard for field test on natural durability of wood due to uneven density in outer section and inner section in bamboo materials. In this study, the time for an average of 60% cross sections of tested specimen of each bamboo species being rotten in field exposure was taken as the parameter for evaluating the natural durability of each bamboo species. The result of field test on bamboo natural durability was shown in Table 2. It can be seen from Table 2 that there were significant differences in natural durability among 11 bamboos, but the natural durability of bamboo was not related closely to its density (see Figure 2). The result was quite different from that of wood, and it was reported that there was a linear relation between density of mature wood and its' natural durability [8~9]. The result of bamboo may be related to the effect of bamboo's chemical components, and abundant nutritive materials in bamboo make it being more susceptible to decay.

Table 2 The average natural durability time of bamboo species with different properties

Species	Inner diameters (mm)	Outer diameters (mm)	Average density/(g.cm^{-3})	Average natural durability (months)
Gigantochloa levis×Dendrocalamus latiflorus Munro No.1	51.76	66.00	0.42	9
Bambusa pervarilis×D. latiflorus No.7	41.00	50.50	0.43	9
B. sinospinosa McClure,	55.30	74.70	0.57	18
*B.pervariabilis×(D. latiflorus+B.textiles)*No.1	39.10	63.44	0.61	15
B.chungii McC1	43.50	5.32	0.62	15
Dendrocalamus giganteus Munro	53.10	68.50	0.65	12
*D.*brandisii	48.00	67.66	0.68	12
*Thyrsostachys siam ensis(*Kurz ex Munro*)* Gamble	27.30	42.70	0.71	21
B. textiles McClure	22.10	31.40	0.75	18
Bamlousa culgaris	64.20	79.24	0.81	15
D.bambusoides Hsueh et D. ZLi	38.24	56.50	0.84	21

4 CONCLUSION

4.1 The study showed that the preservative retention of bamboo declined as the increase of the density of bamboo. There was a linear relation between bamboo density and preservative retention by mass, and the correlation equation was $y=-129.1x +140.6$ ($R=0.9147$).
4.2 11 bamboo species were all belonged to the non-durable grade, lasting less than two years in filed exposure.
4.3 It is reported that there was a linear relation between density of mature wood and its natural durability [8~9], but this study showed that bamboo density is not related closely to its natural durability. It was unclear that the discrepancy was due to the difference in the properties of both bamboo and wood, or it was due to bamboo specimen being not matured enough (only 3 years old for all bamboo species), therefore further study is needed.

References:

1 Zhang Qisheng. Reasonable Utilization of Bamboo Resources. China Wood Processing Machinery. 1995, (4): 23-27.

2 Tang Yizhuang, Yuan Yisheng. Study on antimould and antidecay for bamboo. China Wood Industry. 1990, (2):1-6.

3 Yang Xiaosheng. Advance in bamboo chemical ingredients and its utilizations in China and abroad. Forest Science and Technology. 1997, (5): 33-34.
4 Yu Feng, Gan Jiqing, Li Guangwei. Experiment of Bamboo preservation. Bamboo Research. 1991, (2): 49-52.
5 Tang Yizhuang, Shi Zhenhua. Method for Field Test of Natural Durability of Wood. GB/T 13942-92.
6 Yu Wenji, Jiang Zehui, Ye Kelin. Characteristics Research of Bamboo and Its Development. World Forestry Research. 2002, (2):50-55.
7 Wang Yamei, Liu Junliang, Wang Ximing. Characteristics of Bamboo and Its Preservation Technology. China Wood Industry. 2004(2)：28-29.
8 Liu Lei, Liao Hongxia, Su Haitao. Natural Durability Test of 6 Bamboo Species. Guangdong Forestry Science and Technology. 2005, 21(2): 6-8.
9 Liu Xiuying. Laboratory Decay Resist of fFive Bamboo Species. Forestry Industry. 1997, (1):13-15.

