

Wood in Building Construction

Vol. 3, Issue 3, October - December 2022

ICFRE-INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY, BENGALURU

Indian Council of Forestry Research and Education

(An Autonomous Body Under Ministry of Environment, Forest & Climate Change)



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Shakti Singh Chauhan

Head, WPP Division, ICFRE - Institute of Wood Science & Technology

Ritesh Kumar D. Ram

Scientist, WPP Division, ICFRE - Institute of Wood Science & Technology

Anil Kumar Sethy

Scientist, WPP Division, ICFRE - Institute of Wood Science & Technology

S. K. Sharma

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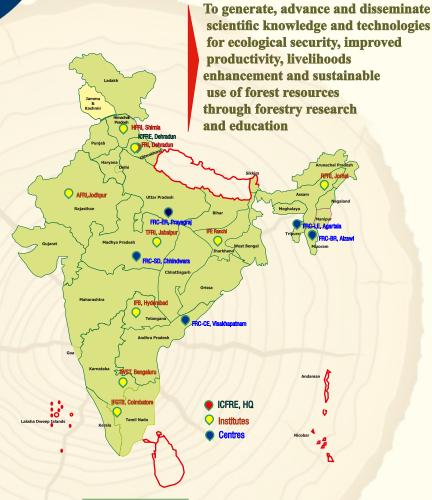


Varieties/ Clones developed

- Developed improved germplasm of many forest tree species.
- Released 47 high performing and disease resistant clones of Eucalyptus, Casuarina, Shisham, Melia and Sarpagandha with a envisaged production gain of more than 20%. The developed germplasm are being made available to the State Forest Departments and farmers for use in plantations.



High performing and disease resistant clone of *Melia* sp.



CYCUS v. 1.0

Casuarina Yield Calculator Utility Software (CYCUS v1.0) software has been developed to facilitate the farmer and other user agencies in yield estimation which requires only observations on girth of 100 sample trees per acre of plantation.

Wood Welding

Wood welding is new to our country. In this technique wood joints can be made without using nails and adhesives making them more natural and chemical free. A wood welding machine has been designed and fabricated at Forest Research Institute, Dehradun. Success has been achieved in spin welding of wood pieces of few species.



Wood Welding Machine



Indian Council of Forestry Research and Education

New Initiatives

Transparent wood- a flexible and biodegradable transparent wood has been fabricated using poplar wood veneer and water soluble polymer- polyvinyl alcohol. The transparent wood exhibited high optical transmittance, high haze and light diffusing property.



Natural wood (Left most), Lignin modified wood (middle) and Transparent wood (right most) placed on a paper with letters "IWST"

Heat storage based modified Solar Kiln

Solar heat storage system based solar kiln has been developed by Forest Research Institute, Dehradun for timber drying. The solar heat is trapped using suitable phase change material (PCM). The New solar kiln is able to trap 39 % more heat in winters as compared to traditional green-house based traditional FRI solar kiln developed during 1970.



Head based storage Solar Kiln

Xylarium

- Collection of authentic wood samples both from India and other countries, depicting wood biodiversity of the country like lightest, heaviest, sweet-smelling, foul smelling, smoothest, streaked, variegated wood and wood of different coloures, etc. The collection of wood cross sectional discs depicting variation in sapwood and heartwood colour is a unique feature of the xylarium.
- Wood identification services.



Xylarium- Collection of Authentic wood samples

Tree hollowness detection technique based on ultrasonic waves

Forest Research Institute, Dehradun has developed ultrasonic techniques (Non-destructive testing) to detect the location and magnitude of the hollowness of the standing tree. This will help to remove the potential human hazards by way of falling down of such trees during a high wind regime in Urban Forestry.



Measurement of hollowness in a tree using ultrasonic detector

Agroforestry models

Various agroforestry models (Poplar, Eucalyptus, Melia, Casuarina and Babool) have been developed to improve green cover, enhance farmers income and to mitigate climate change.



Poplar based agroforestry model with wheat

Innovative Bamboo Bottles

Techniques for making bamboo bottles by using Bamboo Treatment Technologies of ICFRE. Most suitable bamboo species for making bottles are Shil Barak (*Bambusa salarkhanii*) & Barak (*Bambusa balcooa*). One full bamboo is sufficient for making 21 full size bottles and 12 small bottles.



Bamboo bottles

For further details please contact :

Assistant Director General, Media & Extension Division, Indian Council of Forestry Research and Education, Dehradun - 248 006 Phone:- +91-135-222 4814, +91-135- 2755221,



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Wood is one of the oldest building materials known to mankind and over centuries, it has been used extensively for building and construction purposes. With the industrial revolution, human demands shifted towards steel and cement for construction works, and the dwindling supply of naturally grown, large-girth durable timbers from forests further contributed to the rapid shift from wood. However, manmade construction materials are highly energy intensive and non-renewable in nature and their incessant use has resulted in major environmental concerns. Given the increasing challenges posed by climate change the construction sector globally has started looking towards environmental friendly alternatives, especially wood, which is one of the most versatile and renewable construction materials, possessing a unique ability to sequester carbon and lock it away for long periods.

In many countries, wood is the main structural material in building construction, and the concept of multi-storey wooden buildings is now a reality. The introduction of mass timber from plantation grown wood such as Cross Laminated Timber (CLT), Glue Laminated Timber (GLT), etc. has changed the way wood is used in high rise buildings. As a renewable and sustainable building material, mass timber offers numerous benefits over traditional building materials. It has a lower carbon footprint and a faster construction time-frame, and can create beautiful and inviting spaces that promote well-being and health. In the Indian context, wood use is mostly confined to the non-load bearing applications like doors and windows and does not aim to replace the load bearing and energy intensive materials such as steel and concrete. As a result, the potential of wood towards emission reduction in construction activity, has not been tapped to the extent possible.

Wood required for the construction sector needs to be sourced from the trees outside forest, and from plantations. Engineered woods such as plywood, particle board, medium density fibreboard, oriented strand board, etc., are mainly produced from Trees outside Forests (ToFs), and have already been well integrated into building construction, particularly in non-structural elements. However, the concept of mass timber construction in India is still in the infancy stage. Mass timber construction has the potential to offer significant benefits and innovative solutions, in order to meet the growing demand for sustainable housing and infrastructure. Research and development initiatives undertaken by the Institute of Wood

Science and Technology (IWST), Bengaluru and other institutes that explore the potential of using wood from ToF species for manufacturing CLT, GLT and other mass timber products, would provide the necessary impetus to timber-based construction.

I hope that this issue of "Wood is Good" magazine will not only benefit the wood based industries, construction industries, research institutes and academicians engaged in promoting Mass Timber utilization but will also bring awareness to other stakeholders. I congratulate the IWST Bengaluru for their sincere efforts in enhancing the utilisation of Wood.

(Leena Nandan)

Dated: April 3, 2023.













अरुण सिंह रावत, भा.व.से. Arun Singh Rawat, IFS कुलाधिपति , व.अ.सं. विश्वविद्यालय Chancellor, FRI University महानिदेशक भारतीय वानिकी अनुसंघान एवं शिक्षा परिषद् न्यू फॉरेस्ट, देहरादून-248006 (आई.एस.ओ. 9001:2008 प्रमाणित सस्या)

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Preface - Wood is Good

Wood is a renewable resource that sequesters carbon, making it a more environmentally friendly alternative to non-renewable materials. However, due to increased demand of wood and consequently increased pressure on natural forest has resulted in shift from wood to other materials like steel, concrete, aluminium, plastic, glass, etc. Of late, it is realized that these alternative materials are highly energy intensive, non-renewable and contributes significantly to CO₂ emission. Therefore, there is a paradigm shift towards sustainable and renewable building materials and wood is finding its glory in building construction. With the development in mass timber materials like Cross Laminated Timber (CLT), Glue laminated Timber (GLT), etc. from plantation grown timbers, the concept of wood usage in building construction has gone through a complete transformation. Mass timber buildings materials have been shown to have lower embodied carbon than comparable concrete and steel buildings. The importance of mass timber construction lies in its potential to reduce the carbon footprint of the construction industry. Mass timber construction also offers design flexibility, allowing for unique and aesthetically pleasing buildings.

The mass timber has already gained popularity in the western world and many multi-storey building have come-up using mass timbers. The trend is going to further accelerate with increased environmental consciousness. The introduction of such materials also brings in several challenges in terms of suitable building codes, production of mass timber with desired mechanical performance, fire safety, biodegradation etc. Extensive amount of research is being conducted all over the globe in the field of mass timber and their application. The concept of mass timber based wooden building is creating excitement among builders, architects, civil engineers and other stake holders associated with wooden buildings. Therefore it is very pertinent to bring awareness about the development in the field to all the stakeholders and promote the concept considering the ecological and economic advantages. This special issue of "Wood is Good" magazine of IWST Bengaluru focuses on the importance of mass timber in India. Since, mass timber construction has emerged as a promising and innovative solution to the challenges being faced by the construction industry, and we are excited to explore its potential in this issue:

In this issue, we have assembled a range of articles and features that explore the importance of wood as a construction material. We hear from leading researchers, architects and builders who are at the forefront of promoting mass timber in their current or future projects.

I would like to thank contributors and editorial team for their hard work in putting together this issue. I hope that it will inspire readers to think critically about the importance of mass timber construction in India and around the world and to explore new ways of creating sustainable, beautiful, and functional buildings for all.

(Arun Singh Rawat)

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MANAGING COMMITTEE

Shri, NAVNIT R. GAJJAR

President

Mob: +91 98252 25103

E-mail: sunnyyenterprise1717@gmail.com

Shri, DHARMESH C. JOSHI

Hon. Secretory

Mob: +91 99137 77766

E-mail: dharmeshjoshi1@gmail.com

Shri. BHARATH H. PATEL

Hon. Treasurer

Mob: +91 98250 20825

E-mail: ravikiran825@gmail.com

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Mob: +91 98252 25515

E-mail: hemachandrayadav@gmail.com

Shri. SANJEEV GUPTHA

Jt. Secretory

Mob: +91 99252 25067

E-mail: sanjeevguptha.timber@gmail.com

Shri. PRAVEEN BANSAL

Jt. Treasurer

Mob: +91 99099 48025

E-mail: gdm8025@gmail.com

Timber Bhavan: Plot No.-47, Sector-8, Gandhidham - Kutch - Gujarat 370 201

Phone: 02836-230676, 232613

Telefax: 02836-222337, E-mail: kata.gdm@gmail.com

Web: www.kandlatimber.org

IWST ACTIVITIES DURING OCTOBER – DECEMBER, 2022

Gandhi Jayanthi



The 153rd Gandhi Jayanthi was celebrated on 2nd October 2022. Sri. Mahesh, Assistant Professor of St. Joseph's University, Bangalore delivered a lecture on "Remembering Gandhi and his relevance to environmental sustainability". This was followed by Swatchata Abhiyan at IWST campus. Dr. M. P. Singh, IFS, Director, officers, scientists and staff enthusiastically participated in the above events.

Rashtriya Ekta Diwas

On the occasion of birth anniversary of Iron man of India, Sri. Sardar Vallabhbhai Patel, Rashtriya Ekta Diwas / National Unity Day was observed on 31st October 2022. Dr. M. P. Singh, IFS, Director IWST administered the oath of National Unity to all officers, scientists, staff and students of the institute to make India united and prosperous.



Vigilance Awareness Week



Vigilance Awareness Week was observed by IWST, Bangalore from 31st October to 6th November 2022. Dr. M. P. Singh, Director led the staff and students in taking Integrity Pledge. During the week, poster designing & elocution competitions on the theme "Corruption free India for a developed nation" were organized for the staff and students. The week long celebration concluded with address by Dr. M. P. Singh, Director and prizes were distributed to the winners of Competitions.

Institute of Wood Science and Technology (IWST), Bangalore organized one day workshop on "Integration of wood and wood based products in Green Building"

through hybrid mode on 11th November 2022.

In his inaugural address, Dr. M. P. Singh, IFS, Director IWST told that Central Public Works

One day workshop on "Integration of wood and wood based products in Green Building"

Department (CPWD) can be a pioneer in engineering construction with wood and wood based products. Dr. Singh stressed that wood and wood based products can be integrated as a material in green buildings. He also encouraged Sri. H. Nagaraj, CEO, Velanki information system limited, Bengaluru to plan a first of its kind 20 storied green building in Bengaluru.

Sri. Sanjay Pant, DDG (Bureau of Indian Standards), New Delhi briefed that it is very traditional and established practice to use timbers in building constructions all over the world except some of the desert countries, due to lack of timber availability in that geographical area. He provided information on standardization of timber that started in 1947 with the establishment of Indian Standard Institution. He also told that there are 136 Indian standards on timber and timber stores including bamboo and cane products. He informed about various kinds of Indian standards related to timber and assured that he is always ready with IS to support mass timber construction.

Sri. Om Prakash Tripathi, ADG, CPWD, Bangalore Region opined that, in order to construct infrastructure in a way that will avoid all kinds of concrete elements, there is huge requirement of wood for our country. Those who own wood or those who are supposed to conserve the tree/wood, they are also coming forward with the alternative solutions in what manner timber can be used.

Sri. G. Narayanaswamy, ADG, NACIN, Bangalore told that we need to tell the people about the use of wood, as it will help reduce carbon-di-oxide in the atmosphere as well as it provides good returns.

Sri. B.K. Singh, ADG Forest, MoEF&CC, Govt. of India, New Delhi addressed the event and said that the timber is the solution for different problems of carbon sequestration and climate change mitigation. He referred to a study, that around 38% of carbon emission is from the construction/constructed building and structures and that is why decarbonization is the big challenge with increasing population. He suggested

that use of timber in building construction is only option including window and frame to replace the cement and other concrete materials.

> Ar. Bhavana Sharma, Artius Interior Products Gurgoan,

Presentation topic: 'Rethink Wood'

Ar. Bhavana Sharma shared her success

story of the development of Artius, a wood based company. She also shared her experience on how use of wood is successful in making buildings in various countries including Japan with integrated factors like fire, earthquake, termites attack and maintenance. She again emphasized that use of wood in construction delivered zero wastage, zero dust as an intermediate product and a good alternative materials to replace concrete materials with the increasing population at world level which will be working in climate change mitigation.

Ar. Neelam Manjunath, CEO and Founder, CGBMT School of Simple Living, Bangalore,

Presentation topic: 'Let's build with Bamboo'

In her presentation, Ar. Neelam Manjunath gave several examples of multistory buildings made up of bamboo and described about various uses of bamboo at international level along with development of prototypes.

Mr. Kiriti Sahoo, Area Convener, Sustainable buildings (SRC), the energy and research institute, TERI, Bangalore.

Presentation topic: 'Wood- A case study in a green building'

Mr. Kiriti Sahoo talked about the case study in a green building. In his presentation he emphasized that we have to optimize the appropriate wood materials to reduce the wastage for the construction. In his talk, he told that it has become necessary to think over how can we preserve the uses of wood especially wood composites in spite of, solid wood in the construction. He suggested to use more wood by planting trees in urban areas also, as trees act as cooler, greener, and cleaner and reduce the energy demand in the area.

Sri. H. Nagraj, CEO, Velankani Information System Limited, Bangalore,

Presentation topic: 'Timber based construction towards net zero'

In his presentation Sri. H. Nagraj told that we have to

domestically make timber available with manufacturing facilities. CLT, GLT is to be done for using this in construction. Enthusiastically, he told that we need to work on new policies, new guidelines and new frameworks so that government become assured towards timber based construction. He told that, in future, we can have timber based airport and government building in the country.

Mr. George Leuzinger (Architect, ETH Zurich), Timber Structures, Bangalore

Presentation topic: 'Low tech processing of local plantation species towards quality construction timber'

Mr. George Leuzinger's talk was focused on the importance of GLT in construction which is more valuable than solid wood. He told that he is working on conversion of local plantation timber for constructions purposes. He suggested to put up wood engineering towards university, schools, and training campus construction.

Er. M.M. Dalbehera, Senior Scientist, CSIR-CBRI, Roorkee

Presentation title: 'Structural performance of bamboo as mainstream green building material'

In his presentation Er.M.M. Dalbehera discussed about the lack of books that show design of bamboo as a building material and covered overview on bamboo as building materials. He described about the facilities for testing of wood and wood based products. He briefly discussed about different species of bamboo used for structural applications and bamboo as a building material and faces the challenge between demand and supply.

Mr. Prakash Suthar, Windsor Housing USA Inc.

Presentation title: 'Mass timber for construction of high rise buildings'

In his presentation, Mr. Prakash Suthar covered the advantage of mass timber components, meso-elasticity of wood fibres. Three areas were covered by him for



mass timber construction of high rise buildings i.e. design, values and innovations. To construct multi storey buildings in India three things are important, they are mass timber components, design values and standards, which are allowed to do in building coding.

Dr. Jimmy Thomas, Assistant Director Technical Services, Canadian Wood.

Presentation title: 'Sustainable futuristic buildings with mass timber'

In his talk Dr. Jimmy Thomas told that 13th and 16th century construction technology and materials were different and emphasized how concrete materials have negatively affected the environment. He covered both advantage and limitations of wood in constructions. He also briefed about engineered wood, Canadian Wood and told that wood is a gift of nature to humanity, as it is renewable, recyclable, environment friendly and have excellent strength to weight ratio.

Ar. Sandip Mukherji, Quercus Space, Banglore.

Presentation title: 'Thinking different for the love of our planet'

In his presentation, Ar. Sandip Mukherji told that to make furniture, the basic understanding of wood is important. Timber is used to make constructions. He briefed that we have to feel the materials if we want to use them and a lot of challenges are there while using wood for construction in large scale, as TATA, Reliance and other companies have already penetrated the market.

Mr. Ritesh Kumar, Scientist-F, WP Division, IWST, Banglore

Presentation title: Mass timber and multi-storey building construction.

In his presentation Mr. Ritesh Kumar told that steel and concrete require a lot of energy to produce it than timber and it is sustainable material which locks the carbon from the atmosphere. He told that this institute is answerable about the proper seasoning, preservation, finishing of wood.



Short Term Training on Wood Seasoning and Preservation

IWST, Bangalore organized a Short Term Training on "Wood Seasoning and Preservation" from 15th to 18th November 2022 at IWST through physical mode. The technical session covered by subject experts working on wood science and technology included topics like wood structure with relevance to seasoning and preservation, properties and utilization of wood, new developments in wood drying techniques, basics of wood seasoning, seasoning kilns, kiln schedules. seasoning defects, wood deteriorating insects and their management, fungal degradation of wood, wood preservation, preservative



treatment methods. The participants were introduced to wood modification aspects namely thermal modification of wood and surface treatment of wood in terms of coatings and colour. Preservative treatment methods using Bucherie/Sap displacement/Pressure method was demonstrated during the training. Visits to Seasoning and Preservation Plant at Karnataka State Forest Industries Corporation, Bangalore; National Institute of Design, Bangalore; Wood workshop (seasoning kilns), Xylarium and plywood plant at both campus of IWST were also part of the program.



Kannada Rajyotsava

IWST, Bangalore celebrated State Formation Day-Kannada Rajyotsava on 1st Nov 2022 with great enthusiasm. Dr.M.P. Singh, Director wished all the employees on the occasion and the program commenced with hoisting of Karnataka flag by Director. As part of the event, Director addressed the gathering followed by felicitation to retired employees and distribution of prizes to winners of various competition. The program ended with cultural extravaganza by staff & students of the institute.

Krishi Mela 2022

IWST, Bangalore participated in Krishi Mela 2022 organized by University of Agricultural Sciences at GKVK Campus, Bangalore from 3 - 6 November 2022 in the form of a display stall. The visitors especially farmers and general public showed keen interest in cultivation of sandalwood in their farms. Queries related to documentation procedures, financial subsidies, protection, and other management aspects were also clarified by our scientific staff. They were also educated on bamboo cultivation, management and harvesting techniques. Interested farmers were also encouraged to attend training programs conducted on sandalwood and bamboo at the institute.



Azadi Ka Amrit Mahotsav (India@75)

Webinar on Electric Resistance Tomograph (ERT): A Novel Technology in Estimation of Heartwood in Standing Trees

As part of the celebration of Azadi Ka Amrut Mahotsav, the Institute conducted a webinar on Electric Resistance Tomograph (Ert): A Novel Technology in Estimation of Heartwood in Standing Trees on 18th November 2022. About 39 participants benefitted from the webinar. In his presentation Dr. Divakara Scientist – F, IWST, Bengaluru explained about ERT as an advanced non-destructive tool customized tree specific novel German-technology. He explained about ERT as a technology in understanding the inner structure by giving the greater resolution with accurate precision in estimating the heartwood, sapwood and decay in standing trees by taking the example of high value trees like sandalwood (Santalum album) and red Sander (Pterocarpus santalinus). During discussion, participants appreciated the program and showed interested to

know more about the application of ERT in timber, finished products and logs.





Specialized module on Wood Technology

A short term training module was designed as per the requirements of the trainees and two days specialized module on wood Technology was imparted to about 55 State Forest Service Officer Trainees of CASFOS, Coimbatore during 19-20 Dec 2022. The training highlighted on physical and mechanical properties of timbers; defects and their effects on wood utilization, what is commonly known as timber grading; wood identification; bio-deterioration of wood and its



control; preservative treatment for protection of wood; wood seasoning principles and practices; wood and bamboo composites, saw milling and saw doctoring. Advances in wood technology like wood plastic composites and wood modification were also introduced to the trainees. A demonstration on wood seasoning, preservation and WPC techniques was also part of the course. Visit to laboratories, workshops and Advance Woodworking Training Centre was arranged for the trainees.

Sensitization program on Forestry and Wood Science

Sensitization program for officials of Regional Training Center of Indian Audit and Accounts Dept. Bangalore was organized by IWST, Bangalore on 16th Dec 2022. About 25 officers and officials from Indian Audit and Accounts Department participated in the training program. They were sensitized about various global environmental challenges like global warming, biodiversity loss, climate change and its impact. Further officers were appraised about role of forest and use of wood in climate mitigation. They were also



appraised about the research activities of the Institute during their visit to various laboratories and other facilities.

Azadi Ka Amrit Mahotsav (India@75)

Webinar on Agriwood Standards for Certification of Wood in India

As part of this celebration of Azadi Ka Amrut Mahotsav, the Institute conducted a webinar on "Agriwood Standards for Certification of Wood in India" on 26th December 2022. The webinar was attended by wood industry representatives, forest department officials, academicians, stakeholders, scientists and staff of IWST. About 45 participants attended the webinar through hybrid mode. Dr. M.P. Singh, IFS, Director, IWST in his opening remarks gave the background information about agriwood standards developed by IWST and scope for its implementation. Shri.B.K. Singh, IFS., Additional Director General, MoEF & CC, and Chief Guest of the program in his inaugural speech, highlighted the need for improving farmers income by promoting agro-forestry in the country. He stressed upon developing Wood Certification System that is simple, easy



to understand and cost effective for implementation across the country.

Dr. H.R. Prabuddha, IFS, Dy. Conservator of Forests made a presentation on proposed Agriwood Standard developed by IWST for Certification of wood produced on farmlands. In his presentation, he emphasized on developing protocol for Certificate of Origin (CoO) and Chain of Custody (CoC) of wood. Shri. Tridibesh Bandyopadhyay, Co-Founder, M/s.Inqube Innoventures made a detailed presentation on web application developed by Inqube Innoventures to ensure end to end traceability of wood and wood products that can be used to improve agriwood standards developed by IWST.

Dr. C.N. Pandey, Technical Advisor, FIPPI appreciated the efforts made by IWST and Inqube Innoventures and



requested IWST to go for piloting of web application developed by Inqube Innoventures in consultation with FIPPI. Shri. Naval Kedia, President, Federation of All India Timber Merchants, Saw Millers and Allied Industries and Shri. Jikesh Thakkar, Executive Director, AIPM also complimented the efforts made by IWST and expressed their willingness to take it forward in consultation with their respective Associations. Dr. V.K. Bahuguna, Former Director General, ICFRE also appreciated the efforts of IWST and urged to be taken forward for the benefit of farmers and wood based industries in the country.

North East Expo

IWST, Bangalore and its Field Station, Kolkata participated in North East Expo at Guwahati during 16-18 Dec 2022 in the form of a display stall. The visitors especially students, farmers and general public showed keen interest to know about the research activities of the Institute. They were explained about cultivation of various types of bamboos, their management and harvesting techniques. Different wood and panel products developed by the Institute were kept on display and visitors showed lot of interest and enthusiasm to know about those products



International Cultural Jamboree 2022 – Science Mela

IWST, Bangalore participated in International Cultural Jamboree 2022 – Science Mela hosted by Alva's Education Foundation, Moodubidire, Dakshina Kannada District, Karnataka during 21-26.Dec 2022. Students of Scouts and Guides from across the country were exposed to basics and application of physics, chemistry, botany, zoology, astronomy, geography, geology, forestry, agriculture. The mela also covered various forms of Indian culture like folk, dance and music, craft, gardening, nature walk, forestry trail etc. which the children not only enjoyed but also provided scope for knowledge gain and enrichment.





VVK-KVK trainings

Under Vana Vigyan Kendra trainings funded by CAMPA, IWST, Bengaluru in collaboration with Krishi Vigyana Kendra (KVK) conducted training programs on "Sandalwood based agroforestry models" at Kalaburgi and Bidar. Farmers from surrounding areas also participated in the training programs and learned about different agroforestry models.







Ms. Priya Bisht, PhD Scholar of IWST Bengaluru has won the award for Best Popular Science Stories in Augmenting Writing Skills for Articulating Research (AWSAR) Competition 2022 for her research story on the title "Can we see through wood for a sustainable future?". The national competition had more than 4000 entries and Winning prize included cash prize of Rs.10000/-and a certificate.



सत्यमेव जयते

भारत सरकार GOVERNMENT OF INDIA विज्ञान एवं प्रौद्योगिकी विभाग DEPARTMENT OF SCIENCE AND TECHNOLOGY अवसर

(शोध की अभिव्यक्ति के लिए लेखन कौशल) AWSAR

(Augmenting Writing Skills for Articulating Research)

प्रिया बिष्ट

को पीएचडी श्रेणी के अंतर्गत चुने गये 100 लोकप्रिय विज्ञान लेखों में स्थान प्राप्त करने के लिए प्रशंसा प्रमाण पत्र, राष्ट्रीय विज्ञान दिवस, 28 फरवरी, 2023, पर प्रदान किया जाता है।

This Certificate of Appreciation is presented to

Priya Bisht

for securing a position among the top 100 popular science stories under PhD Category on the National Science Day, 28th February, 2023.



डॉ. एस. चंद्रशेखर सचिव, भारत सरकार विज्ञान और प्रौद्योगिकी विभाग

Dr S. Chandrasekhar Secretary to the Government of India, Department of Science & Technology





Wood in Building Construction – A Perspective

Shakti Singh Chauhan*, Anil Kumar Sethy and M.P. Singh

ICFRE - Institute of Wood Science and Technology, Bangaluru *Email: shakti@icfre.org

storey of human beings. Being amongst the most natural and vital materials, historically, wood was viewed as a wonderful gift of nature to humankind. It was the material capable to fulfil a large proportion of man's daily needs and deeds – housing, transportation, occupational tools, fuel, lighting, etc. Traditionally, it was a primary source for construction materials for houses, temples, bridges, boats, etc. all over the world. India was no exception. We find historical wooden structures in the form of old mansions/havelis, temples and other architectural structures throughout the country which are still in exceptionally good

condition (Fig.1). This reflects the abilities of our forefather in recognising the potential of wood as a construction material with complex designs and structures. In case of buildings constructed with other materials such as bricks, and concrete, wood was extensively used in the form of door and window frames, shutters, roofs, etc. In rural India, it was a traditional practice to use wooden logs and poles including palm wood as beams for roofing along with bamboo for thatched or tiled roofs.

India was bestowed with large number of timber species suitable as a construction material with good













Figure 1: Traditional use of wood in building construction as door, window, beam, column and wooden arter

strength properties and natural durability and they were available in abundance. The choice of species was varying from region to region based on the local availability. However, large-scale exploitation of wood started with the industrial revolution to build bridges, lay railway tracks and chug trains along; to pave way for rapid exploitation of mineral wealth and construct

The National Forest Policy was revised and reframed in 1988 with basic objective of conserving the forests with an emphasis on maximizing substitution of wood.

structures way beyond human needs. Simultaneously, other sources of energy, especially coal and liquid fuel from the bowels of earth started substituting wood fuel and modern materials like steel, aluminium, concrete and plastic began replacing wood in many traditional products. While wood is one of the most aesthetically pleasing materials and is relatively easy to work with, as a material in construction sector it started losing its sheen due to concerns regarding the over exploitation of forests for wood, limited availability traditional species from natural forests, certain undesirable properties like degradability, dimensional movements and capabilities to convert modern materials into uniform and consistent products at large scales. Interestingly, industrialization also led to other opportunities for wood use – for writing and packing.

The first Forest Policy was adopted by Government of India resolution of 19th October 1894. The prime objectives of this forest policy were to ensure maintenance of adequate forest cover for general wellbeing of the country, meeting needs of local people followed by maximum revenue collection. However, over harvesting of timber during the two world wars resulted in considerable degradation of forests. Postindependence, the country framed National Forest Policy (1952) for the management of state forests in the country and was formulated on the basis of six paramount needs of the country including the need for sustained supply of timber and other forest produce require for defence, communications and industry. "National Forest" constituted the basis of India's strength and wealth and their management on scientific and business lines was regarded essential for maintaining a supply of wood for industry and of large timbers for defence and other national purposes. With a

global call for conserving nature and natural resources, forest policies were inclined towards forest protection and forest were no longer considered as a source of raw material for wood based sectors including construction.

The National Forest Policy was revised and reframed in 1988 with basic objective of conserving the forests with an emphasis on maximizing substitution of wood. To relieve the pressure on forests for the demands of railway sleepers, construction industry (particularly in the public- sector), furniture and panelling, mine-pit props, paper and paper board etc. substitution of wood was emphasized. Development of substitutes to replace wood and wood products was recognized as the priority areas of research and development needing special attention. Forest-based industries were encouraged to raise the raw material needed for meeting their own requirements, preferably by establishment of a direct relationship between the factory and the individuals who can grow the raw material by supporting the individuals. Farmers, particularly small and marginal, were encouraged to grow wood species required for industries on marginal/degraded lands available with them. As a result, many plantations of pulpwood species like eucalypts gained momentum in the country.

As a consequence of these policy measures, alternative materials such as steel and plastics made inroads substituting wood and wood products in many areas. Stringent measures like ban on cutting live trees from forests and reducing dependency on wood furthered the demand for energy intensive materials in construction sector even for door frames and window Central Public Works Department (CPWD), frames. the principal agency of the Government of India responsible for creating assets and providing comprehensive services completely prohibited the use of wood in construction work in 1993 considering this as a sustainability approach. Though, CPWD banned the use of wood in building construction, the manual on Door and Window Details for Residential Buildings published by the agency in 2006 provided guidelines on standardization of designing and sizes of wooden and metal doors and windows. Further, as per the CPWD guidelines for sustainable habitat published in 2014, it is specified that "more than 70% of total material used in the building interiors should be low energy. Wood is not considered under this category while Bamboo, coir, etc are low energy". The guidelines also specify the classification of building materials as per the energy intensity and wood and wood products are categorized as "medium energy material with energy intensity of 1-5 GJ/t (Table 1).

Table 1: Energy intensity classification of materials used in building construction

Sl No.	Category of Material	Energy intensity (GJ/t)	Examples
I)	Very high energy	>50	Aluminium, stainless steel, plastic, copper, zinc.
ii)	High energy	5-50	Cement, steel, glass, bitumen, solvents, cardboard, paper and lead.iii)Medium energy1-5Lime, gypsum plaster board, burnt clay brick, burnt clay brick from improved vertical shaft kiln, soil cement block, aerated block, hollow concrete block, gypsum plaster, concrete block, timber, wood products, particle board, medium density fibreboard, cellulose insulation, in-situ concrete.
iv)	Low energy	<1	Sand aggregate, fly ash, cement stabilized earth block, straw bale, bamboo, stone.

(Source: CPWD Guidelines for sustainable habitat, 2014)

CPWD has also brought out comprehensive specifications for wood works in their Specification manual 2019. In the manual, timber is classified as Teak wood, Deodar wood, Non-coniferous timbers other than teak and Coniferous timber other than deodar. The list of species that can be used in building construction are also specified in the manual (Table 2).

Table 2: List of Timber Species to be used in construction work

Sl No.	Botanical name	Availability						
		Trade Name	Average unit wt (Kg/m³)	North Zone	East Zone	Central Zone	West Zone	South Zone
1	Tectona grandis	Teak	640	-	Y	X	X	X
2	Acacia catechu	Khair	1010	X`	X	X	Y	Y
3	Acacia arabica	Babul	785	X	Х	X	Y	Z
4	Adina cordifolia	Haldu	675	X	-	-	-	X
5	Cedrus deodara	Deodar	545	X	-	Y	Y	-
6	Mangifera indica	Mango	690	Χ	X	Y		X
7	Pinus roxburghii	Chir	575	X	-	-	1	-
8	Pinus excelas	Kail	515	X	-	-	-	-
9	Shorea robusta	Sal	881	Χ	X	X	-	-
10	Terminalia myriocarpa	Hollock	610	-	X	-	-	-
11	Lagerstroemia lanceolata	Benteak	675	1	-	-	Y	Х
12	Gmelina arborea	Gamari	515	Y	Y	Y	Z	Y
13	Terminalia	Baheda bellirica	801	Х	Х	X	Y	Х
14	Pterocarpus marsupium	Bijasal	800	-	Х	X	Y	Y

Note: The average unit wt. is at 12% moisture content.

