ECOLOGICALLY SOUND FIRE RETARDANCY PROTOCOLS FOR ROUND NATURAL BAMBOO *DENDROCALAMUS STRICTUS*

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by

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Dedicated to my parents

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ABSTRACT

Sustainable development entails adopting a balanced approach which necessitates that while economic objectives are pursued, social and environmental well-being are not compromised but in fact strengthened. The ever increasing demand for timber by various industries poses an imminent and serious danger to the ecology. The need of the hour, therefore, is to find a fast growing and abundantly available alternative, with comparable attributes, that will address this ever burgeoning demand. Bamboo is one such material that carries a great deal of promise. However, while Bamboo is a material which has several excellent properties its behaviour when subjected to fire remains unknown, casting doubts over its efficacy despite its many advantages.

The research work undertaken was focused on assessing the fire retardant behavior of various chemical applicants. *Dendrocalamus Strictus* was treated with five different fire retardants and thereafter its performance against fire was observed and analysed. The fire behaviour of treated Bamboo was assessed using the LOI, LIFT, and UL-94 test methods, while its fire retardant capability was measured on the basis of its Ignition, Flame Spread, Charring Rate, and Char Depth characteristics.

Dendrocalamus Strictus is known to have an Ignition Critical Flux value of 15 kW/m^2, which is higher than that of Wood which is of 12 kW/m^2. Tests conducted on *Dendrocalamus Strictus* and Wood showed a flame spread rate of 0.59 and 0.73 mm/second respectively. This research observed that *Dendrocalamus Strictus* when treated with Melamine Phosphate and Ammonium Phosphate falls in the V0 categories in the UL-94 test, which is a safest category as per standard. Flame

penetration and burning rate were also calculated using the IS 5509 test standard. The morphology of the fractured surface of the treated Bamboo samples were also analyzed using SEM.

Based on these results, it was concluded that the P-N flame retardant is the best treatment option to enhance the fire retardant characteristics and consequently the level of fire safety of Bamboo based constructions.

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TABLE OF CONTENTS

CHAPTER 3

MATERIAL CHARACTERIZATION AND CHEMICAL TREATMENT

CHAPTER 4

TEST METHODS

CHAPTER 5

RESULTS AND DISCUSSION

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AP	Ammonium Phosphate
ASTM	American Society for Testing and Materials
CHF	Critical Heat Flux
CP	Calcium Phosphate
DNA	Deoxyribose Nucleic Acid
DS	*Dendrocalamus Strictus*
EPA	Environment Protection Agency
FGM	Functionally Graded Material
IFRC	Intumescent Flame Retardant Coating
INBAR	International Network for Bamboo and Rattan
IPIRTI	Indian Plywood Industries Research and Training Institute
IS	Indian Standards
LIFT	Lateral Ignition and Flame Spread
LOI	Limiting Oxygen Index
MP	Melamine Phosphate
P-N	Phosphorus and Nitrogen
SEM	Scanning Electron Microscopy
TGA	Thermo-Gravimetic Analysis
UL	Underwriter's Laboratories

LIST OF NOTATIONS, SYMBOLS & UNITS

%	Percentage
Δ	Heat
°C	Degree Celsius
Al	Aluminium
Ave.	Average
B_2O_3	boron trioxide
cm	Centimeter
CO	Carbon monoxide
CO_2	Carbon dioxide
g/m^2	Gram per meter square
gm	Gram
hv	Light
Ka	Acid dissociation constant
Kg	Kilogram
kW/m^2	Kilo-watt per meter square
mm	Millimeter
mm/min	Millimeter per minute
MPa	Mega Pascal
N_2	Nitrogen
O_2	Oxygen
pKa	$- \log_{10} K_a$
S.D.	Standard Deviation

"The Bamboo is literally the stuff of life. He builds his house of Bamboo; he fertilises his fields with its ashes; of its stem he makes vessels in which to carry water; with two bits of Bamboo he can produce fire; its young and succulent shoots provide a dainty dinner dish; and he weaves his sleeping mat of fine slips thereof. The instruments with which his women weave their cotton are of Bamboo. He makes drinking cups of it, and his head at night rests on a Bamboo pillow; his forts are built of it; he catches fish, makes baskets and stools, and thatches his house with the help of the Bamboo. He smokes from a pipe of Bamboo; and from Bamboo ashes he obtains potash. Finally, his funeral pyre is lighted with Bamboo. The hillmen would die without the Bamboo, and the thing he finds hardest of credence is, that in other countries the Bamboo does not grow."

. . . . . Lewin, 1869