Attachment 10

IRG/WP 10-10723

THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION

Section1
Biology

Grading the Performance of 18 Common Bamboo Species

Chen Lifang, Su Haitao, Zhang Yanjun, Wang Yuxia, He Xuexiang,
Ma Hongxia, Xie Guijun
Forestry Industry Division, Guangdong Academy of Forestry, 233 Guangshan 1st Road, Longdong 510520， Guangzhou, China

Paper prepared for the 41st Annual Meeting

Biarritz, France

9-13 May 2010

IRG SECRETARIAT

Box 5609

SE-114 86 Stockholm

Sweden

www.irg-wp.com

Grading the Performance of 18 Common Bamboo Species

Chen Lifang, Su Haitao, Zhang Yanjun, Wang Yuxia, He Xuexiang,
Ma Hongxia Xie Guijun
(Guangdong Forestry research institute, Guangzhou, Guangdong, China 510520)

ABSTRACT

A grading method for assessing the performance of 18 common bamboo species was introduced in this article. The method was based on 4 grade levels with corresponding scores of 4 reference indexes of bamboos including culm diameter, culm-wall thickness, natural durability and preservative treatability. In comparison with the traditional utilization of bamboo, the grading results showed that this grading method was quite useful for evaluating the performance of bamboos, and bamboo species with higher grade level and higher score was more suitable to be used as timber.

Keywords: Bamboo species, Performance, Grading evaluation.

1. INTRODUCTION

In recent years, with serious shortage in forest resources in the world, a broad of non-wood resources have been widely used, such as bamboo, cotton stalk and so on. Bamboo has the most similarity to wood in the morphology, mechanical and chemical properties. In China, processing and utilization of bamboo resources are in a leading position in the world. The species number, planting area, annual cutting volume of bamboo increases year by year. For example, the planting area of bamboo increases 60,000hm^2 per year, and the production of bamboo can reach 18,000,000t every year [1]. Nowadays bamboo is becoming an important forest resource in China, and has a great potential for the development in the near future.

Bamboo has been developed to a variety of products. For example, round bamboo culm is often made into foundation column, scaffold, flooring, wall and roofing, truss, interior decoration, water pipe, bamboo concrete and so on, used for outdoor decoration or structural material. However, the characteristics of bamboo like culm diameter, the natural durability and preservative treatability have direct impact on the in-service performance of bamboo. There are more than 300 bamboo species in China [2~4], and different species of bamboo varies in the utilization due to their differences in properties. However, till now there is no clear rule or guide available for the selection of bamboo for proper uses, and bamboo used to be selected as timber use relied on the experience of the user. Therefore, grading on the performance of bamboos based on their properties will be a fast and convenient way for the user to select bamboo properly, and it will play a very important role in the rational exploitation of bamboo resources and sustainable management of bamboo industry. In this paper, the performance of common sympodial and hybrid bamboos was evaluated comprehensively by using 4 reference criteria and index including the culm diameter, culm-wall thickness, natural durability and treatability of bamboos, in order to develop bamboo preservation technology and utilize bamboo resources efficiently and rationally.

2. MATERIALS AND METHODS

2.1Materials

18 species of Three-year-old fresh bamboo were cut from Guangdong Academy of Forestry, Guangzhou city, including 3 hybrid species and 2 introduced species. Details about bamboos used in this experiment were showed in table 1. All the samples were prepared from culms cut above 1m high from the ground in bamboo plantations.

Table 1 Bamboo species for the experiment

No.	Species
1	*Phyllostachys pubescens*
2	*Gigantochloa levis×D.latiflorus Munro No.1*
3	*Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1*
4	*Bambusa pervariabilis McClure*
5	*Thyrsostachys oliveri Gamble*
6	*B.pervariabilis×D.latiflorus No.7*
7	*B.chungii McClure*
8	*Gigantochloa.atter*
9	*D.asper (Chlt.) Bacher et Heyne*
10	*Gigantochloa apus*
11	*B.sinospinosa McClure*
12	*Dendrocalamus giganteus Munro*
13	*D.latiflorus Munro*
14	*B.textilis McClure*
15	*Fargesia dracocephala*
16	*Thyrsostachys siamensis(kurz ex Munro)Gamble*
17	*D.bambusoides Hsueh et Yi*
18	*Dendrocalamus brandisii*

2.2 Experimental methods

2.2.1 Test on natural durability of bamboos

The test on natural durability of bamboos was carried out according to Chinese national standard GB/T 13944.2-92 *method for field test of natural durability of wood* [5]. Selected Culms were cut into 50cm long. 10 samples were prepared from 2 randomly selected bamboo culms for each bamboo species. Samples exposed in the field were checked and rating the decay every 3 months.