X: Most Commonly Available

Y: Commonly Available

(Source: CPWD Specification Vol I, 2019)

Z: Less Commonly Available

The specification also elaborates on the moisture content for different components like beams, rafters & posts, doors and windows, flooring strips, furniture & cabinet making, etc. It also specifies the need for seasoning and preservation of timber. The other wood based panels and their specifications have also been categorically mentioned. The wood based composites like plywood, particle boards, fiber boards, prelaminated medium density fiber boards, etc are required to be as per the relevant Bureau of Indian Standards (BIS). The specification provides a complete guideline for door, window & ventilators frames, shutter, joints, fixtures, and fixing mechanisms.

Though the specifications of woodworks in building are provided, the use of timber in construction is very limited. Of late, with the growing environmental concerns on using energy intensive materials and climate change threats, the construction sector is looking for environmental friendly materials. It is reported that the construction industry is responsible for a large portion of the total greenhouse gas (GHG) equivalent emissions globally. In 2008 it corresponded to about one third of the GHG emissions (UNEP SBCI, 2009). Since the signing of the Paris Agreement in 2015, CO₂ emissions from the buildings and construction sector have peaked. In 2019, the construction and operation of buildings worldwide was responsible for 13.4 gigatons of energy related CO₂ emissions which is about 38% of the global total. To achieve the Paris Agreement, the global buildings and construction sector must almost completely decarbonize by 2050. Globally, there is a growing demand for more buildings and floor area, with the floor area of the global buildings sector projected to double by 2060, adding more than 230 billion square metres and much of this demand is expected to occur in Asia and Africa. Driven by these trends, global material use is expected to be more than double by 2060 with a third of this rise attributable to materials used in the buildings and construction sector. It hasn't taken too long to realize that wood is one of those materials suiting to the current requirements

sequestering carbon during its production and locking it for a long duration when used for products with long life. Wood is also less carbon intensive to manufacture, transport and process than steel and concrete. Therefore, increasing the use of timber in our buildings is expected to reduce the carbon footprints of construction sector.

Considering the environmental importance of wood as a material, only in

the year 2020, CPWD has removed the ban on use of timber in construction of buildings and habitat projects. Still there are many apprehensions on using wood in construction sector. One of the major issues is the availability of solid wood and particularly species traditionally used and specified in the guidelines. It is important to realize that natural forest cannot be looked up for the raw materials. The wood grown outside the forests (particularly agroforestry) has to meet the increasing demand for wood. Majority of wood-based composites panels (plywood, particle boards, etc.), which are being used by the construction sector, are already being produced from the material grown outside forest. In case of solid wood or timber, the plantation grown materials need to meet the specification requirements in terms of strength, stability and natural durability. The properties of fast grown plantation timbers are no match to the slow-grown and long rotation timber and therefore the use of such timbers for structural and semi-structural applications needs to be tackled in different ways.

A number of engineered wood products like laminated veneer lumber (LVL), glue-laminated timber (Glulam), cross-laminated timber (CLT) have been developed from plantation timbers for increasing the use of wood in building sector. These engineered products offer enhanced dimensional stability, strength and design versatility for project detailing. Product like LVL can easily be used for door/window frames. There are many bamboo based composite materials which may readily be used in the construction sector for partitioning, wall panelling, flooring, etc. global trend on using mass-timber like CLT and Glulam in constructing multi-storey building to minimize concrete and steel. The time is not very far that Indian building sector will also embark on wood-based construction including tall buildings as the concept is rapidly imbibing. Already, there is an increasing interest in building wooden houses using different construction methods and many modern wooden houses have come-up in the recent past (Fig 2).





Figure 2: Modern villas constructed using wood as the major element

A key challenge is the development of design codes/ specifications/guidelines to the material used for construction. Simply copying the familiar forms of codes used for conventional construction in steel and concrete may not be applicable to such buildings due to inherent differences in the material properties. Unlike steel or concrete, it is often the strength or stiffness of connections or joints that also govern the behaviour of timber structures. BIS has already developed specifications for the use of wood in construction sector. A list of major standards related to wood use in construction is given in table 3. In addition to these standards for various wood based composites like plywood, particle board, MDF, LVL, flush doors, block boards, bamboo mat boards, etc. are in place in terms of their manufacturing and required properties and are being used in building constructions.

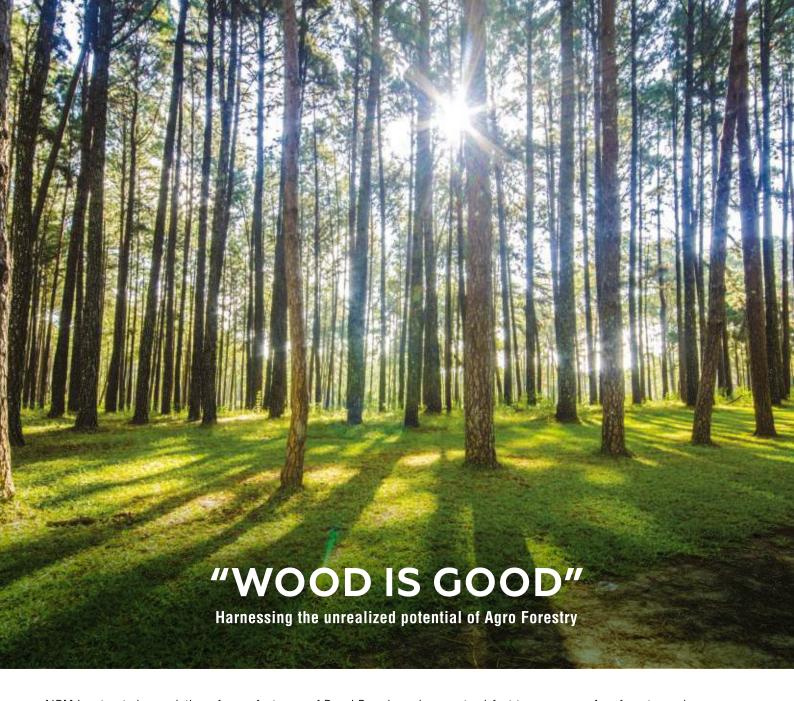
Table 3: List of BIS standards

Indian Standard	Specification for	Recommended species
IS 399:1963	Classification of commercial timbers and their zonal distribution	
IS 12896: 1990	Classification of Indian timbers for door and window shutters and frames	109 timbers species for shutters and 69 timber species for frames
IS 3629: 1986	Specification for structural timber in building	About 186 species in 3 different groups
IS 883: 1974	Design of structural timber in building - Code of practice	About 191 species in 3 different groups
IS 5390: 1984	Code of practice for construction of timber ceiling	27 timber species for ceilings

However, availability of the wood refereed in these standards has become very scarce and as stated earlier, short rotation plantation timbers will be the only major source of timber for such applications in future. Hence, development of engineered structural composites using such plantation timbers offers a sustainable solution and hence it is imperative to develop standards on CLT, Glulam etc. Simultaneously, building design codes also need to be developed for such engineered structural materials. Detailed information on design related issues like seismic and wind resistance, fire safety, durability, dimensional stability, acoustics, connector systems and assemblies need to be readily available prior to building construction. Lack of familiarities about the design requirements for timber structure among the local designers, architect, engineers and permitting authority need to be made aware about the potential of wood-based structures and development of design/structure protocols of these new materials in India.

References

Contact author at shakti@icfre.org



AIPM is a trusted association of manufacturers of Panel Board gearing up stead-fast to encourage Agroforestry and aggressively creating strategies to harness the unrealized potential of Agro-Forestry and form a sustainable product through Agroforestry.

The Member companies in association with Govt. bodies like IWST, IPIRTI & other influential entities are continuously investing efforts & augmenting innovative skills & efficient options on agroforestry for sourcing raw materials from Farmers leading to sustainable livelihood & creating symbiotic mutual beneficial relationship.

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Wood and Wood Products in Green Buildings: An Indian Perspective

Introduction

Real estate development uses about 40% of the energy and it is one of the prime contributors to global warming due to the emission of Green House Gas (GHG) caused by the energy used. Therefore there is an extreme need to develop green buildings. A green building uses less energy, water and natural resources. It generates less waste and provides a healthy living environment for the occupants.

Over the last two decades, there has been a dramatic growth in environmental awareness and concern about the worldwide implications of economic activities on climate and natural resources. Different materials are used in construction projects, including concrete, steel, and wood, and the selection of these materials has a big impact on the environment.

Table 1. Embodied energy of building materials

Material	Energy for production (MJ/Kg)	Weight per volume (Kg/m³)	Energy for production (MJ/m³)	Stress when in use (N/mm²)	Ratio energy per unit stress
Concrete	.82	4001	920	8	240
Steel	30	7800	234000	160	1500
Wood	1	600	600	7.5	80
Bamboo	0.5	600	300	10	30

Wood has exceptional physical properties—it is lightweight and has a very high strength-to-weight ratio, seismic resilience, insulation, and a more predictable behaviour compared to concrete and steel. Agro forestry is an affordable means of capturing carbon while climate change action focuses at some of the most expensive carbon-capture technologies. The construction and associated wood/pulp industries can sustainably fund these.

Despite the fact that the use of wood and timber for building purposes has decreased since the introduction of steel and concrete, numerous wood-based products, such as veneers, plywood, hard board, particle board, etc., have developed significantly for a variety of uses, including the construction of formwork and furniture as well as partitions and interior decoration.

Jagadish Vengala

Associate Professor, Department of Civil Engineering, PVP Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India.

Email: jdvengala@gmail.com

Embodied energy of building materials

Embodied energy concept can be used to evaluate sustainability of various construction materials by comparing the energy required to produce them. The table 1 gives the embodied energy values of various building materials.

Wood and Bamboo require very little energy to makethem into one of the sustainable materials with a low level of embodied energy. Even, the ratios of energy for production to the unit stresses are 80 and 30, or 20 to 50 times lower than the steel.

Green building rating systems in India

The two green building rating systems in India are LEED by IGBC and GRIHA by TERI. LEED is most popular among the ratings and the credits earned through LEED ratings can be traded in the carbon market.

Green buildings as structures ensure efficient use of natural resources like building materials, water, energy and other resources with minimal generation of non-degradable waste. Technologies like efficient cooling systems have sensors that can sense the heat generated from human body and automatically adjust the room temperature, saving energy. It applies to lighting systems too. The predominant green rating frameworks for buildings in India are Green Rating for Integrated

Habitat Assessment (GRIHA), Indian Green Building Council (IGBC), Leadership in Energy and Environmental Design (LEED), and BEE(Bureau of Energy Efficiency). Among the three, BEE is based on the energy usage in the building over its area expressed in kWh/sq.m./year. In this program, buildings are rated on a 1-5 scale, with 5-star labelled buildings being the most efficient.

Green Rating for Integrated Habitat Assessment (GRIHA): (GRIHA) is India's own rating system jointly developed by TERI and the Ministry of New and Renewable Energy, Government of India. It is a green building design evaluation system where buildings are rated in a three-tier process. The process initiates with the online submission of documents as per the prescribed criteria followed by on site visit and evaluation of the building by a team of professionals and experts from GRIHA Secretariat. GRIHA rating system consists of 34 criteria categorized under various sections such as site selection and site planning, Conservation and efficient utilization of resources, building operation and maintenance, and Innovation points.

Eight of these 34 criteria are mandatory, four are partly mandatory, while the rest are optional. Each criterion has a number of points assigned to it. (Table 2).

It means that a project intending to meet the criterion would qualify for the points. Different levels of certification (1-5 stars) are awarded based on the number of points earned. The minimum points required for certification is 50.

All buildings more than 2,500 sq. m, (except for industrial complexes), which are in the design stage, are eligible for certification under GRIHA. Buildings include: offices, retail spaces, institutional buildings, hotels, hospital buildings, healthcare facilities, residences, and multi-family high-rise buildings. GRIHA is a 100 point system consisting of some core points, which are mandatory, while the rest are optional. Different levels of certification (1-5 stars) are awarded based on the number of points earned. The minimum points required for certification is 50.

Points achieved	GRIHA Rating
50-60	*
61-70	$\star\star\star$
71-80	$\star\star\star$
81-90	***
91-100	****

Table 2. Criteria under GRIHA rating System

Criterion number	Criterion name	Points
1	Site selection	1
2	Preserve and protect landscape during construction/compensatory depository forestation.	5
•		
15	Utilization of fly-ash or equivalent industrial/agricultural waste as recommended by BIS in building structures	6
16	Reduce embodied energy of construction is reduced by adopting material efficient technologies and/or low-energy materials	4
17	Use low-energy materials in Interiors	4
18	Renewable energy utilization	5
•		
32	Energy audit and validation	-
33	Operation and maintenance	2
34	Innovation points (beyond 100)	-

Out of 34 criteria, 3. criterions (i.e 15,16,17) wood or other panel based materials can play a vital role.

SVAGRIHA: Small Versatile Affordable GRIHA was jointly developed by GRIHA Council and TERI. SVAGRIHA is a significantly simplified, faster, easier and more affordable rating system and will eventually function as a design-cum-rating tool. It was required that attention be paid to smaller buildings in India which although have small individual environmental footprints but their cumulative effect is far bigger.

SVAGRIHA has been designed as an extension of GRIHA and has been specifically developed for projects with built-up area less than 2,500 sq. mtr. SVAGRIHA can help in design and evaluation of individual residences, small offices, schools, motels, commercial buildings etc. The rating comprises only 14 criteria and the interface comprises of simplified calculators. (Table3). These calculators can be filled using information from construction drawings like areas; and quantities and specifications of materials.

The rating system has 14 criteria. The criteria are divided into 5 broad sub-groups, namely: energy, water and waste materials, landscape and others. It will be mandatory to attempt certain points under each sub-group. The total points that a project can achieve is 50. The rating will be done on a 1-5 star scale.

Points achieved	GRIHA Rating
25-30	*
31-35	$\star\star\star$
36-40	$\star\star\star$
41-45	$\star\star\star\star$
46-50	****

Table 3. Criteria under SVAGRIHA rating System

Criterion number	Criterion name	Points
1	Reduce exposed, hard paved surface on site and maintain native vegetation cover on site	6
2	Passive architectural design and systems	4
9	Rainwater harvesting	4
10	Generate resource from waste	2
11	Reduce embodied energy of building	4
12	Use of low-energy materials in interiors	4
13	Adoption of green lifestyle	4
14	Innovation	2
	Total	50

Out of 14 criteri, 3 criterion's (i.e10,11,12) wood or other wood based materials can play a vital role.

The GRIHA rating gave the following points in prominence as related with wood and other wood based products:

- Composite wood products such as hard-boards, block-boards, lumber-core plywood, veneered panels, particle boards, medium/low density fibreboards made from recycled wood scrap from sawmill dusts or furniture industry bonded with glue or resin under heat and pressure.
- Rapidly renewable materials/products, which are made from small diameter trees and fast growing low utilized species harvested within a 10 year cycle

- or shorter such as bamboo, rubber, eucalyptus, poplar, jute/cotton stalks. Among others, the products include engineered products, bamboo ply boards, rubber, jutestalk boards.
- Products which utilize industrial waste such as wood waste, agricultural waste and natural fibres like sisal, coir, and glass fibre in inorganic matrices like gypsum, cement, and other binders such as fibrous gypsum plaster boards.
- Salvaged timber and reused wood products such as antique furniture.

• 100% of composite wood products with no urea–formaldehyde resins.

Indian greenbuilding Council(IGBC) -LEED rating system

The leadership in energy and environmental design (LEED) is the rating system developed for certifying Green Buildings. LEED is developed by the U.S. Green Building Council (USGBC), the organization promoting sustainability through Green Buildings. The benchmarks for the LEED Green Building Rating System were developed in the year 2000. Confederation of Indian Industry (CII) formed the Indian Green Building Council (IGBC) in the year 2001. IGBC is a non-profit research institution having its offices at CII-Sohrabji Godrej Green Business Centre, which is itself a LEED certified Green building. IGBC has licensed the LEED Green Building Standard from the USGBC. IGBC facilitates Indian green structures to become one of the green buildings.

Table 4. Certification levels of LEED-INDIA rating

Rating	Points
LEED Certified	26-32
LEED Certified Silver Level	33-38
LEED Certified Gold level	39-51
LEED Certified Platinum level	52-69

Table 5. Criteria to be considered for LEED - INDIA rating

Sl.No.	Criteria	Points
	Prerequisites	8
1.	Sustainable Sites	13
2.	Water efficiency	6
3.	Energy and atmosphere	17
4.	Materials and Resources	13
5.	Indoor Environmental quality	15
6.	Innovations and Accredited Prof. Points	5
	Total	69

Material and Resources

Aboue 40% of the carbon dioxide that contributes to the warming of the planet comes from buildings. While some of it is a secondary effect of operational needs such as electricity, air-conditioners, and heating, many GHG's arise from resource extraction, manufacturing and production of the building materials themselves.

Of all the criteria covered by LEED, MATERIALS and RESOURCES has perhaps the broadest application and relevance. They are the ingredients, and choosing them wisely makes all the difference in terms of the overall impact of the building throughout its life. This is where 'Environmental footprint' or 'Life cycle assessment' comes into play. The materials are in the picture from the first round of planning to the final stages of demolition or renovation of a building or product.

Table 6. Credits under LEED India

Credit	Title	Points
Prereq 1	Storage & collection of recyclables	R
Credit 1	Construction waste management	3
Credit 2	Resource reuse	2
Credit 3	Recycled content	2
Credit 4	Local/Regional materials	2
Credit 5	Rapidly renewable material	1
Credit 6	Certified wood	1
	Total	13

In regard with wood and other wood based products, the following credits may be worth mentioning.

Credit: Resource reuse

<u>Intent</u>: Reuse building materials and products in order to reduce demand for virgin material and reduce waste, thereby reducing impacts associated with the extraction and processing of virgin resources.

Requirements:

Use salvaged or refurbished materials for 5-10% of building materials (by value).

Methods suggested like, reuse of partition panels, broken tiles, used carpets.

(Note: Movable furniture like chairs are not accounted for calculation)

Credit: Recycled content

<u>Intent:</u>Increase demand for building products that incorporated recycled content materials, therefore reducing impact resulting from extraction and processing of new virgin materials.

Requirements:

Use materials with recycled content such that the sum of post –consumer recycled content plus one half of the post-industrial constitutes at least 5% of the total value of the materials in the project.

The value of the recycled content portion of a material or furnishing shall be determined by dividing the weight of recycled content in the item by the total weight of all material in the item, then multiplying the resulting percentage by the total value of the item.

Table 7. Typical materials with high recycled contents

Materials	% Recycled contents
Fly ash blocks	30-40
Glass	10-15
Ceramic tiles	20-30
MDF wood	15
Steel	20-25
False roof	25-30

Credit local/regional materials

<u>Intent:</u> Increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the regional economy and reducing environmental impact resulting from transportation.

Requirements: Use a minimum of 20% (extra points for going up to 50%) of building materials and products that are manufactured regionally within a radius of 800 kms (manufacturing refers to the final assembly of components).

Credit: Rapidly renewable material

<u>Intent:</u> Reduce the use and depletion of finite raw and long cycle renewable materials by replacing them with rapidly renewable materials.

Requirements:

- Use rapidly renewable building materials and products (made from plants that are typically harvested within a ten-year cycle or shorter) for 5% of the total value of all building materials and products used in the project.
- Consider use of materials such as bamboo, wool, cotton insulation, agri-fiber, linoleum, wheat board, straw-board and cork.

Green Industry

A green building needs special materials and systems to adapt sustainability compared with a conventional building. In line with the growing trend of green building development, the industry of green materials and services is also developing India. IGBC-

LEED provides two credits for sourcing more than 50% of construction materials locally to promote these green materials and services industries. Local sourcing of construction materials is also to reduce the environmental impact of transportation or the embodied energy.

The commonly required green raw materials include fly ash cement and aerated blocks, recycled aluminium, steel, tiles and wood, low VOC paints, bamboo-based products, HFC-based high-efficiency chillers, green roofs etc.

The prime sources of revenue generation for green buildings are from the non-sustainability discount which gives the green buildings a higher rental value than conventional buildings in the vicinity and the carbon credits earned due to the reduced GHG emissions.

The challenges faced for development of green buildings in India are the extra investment in an unstable real estate market scenario and difficulty in sourcing green building materials and sustainability consultants. The government has launched the Energy Conservation Building Code (ECBC) under the National Building Codes and Standards to promote green buildings in India. The CII – IGBC and other professionals are working to mitigate the challenges faced by green buildings to enable developers to develop and operate green buildings with ease.

Role of wood products in green building projects

Wood products from responsible sources are a good choice for most green building projects – both new construction and renovations. Wood grows naturally using energy from the sun, is renewable, sustainable and recyclable. It is an effective insulator and uses far less energy to produce than concrete or steel.

Wood can also mitigate climate change because wood products continue to store carbon absorbed by the tree during its growing cycle, and because substituting wood for fossil fuel-intensive materials such as steel and concrete result in 'avoided' greenhouse gas emissions. Wood's natural beauty and warmth have been shown to generate improved productivity and performance in schools, offices and better patient outcomes in hospitals. There are a number of ways that the substitution of wood products has an impact on greenhouse gas balances, including:

- Less fossil fuel consumption in manufacturing.
- Reducing industrial process carbon emissions from

cement manufacturing by using wood products instead of cement-based products.

- Carbon storage in wood products and in the forest; and
- When wood bio-fuels replace fossil fuels, fossil fuel emissions are reduced.

In most cases, the rating systems offer credits/point for the use of wood in the following areas: certified wood; recycled/reused/salvaged materials; and local sourcing of materials. In some cases, building techniques and skills (such as advanced framing) and waste minimization are recognized, and most demand that all wood adhesives, resins, engineered and composite products contain no added urea formaldehyde and have strict limits on VOC (volatile organic compound) content.

Wood and other wood based products in buildlings – A CPWD perspective

In their manual, CPWD mentions that "CPWD has been a pioneer in construction industry with regards to sustainable approach as being the first to prohibit use of wood in construction work and playing a lead role in use of fly ash. Under the category on "Reduction in Overall Embodied Energy of Building Materials" Wood is not considered under this category while Bamboo, coir etc are low energy materials.

Under the following sections wood and other wood based products were mentioned in their manual.

Materials:

Materials and recommended sustainable alternatives:

Following are the alternatives to conventional material that may be surface materials – wooden flooring

thermal insulation materials – saw dust and wood shaving

Reusing and recycling potential of different materials

Timber:

The waste timber is not only produced from the demolition of the building, but also from construction of wooden building wherein lot of timber waste is generated. Eachsource has its own system of recycling and reuse of recovered timber from the demolition of a building or the construction of a building. Whenever a building is decided to be dismantled, timber products like doors and windows are the itemswhich are removed as first step and that too in original form. Timber products have aquality of a long service life

which is much longer than the life of the building itself. Hence, in general such products unless eaten by the termites or damaged due to fire do not lose the engineering properties for a long time and can be used multiple times and thus an environmentally friendly product.

The waste timber which has not been recovered in its original form or non-usable in same shape and size can be recycled into new particleboard, medium density fibre-boards or used to make renewable energy. Timber used for recycling has to be free from any other demolition products like concrete, mortar, aggregates, sand, bricks, plastic, metals, tiles etc. Wood chips are produced from good quality wooden waste such as large size lumbers. Some of the particleboard producing companies and the pulp and paper producing companies are still using the recycled chip for their products.

In place of **plastics** (door frames, DSR Item no 9.118): Other options where use of plastics may be considered for appropriate applications, may be:

- 1) Rice husk plastic wood.
- 2) Natural fibre composite panels and door shutters.

Conclusion

Wood products from responsible sources are a good choice for most green building projects – both new constructions and renovations. In most cases, the rating systems offer credits/point for the use of wood in the following areas: Certified wood; recycled /reused /salvaged materials; and local sourcing of materials. In some cases, building techniques and skills (such as advanced framing) and waste minimization are recognized, and most demand that all wood adhesives, resins, engineered and composite products contain no added urea formaldehyde and have strict limits on VOC (volatile organic compound) content.

CPWD prohibited use of wood in construction work since 1993, the work carried out by research organizations like IWST and also demand from wood based industries lifted the ban in July 2020. This will increase demand for wood-based industries, which will boost local economies—particularly in rural areas—create lots of jobs, encourage farmers and others to plant trees in degraded areas, and ultimately increase the nation's production of a wide range of ecosystem services.

References

 $Contact \, authors \, at \, jdvengala@gmail.com$

Rethinking of Building Materials in Green Building Construction

Introduction

·ndia has emerged as one of the largest economies in the world and projects rapid growth in the sectors such as real estate and renewable energies. Construction of buildings was once, a threat to resource depletion and fuel during the 70s and 80s. Further, an increase in oil prices triggered research on improving energy efficiency and alternate energy resources. These necessitated the search for more energy-efficient and sustainable building practices, and thus, the green building movement gained impetus in the last decade. In recent years, due to increasing environmental and health concerns, green building has emerged as the fastest-growing construction and design technology. 'Green building' is a design or practice of enhancing the efficiency of building systems and construction processes through the use of energy, water, materials, resources, and of condensed impacts on human health and environment, considering the life span of a structure or a building. The energy efficiency, modern trends, economy and the sustainability aspects that green buildings possess, makes it more laudable. Traditionally, India has been constructing environment friendly buildings since ancient times. Its traditional building system is mainly based on the application of natural materials like wood, bamboo, agricultural residues, clay, etc., especially in rural and tribal areas surrounding the forest. But, the present trending concept of green buildings began to grow only in late 1990s. India's own rating system for green buildings started in early 2000 with the formation of green rating for integrated habitat assessment (GRIHA) by The Energy and Resources Institute (TERI) and Ministry of New and Renewable Energy (MNRE) and then Indian Green Building Council (IGBC) by Confederation of Indian Industry (CII). Since then, green building movement showed a huge impulse in India over the years. However still, sustainable architecture shows a decline, owing to substandard construction materials and techniques. It has been reported that buildings in India account for 40% of its total energy consumption of which more than 60% of its share is taken by residential projects alone. 'Green building' is the only answer for sustainable real estate sector. Green buildings promote sustainability without disturbing natural ecosystem, and a green home can cut

V. R. Ramkumar*, Manoj Kumar Dubey and S. Hema

ICFRE - Institute of wood Science and Technology, IPIRTI Campus, Bengaluru.

*Email: vrramkumar@icfre.org

down energy consumption, save money and render a major positive impact on environment. India is expected to have a huge market potential for green and eco-friendly buildings in near future.

US Green Building Council (USGBC) reports (Dodge data and Analytics World Green Building Trends Smart Market Report) that green building industry will rise by 20% in India in a couple of years, may be due to the new environmental laws and demand. New high-rise, residential communities and mixed-use development are the top three sectors playing a significant role towards raising the green building market, which is estimated to be two-fold by 2030. Another report on 'India Green Building Market Opportunity Outlook 2020' specifies that, India ranks only second, next to USA with more than 4500 green building projects covering about 4.17 billion ft² of built-up area. The reports add that India has a total of 146 LEED-certified buildings and spaces, representing nearly 2.8 million gross area square meters (GSM) of space. This marks a nearly 10% increase in LEED-certified space in India from 2020, showing a massive market potential of green buildings in the country, driven by increasing awareness levels, environmental benefits and government support. Moreover, initiatives like the smart city mission and increasing concern towards energy efficiency further advances the growth of market potential of green buildings in India.

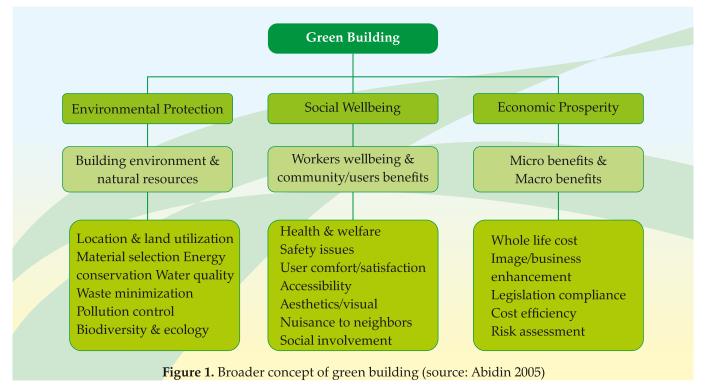
Foremost, green buildings are often recognized for its operational cost savings, wherein new green buildings are expected to yield 14% savings in operational costs and green retrofit buildings yield 13% savings in operational costs over a five years average period. Although, the construction of green buildings add to 7% higher costs than average. India has emerged as one of the leading countries to adopt green and sustainable buildings and developments as the country ranked third in the world on the U.S. Green Building Council (USGBC) annual list of the top 10 countries and regions outside of the US for leadership in energy and environmental design (LEED) in 2021 and henceforth, there is huge potential for further penetration of green building technology in the future.

India has a total of 146 LEED-certified buildings and spaces, representing nearly 2.8 million gross GSM of space. This marks a nearly 10% increase in LEED-certified space in India from 2020.

Green building and its importance

Green building concepts does not involve a single resource or a product but includes complete planning, construction, operation, maintenance, renovation, demolition and land use issues of all resources. The history of GB can be traced in late 19th centuries, when buildings (Lonons Crytal Palace – 1851 and Milans Galleria Vittorio Emanuele II - 1877) were using passive heating systems, such as roof ventilators and underground air-cooling chambers, to moderate the indoor temperature. The concept of GB flourished since the philosophy of sustainable development, introduced

in 1987 in the Brundtland Report, which significantly contributed to the implementation of sustainable development (SD) principles. According to the World Commission on Environment and Development (WCED), development that meets the needs of the present without compromising the ability of the future generation to meet their needs', such that SD will secure economic development, social equality and justice, and environmental protection. The broader concept of green building can be efficiently described by Abidin's diagram (figure 1), which consists of three main responsibilities: environmental protection, ensuring social wellbeing and conveying economic prosperity.



Integrating green building materials into building projects can greatly help reduce the environmental impacts associated with the extraction, transport, processing, fabrication, installation, reuse, recycling, and disposal of these building industry source materials. Thus, to promote sustainability of human society, development and use of green building materials for construction is particularly important, therefore research on green building materials such as timber, wood, etc. is of great importance. One of the main parameters in selection of a green material is that, it should be resource efficient. Resource efficiency generally means the building materials are composed of renewable, rather than non-renewable resources. It can

be accomplished by meeting the following criteria: (i) recycled content: building materials usually consist of identifiable recycled content, including post-industrial content with a preference for post-consumer content. (ii) Natural, plentiful or renewable: building materials are harvested from sustainably managed sources and preferably have an independent third-party certification (e.g. certified wood). (3) Resource efficient manufacturing process: building materials are manufactured with resource-efficient process including reducing energy consumption, minimising waste (recycled, recyclable product packaging), and reducing greenhouse gases. (iv) Locally available: the components of the building materials are obtained

locally or regionally so that one can save energy and resources in transportation to the project site. (v) Salvaged, refurbished, or remanufactured: includes saving a material from disposal and renovating, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product. (6) Reusable or recyclable: building projects that can be easily dismantled and the building materials can be reused or recycled at the end of their useful life. (7) Durable: building materials are long lasting or are comparable to conventional products with long life expectancy.

Wood as a green building material

Considering the above criteria for resource efficiency and the green building concept, wood and wood-based materials (engineered wood products, mass timber products, and others ligno-cellulosic materials) would be an effective solution as a green building materials. The innovation of engineered wood products (EWP) from wood and bamboo can play a crucial role to integrate urban built environment with the natural system and to solve the problem of energy emissions towards green buildings. Wood-based products are known for their high carbon sequestration and low carbon emission. When trees are sustainably harvested as wood products, 50% weight of the wood transforms into carbon that increases the sequestration capacity of wood. Thus, more wood-based structures assure more inherent carbon storage capacity that eventually helps to reduce the carbon footprint on the atmosphere. By integrating the wood-based systems with the hybrid construction, the mass timber products will play an innovative role in achieving all goals for sustainable development with effective resource management.



Hybrid mass timber buildings can reduce global warming potential by 26.5% compared to concrete structures.

Building with mass timber can reduce construction time by 61%.



Europe has experienced double-digit growth rates in last two decades since the use of MTP. However, in the other parts of the globe, these materials are still gaining momentum.