2.2.2 The measurement of culm density

Three samples were prepared from the base, middle and top section of selected culms of each bamboo species respectively, and the average of the density of these samples was taken as the culm density of the bamboo species. The size of each sample 20mm×20mm×culm-wall thickness.

Each samples was dried in (103±2)℃ to a constant weight and weighted immediately. Then it was put into a measuring cylinder with liquid paraffin till it was fully submersed. The density of each sample was calculated as follows:

$$D= W_1 / (V_2 - V_1) \quad (1)$$

Where: D = density of sample, g/cm^3.

W_1 = weight of sample, g.

V_2 = reading value of measuring cylinder with sample.

V_1 = reading value of measuring cylinder without sample.

2.2.3 Test on preservative treatability

Preservative treatability of bamboo sample was characterized by the preservative retention which was calculated according to the weight change of sample before and after a vacuum-pressure impregnation process. The treating process was detailed as follows: After loading the process vessel with bamboo samples, the vessel was vacuumed to -0.08MPa. CCA with 2.5% content was then pumped from the stock vessel into the process vessel. Samples were treated under 1.6MPa for 2.5h, then preservative was pumped back to stock vessel, and samples were unloaded.

The preservative retention could be expressed by two methods- retention by volume or retention by mass. They were calculated according to formula (2) and formula (3), respectively.

$$R= W(\%)\times D\times 1000/100 \quad （2）$$

$$W(\%)=(W_1 - W_0)/W0\times 100 \quad （3）$$

Where： R= preservative retention by volume, kg/m3.

W= preservative retention by mass, %.

D= diameter of treated culm, g/cm^3.

W_1= weight of sample after treatment, g.

W_0=weight of sample before treatment, g.

10 replicates for preservative retention calculation were randomly selected from 2 bamboo culms for each species.

Culm sample was cut into 500mm length, air-dried, and then cleaved into four sections along the axial direction because of its special structure. Preservative penetrated into bamboo mainly through longitudinal tissues, such as vessels and sieve tubes in the vascular bundle, for bamboo has no transverse tissue and the outer of bamboo is rich of silicon and wax, which affected the preservative penetration into bamboo along the transverse direction. In addition, there is often much sediment in the vessels and sieve tubes, and which makes bamboo more difficult to be penetrated by preservatives than wood [9-10].

2.2.4 The measurement of Culm diameter and culm-wall thickness

The culm diameter and culm-wall thickness of the base, the middle and the top sections of the selected culms of each bamboo species were measured respectively, and the average of these sections were taken as that of the bamboo species.

2.2.5 Criteria and index for the grading of bamboos for timber use

Culm diameter and culm-wall thickness and the natural durability of bamboo were important indexes affected on the utilization of culms. The density and the mechanical strength of the culm increase with the increase of culm-wall thickness [6-7], and culms with small diameter and thin wall thickness could tolerate relatively smaller stress and which are also easy to be fractured. The preservative treatability of culms could influence on the competitive power of the sustainable utilization of bamboo. Therefore these four properties indexes of bamboo could be used as grading criteria and index for the comprehensive evaluation of the in-service performance of bamboo. Detail scores set for each index were listed in table 2.

Table 2 Scoring criteria for the grading of the performance of bamboo

Natural durability		Preservative treatablity[6]		Culm Diameter		Culm-wall thickness		Grade	
Average months m	score	Preservative Retention R(kg/m^3)	score	Outer diameter d(mm)	score	T (mm)	score	Total score	Grade
m≤6	2	R＜4	1	d＜50	1	t＜10	1	s≤15	i
6＜m≤12	4	4≤R＜6.4	4	50≤d＜60	3	10≤t＜15	3	15＜s≤20	ii
12＜m≤18	6	6.4≤R＜9.6	7	60≤d＜70	5	15≤t＜20	5	20＜s≤25	iii
18＜m≤24	8	9.6≤R＜24	10	70≤d＜80	7	20≤t＜25	7	25＜s≤30	iv