Several innovative MTP are currently available in the western market as shown in figure 2, however, India has been at early stages. Major types of MTPs include cross-laminated timber (CLT), laminated veneer lumber (LVL), glue-laminated timber (Glulam). One of the most prominent types of mass timber products is CLT which consists of layers of dimension lumber oriented at right angles to one another and glued to form structural panels with exceptional strength, dimensional stability, and rigidity. CLT panels typically consist of three, five, or seven layers of timber plies where each layer can vary

from 15 to 50 mm thick and are glued together with polyurethane, melamine, and phenolic-based adhesives. Fabricated CLT panels can reach a maximum size of 10 feet by 60 feet. CLT panels are mostly used for major structural components such as wall, roof, and floor slabs. Another common type of mass timber product is Glulam. Glulam products consists of individual layers of wood that are placed parallel to each. Similar to CLT, Glulam products are also composed of dimension lumber that are selected based on their structural performance characteristics and bonded together using durable and moisture-protected adhesives. Glulam provides excellent structural strength that allows the developers to use that product



Figure 3. Tallest timber-based structure in the world at 85.4 m, the Mjostarnet building in Norway (courtesy: Voll Arkitekter).

preparing laminated bamboo lumber and crushed

bamboo lumber using Dendrocalamus brandisii, Bambusa vulgaris, B. bambos and Guadua

angustifolia have been developed. Other bamboo

composites such as bamboo mat board (BMB),

bamboo mat corrugated sheets and ridge caps (BMCS),

moulded skin from bamboo mat for door shutters were

developed and commercialized for applications (Bansal

et al. 2013). These bamboo-based composites have the

potential to be used as an alternative to solid wood in

Figure 2. Bamboo composites (courtesy: Moso Studio).

for floor and roof decking, besides typical beams and columns. In India, Institute of Wood Science (IWST) has already initiated research programme on the development of mass timber elements such as CLT, Glulam, LVL and bamboo lumber using different wood from trees outside forest (ToF) and bamboo species. In CLT, the suitability of rubber wood, Melia dubia, Eucalyptus, Silver oak, etc. are being evaluated. The preliminary investigations revealed that CLT made from rubber wood and Melia are better than pinewood-based panels which is very encouraging. Protocols for

Structural systems for mass timber construction

Throughout the last two decades, the mass timber building has experienced steady growth in multi-story construction in US, UK, Europe, Canada and Australia. A research was conducted globally on mass timber buildings of 350 projects during 2000–2021 by Raznjevic et al. (2021) (figure 3), including 300 built, 12 projects in construction, and 38 proposed multi-story timber buildings from 2000 onwards with a minimum height threshold of three stories of mass timber construction. In all these projects, the structural categorization of mass timber buildings is categorized as follows:

- ✓ 1-D Frame structure
- ✓ 2-D Bearing wall
- ✓ 3-D Volumetric modules
- ✓ Combination or hybrid

Frame structures form post-and-beam structures, post-and-slab structures, as well as exoskeleton structures where vertical supports (other than the core) are limited to the exterior. The frame is usually anchored to a core and variations differ based on the presence of additional stiffening elements. The structures can consist only of a timber frame, but to achieve lateral stability, additional bracing systems such as shear walls, diagonal engineered wood products (EWPs) or steel beams, and steel cross bracing are added. Floor slabs can be made of different EWP combinations, such as CLT slabs, ribbed slabs, or CLT or glulam-concrete composite floors.

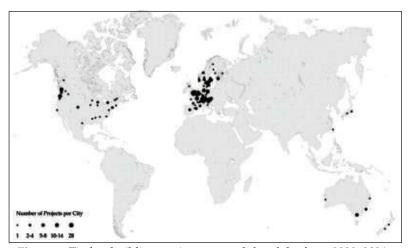


Figure 4. Timber building projects around the globe from 2000–2021 (source: Raznjevic et al. 2022).

Panel walls usually form honeycomb or party wall structures, while some case studies were also formed by only a central core and external load bearing walls, which are connected to the floor slabs. In addition, considerations were also given to external structural elements, such as circulation corridors or balconies

when separate from the main structure. Some of the sub-categories include internal beams or columns, or both. Floor slabs are mostly made of CLT or by box floor and box beam elements.

Volumetric modules, sometimes also referred to as spatial modules or 3-D modules, are made of preassembled volumes consisting of ready-made rooms and services pre-installed. The core can be built separately or modularly, as the building can. Although facades and balconies often come with 3D modules, this category also often exhibits the presence of additional external frame structures for balconies or circulation corridors.

Hybrid structural systems consist of different combinations of the categories. This includes projects in one of the following conditions: (i) lower and upper portions of the building volume are constructed in different ways, (ii) different areas of the footprint are constructed with different systems, and (iii) projects where two systems appear in combination with one another. An additional category is also mass timber combined with light frame construction (mostly in projects in North America), which consists of light-frame walls and CLT floor slabs. Overall, the mass timber buildings will keep on increasing in near future depending on the available technologies, design knowledge, building physics, construction methods, and regulatory requirements. Recent technical

advancements in engineered timber products (EWP) and systems, as well as regulatory adjustments in building code, fire safety and many government initiatives have enabled multi-story timber construction to reach new heights as shown in figure 4.

Building codes, standards and rating systems

Countries also need to address the demand of green building materials in their nationally determined contributions (NDCs) to increase awareness, availability and specification of low-carbon materials from wood and bamboo

A green building is ecologically designed so that it is responsible for the environment and uses natural resources efficiently in all the processes throughout its lifespan. This process involves from planning, construction, operation, maintenance, renovation and demolition of a green building which has to be conducted in an eco-efficient manner. The rating systems are based on modules including sustainable architecture and design, site selection and planning, water conservation, energy efficiency, building materials and resources, indoor environment quality, innovation and development. In specific, the use of wood and wood-based mass timber products in materials and resources, the provisions of building codes and standards are very critical for widespread acceptance as green building materials. Green building certification standards that identify and credit use of materials that mitigate GHG emissions as well as other environmental burdens can support the intended efforts to mitigate and adapt climate change. Globally, leadership in energy and environmental design (LEED) by the USGBC has been widely accepted for green building standards and certification. LEED certified

buildings save money, improve efficiency, lower carbon emissions and create healthier environment for life forms. They are a critical part of addressing climate change and meeting environmentally sustainable goals (ESG), enhancing resilience, and supporting more equitable communities. To achieve LEED certification, a project earns points by adhering to prerequisites and credits that address carbon, energy, water, waste, transportation, materials, health and indoor environmental quality. Projects go through a verification and review process by GBCI and are awarded points that correspond to a level of LEED certification as shown in figure 5. Of all LEED credits, 35% of the credits are related to climate change, 20% of the credits directly impact human health, 15% of the credits impact water resources, 10% of the credits affect biodiversity, 10% of the credits relate to the green economy, 5% of the credits impact community and 5% of the credits impact natural resources. LEED is a holistic

LEED Certified
40-49 points

Silver Certification
50-59 points

Gold Certification
60-70 points

Platinum Certification
80+ points

Figure 5. LEED certification system with colour code.

system that does not simply focus on one element of a building such as energy, water or health, rather it looks at the big picture factoring in all of the critical elements that work together to create the best building possible.

In India, green building certification is given by bodies such as the Indian Green Building Council (IGBC) and Green Rating for Habitat Assessment (GRIHA). IGBC, which was formed by the Confederation of Indian Industry (CII) in 2001. It has developed a green building rating system that conforms with the LEED certification of the USGBC, which is a globally recognised as green building rating system. The IGBC rating system has a scoring system of 100 points for new buildings. These points are divided into various categories, where it is essential for the building to meet the specific requirements to secure points. The certification level is as follows (table 1). Also, the following table 2 lists the best-known green building rating system of India and developed countries.

Table 1. Certification level in buildings				
Certification level	Buildings	Recognition		
Certified	40-49	Best practices		
Silver	50–59	Outstanding performance		
Gold	60–74	National excellence		
Platinum	75–100	Global leadership		

Rating schemes for green buildings			Year	
BREEAM	- Building Research Establishment Environmental Assessment Method	UK	1990	
BEPAC	- Building Environmental Performance Assessment Criteria	Canada	1993	
GBTool	- Green Building Challenge	International	1995	
LEED	- Leadership in Energy and Environmental Design	US	2000	
IGBC	- Indian Green Building Council	India	2001	
NABERS	- National Australian Building Environmental Rating System	Australia	2001	
GHEM	- Green Home Evaluation Manual	China	2001	
CASBEE	- Comprehensive Assessment System for Building Environmental Efficiency	Japan	2001	
BEE	- Bureau of Energy Efficiency	India	2002	
GreenStar	- Green Star Environmental Rating System	Australia	2003	
Protocollo ITACA - Istituto per l'Innovazione e Transparenzadegli Appaltiela Compatibilita Ambientale Italy				
HQE	- High Environmental Quality	France	2005	
GBP	- Green Building Programme	EU	2005	
LEED India		India	2006	
GRIHA	- Green Rating for Integrated Habitat Assessment	India	2007	
DGNB	- Certification System German Sustainable Building Council Certification System	n Germany	2009	
Miljobyggnad (Environmental Building) Sweden			2010	
American National Standard Institute – Green Building Assessment Protocol for commercial (ANSI/GBI)US				
International C	Green Construction Code (IGCC) – International Code Council (ICC)	International	2012	

Energy and emissions from building and construction

To achieve the Paris Agreement, the global buildings and construction sector must almost completely decarbonize by 2050. Figure 6 shows the emissions and energy demand of the building and construction sector. Further, the sector has projected near-doubling of global demand for energy services in buildings and at least a doubling of floor space as developing economies continue to respond to the growing demand for building floor space, access to energy services and economic activities.

To achieve the Paris Agreement, the global buildings and construction sector must almost completely decarbonize by 2050.

expected to get momentum in coming years. Production and utilization of mass timber products in construction is a way for the building and construction industry to contribute toward sustainable development goals. Policymakers, the forest products industry, and resource management organizations need to initiate a

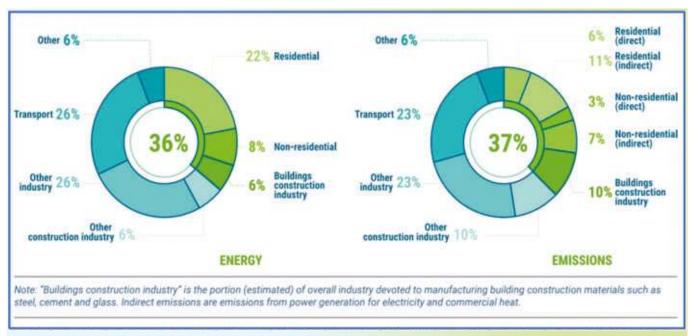


Figure 6. Share of global final energy and energy-related CO₂ emissions in 2020 from buildings to constructions (source: 2021 Global Status Report for Buildings and Construction).

Conclusion

Emissions from building materials and construction processes must be urgently addressed to ensure that the buildings being built in the future are to be optimized for low-carbon solutions across the full-life cycle. This involves maximizing the refurbishment of existing buildings, evaluating each design choice using a whole life-cycle approach and seeking to minimize upfront carbon impacts (e.g., lean construction, low-carbon materials and construction processes, etc.), as well as taking steps to avoid future embodied carbon during and at the end of life (e.g., maximize the potential for renovation, future adaptation, circularity, etc.). With the recent acceptance of timber in the building code, environmental commitments of the country and increasing environmental awareness, the concept of green building in India is gaining attention and

science-based approach to outlining the benefits of using wood and wood-based products in green buildings in India. A multi-disciplinary approach is needed to further develop scientific knowledge and provide technology transfer and education relevant to evaluating and advancing these benefits. It must be noted that the inherent benefits of using wood go beyond economic, social and environmental gains in a long run. Focussing and implementing the initiatives such as research, development, and industrialization for mass timber products in India, outreach and education on the perception of wood and wood-based products, development of standards, codes and certification programmes on the footprint of wood building materials may contribute to achieving sustainable development goals.

References Contact author at vrramkumar@icfre.org





GROWTH with SUSTAINABILITY

Sustainability is at the core of India's Paper industry. Paper is one of the most environmentally sustainable products as it is biodegradable, recyclable and is produced from sources which are renewable and sustainable.

Paper Industry is not only conserving the environment but also regenerating natural resources. Through the agro-forestry initiative of the Indian Paper Industry, more than 1.2 million hectares of land has turned green and thousands of jobs in rural India have been created.

Of the total demand for wood by India's Paper Industry, over 90% is sourced from industry driven agro-forestry. The industry is wood-positive, that is, it plants more trees than it harvests. Pioneering work has been carried out by the industry over the last three decades in producing tree saplings (e.g. Eucalyptus, Subabul, Casuarina, etc.) which are disease and drought resistant and can be grown in a variety of agro climatic conditions. Substantial amounts have been spent by the industry on plantation R&D, production of high quality clonal saplings, technical extension services and hand holding of marginal farmers.

Indian Paper Manufacturers Association

PHD House (3rd Floor), 4/2 Siri Institutional Area (Opposite Asian Games Village) New Delhi - 110 016 (India)
Tel: +91-11-26518379, +91-11-41617188, Email: sg@ipma.co.in / secretariat@ipma.co.in
Website: www.ipma.co.in

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Integration of Wood and Wood Based Products in Green Buildings

Introduction

few years ago, the term "Green building" evoked visual images of homes that were built from natural materials, such as straw bales and mud, typically in a suburban or a village site. They were often seen as being rustic and a bit primitive, rather than modern with primitive construction techniques and materials. This perception has since changed, and green buildings are now seen as being modern and efficient, utilizing the latest in energy-saving technology and materials. Today, the term used for homes suggests 'happiness' and for commercial buildings suggests lower overhead costs, greater employee productivity, less absenteeism, and stronger employee attraction and retention.

Globally, companies as diverse as Bank of America, Genzyme, IBM, and Toyota have already moved into green buildings.

India has also witnessed a significant shift towards green buildings in the recent years with major corporations such as Reliance Industries, Tata Group, Infosys, and Wipro taking the lead in this movement. These companies have taken a number of initiatives such as using alternative building materials, energy efficient lighting, installing renewable energy sources, and using rainwater harvesting systems to reduce their energy consumption as well as reducing their carbon footprint.

Bhawna Sharma

Founder & Managing Director, Artius Interior Products (P) Ltd

Email: bhawna.vibha13@gmail.com

The shift to green

Developing reliable standards and criteria for evaluating green buildings was a key factor in bringing green buildings into the mainstream.

BREEAM (1990, United Kingdom)

The UK government pioneered the green standards movement in 1990 by launching BREEAM-the Building Research Establishment's Environmental Assessment Method at the request of the British real estate industry. BREEAM evaluates the environmental performance of a wide range of new and existing buildings in the United Kingdom.

LEED (2000, United States)

In 2000, the U.S. Green Building Council launched its Leadership in Energy and Environmental Design (LEED) rating program – a coalition of over 6,000 real estate professionals, government and non-profitorganizations, and schools. As part of the program, points were awarded under 6 points and 4 award levels. LEED certification is now mandatory for new and renovated public buildings in dozens of U.S. cities and several states.



Green star rating (2002, Australia)

In 2002, the Green Building Council of Australia synthesised BREEAM, LEED, and other environmental criteria into the Green star rating system, which is tailored to the Australian environment, building practices, and real estate market.

India (IGBC-2001 BEE,-2002 & GRIHA-2007)

It can be notice that Indians were always aware of the Green building concept from time immemorial. Conventional homes with baked red colour roof tiles and clay made walls is a good example of energy efficient structures that were used to keep cool during summers and warm during the winters. Most of rural India is still attached to this building technology using naturally available materials like clay, wood, jute ropes, etc.

As far as India is concerned, it does not have a centre or state level legislation(s) for 'Green building' certification still date. However, there are three primary rating systems- (i) Green rating for integrated habitat assessment (GRIHA), (ii) Indian green building council (IGBC) and (iii) Bureau of energy efficiency (BEE). The rating systems certify a building as a "Green Building" against certain acceptable benchmarks.

In the author's opinion although there are differences in terms of the primary factors (or its relative importance) that GRIHA, IGBC and BEE take into account for rating a building as a 'Green Building', however all of them unanimously consider the use of green building/sustainable building materials and products under the umbrella factor(s) of material use and innovation strategies i.e. technologies that go beyond the traditional green building methods amongst several other factors.

Since sustainability is the key factor, integration of wood and wood based products (as the title of the article suggests) assumes importance towards making a building overall 'Green'.

One could enumerate the physical properties of wood, which makes for such a compelling case for it's inclusion (viz being a renewable source, low carbon footprint), we at Artius prefer terming them as 'divine properties' as a testament that wood is God's own building material — a gift crafted with love, with an incomparable beauty that enriches our lives and homes.

Although due to the advent of technology, coupled with the inherent versatility of wood, makes it capable in various applications inside a home such as: furniture, floors, etc. however historically its primary use was for doors and windows and as a construction material itself.

While the use of one grew, the memories of wooden structures slowly faded as time marched on, leaving only a nostalgic longing for the warmth of a building material that once was. I shall refer to both.

The earliest known use of wood for doors and windows in India dates back to the 5th century BCE, according to the archaeological evidence from the ruins



The Forte Building, Melbourne, Australia.

of the Indus Valley Civilisation in modern-day Gujarat. A doorway discovered at the site of Dholavira reveals that wood was used to construct the frame and a single wooden plank was used to construct the door. This doorway is believed to be around 4500 years old!

Similarly, wood was used as a building material for residential houses in ancient India. Examples include the ancient cities of Hampi and Ellora, both of which featured wooden houses. The ancient cities of Vijayanagara (in presentday Karnataka), Khajuraho (in present-day Madhya Pradesh) and Puri (in presentday Orissa) featured wooden houses, temples and palaces.

Some of the most impressive examples of wood construction in India include the Sun Temple at Konark in Odisha, which was built in the 13th century CE, and the Great stupa at Sanchi, which was constructed in the 3th century BCE.

However, with time, the use of Wood was discontinued as a building material internationally as well as in India due to the following four identifiable reasons:



- 1). First being the lack of technological developments to address certain disadvantages of wood such as its susceptibility to fire, insect infestation, rot, and weathering.
- 2). It was also becoming increasingly difficult to find suitable sources of timber for construction due to deforestation and environmental concerns.
- 3) Wood was not perceived to be as strong or durable as other materials, such as concrete and steel, making it less suitable for use in larger structures and buildings. Examples of this includes the shift from timber framing to steel and concrete in the construction of skyscrapers, which began in the early 20th century.
- 4) And lastly, due to governmental interventions. For example, the Forest Conservation Act of 1980, which limits felling of trees.

We need to re-think wood

While we were consumed with the demand to build more with concrete and steel to address the global housing needs, little time was devoted to the inherent unsustainability of steel and concrete construction. Sustainable development can have different contextual meanings however the underlying theme remains the same – it is a way of living that reduces our impact on the planet and ensures that our needs and those of future generations can be met. It involves balancing economic growth with environmental protection, reducing poverty and improving social wellbeing.

There is no doubt that the rampant cement construction was doing the polar opposite.

According to the World Business Council for Sustainable Development, the cement industry alone is responsible for 8% of global CO_2 emissions, while the steel industry is responsible for 6% of emissions.

Furthermore, the Cement Sustainability Initiative estimates that cement production requires an average of 120–140 litters of water per kilogram of cement produced. In addition to the large amount of energy needed to produce and transport the materials, resulting in significant emissions of greenhouse gases, one cannot disregard the fact that once the building is no longer needed, demolition can be costly and will generate large amount of waste materials.

Furthermore, both steel and concrete absorb and release heat, making them poor insulators and contributing to the urban heat island effect.

On the other hand, the four factors (above) for which the use of wood as a construction material was discontinued in the first place no longer exists as advancement of technology has adequately addressed them making it resistant to fire and/or reduce their flammability rotting and weathering.

Further, using a complicated technology, commonly known as Glued Laminated Timber (Glulam), constructing a structurally stable, fire resistant building made purely out of wood is no longer a dream but a reality. The most cited examples of these around the globe are;



The Dalston Lane Project, London, UK



The Element, Vienna, Austria

- 1. The Forte Building, Melbourne, Australia
- 2. The Maximus Tower, Vienna, Austria
- 3. The Dalston Lane Project, London, UK
- 4. The University of British Columbia, Vancouver, Canada
- 5. The Brock Commons, Vancouver, Canada
- 6. The HoHo Tower, Vienna, Austria
- 7. The Element, Vienna, Austria
- 8. The Treet, Bergen, Norway
- 9. The CLT Tower, Amsterdam, Netherlands
- 10. The Bergen Arboretum, Bergen, Norway

At Artius, we take pride in having been the pioneers of adapting technology to India's climate, and recently constructed a 6,500 square-feet residence in North-Goa, Vagator, with Glulam structural timber using Douglas Fir imported from Canada.

In addition to this, we have also installed door and window systems in over 1000 premium residences across India. We welcome all our readers to visit our manufacturing facility and our experience centres in Gurgaon and Hyderabad to understand the technological process as well as feel the warmth of a wood-home.

Conclusion

Although there is no iota of doubt that wood and wood-based products are important factors for making a building 'green', however we have to be mindful of how wood is sourced, used and managed during the building process.

Wood should be sustainably harvested, certified and or recycled and not from endangered species. Efficient



The Brock Commons, Vancouver, Canada



The University of British Columbia, Vancouver, Canada

wood working practices calls for using prefabricated panels and advanced joinery techniques.

Further, the use of wood may require its interaction with adhesives, fire-retardant chemicals, paints etc. which should also be carefully selected.

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Contact author at bhawna.vibha13@gmail.com

Future Trend in Construction: A Hybrid Approach to Timber Buildings

Introduction

'ndia will be the home to the world's largest population and the largest construction sector worldwide, yet engineered wood products are only used in a small fraction of buildings. The benefits of using wood in tall and commercial construction are undisputed, namely reducing the carbon footprint, shortening construction times, and enhancing seismic and building physics performance. However, in the Indian construction market, wood/engineered wood product has not been considered as a structural material in tall and non-residential construction. Hybrid timber buildings could lead to wood utilization in a more rational way, thus promoting the development of more efficient sustainable buildings. In the long run, this would result in a higher proportion of wood in buildings, which would be beneficial for living conditions, the climate and for society at large.

Hybrid-timber construction systems

Hybrid-timber construction systems combine wood with different materials (e.g. steel, concrete and glass) and techniques to deliver a wide range of structural solutions. Hybrid-timber construction goes further, making other materials such as steel and concrete - an integral part of a building's structural assemblies. This mixing of materials in building systems means designers/engineers/architects can exploit the strength of each—optimizing structural and building performance. A hybrid is something of mixed origin, such as a merging of different materials that combines the benefits of the constituent parts. Regular construction products in softwood/hardwood/short rotation timber can be combined either with other wood materials or with inorganic materials to achieve a better solution. Industries focus on producing suitable products in the following categories:

- ✓ Materials, e.g. engineered wood products (EWP).
- ✓ Components, e.g. composite floor structures in wood, steel and concrete.
- ✓ Systems, e.g. multi-storey structural frames in wood, with stabilising elements of steel or concrete.
 - Timber construction has traditionally been restricted

Siva Avudaiappan^{1,2,*}, Pablo Guindos^{2,3} and V. R. Ramkumar⁴

¹Departamento de Ingeniería Civil, Universidad de Concepción, Concepción 4070386, Chile

²Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD), Pontificia Universidad Católica de Chile, Av. Vicuña Mackenna 4860, Santiago 8331150, Chile

³Department of Structural and Geotechnical Engineering, Pontificia Universidad Católica de Chile, Av. Vicuña Mackena, Santiago 7820436, Chile

⁴ICFRE - Institute of Wood Science and Technology, IPIRTI Campus, Bengaluru

*Email: siva.avudaiappan@uc.cl

in height due to concerns regarding quality raw materials, structural stability as well as fire resistance. However, new approaches (Timber Hybrid buildings) to both the engineered wood that is used as well as the combination of timber and reinforced concrete mean that taller buildings can be constructed. Timber hybrid building refers to the structure form dominated by wood, steel and concrete structure. The most common type of timber hybrid structures is combining a case-inplace concrete core that resists the lateral loads, with the timber structure carrying the reminder of the gravity load and diaphragm loads. According to relevant research, timber hybrid structure gives full play to the best performance of wood, steel/concrete, and has higher bearing capacity, fire resistance and seismic performance compared to pure wood structures [Poirier et al.,2016].

Many studies have confirmed that timber and timber-hybrid buildings have enormous potential to reach higher heights with desired structural and environmental performance [Zhang et al., 2021]. Over the last two decades, North America, Europe and other countries have begun to study the new system of building multi-storey and high-rise timber hybrid structures with other materials, for example, the concrete or the steel. Several feasibility studies for innovative tall timber-based hybrid structural systems were carried out, and many prototype buildings were tested. Meanwhile, several tall timber and timberhybrid buildings, e.g., the 18-story Brock Commons in Canada and the 18-story Mjostarnet in Norway (figures 3, 4 and 4a], have been successfully built and are operating well, which demonstrates great competitiveness in the aspects of structural performance, environmental friendliness, and construction speed [Zhang et al. 2022].

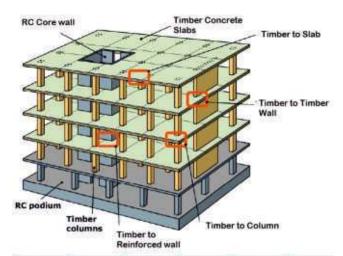


Figure 1. Image of the proposed project "Development of an efficient earthquake resistant timber-concrete hybrid prefab structural system as a sustainable building alternative for Chile " - Pablo Guindos [2].

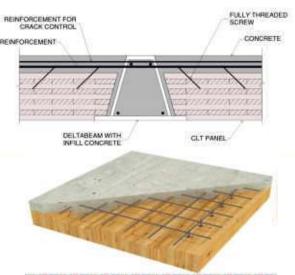


Figure 2. Flat floor structure comprising of CLT-concrete composite panels [5].

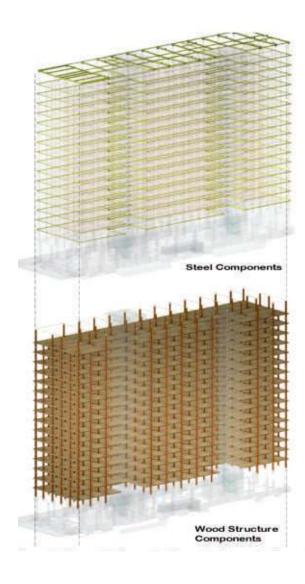
The structural system for Brock Commons is designed as a hybrid configuration as shown in figure 2. The foundations and ground floor as well as the cores (which house stairwells, elevators and service risers) are cast-in-place concrete. The structure on Levels 3 through Level 18 is composed of mass timber columns and floor panels. Connections and specific elements, like the roof structure, are of steel. The results of these projects, confirm that superstructures are significantly lighter than reinforced concrete structures .



Figure 3. 81m Mjostarnet building in Norway [1].



Figure 4. Brock Commons Tallwood house.



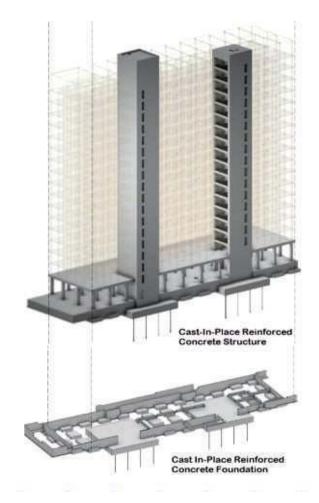


Figure 4a. Brock Commons Tall Wood Building Structural System,
Images courtesy: Acton Ostry Architects Inc. and CadMakers Inc. [3].

Challenges and opportunities in hybrid timber buildings

Advancement in composites, and inspiration for improvements to timber could readily be drawn from the development of reinforced concrete, an excellent example of a highly successful hybrid material. The advantage of combining concrete and steel is that you exploit the strengths of the two materials, while curbing their weaknesses. The combination of concrete and steel rebar has prompted a dramatic expansion of the material's applications: from a few structures in unreinforced concrete, mostly subject to compression forces, that were built before the 1900's, to reinforced concrete, the world's go-to construction material. The huge success of this material has, to a large extent, been due to the successful hybridisation of concrete and steel rebar.

When it comes to wood's weaknesses, one of the shortcomings cited most often are durability and fire

safety, but this problem relates primarily to unprotected structural components outdoors. Structural wood protection, fire protective systems, adequate preservative treatment or chemical modification can substantially improve durability and safety. In addition, some properties of wood listed below can be more difficult to get around in utilization for building systems for engineers.

- a) widely varying strength properties, particularly tensile and bending
- b) Brittle fractures
- c) Relatively low mass
- d) Relatively low modulus of elasticity (elastic modulus)
- e) Difficult to execute stiff fixings/connections
- f) ire safety, durability and serviceability

Also, sagging and vibration issues can be reduced by using a hybrid structural system, known as a composite

floor structure. From a static point of view, this type of structure is highly efficient, as you make optimum use of the materials' properties, i.e. the compressive strength of the concrete and the tensile strength of the wood. Since the elastic modulus of the concrete is three times greater than that of the wood, the resulting bending stiffness of a composite floor structure is considerably higher than an equivalent wooden floor structure of the same height. More mass in the floor structure also has the beneficial effect of increasing resistance to global overturning, a problem that would otherwise require expensive countermeasures in tall and light buildings.

A building's stiffness and mass are key factors that affect its frequency and acceleration due to wind load. Oscillations from the dynamic effects of wind can cause unpleasant sensations and illness to the dwellers of the building, which can render it unusable for its intended purpose. High-rise wooden buildings have low horizontal stiffness compared with equivalent buildings in steel or concrete. This is due largely to the wood's low elastic modulus and perhaps to an even greater extent on the connections between the various wooden components, which usually have significant give in them. A rational way to reduce the risk of windinduced vibrations is, once again, to use a hybrid

solution where a wooden structure takes care of the vertical, downward loads (e.g. permanent loads, imposed load and snow load), while an affixed concrete or steel structure with much higher bending stiffness takes care of horizontal and vertical upward wind loads.

Thanks to the advances in fire separation/firestopping system technology and the production of engineered wood products worldwide, especially the global integration of low-carbon economy, increasing attention has been paid to using and researching structural timber in western countries in the past 2 decades. Therefore, timber high-rise or timber-hybrid buildings are attracting more and more attention worldwide. Engineered timber products, gluedlaminated timber and cross-laminated timber have recently been used to build homes, schools, shopping malls and stadiums, and substantial projects have been completed using timber-based hybrid structures. The National Center of Excellence for the Wood Industry (CENAMAD) has demonstrated the construction of a few Timber Hybrid Buildings in Chile as shown in figure 9. Also, around 350 timber buildings were constructed and are in service from 2000 – 2021, of which a few are shown in figures 5-9.



Figure 5. Central City, Surrey, Canada (Photo courtesy: Nic Lehoux [6]).





Penticton, Canada (Photo courtesy, Cei Architecture [6]).



Figure 8. Column to CLT Slab connection, UBC (Photo courtesy: KK law [6]).





Figure 9. Some recent timber constructions in Chile: (a) Campamento Los Bronces (b) Penuelas Experimental Tower [7].

In the near future, Engineered wood will form a much bigger part of the construction sector in India as well as around the globe. The above-said hybrid timber systems will redefine the possibilities of using timber with steel, concrete and others materials. Using engineered wood combines the potential for prefabrication and rapid construction with lower embodied energy and the potential to delay the carbon emissions for buildings during construction and service cycle. Research and technical reports suggest that timber can be best used in combination with other conventional materials, taking advantage and attributes of individual materials. Buildings and the construction

sector can be optimized towards sustainability, matching the aesthetic, acoustic, dynamic, safety and the fire performance of occupants. It is concluded that in order to promote the development of timber construction industries in India, it is necessary to progress on regulatory, cultural, and material availability issues, where international experience, demonstrative buildings, and the implementation of public policies are crucial.

Acknowledgment

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Sustainable and Futuristic Buildings with Mass Timber

Introduction

Ithough India has a long-standing wood utilization culture, it has been largely on the product manufacturing side rather than building with wood. Despite many fine examples of wood construction existing in India, currently building with wood remains in its nascent stage. However, there is a lot of interest lately in building with wood among architects, builders, hospitality industry and their high net worth income (HNI) clients.

We are increasingly seeing farmhouses, country homes, villas', cottages and resorts being designed and built with wood for its aesthetic value and other benefits. However, all this requires judicious use of certified wood from sustainable sources.

Methods of wood-based construction

Climate change is one of the defining challenges of the 21st century mainly due to the ever-alarming increase in greenhouse gas (GHG) emissions where India is on 3rd position after China and USA (IEA 2021). The construction industry is one of the largest contributors to carbon footprint, greenhouse gas emissions and resource depletion worldwide which is responsible for climate change. As a result, there is growing interest in sustainable building practices that reduce environmental impact while providing safe, durable, and aesthetically pleasing structures. Current building codes and/or building commitments tend to focus on operational emissions and as these emissions are reduced, we must focus

on reduction of embodied emissions to bring down carbon footprint in all forms of construction. There are several types of wood-based building construction methods, each with its unique features and benefits and the most popular among them are given below.

Jimmy Thomas

Forestry Innovation Consulting India Pvt. Ltd. (Canadian Wood), Bengaluru, India

E-mail: jimmy.thomas@canadianwood.in

Tongue and Groove (T & G) style of construction

The T&G style of construction is a very organic and efficient way of building resort cabins, holiday homes at a very cost-effective way. The entire structure is prefabricated in the factory and can be put together onsite in merely few hours depending on the size of the house. The T & G system's interlocking method ensure the house stays safe, strong, cool and dry all year round. If the construction uses double T & G or a laminated wall on outside which further adds to strength, stiffness, wall span and insulation values. Majority of the resort cabins, hospitality houses, etc. in India are made of this





Figure 1. Tongue and Groove (T & G) style of construction.





Figure 2. Post and beam method. Figure 3. Wood frame construction (WFC

technology owing to the ease of fabrication and installation.

Post and beam timber frame construction

Post and beam construction is a traditional building method that involves the use of heavy timber posts and



Figure 4. Mass timber construction using CLT and GLT.

beams to create a sturdy frame. The spaces between the posts and beams are filled with materials like glass, timber panels, dry wall or stone. This type of construction is usually hybrid in nature and popular for its durability and aesthetic appeal.

Log cabin construction

Log cabin construction is another traditional method that uses logs instead of cut timber to create the frame of a building. The logs are stacked and notched to fit together tightly, creating a sturdy and weather-resistant structure. Log cabins are suitable for extremely cold areas where thick walls/insulation are required, popular in remote rural areas and are often used as vacation homes.

Wood frame construction (WFC)

WFC is the most popular method used for making millions of houses in North America, Europe and elsewhere. This system combines stud walls made from structurally graded dimensional lumber, engineered wood and engineered wood panels to make dry walls, floors, and roof assemblies. These structural elements provide, rigidity, support to the interior dry wall and exterior cladding and a cavity for the installation of mechanical systems (MEP) and insulation. Its design flexibility allows to construct a very rigid, resilient and light weight structure which can meet toughest design standards to withstand devastating earthquakes, severe winds and other natural elements, apart from achieving superior energy efficiency and decades-long service life.

Mass timber construction

Mass timber is a category of wood construction materials that refers to large prefabricated engineered solid wooden panels that are used as structural elements. Two types of mass timber that have gained popularity in recent years are cross-laminated timber (CLT) and glued-laminated timber (GLT or glulam). CLT is used for making walls, floors, and roofs while GLT is used for making columns, beams and other load-bearing structural components in a building. Mass timber technology allows construction of multistorey buildings in short period of time without compromising the overall quality and safety of the structure. In recent years, mass timber construction has seen a resurgence due to its numerous benefits enumerated elsewhere. CLT-based construction is becoming increasingly popular in sustainable building projects.

Why not timber? Why mass timber?

Historically, one or two stories buildings usually were made with durable and locally available timber that is thick and large sections in longer lengths. They were allowed natural drying for many months before putting them to fabrication and use.

Fears about fire hazards and biodegradation due to termite, insect or water infestation issues coupled with the influx of other building materials such as concrete, steel etc. pushed the timber-based construction down. Changes in government rules and policies, thanks to the conservational efforts, and resultant scarcity of large timber sections from mature forest trees made timber a less approachable commodity for a common man. Wood available from plantations and agroforestry was mostly of low girth with juvenile/immature characteristics and defects. They were neither suitable nor structurally evaluated for the purpose. Moreover, seasoning inadequacies and shortage of experienced and trained carpenters and skilled labour to undertake the construction and fabrication of buildings made the situation worse.

Although timber has long been used as a building material and later forgotten due to above reasons. However, the recent advances in timber engineering and manufacturing have led to the development of mass timber and brought timber back to the construction world in its new avatar!

History of mass timber (CLT & Glulam) development

Mass timber has a rich history of development and a brief overview of their evolution is provided below.

Glued-laminated timber (Glulam/GLT): Glulam was first developed in Switzerland in the early 20th century, where it was used as an alternative to steel in bridge construction. Its use then spread to Germany and Austria, where it was used in a variety of applications

including residential and commercial buildings. Its popularity increased in the United States during the 1930s and 1940s, with the first American glulam plant established in 1934 in Oregon. Since then, glulam has become a widely accepted material for structural applications due to its strength, durability, and sustainability (source: American Institute of Timber Construction).

Cross-laminated timber (CLT): Development of CLT can be traced back to the 1970s in Austria and Germany, where it was first used for non-structural purposes such as flooring and walls. In the 1990s, the technology was improved and CLT was used for the construction of multi-story buildings. The first CLT building in the world was a six-story apartment building in Switzerland in 2003.

The Brock Commons Tallwood House, an 18-story hybrid mass timber residence at the University of British Columbia in Vancouver, Canada was the first CLT building in North America. It was the tallest mass timber building in the world when it was completed in 2017. Since then, the use of CLT in construction has grown rapidly in North America, with the United States seeing a surge in CLT production and construction in recent years (APA-The Engineered Wood Association).

Ascent MKE Building, Milwaukee, USA is the tallest timber building in the world currently. This 86.6 m (284 ft) structure made mainly of a mix of CLT and GLT is a residential building with 259 luxury apartments in 25 floors (Forest Products Laboratory, USA). Projects like this show what is currently possible and can help companies in the future to implement sustainable solutions like CLT and GLT as well.

In 2018, the International Code Council (ICC) approved changes to the International Building Code (IBC) that allowed taller mass timber buildings to be constructed in the United States (WoodWorks - Wood Products Council).



Figure 5. CLT used as floor, wall and structural panel.



Figure 6. India's first GLT project-CEPT University, Ahmedabad.



Figure 7. Use of mass timber in a residential project, Hyderabad.

Overall, the development and use of mass timber, CLT, and glulam have evolved over the course of the 20th and 21st centuries. From their origins in Europe to their widespread use in North America today, these materials continue to revolutionize the way we approach construction and sustainable building practices.

Benefits of building with timber and mass timber

Timber has been used as a building material for centuries and is still a popular choice today. Here are some benefits of using timber as a building material,

Environmental benefits: One of the most significant benefits of mass timber construction is its environmental sustainability. Timber is a renewable resource that can be sustainably harvested and replanted, and it has a much lower carbon footprint than other building materials such as steel and concrete. Trees absorb carbon dioxide from the atmosphere during photosynthesis, and this carbon is stored in the wood. Wood stores more carbon than is emitted during its harvest, production, transport, and installation —even when transported over great distances. As a

result, buildings constructed with mass timber sequester carbon, helping to mitigate climate change.

Mass timber construction also has lower embodied energy than other building materials. Embodied energy refers to the total energy required to extract, manufacture, transport, and install building materials. Timber requires less energy to process and transport than steel and concrete, making it a more sustainable choice.

Energy efficiency: Timber buildings are naturally energy-efficient due to the insulating properties of wood. Timber has a high thermal mass, which helps to regulate temperature and reduce energy consumption. In addition, timber buildings can be designed to incorporate passive solar heating, which further reduces energy consumption. Wood buildings perform beautifully in terms of noise abatement and energy absorption—cheaper to heat and cool—and studies have shown that wood buildings also contribute to the well-being, serenity and calmness of the occupants.

Global warming: There is a place for concrete, steel and plastics, but when we consider the urgency of the emerging crisis in global warming caused by greenhouse gas emissions wood from sustainable sources comes into its own.

Structural performance: Mass timber construction has excellent structural performance, with high strength-to-weight ratios and good seismic and fire resistance. Timber is also a ductile material, meaning it can deform without breaking, making it more resistant to damage from seismic events than brittle materials like concrete. In the event of a fire, mass timber construction forms a char layer that insulates the structural core, preventing collapse and allowing occupants to evacuate safely. Due to its light weight and high strength to weight ratio, the overall weight of a timber structure is much less compared to its counterparts. As a result, a relatively light foundation only required. Hence building with wood can be the right solution for hill stations and remote areas.

Aesthetic appeal: In addition to its environmental and structural benefits, mass timber construction has aesthetic appeal. Timber buildings are aesthetically pleasing and can add value to any property. The warmth and natural beauty of wood can create a welcoming and comfortable atmosphere in a building and the use of exposed timber can add character and interest to interior spaces. Mass timber components can be finished in a variety of ways, including staining, painting, and charring, providing designers with a range of options to create unique and visually appealing structures.

Modular and quick: Modular prefabricated wood technologies can sped up construction schedules and reduce overall construction costs. Moreover, building with wood is faster and lighter and with a small group of trained manpower requirement, overall neighbourhood disturbance, sound and dust pollutions, etc. are also minimal. A notable advantage is that this technology does not require water for construction.

Cost-effectiveness: Wood buildings are competitive in cost in NA, Europe, Japan and Australia partly due to much faster construction through prefabrication in factories and reduced onsite work, where assembly of modules and finishing works are the only remaining tasks. Although the initial cost of mass timber components may be higher, the prefabricated components can reduce construction time and labour costs. Additionally, mass timber components are lighter than steel and concrete, reducing the cost of transportation and crane rental. Mass timber construction has a lower environmental impact and high energy efficiency which result in cost savings in the long term.

Green buildings certification: Regarding green building certification, such as LEED and WELL, use of certified timber from sustainable sources adds the highest points to achieve top rankings.

Adaptability and service life: The fact that wood buildings are easily adapted or dismantled and re-used adds to their environmental benefits. Wood buildings can be constructed in such a way that they are easily demountable. Although there are examples of woodframe buildings that remain structurally sound after hundreds of years, North American buildings often have a service life of less than 50–70 years, regardless of material, because of the changing needs or increasing land values.

Design flexibility: As CLTs and GLTs are made up of dimension lumber (seasoned, graded and made for the purpose) with known technical properties, individual structural components can exactly be designed and manufactured depending on the load requirements and service conditions. Being light weight structure, the section requirements are much less compared to a concrete of steel structure.

Challenges in constructing buildings with timber or mass timber

Despite its many benefits, mass timber-based construction has many challenges in the market. A major challenge is the availability of suitable timber resources. As mass timber construction becomes more

popular, there is increased demand for timber, which could lead to overharvesting and deforestation if not managed sustainably. As a result, large manufacturers and stakeholders are confined to major timber producing countries only. Customers in countries like India have longer waiting period due to the far exceeding local demand than the available production capacity.

Some of the major challenges in this sector, particularly in Indian context, are summarized below.

- 1. Code compliance: Building codes and regulations often have specific requirements for timber and mass timber construction, such as minimum fire ratings, height restrictions, structural and seismic requirements. Compliance with these regulations is essential to ensure safe and legal construction. Suitable adaptations/modifications are to be made in national building code (NBC) of India so that the use of timber and mass timber will be legal and safe.
- 2. There is hardly any production of engineered wood in particular mass timber products in India. These products will continue to drive opportunity and commercialization and will make their way into the Indian market. Technology is available but no production at scale is in sight which means these products must be imported—this is problematic in terms of timely supply, availability, cost, installation, etc.
- 3. Supply chain and sourcing: As the demand for timber and mass timber grows, ensuring a sustainable and reliable supply chain is essential. Sourcing responsibly harvested wood from certified forests and maintaining ethical and equitable labour practices throughout the supply chain is crucial.
- 4. Structural design: The structural design of timber and mass timber buildings is considered as complex and requires specialized knowledge, skillset and software tools. Engineers and architects need to have a thorough understanding of the properties and behaviour of wood and its different forms.
- 5. Although structural engineering and material science courses are available, no academic institution offers course on timber structural engineering or approach wood as a building material. As a result, there is a dearth of trained and qualified professionals in mass timber design, fabrication, construction, etc. to undertake it as a profession.
- 6. Cost and scalability: While the overall cost of timber and mass timber construction can be lower than traditional construction methods, there can be

- higher initial costs due to the specialized design and construction techniques. Additionally, scaling up production of mass timber products may be challenging due to limitations in the availability of raw materials and manufacturing capacity.
- 7. Fire safety: Wood is a combustible material, and therefore fire safety is a critical consideration when using timber or mass timber. When designed well and fire rated building components are used along with firewalls, automatic sprinklers, and fire detectors/alarms, wood-frame is proven to be as fire safe as other forms of construction.

Overall, timber and mass timber construction can offer many benefits, but addressing these challenges is critical to ensuring safe and sustainable construction practices.

Way forward with mass timber

The use of mass timber in building construction is gaining popularity globally due to its sustainability, aesthetic appeal, reduced construction time and cost-effective apart from health benefits and low noise pollution. As a result, construction industry is shifting towards mass timber as it has the potential to transform the construction industry.

Mass timber-based building construction is still in its early stages, and there are opportunities to explore further. There is a need to develop standards, codes and regulations for its use in construction which can further improve the efficiency and safety of mass timber construction. The adoption of mass timber in building construction is futuristic as it can reduce greenhouse gas emissions and create new job opportunities in the forestry and construction sectors.

To overcome the challenges, an ecosystem consists of designers, structural engineers, OEMs, contractors, skill manpower and enterprising builders/developers and developers has to be created and implemented.

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Contact author at jimmy.thomas@canadianwood.in



Federation of All India Timber Merchants, Saw Millers & Allied Industries

Head Office: Federation of Karnataka Timber Merchants & Saw Millees, White Pearl, Flat 201, Bangalore 560026.



@ e-mail: contact@timberfederation.in

Website:



www.timberfederation.in

Sri Naval Kedia,

President

e-mail: naval@costaawoods.com

Mob: 9830200497

Sri D. Ramakrishna,

General Secretary

e-mail: dwararamakrishna@gmail.com

Mob: 9440176081

Zonal Offices:

East: "Diamond Prestige", Room No. 409, 41A, AJC Bose Road, Kolkata ~ 700017 (WB).

(9 033 - 22640073 / 74

West: "Timber Bhawan", Room No. 409, Plot No. 47, Sector 8, Gandhidham, Kutch - 370201 (Gujarat).

O2836 230676

North: C/O Mahalaxmi Lumbers Pvt. Ltd, 1/57A, WHS Timber Market, Kirti Nagar, New Delhi-110015.

O11 - 41009111

South: Timber Yard, Aryapuram, Rajahmundry - 533101 Andhra Pradesh.

0883 - 2464949

Central: C/O United Timbers, New Timber Market, Fafadih, Raipur - 492009.

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Wood for the Love of Our Planet

Introduction

A

s we progress into a world that is increasingly getting more polluted and poisonous to live in, a cry that was faint a decade ago has increasingly taken centre stage.

'Reduce Emissions'!!

The question is WHY do we need to reduce emissions? The temperature across the planet has been steadily increasing which has resulted in global changes in weather patterns. An increase in one degree can alter the melting patterns of the glaciers and ice belts around the poles. This increase in temperature over the time will also affect rainfall, courses of rivers based on the volume of water flow.

Rapidly melting icebergs and glaciers will raise sea levels to extents that will obliterate small island nations and in some cases countries themselves. Maldives, Lakshadweep islands, the island of Kiribati, some islands from the Andaman and Nicobar islands are prime examples.

This may seem to be far away from us, as we tend to think that a crisis happening in a faraway land is not of concern to us. We however need to understand that crisis's affecting others are will sooner or later become crisis to us as well. Our planet is connected in more ways than we think. A simple ineffectual thing like killing a bee and/or exterminating them can and will cause a crisis of gigantic proportions that can be as severe as wiping out humanity.

Do we need to pause and think a little in the immediate present so that our future is brighter? The answer is a big YES.

The only way to solve an issue is to go to the root of the problem and not treat the symptoms. A brief look at the causes for CO_2 emissions will give us a clear picture on where we need to start.

Fourty percentage of the emissions is from the construction industries. These industries use cement and steel as the main ingredients for construction. Apart from the suspended particulate matter which is generated due to flying cement (which is carcinogenic and leads to tuberculosis as well) ,the amount of CO_2

Sandeep Mukherjee

Founder/Designer, Quercus Space, Bangalore, India

Emial: sandeep@quercuspace.com

generated in the process of making of cement is massive. Steel, which is another important element of construction is also a massive energy consuming material.

There are other factors that contribute to emission; however construction remains the single largest element.

To help reduction of emission, we need to attack this issue and see how to bring down the level of CO₂ emission from this industry.

The answer is to use low emission sustainable materials that can be used in multiple ways to deliver spaces that are residential, commercial or industrial.

Advantages of building with timber

WOOD has been used for eternity as a construction material by humanity. Much before the advent of steel and concrete, we were using wood to build houses. When this was being used in the past, we did not know that this material is so amazing for construction. Wood is easy to work with , uses almost ZERO energy to convert and make things out of, wood sequesters CO₂ instead of emitting it. As we are aware that forests act as carbon sinks and help clean the environment, reduce the presence of CO₂ in the atmospheric air and of course provide shade to sit under.

While one ton of cement (base material for concrete) during production produces almost 1.6 tons of CO_2 , wood does not emit any CO_2 and retains it within ,therefore removing CO_2 from the environment. One cubic meter of wood sequesters 1 ton of CO_2 .

Building with wood had its issues or disadvantages where the wood needed to be left out to season for years together and even thereafter would misbehave. Wood can crack, cup, bend, warp, twist and create havoc for the user if not used the right way. Industrial seasoning of wood made things better (Kiln Drying) and therefore

brought more stability to the timber used due to planned removal of moisture.

With progress in technology in wood-working and new processes being borrowed from alternate industries, a few countries in the West (Austria, Germany, Sweden) started to build timber beams and columns by laminating thinner sections together to achieve a final size. The advantage of this was that the finally constructed beam was completely seasoned till the core and that individual sections tied together gave a lot more strength to the final section. This system is commonly called as 'Glulam' or GLT has now become a standard method for usage in construction.

GLT allowed timber to be used for building multiple floors in tall buildings which changed the course of timber usage in construction. Imagine a tall building that uses 30000 cubic meter of timber for construction, and as a result removes 30000 tons of CO_2 from the environment . The same building in cement and steel would be 6 times heavier and therefore use more material for its foundation and in transportation. A building such as this will emit at least 30000 tons of CO_2 if not more into the environment.

A shift in construction is needed towards using GLT and CLT (Cross laminated timber). CLT is a method of building floor slabs and walls in timber. Where each layer that is laminated is perpendicular to the earlier layer. The construction of CLT is similar to plywood. A 5% shift to timber from concrete across the globe will result in reduced emissions and in an equivalent amount sequestered in the building.

Other advantages of building with timber

Health Benefits

Wooden buildings do not get fungus if proper process of finishing is followed. Unlike cement plastered walls that hold water if there are leakages and therefore get musty and attract fungus, wood once seasoned will not absorb water unless kept immersed in it. No fungus means no respiratory diseases. The natural smell of timber is fresh and invigorating. A house built in timber has a fresh smell within which keeps the mind active and happy. Compare this with a damp cement plastered wall in a brick and mortar building.

Less leakages

Concrete has a way of developing cracks over time due to expansion and contraction. The plaster surfaces on a brick and mortar wall is not flexible and therefore tends to crack. This in turn allows water to seep in and travel all across the inner areas making it impossible to find the source of leakage. Ever so often we need to waterproof the roof of a brick and mortar construction so that we do not have seepage or leakage inside the building. In timber construction all these are planned technically and flexible waterproof layers are used as an integral part of the design process.

Less maintenance

Timber buildings have been around for longer than 600 years in India and overseas. Coastal India along the Konkan and Malabar coast have houses as old as 600 years that are still standing (a visit to the Heritage Village in Manipal will confirm this). Compare this to a brick and mortar house of the same age to understand how much better is timber construction and how much longer it lasts.

Less time to build

The building time of a timber house is fast, precise and efficient. Design for a house such as this is done in great detail and all components are manufactured in a factory. This enables parallel processing of different elements instead of sequential processing. Where a typical construction will take at least 12 to 15 months, a timber construction of the same size will take around 6 months . This apart precision can be achieved which is next to impossible in a traditional brick and mortar construction.

Less head and heart ache

Considering that building in timber needs technology and precision manufacturing, there is no need for unskilled workers at site. The total number of workers at site can be limited and the process of installation is also mechanized. The beams and columns cannot be lifted and moved manually. A brick and mortar construction needs a lot of labour at site giving rise to a plethora of issues and miscommunication. Anyone who has built a house with contractors and labour will know this in detail. Timber construction process is a NO STRESS process.

Fire safety

Wooden constructions are fire safe. As unbelievable as it may sound, wood is safer than steel and concrete in case of a fire. Wooden structural elements that hold a building together and are critical in case of a fire, tend to char on the outer surface resulting in stoppage of oxygen for the fire to burn it through and through. The wood smoulders and extinguishes once the charring happens. This can be compared to steel that buckles in a fire resulting in a building collapse (twin towers is a prime example) or concrete that literally cracks and bursts in high heat.

Although the cost per square feet for timber construction on a slab to slab basis is more than cement mortar/concrete, when we look at the timber construction holistically and over extended time it is cheaper.

Wood is being grown in plantations across the world in huge quantities. These are sustainably managed plantations which follow that chain of custody method and ensure that no timber is illegally felled. India needs to follow suit and start plantations aggressively. Felling and replanting is the only path forward to regenerate resources that can help us save our planet.

Wood is good inside and outside, for furniture and buildings, for big and for small usages.

Let us work with wood to save our planet.





Usage of glue laminated timber for lighting structure in a retail environment



Glue laminated columns and Beams



Edge glued boards in timber for display and storage in Retail



Glue laminated timber for outdoor usage in Maldives





Glue laminated timber for outdoor usage in Maldives



References: Contact author at sandeep@quercuspace.com

Certification of Green Buildings

Introduction

The term green buildings is defined as a structure that has efficient resource utilization and also conscious towards environment throughout the building's life cycle, starting from planning stage to its demolition phase. The traditional building designs take into considerations the economy, usefulness, durability, comfort and are expanded upon and complemented by the green building practise. In addition to maximising the resource conservation throughout the building's lifespan, green building also refers to environmental protection and pollution reduction, enabling occupants to make use of space in a healthy, comfortable, and effective manner, and fostering a harmonious relationship between humans and environment. Low consumption, high efficiency, economics, environmental protection, integration, and optimization are the main goals of green building technology. This article addresses the concept of green buildings and the various agencies that provide buildings with green certification.

Green buildings

Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective of the green buildings is to reduce the overall impact of the built environment on human health and natural environment by:

- Efficient use of energy, water, and other resources
- Improvement of occupant health and employee productivity
- Reducing waste, pollution, and environmental degradation

Building industry produces large amount of emissions which can be reduced significantly if green building approach is adopted. The use of bioclimatic design principles can lower the energy use, and consequently, reduce carbon emissions. Bioclimatic design involves planning

Dishari Chatterjee*, Souvik Ray and Rakesh Kumar

Wood Properties and Processing Division, ICFRE - Institute of Wood Science and Technology, Bengaluru

*Email: bony12.chatt@gmail.com

infrastructure in the context of a particular environment and, whenever possible, taking advantage of its features. This could be as simple as designing a modified building envelope or positioning the structure to use sun's rays for lighting or other energy needs.

Certification of green buildings

Buildings significantly affect the environment both directly and indirectly as they use energy, water, and raw materials during construction, occupation, renovation, repurposing, and demolition. Aiming to reduce the negative effects of buildings on the environment through sustainable design, green building standards, certifications, and rating systems have been developed in response to these findings. A certification is a confirmation that a product meets defined criteria of a standard. Any rating system certification serves as proof of the project's green status and can be an effective instructional and marketing tool for owners, design teams, and construction crews. To promote highly sustainable construction methods, the green building certification provides incentives for customers, owners, designers, and users. Rating



systems also make it apparent that green criteria must be adhered to and what kinds of green products are used should be specified in building plans. Building rating and certification systems are continually being improved to reflect new requirements and objectives for reaching everhigher levels of sustainability.

Green building certification systems are a set of rating systems and tools that are used to assess a building or a construction project's performance from a sustainability and environmental perspective. The planning, design, construction,

operation, maintenance, renovation, and ultimately demolition phases of a building can all be covered by different types of certifications. They are multi-attribute programmes since many products labelling and certification programmes certify items based on lifecycle characteristics. In-depth green building rating



systems like LEED, Green Globes, BREEAM and National Green Building Standard accept product certifications on various levels before assigning a building as green. As a result of shifting market dynamics and rising consumer demand for greener products, the number of green product certifications is increasing.

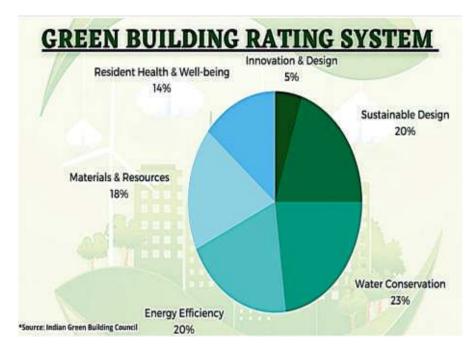
Green building rating systems

Systems for assessing or certifying green buildings shift the emphasis from single components to the project as a whole. A type of building certification system called a rating system assigns points or prizes based on how well a building performs in relation to certain environmental objectives and standards. The ratings range from single-attribute ones, that handle only water or energy, to multi-attribute ones that also

address emissions, toxicity, and overall environmental performance. Even though there are differences in organizational policies, methods, and certification requirements, all of them aim to reduce the overall detrimental effects on both human health and environment. There are green building rating systems for every project type, from single-family homes to large neighbourhoods to business structures. Rating systems are available for both new buildings, which concentrates on choices made during the planning and

design phase and actions performed during construction, and existing buildings, which concentrates on operations and maintenance over the course of the building's life.

Green building practises are now a part of the internal building criteria for new construction in the many states and large cities in various countries all over the world. A first-party evaluation is one that is provided directly by a company connected to the party making the claim or one that stands to gain from it. An interested party, such as trade association, conducts a second-party evaluation. A third-party review is carried out by an unbiased party who has no investment in the assessment's outcome or financial ties to it.



Different green building standards and certification systems

Sustainable design has a wide range of financial and environmental benefits, which are frequently attained through the application of standards, rating, and certification systems. The US Green Building Council (USGBC) estimated that certified buildings can save energy, carbon, water, and waste, resulting in savings of up to 30 to 97% in each case. Additionally, green buildings' operating expenses can be cut by 8–9%.

Higher productivity and improved occupant health are two additional benefits of green buildings that have been linked to the improved interior environmental



quality, enhanced natural daylighting, and healthier building materials and goods. Some of the most commonly used and respected green building rating and certification systems in the market are discussed below:

Building research establishment environmental

assessment method (BREEAM): Building research establishment (BRE), a well-known organization of building research, introduced BREEAM in the 1990 in UK. Many green building certification programmes, like LEED and Green Globes, have their roots in BREEAM. The objectives of BREEAM are to provide sustainable solutions, promote comprehensive approach to sustainability that is based on reliable technologies and enhance the environmental performance of buildings. Management, health and well-being, energy, transport, water, materials, waste,

> land use and ecology, and pollution are the nine categories used to measure performance. The building types that are covered by the standards are determined by

the stage of the building's life cycle. There are five ratings for all BREEAM rating systems other than the six ratings for BREEAM in-use and an interim certificate may be provided for a new construction, refurbishment, and fit out at the design stage, and the final certificate may be given when the work is finished.

Leadership in energy and environmental design (LEED)

The US Green Building Council developed LEED in the year 2000 for rating design and construction methods that defines green buildings in countries around the world. LEED credits are granted in several categories which include integrative process, location and transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation, and regional



priority. Additional points are credited for a particular sustainability tactics, such as the use of low-emitting items, decreased water use, energy efficiency, accessibility to public transit, recycled content, renewable energy,

and daylighting, are included in each category. LEED standards have become more stringent as the market is expanding.

Green globes

The green building initiative (GBI) introduced the green globes, which have their origin in Canada. Seven categories, namely energy, indoor environment, site, water efficiency, materials, and project management are used to assess buildings on a 1000-point scale. A feature specific to green globes is the ability for users to declare that a particular credit might not be applicable to a project. Additionally, there are no requirements. Green globes can be used to assess interiors of both new and



old structures, whether they are commercial or multifamily housing. A self-reported online evaluation survey must be completed in order to apply for a green globes certification.

Living building challenge (LBC)

The Cascadia Green Building Council is the first organisation that introduced the LBC. In April 2011, the Cascadia Green Building Council and the LBC were merged to form the International Living Future



Institute (ILFI). The LBC has strict requirements, including 100% net zero water, 100% on-site renewable energy, and 100% construction waste recycling or diversion. Site, water, energy, materials, health, equity, and aesthetics of buildings are all examined. Currently, this is the most stringent form of green building certification available because all its principles. Twelve months following the project's completion, certification takes place, and compliance is verified on-site. Under the LBC accreditation, the ILFI also offers a certification option for a zero-energy (ZE) building. The ZE certification confirms that a structure is actually using solar, wind, or earth energy to produce more energy than the building's net annual need.

Passive house institute US (PHIUS)

PHIUS oversees the certification process for a passive building standard that was created under a DOE/Building America grant specifically to handle the challenging US climates. When compared to a building that complies with code, buildings that are planned and constructed to the PHIUS+ 2015 Passive Building Standard use 86% less energy for heating and 46% less energy for cooling. They offer a net zero construction framework that prioritises quality and conservation.



They are relevant on a global scale and based on building science, best practises, and the quality control required to produce the greatest outcomes.

The sustainable sites initiative (SITES)

SITES, run by Green Business Certification Inc. (GBCI), provides a thorough evaluation system to identify sustainable landscapes, gauge their effectiveness, and increase their value. For the development projects on sites with or without structures, such as corporate campuses, national parks, streetscapes, houses, and more, SITES certification is presented. Landscape architects, designers, engineers, architects, developers, policy-makers, and other



professionals use SITES to coordinate land management and development with cutting-edge sustainable design. The built environment must include land, which can be planned, constructed, developed, and managed to safeguard and improve the advantages of healthy, functional landscapes.



WELL

WELL, is a performance-based approach for evaluating, certifying, and monitoring aspects of the built environment that have an effect on people's health and well-being. The foundation of WELL is a collection of medical research that examines the relationship between the health and wellbeing effects on occupants of the buildings where people spend more than 90% of their time. Buildings that are WELL Core and Shell Compliant and have WELL certified areas can help create an atmosphere where people can eat better, exercise more, feel better, sleep better, and perform better.

Fitwel

Fitwel, run by The Centre for Active Design is a leading certification programme in the world dedicated to promote the universal health. All buildings and communities will be improved to promote health and well-being as part of Fitwel's vision for a better future. The US Centres for Disease Control (CDC) and Prevention and the US General Services Administration were responsible for the initial development of Fitwel. For both new construction and existing projects, certification is offered. The new building certification includes two certification categories and is applicable to projects that are either in the design phase or are in the construction phase. Fitwel's seven health effect





categories are: improves occupant safety, enhances access to healthy foods, reduces morbidity and absenteeism, supports social equity for vulnerable populations, instil feelings of well-being, and supports physical activity.

Green building certifications in India

There are several certifications available to support and confirm green building construction methods in India. Additionally, since they are fitted with energy-efficient technology and architectural designs, green buildings can contribute to the reduction of energy expenditures. The three most well-known certifying organisations in India are: the Indian green building council (IGBC), green rating for integrated habitat assessment (GRIHA), and leadership in energy and environmental design (LEED).

LEED LEED offers grade based on a project's appraisal of various factors, including its use of water, energy, and sustainable materials. The rating based on these scores is then determined, and is divided into categories like certified (40–49 points), silver (50–59 points), gold (60–79 points), and platinum (80–plus points). The best grade a building can receive is platinum. According to statistics, India is home for more than 1600 LEED-certified structures. Among these are the Anna Centenary Library Building in Chennai, the American Embassy School in Delhi, and Terminal 3 at the Indira Gandhi International (IGI) Airport in Delhi.



IGBC rating systems

The Indian Green Building Council, which was founded in Hyderabad in 2001, is in charge of managing the IGBC rating system, which is supported by the Confederation of Indian Industry (CII). Buildings are rated according to certified, silver, gold, and platinum designations. These include certifications for both new and old structures, along with communities, special economic zones (SEZ), schools, factories, houses, and metro systems. IGBC-rated green structures include Thermax Corporate House, Oval Nest, and the Navi Mumbai Municipal Corporation Building.

GRIHA ratings

In India, the GRIHA rating system was created by The Energy and Resources Institute (TERI). Five stars is the highest rating in the star-based rating system used by GRIHA. The points allocated to each star, such as one star for points between 25 and 40, two stars for points between 41 and 55, three stars for points between 56 and 70, four stars for points between 71 and 85, and five stars for points over 85. GRIHA-rated projects include the Hotel Grand Chola in Chennai, the Indira Paryavaran Bhawan in New Delhi, and the Manipal University Campus in Jaipur.



A few certified green buildings in India

ONGC Green, Dehradun: An iconic building of Uttarakhand, ONGC Green has been named green hills as it reflects the verdant green hills surrounding the Shivalik range. With a total built up area of 14,600 square metre and spread over five floors with the capacity to accommodate 620 individuals, the ONGC Green is a marvel by its own. It can conserve water up to 30% through onsite sewage plant and low flow sanitary sittings. Rain water harvesting is also taken care of at the building.



Suzlon One Earth, Pune The office was created by Pune-based architect Christopher Charles and has obtained a LEED platinum rating since 2010. This majestic tower, which spans 10 acres, is one of the largest green building projects in the nation and one of the first LEED certified structures in India. Renewable energy from both on-site and off-site sources power Suzlon One Earth entirely.

Rajiv Gandhi International Airport, Hyderabad

The sixth-busiest airport in India, located in Hyderabad's city centre, established a standard for environmentally friendly structures. The architecture of the airport is built to conserve natural resources and use less water and electricity. There is a 273-hectare green belt with numerous vegetation on the airport campus. RGIA has achieved energy savings of around 3.97 million kWh and a 3331-ton reduction in carbon emissions during the past two years.



Infosys Limited, Mysore This green building, which is a magnificent structure and is situated in the city of palaces, is the third Infosys building to receive a Platinum rating. The five-story building was constructed with a holistic approach to sustainability in mind, paying particular attention to critical areas like sustainable site development, water conservation, and indoor environmental quality. There is a 40% reduction in energy consumption due to intelligent mechanisms and effective machinery.

Infinity Benchmark, Kolkata

This 560,000 square foot, 20 story building is the seventh building in the world to earn the LEED platinum certification at the time of its opening. The structure is equipped with humidification controls, rainwater harvesting, waste water recycling, and CO₂ monitor sensors. Brick wall blocks make up the building's facade, and thick polyurethane foam decking serves as greater insulation for the roof.