3. RESULTS AND DISCUSSION

3.1 The properties index of bamboos

Since bamboo differs from wood in microstructures and properties, the decay degree of bamboo can not be estimated by the same way as wood. Wood became soft when being attacked by white rot fungi. It's easy to rate the decay degree by awl. Bamboo was easier to be attacked by brown rot fungi than white ones. Decayed Bamboo became brittle but little change in its hardness, therefore it was hard to rate the decay degree before bamboo completely decayed. From the experimental result, it was found that the outer layer of bamboo with a layer of surface cover is more resistant to decay than the inner layer of bamboo. The damage degree of bamboo by termite was easy to rate. Usually the inner layer of bamboo was partly gnawed away while the outer layer of bamboo was intact. In this experiment, the time when the surface area of culm sample for exposure was damaged more than 60% was recorded as the average months for the grading index of the natural durability of bamboo [11-12]. Four properties index of 18 bamboo species were shown in table 3.

Table 3 The properties data of different bamboo species

Bamboo species	Outer diameter d(mm)	Inner diameter d_1(mm)	Culm-wall thickness t(mm)	Time for Natural durability (months)	Average density D(g/cm^3)	Quantity retention W(%)	Volume retention R(kg/m^3)
Gigantochloa levis×D.latiflorus Munro No.1	66.00	51.76	14.24	9	0.42	85.40	8.97
Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1	63.44	39.10	24.34	15	0.62	54.14	8.39
Bambusa pervariabilis McClure	42.90	31.70	11.20	9	0.68	72.33	12.30
Thyrsostachys oliveri Gamble	38.20	22.20	16.00	18	0.69	23.51	4.06
B.pervariabilis×D.latiflorus No.7	50.50	41.00	9.50	9	0.43	78.04	8.39
B.chungii McClure	52.32	43.50	8.82	15	0.62	50.55	7.83
Gigantochloa.atter	57.26	45.40	11.86	21	0.86	37.49	8.06
D.asper (Chlt.) Bacher et Heyne	62.50	43.40	19.10	9	0.45	37.52	4.22
Gigantochloa apus	77.10	61.20	15.90	12	0.55	94.75	13.03
B.sinospinosa McClure	74.70	55.30	19.40	18	0.57	74.97	10.68
Dendrocalamus giganteus Munro	68.50	53.10	15.40	12	0.62	65.37	10.13
D.latiflorus Munro	62.90	50.10	12.80	9	0.35	57.29	5.01
B.textilis McClure	31.40	22.10	9.30	18	0.75	32.74	6.14
Fargesia dracocephala	79.24	64.20	15.04	15	0.81	47.43	9.60
Thyrsostachys siamensis(kurz ex Munro)Gamble	42.70	27.30	15.40	21	0.71	42.09	7.47
D.bambusoides Hsueh et Yi	56.50	38.24	18.26	21	0.84	27.36	5.75
Phyllostachys pubescens	80.58	64.02	16.56	24	0.59	44.56	6.57
Dendrocalamus brandisii	67.66	48.00	19.66	12	0.68	51.79	8.80

3.2 Scoring and grading the performance of bamboos

Four properties indexes of 18 bamboo species was scored firstly according to the data of table 2 and table 3, and then the performance of each bamboo was graded based on total score of the four indexes. The scoring and grading results were shown in table 4.