Wipro Technologies, Gurgaon

The Wipro Campus in Gurgaon has received a LEED platinum certification from the IGBC (under the umbrella of USGBC). The inverted cone, which is carefully positioned at the intersection of two roadways to increase building visibility, serves as the design's primary focal point. A regulated, open-to-sky landscaping courtyard that will help keep the building cool throughout summer is one of its main features. Each open office space has a view of the courtyard, providing plenty of natural light.



Conclusion

The green building concept is crucial for the environment and their eco-friendly designs, enables saving running costs, and effective energy utilization. Green construction helps in reduction of environmental pollutions and thereby raises living standards over time. It also improves people's quality of life and fosters harmony between humans and the natural world.

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INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY,

Peenya, Bengaluru

Key Services

- ▶ Focus is given to problems and needs of the industries in R&D projects.
- Undertaking sponsored projects given by the industries.
- ► Catering need of skilled and trained man power of the plywood and other wood panel industries through one-year Post Graduate Diploma Course.
- Organizing training and education for the industry sponsored candidates through regular as well as tailor made short term vocational courses.
- Provide solutions to technical problems of the industries through regional workshops/telephonic advises and factory visits.
- ► IPIRTI product certification, concession in testing and training fees to member firms.
- ► Formulation of Specifications for the new products developed by the industry and issue of draft amendments to relevant standards.
- Representation of the problems/issues of the industry at the Ministry/Government level.
- ▶ Dissemination of information related to research activities, achievements and other relevant events through IPIRTI News.

Short term Courses offered by The Advanced Woodworking Training Centre (AWTC)

The Advanced Woodworking Training Centre (AWTC) is a premier training centre located in the heart of Bengaluru city. It was established by Institute of Wood Science and Technology (IWST) as the first training centre in India with an aim to enhance skillset of manpower working in wood based industries. So far AWTC has trained more than 2500 professionals. The courses are designed to give first hand experience in handling advanced machines and tools to wrok on various wood and wood products that meet the global standards.

Conventional Woodworking and Finishing (4 Weeks)

Admission Eligibility : 10th Class Pass.

Course Fee : Rs.15,000/- for entire course

Extra : Rs.1,650/- towards Accommodation Charges,

Food Charges (as per actual)

Security Deposit : Rs.5,000/- (Refundable) :Maximum 5 Candidates per Batch

Intake : Maximum 20 Candidates per Batch

Product Designing and Development on CNC Router (4 Weeks)

Eligibility : Completion of Conventional Woodworking and Finishing course

at AWTC

Course Fee : Rs.20,000/- for entire course

Extra : Rs.1,650/- towards Accommodation Charges Food charges

(as per actual)

Security Deposit : Rs.5,000/- (Refundable)

Intake : Maximum 5 Candidates per Batch

Product Designing and Development on PYTHA 3D (2 Weeks)

Eligibility : Completion of Product Designing and Development on CNC

Router at AWTC.

Course Fee : Rs.10, 000/- for entire course

Extra : Rs.1, 650/- towards Accommodation Charges,

Food Charges : Extra (as per actual)

Intake : Maximum 5 Candidates per Batch.



Advanced Woodworking Training Centre
INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY

(Indian Council of Forestry Research and Education)

An Autonomous Body of Ministry of Environment, Forest and Climate Change, Govt. of India

P.O. Malleswaram, Bengaluru – 560 003, India

Website : http://iwst.icfre.gov.in/awwtc/awwtc.htm
Ph : 080-22190149, 150 Fax: 080-23340529
E-mail : awtc_iwst@icfre.org, dir_iwst@icfre.org

Glulam Construction Timber from Local Agroforestry Species: An Architect's Perspective

Introduction

ooking back on many years of industrial practice, it is very clear that we never used wood and for good reasons it was firmly ingrained that we could not use solid wood in construction. Sadly, solid timber is currently reserved only for prestigious traditional tasks and very highly priced interior works. However, the 'brief' for a hospitality project was about to change this, at least for my own practice. On a picturesque rural site, 65 km south of Bangalore, the client wanted to rebuild the typical "Toti Manes" of the region for his proposed resort project; visiting the resort should take the guest 100 years back in time. For centuries these houses were built with stone, earth, bamboo and locally available timber to support the roofing with tiles from the village potters. We were familiar with all but bamboo and timber, and the client approved the sample wall structure with pure rammed earth without cement.

We had, at best, only vague notions on sustainably sourcing and working with local timber, let alone the abundantly available coco palm logs. I had repeatedly seen beautiful bowls and plates from lathe artisans as well as expertly crafted furniture from Kerala from dense palm wood with wonderfully attractive looks, but many people had also warned me against any temptations to use palm wood for construction. Felled logs are regularly disposed off and left to rot. Not surprisingly, our first attempts of taking senile logs to local sawmills to cut suitable sections of 4" x 6" and 3"x 5" were not very encouraging. This was mainly due to the disinterest by sawmill owners. Also, the lack of experience and skill of the sawmill workers and ourselves. In successive seasons, we however achieved better results after spending more time at the sawmill, observing first and then interacting closely with the workers. The delicate and difficult task of identifying suitable senile logs remained unresolved. Nevertheless, we built 40 roofs and open structures over the next few years while also beautifully transforming the land.

In the course of time, we found coco palm timber specialised sawmills in Coimbatore and one such mill was able to select suitable senile logs from the auctions in Pollachi for our solid section requirements. Still, the

Georg Leuzinger

L&S Architects, Bangalore, India & Timber Structures, Bangalore, India

Email: timberstructures@gmail.com

issue of the appearance of soft inner tissue affecting the strength of many members, easily visible after seasoning, persisted frequently. Also, the limited length of only 10' was a serious limitation. The rare beams of 15', 14' or even 12' lengths of good quality were hard to find and hence costly. Our attempts at sourcing from Karnataka's coco palm regions, much closer to Bangalore also failed because of lack of interest and experience at sawmills. Identifying suitable senile trees in the farmers' fields remained the most crucial issue, a task we could not take on ourselves. Looking beyond traditional structures with close column grids, we needed to accomplish longer spans even for Mangalore tiled roofing structures with beams as well as rafters/reapers.

We discussed finger jointing and glue lamination with wood-working agencies, but none were willing to work with us using palm wood and requested us to specify imported pine or teak. Locally sourcing and reliably working with senile palm wood were our key issues and we wanted to find workable and replicable answers. Hence, we decided to give finger jointing and glue lamination a serious consideration by ourselves. We used simple tools and pressed the first sample beams from logs sourced and sawn right next to our office located in the city.

Motivated and energized by these experiments, we designed and fabricated manually operated finger jointing vice and beam press of 20' length at local fabrication workshops. With new confidence, we took up a school project designed with stone masonry, stabilised mud block walls with shallow vaults along with domes and Mangalore tiled Glulam timber roof structures for upper floors. We established temporary seasoning shelters and workshop area relying on the rural power grid. The effort was tremendous and exhausting. After successful completion, it became clear that we needed to establish a permanent workshop and continue the R&D with our energetic and keen team of carpenters from Tamil Nadu.



Figure 1. The 30 feet Hydraulic Beam Press.

We found a shed of 3000 sq.ft. with industrial power and a supportive landlord in sylvan surroundings, close to our head carpenter's and our own houses. We stocked up several truckloads of palm timber planks and revised and redesigned equipment. In early 2020's, our new hydraulic press of 30' length was ready, built with local fabrication resources and friendly hydraulic experts. After successful trials, we were ready for a new and more demanding contemporary structure with external steel rod post tensioning for all main members. The rigorous selection of planks necessary for high quality Glulam beams led to a high rejection rate of the already seasoned planks. Realising this high rejection quota, we decided to also stack up alternative local species like Melia dubia and Silver oak and in the process, by chance, found an able person to source more suitable senile coco palm logs.



Figure 2. Full scale erection of pyramid roof in coco palm glulam at the workshop.



Figure 3. Detail compression posts with steel rod tensioning with Glulam coco palm timber.

While these palm logs show better quality with lesser amount of soft-core tissue, we still needed to supervise the sawmill work very closely. We recently tripled the area of our seasoning stands and continued to improve our technical infrastructure. In 2021, we incorporated "Timber Structures" as a design-cum-build agency with our own Glulam process with locally sourced wood species. With "Timber Structures" we want to work with architects and engineers to realise attractive roofing structures to showcase the beauty, relevance and economy of such solid timber works. Currently we are also expanding our roofed working areas to accommodate a new beam press of 40' length and 8" beam width for curved Glulam members which will be showcased in the roof itself.

With curved Glulam beams we would like to achieve portal frames for open hall structures up to 45' or even 50' span at the lowest possible structural cost and compete with conventional structural materials more effectively. We wish to bring solid timber construction back to architects and clients and hope to popularise the use of local plantation wood processed locally with minimal energy for local projects. Stocking and working with different wood species is more complex than what we initially thought. Saw milling, seasoning and processing is different for different species. Hence, we need to build specific competence, shop floor practice and joinery for all species. We aim at building trust with owners and architects through successfully completed projects, however small they might be. Most people's concerns and doubts are about the strength and durability of solid wood structures, but we are also observing how an increasing number of people are attracted to the charm of wood structures and their obviously positive sustainability factors. Importing graded timber with forest stewardship labels from the big northern producing regions is perhaps a good catalyst to mainstream the use of wood but investing in research and efforts to build up our own non-forest timber economy is also wise for sure.



Figure 4. DIS Anganvadi with Glulam coco palm sections.

For the months and years ahead, we want to contribute towards increased collaboration and research to address the growth of solid timber construction from local non-forest wood species through the following:

- Central departments and research institutions to address the need and opportunities for non-forest tree growing on private and government lands.
- Increased training for sawmill and woodworking establishments.
- Focus on timber engineering and material testing at educational institutions.
- Focussed R&D by machinery manufacturers, adhesive industries and joint hardware and fastener manufacturers.
- Architects and structural engineers to build knowledge and competence for contemporary timber construction.

We have started our low tech, low capital "Timber Structures" venture to set the ball rolling for architects, project owners and the general public to understand and observe the feasibility of solid wood construction. Working with local wood species in the presently very informal environment of growing, harvesting and sawing such timber, as compared to working with imported graded timber from northern countries with their established forest economies is much more difficult. Many obstacles and hurdles have to be overcome.

It will, however, be ultimately rewarding to see a healthy growth in this new field and demonstrate the inherent advantage of more sustainable construction based on local wood growth from non-forest lands. For our path forward we need to find interested institutional material testing partners to systematically test our Glulam products and establish the necessary data to enable the structural engineers to work with Glulam materials from local source and production. We consciously concentrate on linear Glulam development to keep initial capital requirements low coupled with open-source practice for equipment development; we hope to achieve mainstream acceptance of such products soon.



Figure 5. A resort dining hall with solid section short span coco palm timber.

We anticipate the coming up of regional Glulam production centres for standardised Glulam products for frequently used sections and special sections against orders. Enterprising saw millers are clearly in the best position to add the required facilities and equipment for Glulam production to add a new vertical and consolidate their operations. Solid palm timber door frames, flooring planks and other such items can easily be added to the product range.

References

 $contact \, author \, at \, timber structures. blore @gmail.com$

INDIAN LAMINATE ILMA MANUFACTURERS ASSOCIATION



Strength of Unity

6TH INTERNATIONAL CONFERENCE ON LAMINATES

Indian Laminate Manufacturers Association (ILMA) is nonprofit making organization of manufacturers of Decorative and Compact laminates or high pressure laminates, Particle Boards, Plywood and Pre-lam (Short Cycle Laminates). It is the only registered association of the laminate industry at national level and we are proud to complete 20years since 1998. More than 140 manufacturers of Laminates of India are the registered members of ILMA.

ILMA is a place where companies collaborate to get more opportunities to grow their business. ILMA is a symbol of Indian Laminate Manufacturer's unified commitment to provide seamless & world-class decorative surfaces. ILMA assembles its manufacturers on a unified platform & voices out its fair opinions. It unanimously provides a healthy competition, creating great opportunities by using different strategies and combining the views of the manufacturers.

Key Achievements

- 1. Organized six International Conference on Laminates between 2010 to 2018
- 2. ILMA Institute of Technology to enhance production capabilities of members employees
- 3. Restrict import of low quality laminate
- 4. Study on Cleaner Production
- 5. Launch of Technical book on laminate
- 6. Catalogue shows at National and International Level
- 7. Launch of awareness video on Laminate application
- 8. Networking with members for raw materials, production, market and government policy related issues
- 9. Export incentive benefits to laminate exporters
- 10. Support to PM Cares fund during pandemic

Upcoming Events

- 1. 7th International Conference on Laminates during Delhi wood March 2021
- 2. Catalogue show at Interzum, Germany 2021
- 3. Online technical workshop on production and environment aspects during October 2020.
- 4. Environment clinic with Pollution control board (December 2020)

FOR REGISTRATION

Laminated Veneer Lumber: An Innovative Sustainable Building Material in India

Introduction

imber is an integral part of the construction industry which plays a vital role in the growing economy. With booming construction activities, the demand for structural timber follows an exponential curve whereas the supply of the same is dwindling. Due to the ban on commercial logging from the natural forests by the Hon'ble Supreme Court of India, timber industry is forced to produce quality structural products from trees outside the forests (TOF). The challenge in doing so is that the plantation timbers which are harvested in short rotation periods are of no match to the performance of the timbers which are harvested at the age ranging from 80 to 100 years. To mitigate the shortage of quality conventional timber for structural / load bearing applications, efforts to study the feasibility of producing high grade structural wood composites from the available short rotation plantation timbers are ongoing. Also, ideal adhesive system with reduced or zero harmful emissions are being worked out so that these composites can be used indoors without causing noxious effect on human health.

Construction of timber structures which are expected to bear the load such as columns and beams in wooden houses and bridges demand huge amount of engineered materials suitable for structural applications (Tenorio et al. 2011). Timber harvested from plantations cannot typically be used for heavy timber structure due to its uncertain material properties which limits its load bearing ability. Also the short rotation plantation timbers are prone to decay, insect, fungus and termite attacks when used for exterior applications where it is subjected to weathering as a result of which accelerated ageing, splitting and deformation are bound to occur shortening its service life impairing its engineering safety (Zi-xiang et al. 2016). In such a scenario, it is the need of the hour to find possible alternatives for conventional timber possessing high strength suitable for structural applications. Engineered wood/timber such as glue lam timber (GLT), cross-laminated timber (CLT), laminated veneer lumber (LVL), etc. are some of the examples for composite wood known as mass timbers that are considered as innovative and sustainable building materials used for structural applications such as beams, columns and railings, etc.

V. Prakash

ICFRE - Institute of Wood Science and Technology, IPIRTI Campus, Bengaluru

E-mail: vijayp@icfre.org

One of the cost-effective ways to manufacture the engineered composites for wood structures is in the form of LVL, where the material properties of fastgrowing plantation timber are synthetically enhanced (Sultana et al. 2015). Manufacturing LVL includes veneer peeling, clipping, drying, veneer gluing, assembling and laminating veneers in to a composite in a hydraulic hot press under heat and pressure (Ozcifci 2009). The natural defects like knots, cracks, etc. that are present in trees/logs during its growth are inherited when these logs are converted in to sawn timbers. In order to nullify the effect of these inherent defects during the service either in terms of physical and mechanical properties or in terms of aesthetic appearance, these logs can be peeled in to veneers and then glue bonded with suitable synthetic resin either by removing the defects or by distributing the defects throughout the span of the composite.

Manufacturing process

LVL is a structural composite made by laminating preservative treated (IS: 401, 2001) veneers, 1.5 to 4.2 mm thick, with suitable adhesive and with the grain of veneers in successive layers aligned along the longitudinal (length) dimension of the composite. Its applications include all the end uses to which structural wood has been traditionally used, such as, beams, rafters, stringers, joists, posts and framework construction, stiles, rails and frames of doors and windows, vehicle bodies, railways coaches, containers, framework of furniture, cabinets, shelving, etc. (IS: 14616, 1999). Generally, LVL can be manufactured by using low grade logs (i.e. logs with presence of many knots, lower density and mechanical properties, etc.). LVL can be made from a range of wood species, such as beech, birch, poplar, spruce, douglas fir, etc. The effects of ply organization on the mechanical properties of LVL elements have been studied, demonstrating that poplar and beech LVL beams offer a higher bending strength and modulus of elasticity (MoE) compared to solid elements (Burdurlu et al. 2007).

By using continuous press, LVLs of long span length preferable for structural applications can be manufactured as shown in figure 2, a and b.

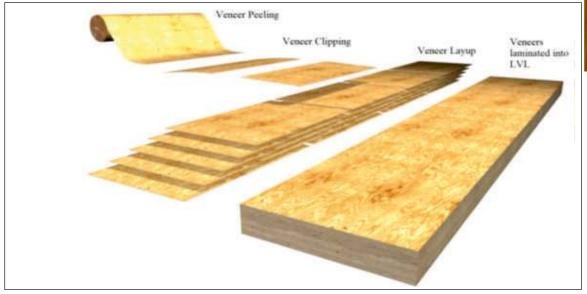


Figure 1. Manufacturing process of LVL.

Source: https://www.raute.com/industries/lvl-production/





Figure 2. (a) Prepressed LVL billet of long span.

Figure 2. (b) Long span LVL.

Source: https://www.raute.com/lines-and-machines/lines/lvl-lay-up-and-pressing/

In some cases, cross band veneers, i.e. veneer whose grain direction is perpendicular to the grain direction of the primary veneers are allowed as shown in figure 3. Thin LVLs can be bonded by face-gluing to achieve an LVL product of higher thickness, called glued LVL (GLVL).

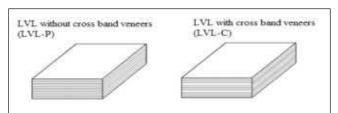


Figure 3. LVL without cross band and with cross band. Source: https://puutuoteteollisuus.fi/images/pdf/LVL_bulletin_eng.pdf

Mechanical properties of LVL can be further enhanced by providing suitable reinforcement at optimal locations within the thickness of the composite (Bakalarz et al. 2019). Poplar (Populus euramericana cv.), one of the most important fast-growing tree species in

China is utilized mainly for non-structural applications. It is found that reinforcing LVL from poplar species with carbon fibre reinforced polymer (CFRP) enhances its mechanical properties advocating it to be used for structural applications. LVL with single reinforcement (LVL-SR), i.e. reinforcement provided on one side of the lumber yielded a 40% increase in the modulus of elasticity (MOE) whereas LVL with double reinforcement (LVL-DR), i.e. reinforcement provided on both sides of the lumber yielded 67% increase in the MOE as compared to the control sample (Wei et al. 2013). Similarly, the modulus of rupture (MOR) was enhanced appreciably as shown in figure 4.

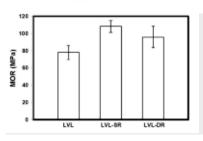


Figure 4.
Bending MOR of three LVL configurations (Wei et al. 2013).

Properties such as strength and stiffness of LVL made of poplar reinforced with fibre reinforced polymer (FRP) made of carbon and basalt was studied and it was found that these properties significantly improved with the reinforcement (Rescalvo et al. 2022). Similar studies have shown that the weakest wood material obtained the greatest improvements in their mechanical properties when reinforced, allowing to obtain stiff second quality poplar LVL, or strong second quality douglas fir LVL (Rescalvo et al. 2020).

Applications

High mechanical properties of LVL makes it ideal for structural applications (Rahayu et al. 2015). The modulus of rupture in bending of LVL is higher than solid wood with less variations because of the even distribution of natural defects such as knots, slope of grain or splits (Laufenberg 1983). Due to its composite nature, LVL is stronger, straighter, more uniform and also much less likely than conventional timber to warp, twist, bow or shrink. Durability, light weight and dimensional stability makes LVL to be used for headers, columns, rim boards, I-beams, large span prefabricated house and other such structural applications. Uniformity trough out the span, ability of production from regional short rotation plantation timbers such as Melia dubia has made LVL to be considered as an important solution concerning raw material economy as converting the logs in to veneers results in higher percentage of recovery from short rotation small girth logs (Prakash et al. 2019).

Based on the uses, LVL is divided into two categories: structural and non-structural, where the structural LVL is used in the high-bearing-capacity field and non-structural LVL is applied in areas protected from loads or which require a low carrying capacity

LVL is uniform and comparable to solid timber in strength. Its strength can be enhanced by using suitable reinforcement up to a level comparable with concrete and steel.

(Qureshi et al. 2015). LVL is used in structural framing, where high strength and stiffness are required. LVL is also more dimensionally stable than solid sawn lumber and it may be produced in large dimensions from small logs (Kamke 2004).

Advantages of LVL

LVL is uniform and comparable to solid timber in strength. Its strength can be enhanced by using suitable reinforcement up to a level comparable with concrete and steel. It is also more durable and less prone to shrinking or warping, although its durability to some extent depends on the species of timber used in its manufacture. Other advantages of LVL in construction are its relative low cost, and the fact that it can be manufactured at any length and desired shapes which creates a great opportunity in architectural design of timber structures. A worth noting example for versatility of LVL is Metropol Parasol shown in figure 5, which is a mass timber construction located at La Encarnacion square in the old quarter of Seville, Spain. Having dimensions of 150 by 70 m (490 by 230 ft) and an approximate height of 26 m (85 ft) believed to be the wooden structure in the world built using highly loadbearing Finnforest Kerto LVL manufactured in Finland.





Figure 5. Metropol Parasol in Seville.

Source: https://www.architecturedesign.com.au/features/product-in-focus/laminated-veneer-lumber-lvl-product-review-and-lea

Another such example is Netball Central of Austalia shown in figure 6. It is the first sports facility to be built at Olympic Park since the Sydney 2000 Olympic Games. This giant wooden shed, a gable-roofed portal frame of LVL, is large enough to house five international-standard courts; a show-court seating 800+ people; education rooms; player, official and spectator facilities; Netball NSW offices and NSW Swifts training facilities—all within a tight, triangular site.









Figure 6. Netball Central located at Sydney. Source: https://www.scottcarver.com.au/our-projects/netball-central

Research prospect

The Consortium for Research on Renewable Industrial Materials (CORRIM), has conducted a life cycle inventory (LCI) for major wood products and wood production regions in the United States. Their study 'Cradle to gate life cycle assessment of laminated veneer lumber production' has analysed the energy and material inputs and outputs associated with the production of LVL from which it is observed that 186 kg CO₂e were released in the production of 1 m³ of LVL whereas the same 1 m³ of LVL stores 954 kg CO₂e (Puettmann et al. 2013). These findings suggest that there is a net carbon stored in LVL, terming it as green product, when compared with products such as steel which are used for similar applications. Replacing steel with LVL also contributes towards the reduction of global warming and negative impact on the climate change. Promoting usage of high quality LVL in place of steel should be considered to erect structures similar to the examples given above which encourages the industries to take up mass production which brings down the product cost. Strength of LVL can further be increased with reduction in thickness by providing suitable reinforcement at optimal distance from the surface. Reinforcement can either be single or multiple depending on the target strength properties which relies on the end use applications. Usage of LVL for interior applications has to be encouraged to support the growth of its market in India. LVL for interior applications such as furniture, structural members, namely window and door frame, rails and stiles of flush door, etc. should be manufactured using moisture resistance (MR) grade adhesives as boiling water proof (BWP) grade resin (phenol formaldehyde, melamine, etc.) bonded LVL for such applications results in injudicious usage of resources and increases the production cost which hinders LVL market growth. To support this, policies such as product standards are to be changed accordingly. Suitability of regional plantation timber for manufacturing LVL should be studied by research institutes to encourage industries to adopt such technologies by which employment generation can be achieved to a certain extent apart from developing alternate structural material to steel and concrete whose manufacturing has more negative impact on the environment. LVL also acts as carbon sink during its service there by contributing to the well-being of the environment.

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Common Facility Centre at IWST

Common Facility Centre (CFC) has been established inside IWST campus during the year 2016. The CFC houses many modern wood working and bamboo processing machines. CFC extends wood and bamboo processing facilities to various stake holders,

self-help groups, NGOs, wood based small scale/cottage industries and local artisans. All the machines can be used on payment basis during all working days (Monday to Friday) from 9:00 AM to 5:30 PM. The details of available wood working and bamboo machines and their description are given below.

A. List of Wood and Bamboo Working Machines

No.	Name of Machinery	Description
1	Surface Planer	Suitable for removing rough surface of the wood by planing.
2	Thickness Planer	Suitable for sizing the piece of wood in two dimensions
3	Sliding Table Panel Saw	Suitable to cut a wood lumber/panel board to the required sizes in different cutting like rip cut, & scoring for pre lamboard.
4	Small Table Circular Saw	Suitable for rip cutting, cross cutting, and chamfering of wood.
5	Multi Spindle boring	Suitable for multi boring on wood/panel boards like vertical, horizontal
		and angular bores.
6	Spindle Molder	Suitable for edge profiling and contouring.
7	Belt Sander	Suitable for sanding the surface
8	Finger Jointing Machine	Suitable for joining small solid wood pieces
9	Seasoning Kiln	Suitable for seasoning the wood(Capacity: 200 cft)
10	Bamboo Cross Cutting	Suitable for cross cutting of Bamboo culms.
11	Bamboo Semi Half Splitting	Suitable for splitting the bamboo culms to rectangular strips.
12	Bamboo Variable Size splitting	Suitable for splitting the bamboo culms to number of strips.
13	Bamboo External Knot Removing	Suitable for removing external knots of bamboo culms.
14	Bamboo Thickness Planning	Suitable for thickness planning of bamboo strips to variable size.
15	Bamboo Slat Gluing	Suitable for gluing the bamboo strips for making panel of different sizes.
16	Bamboo Panel Drier	Suitable for drying glues bamboo panels.

To use the facility and for further details, please contact:

Officer incharge of Common Facility Centre, **Institute of Wood Science and Technology**18th Cross, Malleshwaram, Bangalore Ph:080 22190178, E Mail: cfc_iwst@icfre.org

One year Diploma in Advanced Woodworking

Course Description:

The Diploma Course was launched in the year 2018-19 jointly with M/s. Biesse Manufacturing Company Private Limited. This program offers an excellent opportunity for trainees to acquire required skill set to work on wood and wood products. This course structured to provide first hand experience in handling state of the art machineries to make them employable in wood based industries. This course has eight major modules namely, Fundamentals of wood materials, Fundamentals of Engineering, Wood processing using advanced machines & allied processes, Loading & unloading systems, machinery safety, maintenance of machines, Assembly & Joinery, Advanced application of software (CNC, CAD/CAM & 3D-Pytha) and project work. Upon successful completion of training, the trainees will be able to handle most of the advanced woodworking machines that are used in the wood based industries.

Eligibility : Pass in Pre-University Course/Senior Secondary/ XII/ Equivalent from

recognized Board. (Graduates in Science / Forestry / Engineering are

encouraged to apply).

Course Fee : Rs. 50,000/- for the entire course

Extra : Rs.1,650/- per month towards Accommodation Charges Food Charges

(as per actual)

Security Deposit : Rs. 5,000/- (Refundable)
Intake : Maximum 30 Candidates



INSTITUTE OF WOOD SCIENCE AND TECHNOLOGY

(Indian Council of Forestry Research and Education)

An Autonomous Body of Ministry of Environment, Forest and Climate Change, Govt. of India P.O. Malleswaram, Bengaluru – 560 003, India Website: http://iwst.icfre.gov.in/awwtc/awwtc.htm Ph: 080-22190148, 150 Fax: 080-23340529 E-Mail: awtc iwst@icfre.org,dir iwst@icfre.org

Suitability of Hardwoods for Cross Laminated Timber Production

Introduction

n the 1990s, Europe saw the emergence of cross-laminated timber (CLT) as an engineered wood product (EWP) that has subsequently given rise to a new category of structural timber products known as 'mass' timber. It is a wood-based engineered solution and an alternative to concrete, masonry, and steel systems. To construct CLT, a kind of prefabricated engineered wood, layers of boards are stacked (typically at 90 degrees) on their wide sides and, rarely, on their narrow faces as well and bonded together using structural grade adhesive (figure 1). In some structural applications, it may be essential to laminate layers of wood at angles other than 90 degrees. CLT generally has an odd number of layers, such as 3, 5, or 7, but may contain more levels. CLT products are available in widths of 0.6 m, 1.2 m, 2.4 m, and 3 m and lengths of up to 18 m, and thicknesses of up to 508 mm. Currently, majority of CLT is used for flooring, walls,

and other construction components. There are several advantages in using CLT for prefabricated wall and floor assemblies, and the reinforcement effect provided by the crosslamination in CLT also greatly boosts the splitting resistance of CLT for certain types of connection systems.

As specified by the American National Standards Institute (ANSI), CLT is produced by gluing together the longitudinal and

transverse layers of solid-sawn lumber using structural adhesives to form a solid rectangular element intended for roof, floor, or wall applications. Because of the crosslaminated structure, the qualities such as rigidity, stability, and mechanical properties are enhanced. By using the computer numerical control routers, the CLT panels are cut quickly and accurately to size and openings are made for windows, doors, and service channels during manufacturing. After the prefabrication, the panels are brought to the building site, where they are linked using metal connectors such

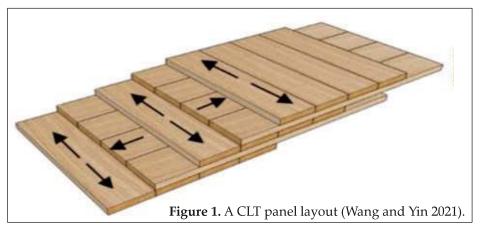
Priyank Maithani*, Anil Kumar Sethy, Shakti Singh Chauhan and Navneet Singh Sirswal

Wood Properties and Processing Division, ICFRE - Institute of Wood Science and Technology, Bengaluru

*Email: pmaith.2010@gmail.com

as steel angles and metal splines and attached with self-driving screws and dowels (Crespell and Gagnon 2011).

CLT has performed well in fire (Rizzo 2012) and seismic evaluation, enabling the spans that would be unachievable with conventional wood materials (Ceccotti et al. 2003). CLT is a structural material alternative to steel and concrete that enables faster installation times, reduced construction costs, less waste, and less environmental harm. There is evidence that using wood in building is more environmentally friendly (Hubbard and Bowe 2010), though its popularity has been criticized for its environmental and fire safety issues (Alter 2015). CLT structures have less embodied energy, lower ozone depletion and global



warming potential as well as lower eutrophication effect than either concrete or steel (Robertson 2011; Chen 2015).

The great majority of CLT produced is made up of softwoods such as Norway spruce (Picea abies), White fir (Abies alba), Scots pine (Pinus sylvestris), European larch (Larix decidua), Douglas fir (Pseudotsuga menziesii) and Western larch (Larix occidentalis) (Brandner 2013). However, there is a growing need for hardwood species CLT (Tratzmiller 2010; Hovanec 2015; Jeitler et al. 2016; Franke 2016). The desire to use

underutilized or low-value hardwoods (Callegari et al. 2010; Thomas and Buehlmann 2017) and changes in forest composition, particularly in Europe, are the further considerations (Schelhaas et al. 2015; Franke 2016).

This study reviews the existing literature on the production and use of hardwood cross l a m i n a t e d timber (CLT) and explores its technical and economic viability. Insights on CLT's ecological, cost-effectiveness, and aesthetical features have drawn the attention of construction professionals, developers, and academics all over the globe. Despite the growing interest in the possibility of manufacturing CLT from a wide range of hardwood species, practically now all the CLT buildings are made from softwoods. In spite of this, the fundamental impetus for researching the possibilities of hardwood CLT has been the search for high valueadded applications for underutilized or low-valued hardwood species, as well as the desire to capitalize on the unique mechanical capabilities of certain hardwood varaieties. Although there is a paucity of knowledge, it seems that hardwood CLT is theoretically viable, and have fascinating uses. Before the hardwood CLT can become a reality, the hardwood sector must overcome certain obstacles highlighted in this article. This article also highlights the latest developments made by Institute of Wood Science and Technology, Bengaluru in the production of hardwood CLTs.

Research status on hardwood CLT

Research on hardwood CLT is progressively gaining worldwide interest, with North America and Europe ahead. Hasslacher Norica Timber, a manufacturer of forest products with facilities in Austria, Slovenia, and Russia, collaborated with Graz University of Technology to evaluate the mechanical properties of CLT manufactured from birch (Betula pendula), harvested from the St. Petersburg region of Russia. This material was used to create a multi-story building in Graz, Austria, and a single-family residence in St. Magdalena am Lemberg, Germany (Jeitler et al. 2016). The mechanical testing was conducted in compliance with EN 1995-1-1 specifications. It was determined that Birch CLT has a rolling shear strength of 1.8 N/mm², bending strength of 38.1 N/mm², modulus of elasticity (MOE) of 15,349 N/mm², and compressive strength of 38 N/mm². Spruce CLT has a rolling shear value between 0.7 and 1.2 N/mm². Birch CLT showed higher mechanical properties than softwood CLT, resulting in a 10 to 15% reduction in the quantity of wood necessary to build a detached house.

University of Stuttgart researchers have also

experimented with beech-spruce hybrid CLT (Aicher et al. 2016). European beech (Fagus sylvatica) wood was subjected to three distinct rolling shear tests. Shear collapse throughout the length of spruce layers was the most common catastrophic occurrence. In terms of strength and stiffness, the authors determined that hybrid CLT is preferable than CLT constructed entirely from spruce (Aicher et al. 2016). Franke (2016) also prepared and evaluated beech CLT panels of 120 mm with varied layer thicknesses (2.4, 10, 20, and 33 mm). The samples were subjected to shear, bending, compression, and delamination tests. The tested samples showed a greater rolling shear (4.8 times), bending strength (1.7 times) and compression strength perpendicular to the grain (1.8 times) than spruce CLT. After a comprehensive analysis of the data, the scientists concluded that beech CLT provides interesting applications where CLT panels may be employed as plates and shell components loaded out of plane and in plane direction.

The Bern University of Applied Sciences analysed the market for glued hardwood products in 2015 (Naher et al. 2015). While beech (Fagus sylvatica) comprises 18% of Switzerland's overall standing forest inventory, this species has not yet developed a strong position on the Swiss market (except as firewood). Therefore, Naher et al. (2015) investigated the possible applications of beech-based products in the building materials industry, focussing on beech glulam and beech crosslaminated wood. The researchers examined the market potential of beech glulam and beech cross-laminated timber by analysing their product specifications, important applications, alternative goods, and market rivalry. According to them, beech permits both larger as well as smaller spans and more aesthetically pleasing for structural timbers, however its full potential cannot be completely realised without improved connectivity. For the purpose of this research, Naher et al. (2015) assessed the possibility of employing beech glulam and beech CLT in the building of a Swiss sports stadium. Under four use scenarios ranging from light to heavy, the authors determined the required amount of wood for the arena. Early estimates for the sports arena indicate that hardwoods, with their better mechanical properties, offer a great deal of construction potential. A hardwood glulam/CLT structure utilizes less wood than one produced from softwood to provide the same functionality.

Another research conducted at Laval University in Quebec, Canada, examined the large-leaf beech (Fagus grandifolia Ehrh.) as a prospective source of raw material for CLT (Essoua and Blanchet 2017). The major

objective of the study was to examine the performance of a variety of polyurethane adhesives employing block shear and delamination tests. According to the researchers, the significant volumetric swelling and shrinkage of beech wood (26.9% and 19.0%, respectively) have issues with the adhesives used in this kind of panel. However, the results of this investigation are within the range permitted by the Canadian criteria for block shear and delamination tests. The authors suggested that more testing of CLT panels are essential. They noted that the information offered here may be useful since it offers new opportunities for enterprises that manufacture structural wood products using locally produced materials.

From an engineering perspective, Zollig (2013) describes the constraints of wood construction for spans exceeding 8 x 8 m (column grid) and weights above 500 kg/m². Numerous experiments were conducted to determine the optimal geometry of the grid arrangement, the impact of rolling shear stresses on layer thickness and orientation, the viability of different species or species mixtures, and the effects of pedestal head cap form on structural integrity. Hardwood CLT, such as beech or ash, is about 275% stronger than softwood CLT, and the lamella thickness is crucial to the performance of the component. The geometry of pedestal head cap tests indicated a high fracture strength of hardwood-based constructions, demonstrating the viability of hardwoods in the construction of long-span structures. The reviewed literature, however, reveals that it is technically possible to construct CLT with certain hardwood species, leading to structural performance that is on par with, if not superior to, commercially available softwood CLT. Hardwood CLT's superior strength properties (bending strength, compressive strength, shear strength, and rolling shear modulus) are its most notable benefit. Research into the production of CLT from hardwood species is often driven by a desire to find new, valuable applications for the material, which is both plentiful and often neglected. Some researchers have also speculated that the use of hardwoods in CLT might lead to novel contexts for this kind of engineered wood.

Utilization of hardwood CLT

CLT made from hardwood is frequently utilized in industry, however literature on this issue is very scanty. Hasslacher Norica Timber, an Austrian forest products business, utilized birch CLT to construct a home near Lemberg (Jeitler et al. 2016). The company continues to provide commercially available Birch CLT (Hasslacher Norica Timber 2017). The British design company

Waugh Thistleton is constructing a new factory and headquarters for the furniture manufacturer Vitsoe using beech CLT (Thompson 2017; Waugh 2017). Several US forest service-funded projects have examined the feasibility of producing CLT from low-value or low-grade hardwoods. IKD, an architectural design business located in Indianapolis, Indiana, constructed a prototype utilizing panels made from ash, hickory, oak, and maple supplied from the state (Brindley 2017).

The American Hardwood Export Council, a trade group for the US hardwood industry responsible for the growing demand of US hardwood timber abroad, has contracted out the construction of yellow poplar (tulipwood, Liriodendron tulipifera) CLT buildings (American Hardwood Export Council 2016). One such instance is the Endless Stair, which debuted at the 2013 London Design Festival. The Endless Stair is a huge structure with 15 interconnected stairs, designed by Rijke Marsh Morgan Architects and constructed by Arup. The three-layer CLT used for the stair treads and handrails was constructed from yellow poplar wood (Slavid 2013). A life cycle study was also mandated by AHEC to evaluate the full breadth of the project's environmental effect. It was discovered that the carbon content of the wood alone exceeded the entire carbon emissions from production, shipping, and assembly of the project. According to the results, the 100 m³ of yellow poplar on the Endless Stair may be regrown in less than 2 min. Alison Brooks architects exhibited their most current design, The Smile, on the Chelsea College of Arts campus in London more recently. Once again, Arup was responsible for the engineering. The Smile's astounding dimensions are 111 feet in length, 11 feet in height, and 15 feet in breadth due to its curved and hollow design.

In Indiana, one can encounter another instance of hardwood CLT in a structure. IK design constructed the conversation plinth at the Cleo Rogers Memorial Library in Columbus, Indiana utilizing CLT manufactured from hardwood lumber scraps. The conversation plinth was made by Yugon Kim and Tomomi Itakura. According to Yugon Kim, the structure demonstrated the superiority of hardwood CLT over softwood CLT.

Challenges

EN 16351 and ANSI/APA PRG 320 both specify the production procedure for CLT. Almost every nation follows these guidelines while manufacturing CLT. The majority of hardwoods are excluded from these normative frameworks. Only poplar is regarded a

hardwood in Europe, and our knowledge of the other species is at best limited. This is a significant challenge, since standardization of species is required prior to their mass production. Since there are no commercial sources for hardwood CLTs, their usage in manufacturing is very limited.

The majority of hardwoods and softwoods have specific gravities (SGs) higher than 0.35, although the standards exclude subalpine fir (0.32 SG), Northern white cedar (0.31 SG), and Western red cedar (0.35 SG) (0.32). Despite the importance of species-specific shrinkage in delamination, adhesion, and structural design, ANSI/APA PRG 320 does not account for it. Hardwood species often display 30% larger shrinkage values than softwoods, which might have implications on the design, production, and service performance of CLT panels. The same problem applies to the European standard.

The wood used to manufacture CLT must have a moisture content (MC) between 12 and 3%. The moisture content of softwoods used in building is reduced to 15–19%. Wood with a moisture content (MC) between 6 and 8% is ideal for furniture, flooring, kitchen cabinets, and millwork. As a result, the hardwood sector has a wealth of expertise in drying timber to lower moisture levels; yet, drying periods for hardwoods are often longer than softwoods of the same thickness and final moisture content (Simpson and Hart 2000). Eastern white pine (Pinus strobus) needs just two to three days to go from air-dried state (initial MC of 20%) to 6% MC, but drying rates for yellow poplar (one of the quickest drying hardwood species) are six to ten days from green condition (Simpson 1991). The quantity of volatile organic compounds (VOCs) generated during the drying process differs between hardwoods and softwoods, with most hardwood species emitting less VOCs. Compared to the 3.0 lb/MBF (1 MBF is equal to 1000 board feet) of VOCs created by drying southern yellow pine, yellow poplar creates just 0.71 lb/MBF of VOCs throughout the drying process (Rice and Erich 2006). Less volatile organic compounds are produced during the drying process of hardwood as compared to softwood, making it more eco-friendly (Milota and Mosher 2008).

Hardwoods are favoured by structural designers and planners because of their superior mechanical properties, which potentially permit lower cross sections and longer spans or the support of higher loads. Compared to softwoods such as spruce, hardwoods such as oak, ash, and beech can withstand 2.5 times as much tension, and 1.5 times as much bending and compression, when measured perpendicular to the

grain. Likewise, the modulus of elasticity is crucial for flooring. 95% of a CLT panel's stiffness is attributable to its outside layers. Consequently, hybrid panels might be manufactured with hardwood on the outside layers and a material with lower stiffness and strength in the core, reducing both cost and weight (Franke 2016).

Regarding the glue adhesion and other properties, the hardwoods differ from those of softwoods and this must be accounted for in any designs of CLT manufactured with hardwood species. Hardwoods need a bigger press capacity than softwoods because of their denser, harder, and stiffer wood. Due to the larger dimensional changes brought by moisture variations, the increased density may also produce bond line strain (Essoua and Blanchet 2017; Martins et al. 2017). Hardwoods have more extractives than softwoods, and the acidity of these extractives may hinder or halt the curing process. Therefore, adhesives suited to either hardwoods or softwoods must be developed. Whenever feasible, one should use a thick glue line, and it may be needed to prime or otherwise prepare the surface beforehand. To overcome these challenges, it is essential to collaborate closely with the glue manufacturer.

Cost analysis

The cost of wood is the major element in CLT production and is sometimes estimated to account for almost half of the total manufacturing expenses (Anderson 2016). Consequently, the price of wood is a crucial determinant of whether or not hardwood CLT is a feasible alternative. The costs of CLT should be determined by factoring its differences in the market value of other structural materials. It is usually believed that the relatively high costs for wood structural connections result in a 10-15% premium for a bare wood structure over a comparable steel or concrete building. Despite the fact that the structural frame accounts for less than 20% of overall building expenditures, a CLT structure may be up to 5% more costly than one made from traditional materials (steel, concrete) (Lawrence et al. 2016). In Europe, the market price for CLT built from spruce (Picea abies) or fir (Abies alba) was around \$700 per cubic metre, according to Swiss CLT manufacturer contacts; however, best estimate for the cost of test CLT manufactured from beech was \$3200 per cubic meter (Leibundgut 2016).

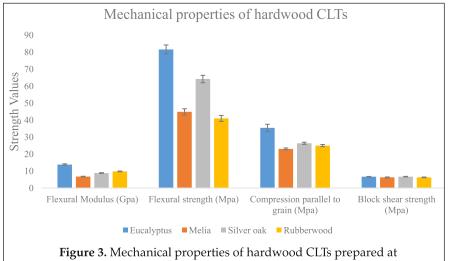
Hardwood and softwood timber are graded, processed, and priced differently owing to their very dissimilar ultimate uses. Hardwoods are used for more visually pleasant applications, including furniture,

flooring, and millwork, than softwoods. Hardwood timber grades are visually determined by the number of clean cuts (imperfection-free sections) that can be sawn from a single board, while softwoods are primarily evaluated based on their structural performance. Hardwood logs are often sawn to maximize B-grade recovery, but softwood logs are typically sawn to maximize throughput and value depending on the dimensions that provide the maximum return based on current market price. Despite the fact that hardwood sawmills tend to be bigger and more efficient than their softwood counterparts, the hardwood lumber industry is more fragmented and consists of a number of smaller mills with lower productivity. There are many reasons why hardwood lumber is costlier than softwood timber.

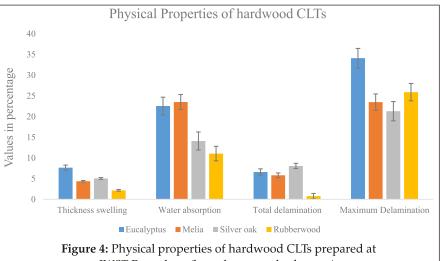
In today's highly competitive construction market, the feasibility of hardwood CLT rests greatly on its ability to compete on price. Therefore, hardwood CLT must either have lower manufacturing costs or provide benefits over softwood CLT to command a premium pricing (Thomas and Buehlmann 2017). Using inferior logs to conastruct CLT or less expensive species, in combination with softwoods, is an exciting new technique for reducing costs (Essoua and Blanchet 2017). Even if material prices decrease, the processing of a product with more flaws and smaller dimensions may raise manufacturing costs. White oak and chestnut are examples of hardwood species whose inherent resistance to weather and moisture, strength that allows for fewer components, and aesthetic quality like colour are among the many desirable characteristics of hardwood CLT that are difficult to achieve with softwood CLT. Hardwood CLT may replace softwood CLT in many applications; but, if the former cannot be made more cost-effective, the latter may remain a specialised product utilized only in areas of structures that are sensitive to bigger weights or broader spans.

Indian context

In the Indian context, Institute of Wood Science and Technology, Bengaluru has made some progress in this direction. Rubber wood (Hevea brasiliensis), Silver oak (Grevillea robusta), Eucalyptus (Eucalyptus hybrid), and Melia wood (Melia dubia) are among the fastgrowing plantation timbers that the institution has successfully used to prepare CLTs. The physical and mechanical properties of the aforementioned hardwood species were examined in line with the European standard EN 16351, since there is little information about them in presently available global standards. These plants are grown for the advantages they provide to agroforestry and farm forestry systems. Not much research has been conducted on these species to explore CLT. Figure 3 shows the mechanical properties of different CLTs prepared at Institute of Wood Science and Technology, Bengaluru. The physical properties of different CLTs has been highlighted in figure 4.



IWST Bengaluru (vertical bars show standard errors).



IWST Bengaluru (bars show standard errors).

It is clearly evident from the data that fast growing plantation species have a vast potential in terms of mechanical properties. Since hardwoods have higher shrinkage and swelling coefficients than softwoods, the orthogonal arrangement of layers in CLT panels can help us in overcoming such issues. The superior qualities as well as the potential of hardwoods can be utilized for developing sustainable construction material and promoting the concept of green building.

Conclusion

Hardwood CLT, constructed from a range of hardwood species, offers promise as a novel solution to many challenges in construction industries. The hardwood forestry and sawmilling sectors might benefit from the availability of a market for industrialgrade hardwood CLT products. As a CLT raw material, hardwood has its own unique difficulties. To achieve the required technical standards for hardwood to be recognized as a material in the current CLT standards, the hardwood industry will need to collaborate. Prior to competing in the building industry, hardwood CLT needs improvement in areas like sourcing, grading and adhesive bonding. The hardwood business must be resourceful to mitigate the negative effects of higher hardwood CLT price as compared to softwood CLT prices. Hybrid panels that include a core of softwood with layers of higher-quality mechanical hardwoods may have economic value. These hybrid panels may deliver the requisite decay resistance and acoustic qualities in a cost-effective manner. Widening the market for underutilized and/or low-value hardwoods may benefit the economic well-being of all stakeholders involved in the hardwood value chain.

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Wood Technologist Association (WTA) is India's apex non-government organisation of plywood & other wood-panel based industries, providing a unique platform for all stakeholders: Government - Research Institutions – Industry – Machine Manufacturers - Technologists - Agroforestry Farmers, to interact and introduce path-breaking measures for progress of the industry.

WTA strives to make true the vision of Hon'ble Prime Minister Shri Narendra Modi of making wood-sector "ATAMNIRBHAR" and for past 12 years has been relentlessly pursuing the cause of its stakeholders, addressing their key issues and seeking suitable policy-changes with Government agencies (MoEFCC, FRI, IPRITI, FIPPI, IWST and others).

WTA, led by President: Shri S.C. Jolly & a team of professionals' technologists / field-experts, also collaborates with international wood-chambers / associations for mutual co-operation & adoption of best practises in the industry. WTA has organised host of conferences, seminars, training workshops, awareness campaigns and Industry-meets for taking forward initiatives of the industry.

WTA is a member of:

- 1. Bureau of Indian Standards (BIS) CED-9 CED-20 Committees.
- 2. President WTA (Shri S.C. Jolly) is a Member of Managing Committee of FIPPI.
- 3. President WTA (Shri S.C. Jolly) is a Member of Steering Committee of IPRITI.
- 4. President WTA (Shri S.C. Jolly) is a Life Member of IWST, Bangalore.
- 5. WTA, since the past decade, is in continuous dialogue with Ministry of Environment, Forests & Climate Change (MoEF&CC) and made representations to their Hon'ble Ministers: Shri Jairam Ramesh, Shri Anil Madhav Dave, Dr. Harsh Vardhan and recently to Shri Prakash Javdekar for bringing forth relevant issues of plywood industry.
- 6. WTA submitted Memorandums to MoEF&CC on various occasions for considering demands of the Industry /Stakeholders for driving suitable policy-changes like reduction in GST, lease of barren-land to farmers for enhancing green cover by plantation drives, research & development on Melia Dubia as substitute of face-veneer, foreign-currency savings through reduction in imports, transportation-subsidy and similar issues. Recently, on WTA's perusal, the e-Transport facility for farmers was agreed upon by Government of India.
- 7. WTA and FRI (Dehradun) collaborated under Green India Mission to organize Industry-Institute- Farmer- Meets at Ludhiana (Punjab), Yamunanagar (Haryana) and Pantnagar (U.P).
- 8. WTA's key role in agroforestry was explained to Shri C.K. Mishra (Secretary, MoEF&CC) by Shri Manoj Gwari (Secretary, WTA) at a meet organized at Forest Research Institute, Dehradun.
- 9. WTA hosted international delegations from Malaysia, China and Ghana for partnership dialogue with Indian Plywood Business Groups. In a recent visit of Sarawak Timber Association from Malaysia, WTA coordinated and organized their meetings with IPIRTI and other agencies.
- 10. WTA, under aegis of Shri S.C. Jolly, started the National WhatsApp Group: "Agroforestry" bringing together key decision-making administrators, leading industrialists and other subject-matter experts, during the COVID times for suggesting and implementing the way-forward for overcoming challenges being faced. The patronage and active-participation of all members including Additional Secretary Dr. Alka Bhargava, Dr. Arun Rawat (DG, ICFRE & Director, FRI), Dr. M.P. Singh (Director IPIRTI & IWST), and other eminent personalities (Industry Association heads, Senior-Industrialists & Technical experts) has brought out innovative & viable solutions.
- 11. WTA participated and organized multiple webinars in which leading subject-experts shared views / opinion about how to tackle the problems being faced by each stakeholder
- 12. WTA (Shri G. Rajput, V.P) participated in R&D work with Senior Scientist Shri D.P. Khali, FRI.
- 13. WTA organized numerous hands-on trainings with the Industry for aspiring Technologists.
- 14. WTA assists in industry placement of Technologists pan-India as per their skill-set.

WTA, in coming times, endeavors to take forward the best-interest of Indian Plywood Industry!

5B-F, Professor Colony, Yamuna Nagar, Haryana (India)

E-mail ID: woodtech_india@rediffmail.com Contact: +91-78958 87383

Cross-Laminated Timber from Plantation Species: Silver oak and *Melia dubia*

Introduction

ass timber products such as cross-laminated timber (CLT), glued-laminated timber (glulam), -nailed-laminated timber (NLT), and structural composite lumber (SCL) are increasingly used for building applications. CLT is a wood panel product made from gluing together layers of solid-sawn lumber. Each layer of boards is oriented perpendicular to adjacent layers and glued on the wide faces of each board, usually in a symmetric way so that the outer layers have the same orientation. CLT is a stiff plateshaped product composed of an appropriate number of layers 3, 5 or 7, where each layer is made of boards placed adjacent to one another, and where neighbouring layers are most often glued at an angle of 90° to one another. This multi-layered and highly optimized structure provides in-plane and out of plane carrying capacity, so it can be used as wall and floor panels. The product is characterized by a high level of prefabrication and hence the on-site work is rapid, mostly involving only assembly and connection of individual panels. By gluing layers of wood at perpendicular angles, the panel is able to achieve better structural rigidity in both directions similar to plywood but with distinctively thicker laminations.

The excellent performance of CLT with its environmentally friendly attributes, ease of application, quick assembling, etc. has made it one of the preferred material for designers. The CLT has the advantages of high prefabrication rate, design flexibility, thermal insulation, eco-friendly, convenient transportation and fast installation, and low damage to the site environment. Thus, it is considered as the best substitute for traditional building materials. The crosswise layup method in the CLT makes it possible to fully use the material characteristics of the high tensile strength of the wood in the direction of the grain and the high compressive strength in the transverse direction.

Most important activities involved in the development and manufacturing of CLT around the world include research, development, production, fabrication, utilization, and standardization. Only a few

B. S. Mamatha, D. Sujatha, D. N. Uday, V. Prakash, Anand Nandanwar, M. C. Kiran and Manoj Kumar Dubey

ICFRE – Institute of Wood Science and Technology, IPIRTI Campus, Bengaluru

Email: sheshagirimb@icfre.org

countries have buildings constructed with CLT panels and not all the countries have established CLT manufacturing standards. Manufacturing of CLT and using in the construction of building require specific standards. These manufacturing standards correspond to the steps of producing CLT of consistent quality for construction purpose. Standards provide uniform specifications for evaluating the properties of CLT relating to the material properties of the timber boards such as strength, stiffness and usage of structural adhesives. These standards would facilitate the use of local timber/plantation species, suitability and appropriate method of manufacture of CLT.

CLT can be prepared by mechanical fastening or by bonding with adhesive. Adhesive bonded are more preferred because of their durability and fire resistance, and enhanced performance. Adhesive-bonded CLT segment is witnessing a higher growth rate in the global CLT market. Adhesives play a major role in the performance of CLT. The adhesive used in CLT applications needs to meet stringent product standards. It also must comply with the manufacturer adhesive specifications. Adhesives such as phenol resorcinol formaldehyde resin, polyurethane resins, melamine urea formaldehyde resin and emulsified isocyanate resin are generally being used for the manufacturing of CLT.

CLT is not produced in India. In India, plantation species such as poplar, eucalyptus, silver oak, *M. dubia*, rubber wood are mainly used for plywood, particle board and medium density fibre board. Silver oak and *M. dubia* are the two major plantation wood species in southern states of India. Now we aim to utilize these fast-growing plantation species as mass-engineered timber. For the manufacture of CLT cold setting adhesives are generally used. In this study phenol formaldehyde resin adhesive was formulated with hardeners accordingly for curing at ambient temperature for the manufacture of CLT.

Prior work

According to Guo (2007), laminates used in manufacturing of CLT should not be too thick or thin. For n overall thickness dimension, if the laminate is too thick, it will cause the structure of the component not to be uniform, which could cause a defect that is too concentrated. If the laminate is too thin, not only are there higher demands of the manufacturing process, but it also increases the amount of wood and resin (Wang et al. 2018). Omar Espinoza et. al. (2016) stated in his report that the most important research needed for CLT development are in the areas of structural performance and connections, moisture performance, and market research. In Austria, the widely accepted standard for CLT layer thicknesses are 20 mm, 30 mm and 40 mm. During the production of single-layer panels, the suitability of the adhesive system used for edge bonding must be assured in the framework of an internal and external quality control procedure. Examples of frequently used and suitable adhesive systems are aminoplast adhesives (type I: melamineformaldehyde, MF; melamine-urea-formaldehyde, MUF) and one-component polyurethane adhesives.

Brandner (2013) defines the required surface bonding pressure as a function of the (i) adhesive system, (ii) the timber species, (iii) the geometry of the adherents regarding roughness and flatness of the surface and allowed tolerances in thickness, (iv) the adhesive application system and (v) the applied quantity of adhesive. Brandner (2013) has stated that the types of adhesives can be differentiated first into close contact and gap-filling adhesives and secondly into swelling (e.g., polyurethane adhesives) and shrinking adhesives (e.g., aminoplast-adhesives and phenoplastadhesives). According to Kairi (2009), these characteristics have a significant impact on the required pressure. Phenol and melamine based adhesive system requires pressure of 1.40-2.00 N/mm² where polyurethane bonding can theoretically be done with 0.01-0.10 N/mm² (Kairi 2009 as cited in Brandner 2013). In addition, the applied pressure for face bonding needs lumber characteristics and lumber species into consideration.

Materials and methodology

Silver oak (8–10 years old) and *M. dubia* (4–5 years old) species were studied for the manufacturing of 2 ft x 4 ft CLT. Phenol formaldehyde resin was used as adhesive for the manufacturing of CLT. Lumber of 70 mm width with a thickness of 18 mm / 21 mm and moisture content of 11 to 13% were used for the study. The planed and kiln-dried lumbers (battens) are graded visually. The batten of high grade is segregated for

outer layer and selected according to visual criteria. Battens in the lumber with large knots, bark inclusions, etc. are cut out during grading of surface class. These lumbers are planed on four sides to ensure dimensional integrity and proper adhesion. The lumbers are edge jointed forming each layer using a phenolic adhesive of requisite pH by applying lateral side pressure. The layers are formed with adhesive surface bonding on the faces of the layers and are stacked in alternating directions to create the bond. Then the layers are compressed in a stack of multiple layers to produce CLT. Detailed process of

Primary plank selection and lumber grouping: Visual grading was done and planks were segregated (figure 1). The presence of knots deviates the grains in the surrounding wood and reduces the strength. The size and position of knots affect the strength. Hence timber without knot is preferred. Silver oak species planks were found to have very less or negligible level of knots, whereas the *M. dubia* species had more knots. From the available *M. dubia* stocks, planks with very less knots were selected for further processing.

manufacturing are discussed below.





Figure 1. Lumber grouping, visual grading.

Lumber planning and cutting (battens): Planks are then cut to a length depending on the specific needs. The thickness and width of the lumber used were 18 mm/21 mm and 70–80 mm, respectively.

Lumber grouping: For the construction of CLT, three layers are formed. The timber that has better aesthetic and structural properties are used as the surface layers of the CLT panel.

Moisture content of the wood: In the manufacturing of CLT, it is important to avoid the development of appreciable internal stresses when the sample is exposed to conditions that change the moisture content. Abnormal changes in moisture content after gluing includes shrinkage and swelling of the wood that cause stresses and possible checking in the wood or along the glue line. Maximum moisture content of 11% at the time of gluing was taken for laminating timbers. Uniformity of moisture content between lamination (2% variation within the timber) was maintained to avoid internal stresses.

Gluing: As these wood materials are subjected to high stresses, few measures were carried out for the proper gluing to develop full bond strength. The measures taken are given below:

- I. Surface of the lamination to be glued is checked for requisite moisture content of 11–13%.
- ii. The mating surfaces are made sure to be smooth, clean and free from contamination.
- iii. Glue of requisite properties is used and made sure that the whole contact area of all surfaces to be bonded are wet with glue.

Glue application and pressing of laminate: Glue is applied using brush (figure 2) and pressed in hydraulic press with application of lateral pressure of 13–15 kg/cm² at the ambient temperature. For single layer assembly of CLT, a curing time of 6 h at the ambient temperature was employed. Figures 3 and 4 depict the assembly layup and pressing with lateral pressure.



Figure 2. Adhesive application.



Figure 4. Lateral pressure application.



Figure 3. Edge assembly layup.



Figure 5. Surface planning.

Final assembly layup: The single layers of CLT is downloaded from the hydraulic press and the surface of the composition is planned in a planning machine to ensure uniform smoothness/thickness (figure 5). The planed layers of CLT are taken for final assembly layup. The assembling technique is comparable to plywood production where adjacent layers are assembled perpendicular to each other. For a three-layer construction, the middle layer is glue coated on both the sides by brush (figure 6).



Figure 6. Adhesive application for middle layer of CLT.

CLT pressing: After the layup of the CLT element, the panel is finally face bonded with a hydraulic pressure. Assembled pre-product is loaded into the press and applied a pressure of 14–15 kg/cm² for a period of 6 h in the ambient conditions (figure 7). After stipulated time of pressing, boards are unloaded and stacked for stabilization. Figure 8 displays the 2ft x 4ft CLT from silver oak and M. dubia species.



Figure 7. Assembly layup for CLT under pressure in hydraulic press.





Figure 8. CLT from silver oak and *M. dubia* (2ft x 4ft).

Results and discussion

This study was undertaken to manufacture 2 ft x 4 ft CLT and evaluate the properties of CLT by utilizing silver oak (8-10 years) and M. dubia (4-5 years). Phenol formaldehyde resin was used as adhesive for the manufacturing of CLT. Density of the CLT were in the range of $500 \, \text{kg/m}^3$ at 10–12% moisture content. The panels swelled at maximum 2.38%, after $24 \, \text{h}$ of soaking in water at ambient conditions. In this study, the effect of glue and pressure on the properties were analysed. Block shear strength were studied to understand the bonding properties and optimizing the process parameters for the manufacture of CLT. The results of block shear and delamination test showed that the level of applied pressure had a significant effect on the bond quality and wood failure. Three-point bending test were carried out to assess their mechanical properties.

Table 1. Comparisons of bending strength of CLT with other species of other countries.

Species	Age (year)	Type of wood	Type of adhesive	Density kg/m3	MOR N/mm 2	Source
Beech wood	20	Hard	_	0.690	43.8	Steffen Frankie 2016)
Spruce	_	Soft	_	0.470	26.4	Steffen Frankie (2016)
Acacia magnium	20	Hard	PUR/PRF	0.673	27/36	Mohd Yusof et al. (2019)
G. arborea	10	Hard	EPI	0.480	18.0	Munoz Freddy et al. (2022)
T. grandis	15	Hard	EPI	0.630	44.0	Munoz Freddy et al. (2022)
Eucalyptus grandis	20–25	Hard	PUR	0.540	24.5	Yuchao liao <i>et al.</i> (2013)
Pinus radiata		Soft	_	0.49	26.1	Concu <i>et al.</i> (2013)
Pinus radiata(Australian)		Soft	_	_	25.5	Sigrirst et al. (2014)
Pinus radiata		Soft	MUF	0.45	44.5	Wang et al. (2014)
Silver oak	8–10	Hard	PF	0.523	50.9	our study
M. dubia	4–5	Hard	PF	0.5	39	

^{**:}our study

CLT made from silver oak species has shown higher bending strength of 50.9 N/mm² when compared to the results reported by researchers, however using polyurethane, MUF, PRF resin, whereas M. dubia of 4-5 yeras age CLT has shown MOR of 39.6 N/mm². Block shear strength of silver oak and M. dubia is found to be 5.23 and 4 N/mm², respectively. Age of species used mainly influenced on the bonding properties of the board. The properties of these Indian hardwood plantation species of lower diameter girth were almost comparable with the bending strength of European countries hardwood species. These results indicate that the CLT panels manufactured from silver oak and M. dubila lumber are promising for structural application. Soft wood species such as spruce and Pinus radiate showed bending strength of 26-27 N/mm². While comparing with hardwood species of 20-year-old CLT, beech wood of the density 600-650 kg/m3 made by Franke reported a bending strength of 43.8 N/mm². CLT from Acacia magnium of 20-year-old has shown MOR of 27 N/mm² with PUR resin and 36 N/mm² with PRF resin. The CLT made using silver oak species in this study exhibited higher MOR. According to Toong et al. (2014), the factor that influences the wood quality in CLT is

density, as it is related to both the mechanical strength and shrinkage properties of timber.

Conclusion

Plantation species, namely silver oak and *M. dubia* are found suitable for the manufacturing of CLT. However, silver oak species of 8–10 years of age group was more practically feasible in aspects such as lesser knots, sawing or dimensioning of timber and seasoning or conditioning of timber, for the manufacture of CLT. As per IS: 3629, CLT made from silver oak and melia dubia species comes under Group c timbers for structural applications. Utilization of these plantation species in structural application by way of CLT construction has a potential as well as promising green building alternative.

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Contact author at sheshagirimb@icfre.org

The Development of Polyurethane-Bonded Rubber Wood Glued-**Laminated Timber**

Introduction

imber has been used in construction since the ancient times. Previously human beings used timber and stone for constructing houses, where timber played an important role in bearing load in the form of beams and columns. With the industrial revolution and modernization, human demand shifted towards steel and cement for construction works and now steel and cement have completely replaced timber for heavy constructions. But in the last couple of decades, there has been a renewed interest in the use of timber in construction. People are becoming more concerned about sustainability and carbon footprints. Production of steel and cement needs huge energy inputs during mining which in turn pollutes and harms the environment. The production of steel, cement, aluminium, and brick consumes around 17% of the world's fossil fuel energy and the use of these materials accounts for 10% of fossil fuel consumption in building constructions alone (Oliver et al. 2014). Of that, 8% of CO₂ emission is from the manufacturing of cement (Oliver et al. 2014), and worldwide cement manufacturing has increased thrice from 1.5 to 4.6 billion metric tonnes from 2000 to 2015 (Scrivener et al. 2016). These construction materials are very energy and carbon-intensive thereby causing environmental pollution.

The entire globe is now facing the problem of climate change because of the greenhouse gas emissions, anthropogenic emissions (IPCC 2014) and also due to population growth (Tipple 1994; Angel 2000; Wetzstem 2017). The construction industries are responsible for emitting more greenhouse gases (GHG). One-third of the GHG emission is caused by the construction industry as assessed in 2008 (UNEP SBCI 2009). If this figure increases continuously, then by 2050 the total GHG emission will increase by 35-60% of the present carbon budget (Churkina et al. 2020). Hence, it is important to address such problems which pose danger to human existence.

Wood serves as a better candidate for sustainability and can replace the carbon-intensive building materials because of its renewability and low carbon footprint in

Navneet Singh Sirswal, Priyank Maithani, Kamal Mishra and Anil Kumar Sethy*

Wood Properties and Processing Division, Institute of Wood Science and Technology, Bengaluru, India

*Email: aksethy@icfre.org

manufacturing. Wood as a construction material is gaining weightage over steel because of its high strength-to-weight ratio and it attracts engineers and architects as potential material for high-rise buildings (Jamshid et al. 2017). Wood also has another major property in the context of architecture, i.e. better fire resistance property, which is contradictory to popular belief. In low-rise buildings, large sections of wooden structural members already showed better results in fire resistance.