Table 4 Scoring and grading of different bamboo species

Bamboo species	Average score					Grade
	Natrual durability	Treatability	Diameter	Culm-wall thickness	Total score	
B.textilis McClure	6	4	1	1	12	i
B.pervariabilis×D.latiflorus No.7	4	7	3	1	15	i
Thyrsostachys oliveri Gamble	6	4	1	5	16	ii
D.latiflorus Munro	4	4	5	3	16	ii
B.chungii McClure	6	7	3	1	17	ii
Bambusa pervariabilis McClure	4	10	1	3	18	ii
D.asper (Chlt.) Bacher et Heyne	4	4	5	5	18	ii
Gigantochloa levis×D.latiflorus Munro No.1	4	7	5	3	19	ii
D.bambusoides Hsueh et Yi	8	4	3	5	20	ii
Gigantochloa.atter	8	7	3	3	21	iii
Thyrsostachys siamensis(kurz ex Munro)Gamble	8	7	1	5	21	iii
Dendrocalamus brandisii	4	7	5	5	21	iii
Dendrocalamus giganteus Munro	4	10	5	5	24	iii
Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1	6	7	5	7	25	iii
Gigantochloa apus	4	10	7	5	26	iv
Phyllostachys pubescens	8	7	7	5	27	iv
B.sinospinosa McClure	6	10	7	5	28	iv
Fargesia dracocephala	6	10	7	5	28	iv

From Table 4, it can be seen that most bamboo species were belonged to grade ii or grade iii. In generally, 9 bamboo species including *Gigantochloa.atter, Thyrsostachys siamensis(kurz ex Munro)Gamble, Dendrocalamus brandisii, Dendrocalamus giganteus Munro, Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1, Gigantochloa apus, Phyllostachys pubescens, B.sinospinosa McClure* and *Fargesia dracocephala* were belonged to grade 3 or grade 4 with higher scores of four properties index, and they performed better in service as structural wood materials than other species, especially for using in outdoors. In order to test the reliability of this grading method, the traditional utilization of these bamboo species were listed in table 5 and compared with the grading results.

Table 5　The traditional application of different bamboo species

Bamboo species	Grade	Traditional application[13-14]
B.textilis McClure	i	It is a species with straight culm, long internode with smooth knot and thin culm-wall. It is mainly used to produce bamboo strips for handicraft, cable and rope, and also used for paper making.
B.pervariabilis×D.latiflorus No.7	i	It is a species with fast growth, good adaptability, straight culm, high output ect. It could produce both culms and eadible shoots, and culms were mainly used for papermaking or as agricultural material.
Thyrsostachys oliveri Gamble	ii	It is an excellent ornamental bamboo species. It is also used in the temporary buildings. But it is too brittle to produce bamboo strips.
D.latiflorus Munro	ii	It is the most widely distributed species in south China. It is a culm and shoot-producing species with huge and straight culm. It can be used for structure materials, raft, pipe, bar and so on. It could be used as raw material of panel board with thick but soft culm-wall.
B.chungii McClure	ii	It is a common economic bamboo species in south China with straight culm. The bamboo strip has good flexibility and is a great material for interweaving basket, mat and so on.
Bambusa pervariabilis McClure	ii	The culm has small Taperness and good natural durability. It is a traditional material for building and agricultural supporting posts.
D.asper (Chlt.) Bacher et Heyne	ii	It is a species with fast growth and strong reproductive. It can produce both culm and shoot, and is a good raw material of wooden industry.
Gigantochloa levis×D.latiflorus Munro No.1	ii	It is mainly cultivated for shoot.
D.bambusoides Hsueh et Yi	ii	It is a good timber bamboo species as well as ornamental plant.
Gigantochloa apus	iii	It is a newly introduced species.
Thyrsostachys siamensis(kurz ex Munro)Gamble	iii	It is one of the most excellent bamboo species for timber , shoot and ornament. It has nearly solid culm and good natural durability, and is often used as beams of buildings by the local people.
Dendrocalamus brandisii	iii	It can be the most excellent bamboo species for timber and shoot in the world. It grows fast with high yield. It can produce 4.5~7.5 million m^2

		bamboo timber per hectare. It is also a great raw material for papermaking.
Dendrocalamus giganteus Munro	iii	It is widely used in the building construction and handicrafts, eg. the bamboo house of Dai ethnic group.
Bambusa pervariabilis×(D.latiflorus+B.textiles) No.1	iii	It is a good ornamental bamboo species with obvious yellow and green culm.
Gigantochloa apus	iv	It is an introduced bamboo species from India. It is a timber and shoot-producing species and can survive under -2℃.
Phyllostachys pubescens	iv	It is the most widely distributed and largely planted species in China and widely used as building materials, food and ornamental plants.
B.sinospinosa McClure	iv	It is a tall and strong bamboo species, and can be used as building materials, raft, pipe, bar, hedge, food etc.
Fargesia dracocephala	iv	It is a bamboo species with high yield but poor natural durability. It is also one of the favorite food resources of the giant panda.

It can be seen from table 4 and table 5 that grading results of 18 bamboo species were similar to their traditional utilization. For example, *Dendrocalamus giganteus Munro* was one of the important bamboo species for timber use, and it belonged to grade iii with score 24; *B.sinospinosa McClure* got the highest score and mainly used as structural materials, though it has not been widely used due to its thorny culm which is difficult to be cut. *Dendrocalamus brandisii* was mainly used for edible shoots because of its poor natural durability. But it could be a good species for timber use after preservative treatment since it was good in treatability and high yield.

4. CONCLUSION

4.1 There are varieties of bamboo species with different morphology, mechanical and chemical properties, so the performance of bamboos is also different from each other. A grading method for the evaluation of the performance of bamboo species were studied, in order to provide guide for the user to select bamboo for timber uses like structural materials and building materials and so on. The method was based on four grading index including culm diameter, culm-wall thickness, natural durability and preservative treatability of 18 common bamboo species. Scores were set for each grading index firstly and then total score of the four index of each bamboo species was divided into 4 grades.

4.2 The grading study showed that the higher total score of four grading index of bamboo, the higher grade it was belonged to, and as well the more suitable to be used as timber it was. The grading method was basically reliable and advisable, and was compatible to the traditional utilization of bamboo species. For example, *B.textilis*

McClure and *B.chungii McClure*, belonging to low grades (i, ii), is mainly used for craft interweaving as it was used traditionally.

References

[1] Zhang Qisheng. Reasonable Utilization of Bamboo Resources. China Wood Processing Machinery. 1995, (4): 23-27.

[2] 2 Tang Yizhuang, Yuan Yisheng. Study on antimould and antidecay for bamboo. China Wood Industry. 1990, (2):1-6.

[3] Yang Xiaosheng. Advance in bamboo chemical ingredients and its utilizations in China and abroad. Forest Science and Technology. 1997, (5): 33-34.

[4] Yu Feng, Gan Jiqing, Li Guangwei. Experiment of Bamboo preservation. Bamboo Research. 1991, (2): 49-52.

[5] Tang Yizhuang, Shi Zhenhua. Method for Field Test of Natural Durability of Wood. GB/T 13942-92.

[6] Ma Lingfei, Han Hong and Ma Naixun. Fiber morphology and physical-chemical characteristics of some scattered bamboo wood[J]. Journal of Zhejiang Forestry College. 1993,10(4): 361-367.

[7] Zhang Jingwen, Wang Huazhong, Ma Naixun, etc. Fibre morphology and main physical and chemical properties of some bamboo wood of phyllostachys. Forest Research. 1995,8(1):54-61.

[8] Wang Yamei, Liu Junliang, Wang Ximing. Characteristics of Bamboo and Its Preservation Technology. China Wood Industry. 2004(2)：28-29.

[9] Li Yudong,Paul Morris,Tian Zhenkun, etc. Use category and specification for preservative-treated wood. LY/T 1636—2005[S]. Beijing, 2006.

[10] Yu Wenji, Jiang Zehui, Ye Kelin. Characteristics Research of Bamboo and Its Development. World Forestry Research. 2002, (2):50-55.

[11] Liu Lei, Liao Hongxia, Su Haitao. Natural Durability Test of 6 Bamboo Species. Guangdong Forestry Science and Technology. 2005, 21(2): 6-8.

[12] Liu Xiuying. Laboratory Decay Resist of fFive Bamboo Species. Forestry Industry. 1997, (1):13-15.

[13] Wang Yuxia, Zhang Guangchu and Li Xingwei. An evaluation on shoot quality of sympodial bamboo species and their hybrids[J]. Journal Of Bamboo Research. 2005, (4):39～44.

[14] Zheng Qingfang, Lian Qiaoxia, Zheng Rong etc. Function in gardening, classification and evaluation of ornamental bamboos [J]. Journal Of Fujian College Of Forestry. 2002, 22 (4):295～298.