In the past, availability of large-sized cross-section timber was abundant, but in the current scenario, the engineers are dependent on plantation wood for construction. The technology of manufacturing glued laminates, specifically glulam has come to the help of architects and structural engineers in Europe and around the world (Radosław et al. 2020). Glulam was introduced by Hetzer in 1906 (Oslo 1906). It gives better quality with a large cross-section as well as longer span and in the last 100 years, glulam has gained a lot of popularity among engineers and architects because of its desirable sizes and properties like light-weight, stiffness, durability, strength and easy processing.

Glued-laminated timber (GLT), also known as glulam was developed in Europe. Because of its environmental friendly nature, GLT has become one of the most focussed global construction materials. GLTs are panels formed by parallel layers of wood glued to each other. In this study, four-layered and five-layered GLT were manufactured from rubber wood (Hevea brasiliensis) using polyurethane (PUR) adhesive. The objective of this study was to characterize the structural properties of glulam from rubber wood. The effect of lamella thickness on glulam property was also assessed. Results show that mechanical properties of five-layered glulam were better than four-layered glulam and the properties were comparable to that of solid rubber wood. The physical properties of four-layered and fivelayered glulam were as per the requirement of European standards (EN: 14080-2013). The results confirm that rubber wood glulam is suitable for structural applications and could be a potential alternative construction material.





There are different adhesives that guarantee the strength of the glulam under bending and dynamic load. Melamine-urea-formaldehyde (MUF), phenol-resorcinol-formaldehyde and also polyurethane-based resin are quite popular among engineers for glulam manufacturing (Radosław et al. 2020). Pressing of the assemble panels is done as per the species and specification mentioned in EN.14080:2013. In the manufacturing of glulam, eliminating the defects is necessary to get the desired strength (Philipp 2015).

Although glulam has already been a commercial product in the Western countries and finds extensive application in construction as structural member, its manufacturing as well as use are still at the early stage in India. One of the main reasons is lack of availability of information on the properties of GLT from local timbers. In this context, this article presents the physical and mechanical properties of GLT made from rubber wood.

Materials and methods

Rubber wood planks with density of about 600 kg/m³ and moisture content 12±3% was procured from the local market in Bengaluru. The planks were visually graded to remove defective pieces and then subjected to planning. The planned planks were applied with one component polyurethane adhesive and assembled with

the grain direction parallel to each other. The assembled layers were then pressed under a hydraulic press with a specific pressure of 1MPa for 2 h. Two types of lamella patterns, namely four-layer

and five-layer were tried to ascertain the effect of number of lamellae on the properties of glulam. The final thickness of glulam was 60 mm. For a four-layer construction, 15 mm thick lamellas were used, while for five-layer layup, 12 mm thick lamellas were used. Then the bonded panel was conditioned at room temperature for one week prior to trimming and sample preparation.

Physical properties of glulam

Physical properties of the glulam were tested as per European standard (EN: 13080-2013). Delamination and swelling

testes were carried out to ascertain the stability of the board against moisture absorption. For delamination tests, GLT samples were impregnated with water using a vacuum-pressure impregnation method. At the beginning, the samples were evacuated for 30 min by applying a vacuum of 70 kPa to 85 kPa followed by a pressure of 600 kPa to 700 kPa pressure for a period of 120 min. Then the samples were removed from the treatment chamber and subjected to drying in an oven until the samples achieved a weight which was equal to 100–110% of their original weight. Then the samples were assessed for delamination. The percentage of total delamination and maximum delamination was calculated using the following equations:

Swelling test

This test was conducted to find the swelling behaviour of GLT samples. The samples were submerged under water for around 48 h. Weight and volume of each sample was taken before and after dipping. Data was collected and analysed to ascertain the moisture uptake and swelling percentage.

$$Total \ delamination \ \% = \frac{Total \ delamination \times 100}{Total \ glue \ lines} \ .$$

$$Max \ delamination \ \% = \frac{Maximum \ delamination \times 100}{Total \ glue \ lines}$$







Figure 2. Delamination test sample of rubber wood glulam.

Mechanical properties of glulam

Mechanical tests were carried out to find the bending strength, modulus of rupture (MoR); bending stiffness, modulus of elasticity (MoE) and block shear strength. Four-point bending test was carried out to determine the MoR and MoE, while block shear test was carried out to find the shear strength of the adhesive





Figure 3. Swelling test sample of rubber wood glulam.

bond.

Four-point bending test was carried out using a universal testing machine (UTM) as per the procedure mentioned in the EN: 14080-2013 (figure 5). The sample dimensions for the bending test were $1150 \times 90 \times 60 \text{ mm}^3$ and continuous load was applied through the moveable head of the UTM moving at a speed of 4 mm/s. MoR and MoE of GLT samples were calculated using the following formula:

Where F is maximum load (N); L is support span (mm); b is width of test specimens (mm) and d is depth of test specimens (mm).

where f2 and f1 represents an increment of loads on the straight line portion of the load-deformation curve

$$\mathbf{MoR} \left(\frac{N}{mm^2} \right) = \frac{FL}{bd^2} .$$

graph (N); w2 and w1 is the increment of deformation corresponding to f2 and f1 (mm); a is distance between the loading position and the nearest support in a bending test (mm); G is the shear modulus and it is taken as infinite; I is the span length in bending (mm) b is

MoE
$$\left(\frac{N}{mm^2}\right) = \frac{3al^2 - 4a^3}{2bh^3 \left\{2\frac{(f2 - f1)}{(w2 - w1)} - \frac{6a}{5Gbh}\right\}}$$

width of test specimens (mm) and h is depth of test specimens (mm).

The sample size of the block shear strength test was $62.5 \times 50 \times 50 \text{ mm}^3$ as mentioned in IS: 1708-1986 with a notch to hold the load (figure 6). The loading speed was 1 mm/s. The maximum shear strength was calculated using the following formula:



Figure 4. Bending test sample of rubber wood glulam

Results

Delamination

As per EN: 14080-2013 standard, the total delamination should be less than 5% and maximum

Block shear strength (N/mm2) =
$$\frac{F max}{A}$$

Where F max = maximum load (N); A = cross-sectional area (mm²).



Figure 5.
Block shear test on rubber wood glulam samples.

delamination for a single glue line should not exceed 40%. The results pertaining to the delamination tests are shown in table 1. It is apparent that the total delamination as well as maximum delamination for both four-layer and five-layer GLT were well below the values recommended by EN: 14080-2013. Further, it can be noted that five-layer GLT showed higher delamination as compared to four-layer GLT. It was

expected as the number of glue lines in five-layer GLT are more compared to four-layer GLT. Hardwoods generally exhibit more shrinkage and swelling due to their porous structure (presence of vessels) compared to softwood (non-porous wood). In spite of higher shrinkage and swelling tendency of rubber wood, the glue lines were still intact following the delamination tests.

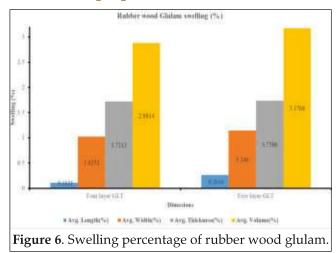
Table 1. Total delamination and maximum delamination for rubber v	wood glulam (%).
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	Four-la	yer GLT	Five-layer GLT		
GLT properties			Total delamination	Maximum delamination	
Maximum			3.2	17.52	
Minimum	0.96	10.23	1.78	11.73	
Mean	1.03	11.05	2.24	14.56	

The results pertaining to the swelling behaviour of rubber wood GLT samples are shown in figure 6. Volumetric swelling was marginally higher for fivelayer GLT as compared to four-layer GLT. The average volumetric swelling was 2.9% for four-layer GLT and 3.2% for five-layer GLT. Swelling values are maximum along the thickness (tangential direction) followed by along the width (radial direction) and least along the length (longitudinal direction). Shrinkage and swelling in wood are generally least along the grain direction (along the length) as compared to across the grain directions. Further shrinkage and swelling in radial direction are lower as compared to tangential direction. Solid rubber wood has been reported to exhibit tangential shrinkage of about 5.1%, radial shrinkage of 2.3% and volumetric shrinkage of about 7.5% (wooddatabase.com). The volumetric swelling obtained for rubber wood GLT were significantly lower than that of solid rubber wood. This indicates that adhesive

bonding, besides creating a barrier against moisture uptake, might also be restraining the wood from free movement.

Mechanical properties



Strength and stiffness are important parameters that determine the suitability of a material for structural applications. Bending properties of rubber wood GLT samples were determined and compared with that of solid rubber wood. The results are shown in figure 6, a and b. Five-layer GLT has almost similar MoR and MoE as that of solid rubber wood, while four-layer showed lower values.

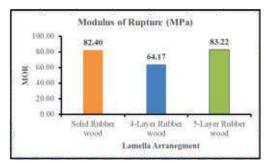


Figure 6. (a) MoR

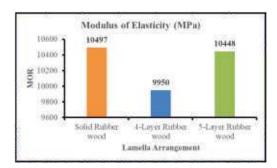


Figure 6. (b) MoE of rubber wood GLT samples

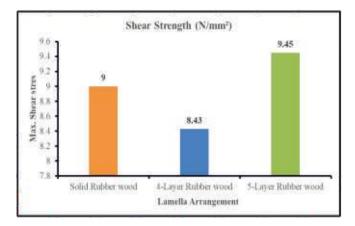


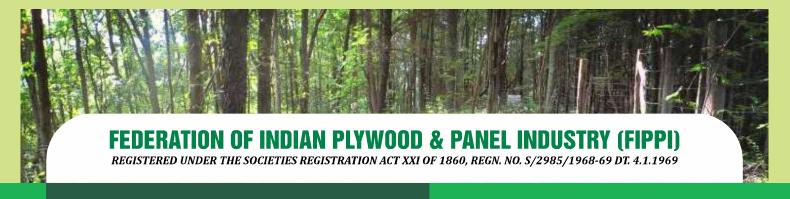
Figure 7. Shear strength rubber wood samples.

Conclusions

Suitability of rubber wood for manufacturing of glulam was assessed in this study by using polyurethane adhesive as a binder. Physical and mechanical characterisation of the GLT was carried out in terms of delamination, volumetric swelling, bending strength, bending stiffness and block shear strength following relevant standards. Effect of number of layers on the properties of GLT was also assessed. Delamination of layers in the GLT was well within the recommended values. Five-layer GLT showed marginally better mechanical properties than fourlayers GLT. Bending strength, bending stiffness and shear strength of GLT were almost comparable to that of solid rubber wood. As construction of GLT provides opportunities to minimize the variations present in the wood, architects and structural engineers can use this structural material with more confidence than a solid wood.

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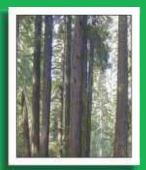
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Part of FIPPI Achievements

With great efforts of Federation of Indian Plywood & Panel Industry (FIPPI), an Apex representative body of Plywood / Panel / Other Allied products including Furniture and Wood / Bamboo Working Machinery Manufacturers in India alongwith close cooperation with various Ministries and Premier Institutes through Agro and Farm Forestry and other Captive Plantation programme, the dying woodbased industry is again reviving in the country to produce various standard products like Veneer, Plywood, Panelboard, Particleboard, MDF, Laminates etc. which are internationally accepted. Further with great pursuance of the President and Senior Executive members of FIPPI we are highlighting and representing the crucial issues confronting the Plywood & Panel Industry. FIPPI also publishes quarterly Journal Indian Wood & Allied Products highlighting the development taking place in India and abroad, market profile, world timber market report, statistics, international exhibition and conferences, articles, write-ups etc.

FIPPI is cordially inviting all plywood / panel / bamboo / Laminates and other allied products manufacturers to become active member for the strengthening the platform of FIPPI and working for the development of the industry which is Internationally recognized by ITTO, FAO, European Union, IWPA, BIS, MoEFCC, Ministry of Commerce & Industry, BIS, FICCI, CII and other renowned Organizations.



















FEDERATION OF INDIAN PLYWOOD & PANEL INDUSTRY (FIPPI)

404, Vikrant Tower, 4, Rajendra Place, New Delhi110 008, India Ph.: (Direct) +91-11-25755649, Other Nos. +91-11-25862301 Fax: +91-11-25768639, E-mail: fippi@fippi.org

Website: www.fippi.org

Mass Timber Construction - An Efficient Construction Technique

Introduction

imber is used as construction material since several years, but the research covering the prediction of the strength of structural timber is still under development stage. At present, the common conception is that the strength properties have to be determined for each timber species individually. By combining these strength properties to features which can be measured for the timber (either visually or by machine measurements), strength graded timber can be supplied to the market. In India, there are more than 1600 commercially available timber species among which 150 of them can be used for engineering purpose. Further a majority of these wood species are hardwoods. These wood species are often used when high strength and high durability are required. At present, timber is increasingly produced from sustainably managed forests. In India, the evaluation of the strength of a timber species is guided by IS 1708:1996 where grading rule is not applied. Thus, to use timber in structures, grading rules have to be formulated based on the strength properties. For machine grading, for example, the density and modulus of elasticity are used. For softwoods species, machine grading is more accurate and gives higher yields in the higher strength classes in comparison to visual grading. But for hardwoods, a major problem for visual grading is that the most important feature for the mechanical properties, the slope of grain, is very difficult to measure in practice. There is a code of practice for design of structural timber for building as per IS: 883-2016 which covers the general principles involved in the design of structural timber in buildings except timber pile foundations, structural use of plywood, design of structural timber joints and fastenings and timberconcrete composite construction. There is no code of practice for design of mass timber structures (eg. CLT) in India which is predominantly required in design timber structures for more than two storey buildings. Construction materials must be produced utilizing renewable, low-energy resources. Many of the countries in USA, North America, Oceania, Europe, Asia, etc. are building multi-story structures using mass timber construction which is an emerging technology to

A. Sil

ICFRE - Institute of Wood Science and Technology Field Station, Kolkata

Email: silchief@gmail.com

build houses faster, and pollution free. With market demand, the material costs change at par with increase of land prices. Hence the designers are now focused on prefabricated mass timber solutions to speed up project completion, assembly of structures at site with fewer workers in less time and also save money while adding value.

Mass timber construction

Mass timber construction can be considered as one of the most effective and viable timber constructions in construction point of view. It basically uses a renewable resource i.e wood and is supported by different prefabricated components that are built offsite and erected and installed at site with reduced reliability on labour and also in shorter span of time. In India, mass timber construction is still in the early stage and there is lack of proper design codes. Its adoption in a range of commercial real estate projects shows an upward trend. Cross Laminated Timber (CLT) panels can be used for walls, floors and roofs in both load-bearing and nonload-bearing structures in mass timber construction. The flexibility in thickness and sizes of CLT panels very much fulfill the requirements of different types of building designs. Initially CLT panels were used for low and mid-rise buildings but in recent years it is also being used in construction of high-rise buildings. It is also considered as a good substitute to concrete and steel due to its strength to weight ratio and favourable carbon footprints. Conventional construction methods need longer construction times, which lead to unorganized settlements and significantly increases global carbon emissions. In current scenario, there is a need to build accessible, healthful homes that are sustainable and use improved construction technology.

Grading of timber for structural use

Safety of any timber structure will depend upon different factors like the correct mechanical strengths, good prediction of the structural behavior of the design aspects and good workmanship during the execution of civil construction work. However, if the size effect for the grading rule has been established for a similar species, then fewer sizes may be tested. In India, the structural timber could be graded after seasoning in accordance with IS 1331: 1975 into the following three grades (a) Select grade, (b) Grade I, and (c) Grade II. To know the design strength value of timber used for structural purpose, relationship between the characteristic strength value and the design strength value is essential before coming to a conclusion. Figure 1 shows the relationship between the characteristic strength value and the design strength value which is defined by equation below:

$$Design strength = \frac{The characteristic value}{The material factor}$$

It is clear that when the material factor is a fixed value, and Rk is a fixed percentage fractile of the distribution, the variability in timber strength properties influences the reliability of the structure. During grading, the structural beams are assigned to three grades (a), (b) and (c). The 5 percentile are indicated with vertical dashed lines as depicted in Figure 2. The grading has two effects: the 5 percentile of grades (b) and (c) are higher than the 5 percentile of the ungraded population and the variability in strength properties of the three grades is much lower than that of the ungraded material. These are limit values for the prediction values that determine which strength class the timber can be assigned to. The strength values of timber can only be verified on the basis of the properties of a sample that is tested destructively. For small numbers of pieces in a sample, the characteristic values of a strength grade can vary significantly between tested samples. The characteristic strength value of strength properties of timber can be determined irrespective of the number of pieces in a sample. Hence for hardwood timber, the assigned strength classes can be determined

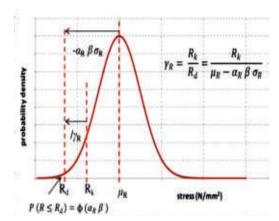


Figure 1. Co-relation between characteristic strength value and design strength

in a reliable way and the yield in the higher strength classes can be increased. This will contribute to an economic, safe and sustainable application of timber in structural applications.

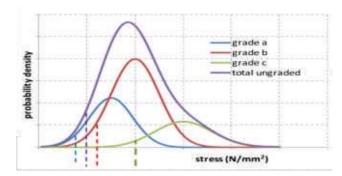


Figure 2: Effect of strength grading of Structural Timber

Source: Doctoral Thesis titled "Species independent strength grading of structural timber" by Geert Ravenshorst, 2015

Determination of mechanical properties of structural timber

In India, standard test methods are available to determine the mechanical properties of timber (IS 1708-1986). These tests are normally performed on timber which has been conditioned to about 12% moisture content. The size of the specimens and the rate of loading are mentioned in the test protocols. Bending properties like modulus of elasticity (MOE) and modulus of rupture are normally determined by symmetrically loading a specimen at two points. This method is referred to as 'Two-point' bending test and the intent is to create a zone of constant moment with no shear of the beam under test. The modulus of elasticity is determined from the slope of the load-mid span deflection curve and the bending strength or modulus of rupture is determined from the maximum load that it sustains. The load shall be applied continuously throughout the test such that the movable head of the testing machine moves at a constant rate of 3 mm/ minute. Deflection of neutral axis shall be measured at the mid span between two points equidistant from mid span by suitable Universal Testing Machine with gauge length of 40 cm, the deflection was measured at suitable load intervals up to the limit of proportionality and till the maximum load.

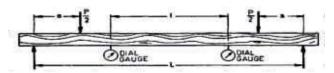


Figure 3. Timber sample under two point static bending

Characteristic values of modulus of elasticity (MoE) and bending strength

Characteristic value is generally a value that corresponds to a fractile of the statistical distribution of a timber property. For modulus of elasticity, the fractile is the 5-percentile and the mean value is also a characteristic value. Due to the presence of random defects, the testing of samples from a population will result in mechanical properties which can be represented by a statistical distribution. Limit state design codes are based on characteristic values of these properties and are determined as the weighted means of the sample lower than 5-percentiles for strength properties and density, whereas the weighted mean of the sample averages (50-percentile) is used for determining modulus of elasticity. For each sample, the 5-percentile strength value is found by ranking all the test values for a sample in ascending order and finding the value below which 5% of the values fall. A larger test sample will usually give a much more reliable estimation of the 5-percentile value and a variety of statistical methods are employed to fit the data distribution, with a log normal analysis being one of the

more popularly used one. After adjusting the value of modulus of elasticity (MoE) for each sample (minimum five specimen) the characteristic value of bending strength can be calculated from the equation prescribed in BS EN 384:2004. The characteristic bending compressive strength is defined as the bending strength below which not more than 5% of the test results are expected to fall. From the normal or the Gaussian distribution curve, the 5th percentile corresponds to 1.65 standard deviations below the mean. Though the bending strength of the samples exhibit variations, when plotted on a histogram are found to follow the shape of a bell shaped curve as shown in Figure 4.

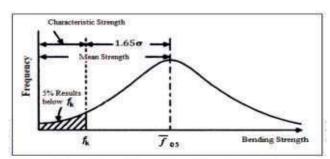


Figure 4. Normal distribution curve

Table 1. Strength classes- Characteristic values of timber

Type of timber species	Strength classes	Bending Strength, $f_{m,k}$	Mean Modulus of Elasticity (Parallel to the grain), E _{0,mean}	5% Modulus of Elasticity (Parallel to grain), $E_{0.05}$	Mean Modulus of Elasticity (Perpendicular to grain), $E_{0.90\text{mean}}$
		N/mm²	kN/mm²	kN/mm²	kN/mm²
	C14	14	7	4.7	0.23
	C16	16	8	5.4	0.27
cies	C18	18	9	6.0	0.30
Soft Wood Species	C20	20	9.5	6.4	0.32
poc	C22	22	10	6.7	0.33
it W	C24	24	11	7.4	0.37
Sof	C27	27	11.5	7.7	0.38
	C30	30	12	8.0	0.40
	C35	35	13	8.7	0.43
	C40	40	14	9.4	0.47
	C45	45	15	10.0	0.50
cies	C50	50	16	10.7	0.53
Spe	D30	30	10	8.0	0.64
poc	D35	35	10	8.7	0.69
Hard Wood Species	D40	40	11	9.4	0.75
Hard	D50	50	14	11.8	0.93
	D60	60	17	14.3	1.13
	D70	70	201	6.8	1.33

The characteristic values of samples can be selected as per the sampling plan. Any suspected difference in the mechanical properties of the population distribution may be due to growth regions, sawmills, tree size or method of conversion. This should be represented within the number of samples selected, by a similar proportion to their frequency in the population and this should be the major influence in determining the number and size of samples.

Strength Classes - Characteristic Values

The European standard BS EN 338:2003 (E) strength class system assigns structural timber to grades or strength classes with defined properties. It comprises twelve classes for poplar and softwood species and six classes for hardwood species as mentioned in table 1. In the table, the letters C and D refer to coniferous and deciduous respectively while the numerical values represent the characteristic bending strength in MPa for the strength class. Timber populations are assigned to a strength class if the characteristic values of bending strength and density of the population are equal to or

greater than the values for the strength class and if the characteristic mean modulus of elasticity in bending equals or exceeds 95% of the value for the strength class. All the properties tabulated in the table 1 are compatible with timber at a moisture content consistent with temperature of 20° C and RH of 65%.

Permissible stresses limits

Fundamental stress values of different species of timber are determined on small specimen in accordance with Indian standard IS 1708 (Parts 1 to 18): 1986. To these values are then applied appropriate reduction factors given in the relevant table of IS 3629: 1986 to obtain the permissible stresses. The minimum permissible stress limits for different groups of timber applicable to Grade I of structural timbers shall be as per table 2, provided that the following conditions are met which are (a) timber should be of high or moderate durability and be given suitable treatment, (b) timber of low durability if used shall be after proper preservative treatment in accordance with IS 401: 1982 and (c) loads should be of continuous and permanent type.

Sl No.	Strength Character	Group A	Group B	Group C
1.	Bending and Tension along grain	18.0	12.0	8.5
2.	Shear Strength (Horizontal)	1.05	0.64	0.49
3.	Shear Strength (Along with grain)	1.5	0.91	0.70
4.	Compression Strength (Parallel to grain)	11.7	7.8	4.9
5.	Compression Strength (Perpendicular to grain)	4.0	2.5	1.1
6.	Modulus of Elasticity	12.6	9.8	5.6

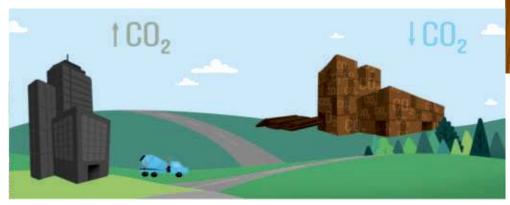
Design considerations

All structural members used to design assemblies or framework in a building in combination with the floors, walls and other structural parts of the building shall be capable of sustaining, with due stability and stiffness the whole dead and imposed loadings as specified in appropriate codes of IS 875: 1987 without exceeding the limits of relevant stresses specified in this standard. The worst combination and location of loads shall be considered for designs. Wind and seismic forces shall not be considered to act simultaneously. Design mass timber structures against seismic forces needs to be included separately in Earthquake Resistant Design and construction of buildings (IS 4326:1993).

Timber the most carbon friendly building material for mass building

Timber is most widely used in mass building in European countries because of its efficiency, durability and usefulness. It is one of the oldest building materials known to human beings. But due to less supply of naturally grown large girth durable timbers from forests and availability of various alternate construction materials, there has been less usage of wood in construction sectors. For the last three decades, timber has been replaced by steel and aluminum in different components of building construction. It is estimated that construction of buildings contributes to about 40% of the total CO_2 emission worldwide. One of the greatest attributes of wood is that it is a renewable resource, it has low carbon impact and low embodied energy. The amount of energy needed for producing wood products

is much less than comparable products made from other materials. Carbon in wood remains stored until the wood deteriorates or is burned. Architects, product designers, engineers and homeowners are increasingly choose certified building products that are from sustainable resources. Wood is considered to be one of the



most environment friendly material sequestering carbon during its production as its locks it for a long duration when being used for products with long life. In structural applications, wood is being converted into timber by sawing it into thick slabs and planks. Timber is also less carbon intensive to manufacture, transport and erect than steel and concrete structures. More than 50 different forest certification systems in the world

represent nearly 700 million acres of forestland and 15,000 companies involved in producing certified products. In terms of forest acreage under certification, Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) dominate in the United States. A number of comparative studies of residential construction have shown that timber elements have less global warming emissions than steel or concrete along with embodied energy as shown in table 3.

Table 3. Embodied energy and CO2 emissions in construction materials

Material	Wood	Concrete	Steel
Embodied energy : MJ/Kg	1.2	1.2	32.0
Emission: kgCO₂/kg	0.0000	0.0194	0.5168

Source: ICE manual of construction materials Vol. 2 Mike Forde, University of Edinburgh and https://carbonremoval.economist.com/

Conclusion

In civil engineering, limit state design method is a philosophy under which engineering structures are designed keeping in mind that the probability that a number of performance criteria are exceeded is deemed to be acceptable during functional lifetime of the engineering structure. Structural engineers must make calculations to ensure that a particular design doesn't collapse in future and is strong enough. They must choose an appropriate value of material strength of timber to use it in calculation during using the structural timber in application such as buildings, bridges, decks, girders etc. In India, the design codes using this material strength based on a characteristic value is lacking. Characteristic material properties are divided by structural timber partial safety factors to arrive at certain design values, which structural or civil engineers can use in their calculations. Here, Bureau of Indian Standards can play a leading role in formulating design standards for mass timber construction which is a quicker construction process and shifting the nation toward a repeatable, stronger, resilient, durable, energyefficient, and natural housing option.

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Integration of Wood and Wood Based Products in Green Building The New Bamboo: Future from the past

Introduction

B amboo has been used as a common building material since time immemorial by the Indian civilisation as well as the Chinese and Japanese civilisations. In India, bamboo framed roofs covered with thatch have been adopted since historic times. There is evidence of bamboo being used in opulent structures like palaces in China's Qin dynasty, in third century BCE¹. Widespread use of bamboo as a construction material can be seen in vernacular housing in Asia, Africa and South America, where the plant grows indigenously.

Bamboo is a fast-growing renewable resource. It has

remarkable properties like high strength combined with the advantage of low weight and easy work-ability. Bamboo when used in construction is easy to build structures, resilient to wind and can even withstand earthquakes. They can also be easily repaired in the event of damage, thus making them eco-friendly. These are the reasons we can see widespread usage of bamboo in indigenous houses, bridges, and supporting structures.

Research in suitability of bamboo for mainstream construction reveals bamboo to be structurally comparable and in some cases advanced to conventional building materials. In the contemporary

context, bamboo has seen significant use in the building industry as architects and engineers attempt to push the limits of bamboo's structural capabilities.

There are however a few important considerations which currently limit the use of bamboo as an universally applicable construction material:

Durability: bamboo is subject to attack by fungi and insects. For this reason, untreated bamboo structures are viewed as having a life of no more than five years.

Jointing: although many traditional joint types exist, their structural efficiency is low. Considerable research

Neelam Manjunath

Proprietrix,

Manasaram Architects, Bangalore, India

CEO, Founder and Managing Trustee, Centre for Green Building Materials and Technology, Bangalore, India

Email: cgbmtblr@gmail.com

has been directed at the development of more effective jointing methods.

Flammability: bamboo structures do not behave well in fires, and the cost of treatment, where available, is relatively high.

Lack of design guidance and codification: the engineering design of bamboo structures has not yet been fully addressed.

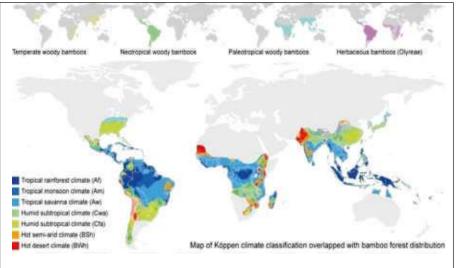


Figure. 1.1: World map showing bamboo distribution according to Koppen climates ²

1. Bamboo in traditional construction

Due to its wide availability in tropical, subtropical and temperate climates, Bamboo has been extensively used in vernacular construction in these regions of the world. Figure 1.1 depicts the distribution according to climate ² conditions.

1.1 Tropical c limates

Tropical climate offers optimum conditions for most bamboo species, it is extremely fast-growing and can grow upto 3-12 inches per day in these conditions.

1.1.1. South America

Bamboo construction in South America dates to prehistoric times: pieces of bamboo mixed with clay from walls of the Late Valdivia and Machalilla cultures (3,500 BCE) were found in Guayas, Ecuador³.

A traditional pre-Hispanic construction system of South America comprises a wooden frame with a lattice infill of bamboo or reed, covered with mud. This basic wattle and daub system have different names across South America – "bahajareque" in El Salvador and Colombia, "Quincha" in Peru, "Cuje" in Cuba, "Pao pique" in Brazil, and "Tabiquería" in other parts of South America⁴.

Figures 1.2 and 1.3 depict views of the traditional South American wattle and daub system.



Figure 1.2:Bamboo Resilient Homes, Manizales, Colombia ⁷



Figure 1.3: Manizales 6

Species of bamboo commonly used in this construction method include Arundo donax, Gynerium sagittatum, Phragmites communis and Guadua angustifolia.

The elasticity of the bamboo canes and lightweight of materials makes this system anti-seismic and viable to construct two-storey dwellings.

1.1.2. Central Africa

In Ethiopia, the Oxytentra Abyssinica and Yushania Alpina species of bamboo are used in the construction of the traditional "Sidama" house.



Figure 1.4: Erection of domed roof



Figure 1.5: Finished⁸

The foundation of the Sidama house is constructed using Juniper tree poles and thin strands of bamboo placed up to 100 to 150cm around the perimeter of the dwelling⁶. Walls are constructed with split bamboo strips as well as whole bamboo canes of small diameters (Figure 1.4). The inner wall may have a "hilo" (linear) or "himbiro" (diagonal) weaving pattern of bamboo. The outer skin of the dwelling is made using the skin shed by the bamboo shoot. This acts as a waterproofing layer and is woven in a pattern known as "fuko" (Figure. 1.5). A dome-shaped roof is made with a triple layer of bamboo splits, ropes for structural support, and culm sheaths for insulation and rain protection.

1.1.3. India – central states and river planes

A variety of species of bamboo are found in India due to its diverse climatic conditions. This results in diverse building systems across the country.

In the rural and tribal river plane areas of Bihar, Bengal and Orissa, houses built of bamboo consist of walls made of mats of splits or flattened bamboo, mud flooring, and bamboo-reinforced lime surki flat slabs⁸. Figure 1.6 depicts a bamboo house on the bank of the river Brahmaputra.



Figure 1.6: House on Brahmaputra riverbank (India) 10



Figure 1.7: Bamboo House, Madhya Pradesh (India)

In Central India traditional bamboo dwellings feature vertical supports made of thick bamboo canes, walls of plaster-covered bamboo mats, and wooden truss roofs with bamboo rafters and purlins covered by country tiles or thatch. The timber doors and windows are covered with bamboo shutters and bamboo jaali is used for light and ventilation. Figures 1.7 depict a bamboo house in Madhya Pradesh.

In desert regions, bamboo is used as reinforcement in walls, boundary walls and in roof structures. In south India, bamboo finds use in walls in a wattle and daub system along with mud plastering.

1.1.4. South-east Asia



Figure 1.8: A hill tribe house, Chiang Rai (Thailand) 12



Figure 1.9: Traditional Thai house 12

In southeast Asia flooding is a recurrent threat. Here, traditional bamboo construction takes the form of lightweight dwellings raised on stilts. In Thailand, dwellings are constructed of bamboo feature walls of woven split bamboo, bamboo floors, roofs and joists ¹⁰, as seen in Figure 1.8 and 1.9. In the Philippines, Nupa huts are similarly made of woven split bamboo, while bamboo slats and poles form supporting structures

1.2. Sub-tropical climates

1.2.1. India: North-eastern states



Figure 1.10: Houses on mountain slopes, Mizoram ¹³



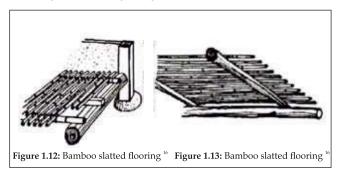
Figure 1.11: Bamboo building at Guwahati, Assam 13

In the north-eastern states of India, the indigenous communities of Riang, Mizo and Adi Gallong build hill houses of bamboo, comprising bamboo stilts, flooring made of splits or flattened bamboo, walls of woven bamboo mats and roofs of bamboo thatch (Figure 1.10 to 1.11)⁸. In Assam, houses of bamboo are constructed on a plinth base with wattle and daub walling in combination with wooden poles.

1.3. Temperate climates

Bamboo has been used as building material in China, Korea and Japan for more than one thousand years. In North China, Japan and Korea, where the climate is cold and with drier air, bamboo is used extensively as an interior building element, in visual screens, woven floor and ceiling matting.

In Japan, bamboo blinds called "Sudare" (Figure 1.14) have been in use for 1400 years 14. Sudare is made by weaving together uniformly-sized bamboo slats with string or yarn. They are typically used in summer since they provide better ventilation and insulation from heat than "Shoji" screens made of paper, wicker or cloth. "Engawa", traditional Japanese porch-like structures, which connect the interior of the dwelling with the outside environment, is constructed azlong bamboo flooring and roofing 15 (Figure 1.12 to 1.15).



Traditional Korean buildings featured walls comprising of mud applied to a bamboo framework¹⁸.



Figure 1.14: Japanese Sundare bamboo blinds 17

Large dwelling structures called Tulou were built in China's Fujian province between the 12th and 20th centuries employed bamboo to strengthen the walls. The walls of Tulou were up to 3m thick, and were built by compacting earth mixed with granite, wood and bamboo chips, which served as additional reinforcement.

In Chinese culture, bamboo is a symbol of oriental beauty. It represents the character of moral integrity, modesty and loyalty. It also stands as an example of elegance. The Chinese love bamboo, and bamboo culture have been rooted in their minds for a long time.



Figure 1.15: Japanese Engawa with bamboo flooring ¹⁸



Figure 1.16: Traditional Dai house with thatched ¹

Bamboo has also been used in architectural art from a long time. During the Han Dynasty skillful craftsmen built a magnificent palace for Emperor Hanwudi with bamboo. In southern China where bamboo is abundant, bamboo stilt houses are common residences for the people. Today, some minorities in Southwest China, like the Dai people in Yunnan, still live in the two-storied bamboo stilt houses — the upper floor of the house contains bedrooms, kitchens and balconies, and the ground floor is used to house poultry and domestic animals as shown in figure 1.16.

2. Bamboo in contemporary constructions

Bamboo being a versatile and sustainable material has been used in traditional constructions since time immemorial. In contemporary construction as well bamboo continues to be highly utilised. It's usage varies from structural components in houses, large structural systems like bridges to smaller elements such as doors and windows, fencing etc.



Figure 1.17 Bamboo reinforced slab with bamboo fibre,



Figure 1.19: Naman Conference Hall, Vo Trong Nghia 23



Figure 1.21: Panyanden School, Marcus Roselieb²⁶

More recently it has also been used as ornamental elements for facades. For the structural use of bamboo, building professionals are exploring and utilising its strength and properties in many novel ways.

Architects like Simón Vélez, David Sands, Neelam Manjunath, Vo Trong Nghia, IBUKU etc. have led the way in bamboo projects that celebrate the material's structural and environmental advantages.

Figures 1.17 to 1.22 portrays different kind of built forms with bamboo.



Figure 1.18: Nomadic Museum, Simón Vélez 22 Bamboo Symphony, Manasaram Architects²¹





Figure 1.20: "Pacific Queen Bamboo" House model, David Sands 24



Figure 1.22: Bamboo bridge, by ASF-ID Indonesia 25

3. Bamboo as a futuristic material of construction

Bamboo has always been associated with cheap, low-quality housing. This may perhaps be due to its extensive use in non-urban regions and communities over the world. However, the growing importance of green building and low-energy building concepts has put bamboo at the forefront of construction for the future including it's usage for housing on Mars!.

In the recent past, Bamboo has been developed in many building products like ply boards, veneers, roofing sheets and flooring material(an example of BMCS is shown in Fig.1.23). Architects and engineers around the world are pushing the possibilities of bamboo construction by making use of its structural properties. Some future possibilities for the material include multilevel structures, bamboo grid-shell structures, bamboo reinforcement and processed bamboo buildings made of bamboo composite products.

Figures 1.24 to 1.28 depicts different types of value added products from bamboo.





Figure 1.24: Grid shell structure for bamboo symphony²¹



Figure 1.25: The Green School, Bali, Ibuku²⁷



Figure 1.26: Bamboo Reinforcement²⁸



Figure 1.27: Bamboo Pavillion, University of Mexico²⁸



Figure 1.28: Interior of House of 5 elements, Manasaram Architects²¹

4. Market of bamboo in construction

The global bamboo market was valued at USD 72,102.4 Million in 2019 and is expected to reach over USD 98,757.9 Million by 2026, growing at a CAGR of around 5.5% during the forecast period from 2020 to 2026.

4.1. Global bamboo market The driving forces which contribute to the growth are (a) growing demand for bamboo fiber and (b) increasing investment in clothing and furnishing. Bamboo fiber is thinner as compared to hair and has a round and smooth surface which makes it abrasion proof. Its anti-fungal, and antibacterial features have added to the upsurge in the demand for bamboo fibre.

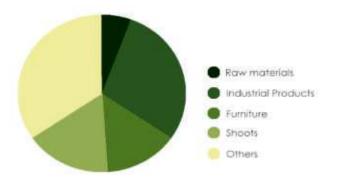


Figure 1.30: Global bamboo market share by application³²

On the basis of the end user, the global bamboo market is segmented as construction, wood and furniture, paper and pulp, textile, medical, agriculture, and food products. Wood and furniture segment is expected to account for the major share, followed by construction segment,

attributed to rising demand for quality furniture across the globe. Figure 1.30 shows the global bamboo market share by application.

4.2. Global bamboo market:

regional analysis China is the largest producer of bamboo across the globe followed by India with a significant growth rate over the forecast period. In terms of volume, Asia Pacific is expected to dominate the global bamboos market over the forecast period, owing to rising demand for furniture with the rapid growth of per capita income of the consumer in the region. The paper and pulp industry in India and China are among the most established industries growing at significant rates.

4.3. Indian market: The Indian bamboo products market is expected to grow at a steady rate during the forecast period. The Indian market is driven by the growing popularity of bamboo products as a substitute for tropical timber on account of their numerous benefits. Additionally, government initiatives aimed at tackling the problem of erosion in forests and increasing awareness for the use of environment-friendly resources are further expected to propel the market during the forecast period.

The Indian market is segmented based on species, application, end-user industry, and region. Based on species, the market can be categorized into Bambusa Tulda, Bambusa Bambos, Dendrocalamus Strictus and others.

The Bambusa Tulda species is expected to dominate the market owing to its widespread use in the construction industry and for making furniture, mats, handicrafts, among others. Additionally, this is an edible variety and is also used as wind breaks. Based on the end-user industry, the market can be fragmented into wood and furniture, construction, paper and pulp, textile, medical, agriculture and others. The paper and pulp industry is expected to dominate the market on account of the favourable government excise policy, rising government's spending on education and increasing activities in print media.

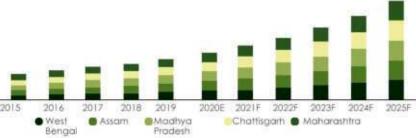


Figure 1.31 depicts the increase in regional market for bamboo. Figures 1.60 depicts the growing volumes of bamboo imports into India.

References:

Contact author at cgbmtblr@gmail.com

TESTING AND TRAINING SERVICES @IWST

Testing Services

- Identification of wood
- Physical properties of wood tests (Specific Gravity/Density of Wood, Moisture Content, Shrinkage)
- Mechanical properties of wood (Static Bending, Compression Parallel to Grain, Compression Perpendicular to Grain, Tension Parallel to Grain, Tension Perpendicular to Grain, Hardness, Shear, Nail Holding Power, Screw Holding Power)
- Determination of calorific value of wood
- Thermo gravimetric analysis of lignocellulosic material
- Determination of penetration and retention of preservative in the treated wood
- Wood polymer composites
- Preservative solution analysis
- Proximate analyser (fixed carbon content, volatile content, ash content and moisture content)
- Estimation of percentage of Sandalwood oil and GC analysis of oil
- Distillation of essential oil and estimation of oil yield by hydro distillation method
- Identification services decay fungi/mould
- Supply of fungus culture per tube
- Testing of bio-efficacy of preservatives/ insecticides against borers
- Sandalwood farming and managing its health Consultancy
- Testing of wood preservatives/fire retardants
- Specific information by post

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- Sandalwood: Tissue Culture Techniques
- Sandalwood: Seed Handling, Nursery and Plantation Technology
- Wood Seasoning and Preservation
- Sandalwood: Farming and Management of its Health
- Extraction and Quality Assessment of Sandalwood and other Essential Oils
- Wood Modification
- Field Identification of Important Timbers
- Clonal Propagation of Melia dubia
- Sandalwood: Establishment and Maintenance of Healthy Nurseries and Plantations
- Insect Pest Management
- Bamboo Agarbatti Stick Making

For further details, please contact:

The Head, Extension Division

Institute of Wood Science and Technology

18th Cross, Malleswaram, Bengaluru - 560 003

Phone: +91-80-22190197, 201, E-mail: extension_iwst@icfre.org

Benefits of Bamboo as Mainstream Green Construction and Building **Material**

Introduction

ny building that is designed, constructed and maintained for the health and well being of the occupants while minimizing the negative impact on the environment falls under the category of green building. Other factors like resource-efficient site design and development practices helps to reduce the environmental impacts and improve the energy performance of newly built house. Bamboo is a green option since it qualifies under many of the categories for eco-friendly building material viz low energy consumption, sustainability, fast growing, environmental friendly, high strength to weight ratio and reduction to soil erosion.

Bamboo is a flexible material with good strength to weight ratio. In case of light weight means that when an earthquake hits, there is less mass to create stresses on the structure. The energy is being dissipated, and all that movement makes bamboo houses to survive strong earthquakes. Ministry of Environment and Climate change, Government of India has recommended bamboo-based houses, which have been developed and successfully tested in earthquake-prone areas of the country. Bamboo is an earthquake resistant structural member and it can be used as a predominant structural member. In India and probably in North and North-Eastern parts, bamboo continues to be used in traditional and rural areas as a cost-effective housing material. Being a naturally grown material, bamboo elements would be an ideal material for vernacular houses in the regions where they are available.

Moreover, bamboo based housing system requires lower operating costs and increases thermal comfort. They have enhanced durability and low maintenance. Thus bamboo and bamboo composites have immense potential to serve as a green building material in innovative and aesthetic housing. Armed with a wide gamut of advantages, bamboo composites have a key role to play in the growing markets in India. The developmental efforts for finding newer composites for existing and novel applications is the need of the hour. Considerable expertise exists in India in the technological institutions and a few manufacturing

ICFRE-Institute of Wood Science and Technology Field Station, Kolkata

E-mail: silchief@gmail.com

industries, the usage of composites in all these years has been limited to multiple commercial applications and potential for export have also not been tapped even in a limited way.

Background: relevance to current requirements

India has a rich diversity of bamboo and they belong to the family Poaceae, and sub family bambusoideae which comprises both lignified and herbaceous bamboos and bamboo allies. In India there are 115 species which are from Indian sub-continent whereas 63 species are under 13 genera from present day India and among others 115 species under 20 genera. The North Eastern region of India has about 50% of total bamboo species available in India. There is boom in construction and civil engineering activities resulting in increased demand of of building materials. This has posed many challenges due to increased use of non-renewable materails such as steel, concret, aluminum. This has also created opportunities for innovative and unconventional renewable resources to emerge such as bamboo. Buildings account for nearly 40 % of the total energy consumption globally. Energy efficient technologies can reduce the energy consumption approximately by 60 %. In India, the building sector accounts for about 35 % of the nation's total energy consumption and is growing at 8% rate each year. Hence there is a need for energy efficiency and economical methods of construction using bamboo as one of the green building materials towards sustainable growth.

Significance of bamboo housing technology

Bamboo based housing system has very high potential for mass housing, housing in disaster prone areas and for earthquake resistant structures and other applications like farm houses, resorts, eco-tourism camps etc. The low mass of the bamboo based building is an advantage under earthquake loading as compared to masonry and concrete buildings. The housing technology developed by the IWST is different from conventional bamboo construction practices. The method uses round bamboo as column, rafter, purlin and truss as main load bearing element, split bamboo for grid walls plastered with cement. Bamboo Mat Board (BMB) is used as gusset in combination with mild steel





Figure 1. Testing of prototype bamboo House on shake table under seismic simulation

bolts for load bearing joints in roofing structure and Bamboo Mat Corrugated Sheet (BMCS) for roof cladding. Seismic performance of bamboo housing developed by the institute has proven to withstand a simulated earthquake test carried out using shake table test at Centre for Power Research Institute (CPRI), Bangalore. The prototype bamboo house having mass of 2636 Kg and size 2.7m x 2.7m was tested on shaking table. A seismic simulation of 30 seconds was carried out on the bamboo house for a design spectrum of zone IV and zone V classification as per IS 1893 (Part-1):2016.

Necessity of bamboo housing in earthquake prone areas in India (Disaster Management)

In addition to poverty and unprecedented population growth, natural calamity is another important issue to be dealt with. The North and North eastern parts of India fall within seismic Zone-IV which makes it vulnerable to earthquake. Every year vast majority of the population suffer from various kinds of natural disasters viz. flood, landslide, earthquake and lose their houses, lives and properties resulting in breaking of social system and leading to an unstable life. These disasters are very difficult to manage especially for rural and tribal areas where limited economic and natural resources further deteriorates affected lives. Such reality has also compelled to think about options to re-settle affected populations in a short period of time to provide them immediate relief and re-start their social life. In view of the above, bamboo and bamboo composites based housing system can be thought of. These type of houses can be constructed quite quickly for immediate and long term rehabilitation for post disaster relief.

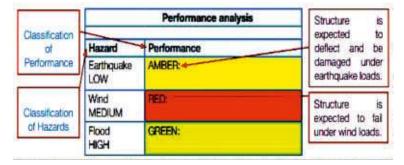


Figure 2. Performance analysis of the bamboo houses with respect to different hazards due to natural disaster

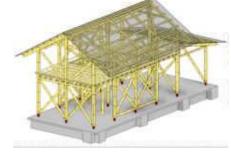


Figure 3. Typical bamboo house designed to cater natural calamity

Availability and acceptance

Availability is the measure of how easily accessible the bamboo is in that region and acceptance is the willingness to use the material. An available and accepted resource can minimize transportation costs and also it negates benefits of an alternative material over other local materials. Bamboo has high compressive strength and low weight which can be the most used building material as substitute for concrete,

especially in those locations where it is found in abundance. Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three times faster than most other plants. They are renewable and extremely versatile resource with multi-purpose usage. Bamboo housing is a major area of application, especially in the wake of residential shortages around the globe. A thorough treatment of bamboo is required to protect it against insects and rot before it is put into use.





Figure 4. A Bamboo Guard House (Left) and Gazebo (Right)

Bamboo as a structural material

1. Design provisions

Structural design has information of equations, detailed guidelines and construction practices. Considering the above, the Bureau of Indian Standards (BIS) has formulated an Indian Standard on the subject namely IS 15912:2012 'Structural design using bamboo-Code of Practice'. The Code has been developed taking into cognizance and advantage of various properties associated with bamboo, for effective structural use of bamboo in the country. The standard covers the general principles involved in the design for structural use of bamboo with regard to mechanical resistance and durability of structures.

2. Mechanical properties

Mechanical properties of bamboo may vary depending on the analysis. Properties required for structural design and applications include tension, compression, bending strength, shear strength, modulus of elasticity and rupture. These mechanical properties provide the framework for bamboo's implementation in structural design.

(a) Tension

Tension forces are experienced in a variety of structural members viz. beams, truss-members, tie beams and others. Bamboo has high tensile strength which creates an advantage over other structural materials. The tensile strength of bamboo has to be taken into consideration while designing bamboo structures. Many parameters affect the tensile strength, including node placement, age and moisture content. The tensile strength at the nodes is approximately 80% of the tensile strength at the internodes.

(b) Compression

The compressive strength of bamboo allows structural engineers to design columns, strud members, and other compression members in bamboo structures. Bamboo compressive strength increases with age, while nodes and moisture content do not affect compressive strength.

(c) Bending and shear

Bamboo bending strength is critical to determine the member size and span length. Bending strength of a bamboo member is determined by the span. Shear governs for short members, and pure bending governs for long members, generally depending on load intensity, strength of the species, and span.

(d) Modulus of elasticity

The modulus of elasticity of bamboo indicates bamboo's flexibility and behavior. It helps to predict the culms' change in length based on axial loading in tension or compression, and is also used to determine member deflection. Thus, structural engineers should use determined value from testing in design. Maximum tangential strength is determined by bamboo's tangential modulus of elasticity, which is approximately one-eighth of the longitudinal modulus.

(e) General pproperties and ffailures

Properties and failures of bamboo in design include the inherent variation of culms and buckling. Culm variation contributes to the difficulty of designing bamboo structures and obtaining accurate quantitative data. Bamboo is weak because of variation in the cross-section, which can substantially impact the bending and axial stiffness of the culm. Both properties are avoidable through quality control and design checks throughout the design and construction process.

Table 1. Important strength properties of some bamboo species

Species	Country	Specific Gravity	Moisture Content (%)	MOR (Kg/cm²)	MOE (Kg/cm²)	Crushing Strength (Kg/cm²)
Bambusa bambos	India	0.651	15.5	674	65,000	483
Bambusa bambos	Puerto Rico	0.580	10.0	918	1,20,000	367
Bambusa bambos	Indonesia	-	15.5	905	-	421
Bambusa blumeana	Philippines	0.503	Green	308	86,400	349
Bambusa nutans	India	0.716	16.0	545	85,000	508
Bambusa tuldoides	South America	0.830	11.0	1,547	1,62,000	-
Bambusa vulgaris	Puerto Rico	0.700	10.0	1,224	1,59,000	584
Bambusa vulgaris	Indonesia	-	17.0	860	-	254
Dendrocalamus asper	Indonesia	-	15.0	1,054	-	322
Dendrocalamus strictus	India	0.743	12.0	1,407	1,66,777	619
Dendrocalamus strictus	Puerto Rico	0.620	10.0	1,709	1,77,000	534
Giganto chloaapus	Indonesia	-	14.8	893	-	383
Giganto chloaatter	Indonesia	-	14.5	1,219	-	350
Giganto chloalevis	Philippines	0.539	Green	2289	6,960	396
Giganto chloaverticillata	Indonesia	-	14.9	960	-	365
Guadua augustifolia	Puerto Rico	0.82	010.0	1,448	1,76,000	-

Source: INBAR Technical Report No. 3

Bamboo concrete composite construction

Due to scarcity and high cost of reinforcement material, especially steel, there was an ardent need to look up for some alternate material so that it can be used as reinforcement in concrete. The use of bamboo has always been attracting the attention of engineers, architects and builders in exploring its possibility for use as reinforcement in low cost structures. The ultimate tensile strength of some of the species of bamboo is nearly the same as that of steel at its yield point. On an average, it varies from 1400 to 2800 Kg/cm². It was for this high value which attracted the attention of investigators for the use of bamboo as reinforcement.

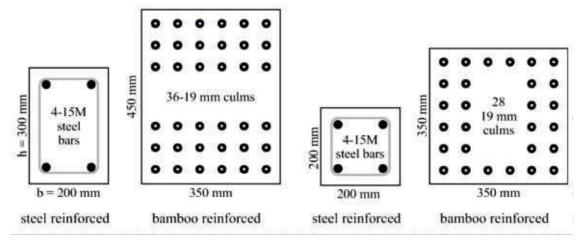


Figure 5. Comparison between steel and bamboo reinforced composite bay frames Source: www.link.springer.com/article/10.1617/s11527-018-1228-6)

Seasoning and preservation treatment of bamboo

Properly seasoned and treated bamboo are mandatory requirement for structurally safe, economical and long lasting bamboo structures or for construction of bamboo houses. There is a need for setting up treatment plants near bamboo growing areaa for (a) value addition to bamboo and (b) ensuring continued and sufficient supply of bamboo in bamboo depots. Joint Forest Management (JFM)s can set up these units creating large livelihood opportunities to otherwise economically poor and marginalized bamboo communities. Service life of bamboo must be considered before structural use of bamboo commences. Lack of long-term service life negates any benefit or sustainable aspect of using bamboo as a structural material for commercial purposes. The expected service life of bamboo must be extended longer than twenty-five years in order to encourage its use as a structural material. Without this development, the use of bamboo as a structural material is not feasible for commercial use. A thorough treatment of bamboo is required to protect it against insects and rot before it is put into use. Commonly a mixture of Borax and Boric acid or CCB with pressure impregnation is utilized for this purpose. Another procedure generally employed is to boil bottom portion of bamboo for column foundation with creosote oil.

There is very limited use of bamboo as foundation material because when in contact with moisture laden surface they decay fast. However, this issue can be sorted out to quite an extent though proper treatment. Moisture has a great influence on treatability of bamboo (Figure 2). The various types of foundations constructed with bamboo are:

- (a) Bamboo which is in direct contact with ground surface.
- (b) Bamboo fixed to preformed concrete footings
- © Composite bamboo or concrete columns
- (d) Bamboo piles

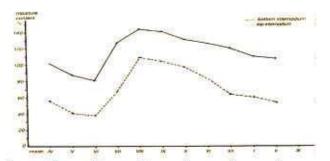


Figure 6. Seasonal changes of moisture content in bamboo

Skilled manpower development

In using bamboo as a structural or building material, there should be capacity building measures at every level of design namely: (a) Supervision level and (b) Execution level. Institutes like IWST provides vocational education and training programs with emphasis on hands-on experience of construction of energy efficient houses. Skilled manpower for the bamboo construction sector to be tied up with NGOs, grass root level workers and engineers to work in coordination so as to promote its importance as sustainable building material. There is an ardent need to include bamboo as building material in curriculum for civil engineering and architecture degree courses in India where there can be a source of skilled manpower. Here role of architects is crucial for knowing the properties of bamboo in design of structures.

Techno-Economic viability

The conventional construction technology along with spiraling cost of traditional building material makes building unaffordable and may be a distant dream for an average income salaried person. Whereas, bamboo houses are energy efficient and saves up-to 60% of cost of masonry construction. Moreover, if fly ash is being used as partial replacement of cement, it saves the construction cost and minimizes the carbon emission from masonry and concrete in the tune of 30%. Use of treated bamboo and bamboo composite products makes the building much more sustainable and affordable.

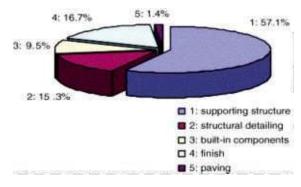


Figure 7. Environmental and economic assessment of bamboo as a building material

Source:www.sciencedirect.com/science/article/abs/pii/S0950061805001157

Commercial opportunities

Bamboo houses built with bamboo as structural members and bamboo composite material can be used for pre-fabricated housing systems. This technology will

be highly useful particularly for relief agencies for disaster management. Besides the benefits of a quick supply of bamboo houses or shelters in large quantities, the design of a bamboo based modular housing production chain will also directly benefit the bamboo growers, harvesters and employees of the building industries by generating direct and indirect employment and linking them with industries in preprocessing and processing of panel components. This will lead to the development of long term rural-urban market linkages. These types of pre-fabricated houses can be used by highway workers and urban infrastructure. Bamboo housing and related industries



available in various parts of India, due to lack of treatment facilities, the end users are being compelled to buy bamboo at high price with added transportation cost.

Conclusion

Resilience coupled with light weight makes bamboo an ideal building material for housing in disaster and earthquake prone areas. It has the capacity to withstand repetitive loadings and absorb more energy and show larger deflections before collapse and thus it is safer under earth tremors. As the design guidelines were inadequate, the application of bamboo as an



Figure 8. Different types of bamboo houses

can provide direct employment opportunities to the local communities through cultivation, management, pre-possessing and processing stages. In order to promote sustainable use of Bamboo in construction and related activities, the Bureau of Indian Standards (BIS) has a series of standards on bamboo preservation, testing, products and structural design of buildings using bamboo. It may particularly be noted that the Standard on structural use of bamboo has since been revised and updated in National Building Code 2016.

Challenges

a) Lack of availability of trained labour:

Bamboo processing requires a certain degree of technical proficiency which is currently insufficient.

b) Low levels of quality assessment and absence of standardization:

The absence of quality standardization in bamboo products, as well as for bamboo poles has created a significant problem for exports in India.

c) Treatment at site:

There is a need for minimal facility to build treatment process for bamboos at site. Though bamboo is

engineering material was largely based on practical and engineering experience. The usage of natural fiber based composites from bamboo in post disaster management may be cost effective to other building materials. Local industries producing bamboo based pre-fabricated modular housesneed to be promoted which would benefit the environment, local building enterprises and families, particularly poor rural people, slum dwellers and homeless disaster victims who can't afford expensive houses. Moreover, bamboo houses developed by institute like IWST consumed 7.1 times less energy than that of a conventional house of similar dimensions. Low cost bamboo houses are cheap and safe alternative to the shelters of plastic, wood and stone that are currently being used by many homeless people.

References: Contact author at sila@icfre.org

Bamboo Strand Lumbar as a Sustainable Building Material for Structural Application

Introduction

amboo is a naturally occurring sustainable composite material that grows abundantly in most of the tropical countries. India has the world's second highest resource of bamboo in the world. About 148 bamboo species in 29 genera have been found in India. The primary chemical constituents of bamboo are cellulose, hemicellulose and lignin. The fibres are longitudinally embedded in the matrix of parenchyma and consists of cellulose micro-fibrils that providing excellent mechanical properties. Bamboo has been considered as one of the oldest building material used by mankind. It is being widely used for household products and extended to industrial applications due to advances in processing technology and increased market demand. Bamboo has found its utilization for household utilities such as containers, chopsticks, woven mats, fishing poles, cricket boxes, handicrafts, and chairs etc. It is also used as a structural material for bridges, water transportation facilities, and scaffoldings. Existence of massive plantations of bamboo throughout the country serves as an excellent source of raw material for various end uses. The availability of quality wood has declined, whereas the demand for timber in structural application has increased in today's modern industrialized world. The phenomenon has encouraged researchers and industries to explore new and widely available alternative resources like bamboo for its utilization as a sustainable building material. Wood and mass timber products such as glued laminated timber and cross laminated timber have recently gained popularity in the green building community because of their environmentally beneficial characteristics in comparison to widely accepted building materials such as steel and concrete. Wood is being promoted as a renewable, biodegradable, high carbon sequestering material, low in embodied energy, and less pollution created during production. Bamboo has similar environmental characteristics. Most notably, it is highly renewable, as bamboo culms can attain maturity in about 3-5 years. Its strength is comparable to that of wood, which makes the bamboo an appealing candidate for a structural material.

Vipin Kumar Chawla*, S. R. Shukla and B. U. Kelkar

ICFRE - Institute of Wood Science and Technology, Bengaluru-560003, India

*Email: chawlavp@icfre.org

Even though bamboo has a great potential to substitute timber in several applications, use of round bamboo culms in construction and building sector is still limited due to some of its undesirable properties such as an irregular and hollow cross section and the presence of nodes. These peculiar characters creates lot of difficulties to use bamboo as a construction material. Low resistance against fungal and insect attack, rapid absorption of water, and susceptibility to insects of starch being present in bamboo has also been reported. Bamboo, however, also possesses a number of unique properties that make it attractive for use as a construction material. Unlike most hardwoods, which take 50 to 60 years to fully mature, bamboo takes between 3 to 5 years only with daily growth rates of up to 100 cm having been reported. The carbon sequestration rate for bamboo is similar to that of a hardwood forest and the material can therefore act as a carbon sink. As such, the environmental benefits of using bamboo in construction are similar to that of wood. Mechanical properties, especially flexural strength, stiffness and tensile strength of bamboo are comparable to commonly used timber species. The oven-dried density of bamboo varies between 500 and 800 kg/m³, which is very much similar to most of the softwood species of structural importance. Additionally, metabolic processes in bamboo do not produce organic and inorganic by-products such as polyphenols, resins, and waxes, providing an added advantage for its utilization as a raw material for development of value added products.

Recently, bamboo is being studied extensively by researchers as a source of raw material to produce several value-added structural composites to suit the needs of building and construction sector. Bamboo can be converted into various engineered composite materials such as Woven bamboo mat composite (BMC), Laminated Bamboo Lumber (LBL), and Bamboo Strand Lumber (BSL). Transforming bamboo into these

composites increases its utilization potential as a structural material. BSL is a relatively new concept which involves conversion of bamboo culms into fibre strands that are bonded using a structural grade adhesive such as phenol formaldehyde, under high pressure and heat to form a composites having standardized cross section. BSL provides added advantage of high raw material utilization in comparison to other composites, along with possibilities to incorporate preservatives and fire retardants for improving its longevity in long term load bearing applications. With adequate research, it is conceivable that BSL could become a sustainable alternative to current building materials in several parts of the world. The scope of this product is to develop high strength materials from bamboo strands and reduce the pressure on natural forests for the demand of solid wood in building sustainable cities and communities that ultimately help to achieve the Sustainable Development Goals (SDGs).

Methodology for making bamboo strands lumber

For the manufacturing of BSL two raw materials were used, namely Bambusa bambos species of bamboo and a single stage conventional phenol formaldehyde resin with 1:1.8 weight ratios.

Primary Conversion and preservative treatment of bamboo

First, the length of the bamboo was measured, and markings were done on the top, middle, and bottom portions of the bamboo. After marking the portions, cross-cutting of bamboo was performed to cut the bamboo culms into the desired lengths. After crosscutting the bamboo, the outer nodes were removed. Then splitting was performed to split the bamboo culms into the desired width of 10 mm to 15 mm. To obtain a smooth surface for the bamboo strips, the internal node was removed. The outer green skin of the bamboo was scraped off. This process eliminates decontamination and improves the appearance of the strips. The skin removal process can be done either by a machine or manually. When scraping the skin, it is important to apply force evenly along the culm surface to ensure a uniform colour. The hydrothermal treatment of bamboo strips was performed prior to crushing them into fibre strands. This step allows the bamboo strips to become softer and easier to crush and the fibres would not break during crushing. Hydrothermal treatment can be accomplished using two methods - Boiling or Steam heating.

In the boiling method, bamboo strips were kept in a closed tank filled with water. The level of water was kept above the level of strips, and then the tank was heated. The advantage of this method is that preservatives can be added in boiling water. In this study, borax boric acid was used as preservative. Borax melts at 65 °C. Thus, it dissolves into boiling water. The bamboo strips were cooked for approximately 45 min in the solution. Another advantage of boiling method is that it retains the natural colour in the strips. The following steps were taken to prepare BSL.

- a) Crushing of strips: Crushing was performed manually by hammering and disintegrating the fibres from the bamboo.
- b) Drying of crushed bamboo strands: The purpose of drying of crushed bamboo strands is to reduce the moisture content to a range suitable for gluing. Strips contain more than 30 % moisture, and if the drying is not completed, then crushed bamboo strands will not absorb a sufficient amount of resin. Generally, the suitable moisture content for gluing is 6 to 8 %. Therefore, the strips were dried in an industrial furnace at temperature of 50 °C to 60 °C for 36 h to reduce the moisture content of strands to desirable level.
- c) Resin application: Resin was applied by dipping the crushed bamboo strands in diluted resin for making bamboo strand lumber. Conventional PF resin was used and the same amount of water (1:1) was added into resin to reduce its viscosity. The crushed bamboo strands were kept immersed in the resin for 5 to 10 min.
- d) Air Drying: Resin dipped crushed bamboo strands were kept under normal atmospheric conditions for air drying by keeping the strips in vertical positions with support in a container for 3 to 4 h to drain out excess resin from the strands.
- e) Oven Drying: The gluing moisture content of the strands was maintained between 10 to 12% before pressing. After air drying, the strands were kept in an industrial furnace at 50 to 60°C temperature until the moisture content of the strands reached 10 to 12%. Over-drying was avoided because over drying of the strips can also leads to poor bonding of the lumber.
- f) Assembling and hot pressing: After the strands attained the desired moisture content, the strands were assembled in such a way that fibre direction of all the strands were parallel to each other. Next, the strands were wrapped with bi-axially oriented polypropylene (BOPP) film for lamination and both ends were tied firmly with thread. The width of the

assembled strips was measured, and the same width in the hot press was set by adjusting the guider plates. The assembly was loaded into the hydraulic hot press (Hydraulic Hot Press; WMW AG/Machine trading Messe-Allee 10a, 04158 Leipzig, Germany). In this press, one hydraulic cylinder was placed at the base house that could move up and down. The gap between the two platens was 19 mm and was set by moving up the bottom cylinder. This gap was set after loading the assembly. The thickness of the lumber depends on this gap. Another two hydraulic cylinders were placed inside houses, which give lateral pressure. The bottom and top cylinders of the hydraulic hot press only gave the contact pressure to the assembly, while the two lateral cylinders exerted the side pressure of 15 kg/cm². This pressure was transmitted through guider plates. The assembly was pressed by side pressure at a temperature of 145 ± 5 °C for 22 min.

- g) Trimming: Trimming was done to give proper size and shape to the lumber. It also removed defects present in the edges. This process involves cutting the four edges of the board to obtain a board of required size and perfect square.
- h) Sanding: The process of sanding involves the removal of a small extent of the surface layer from a panel by using abrasive materials. Sanding is done to produce a panel of required thickness having thickness uniformity within specified limits, to produce a clean, smooth surface finish suitable for subsequent polishing, painting, or overlaying, and to clean up splits or remove handling dirt such as dust and finger marks.

The process for the manufacturing of bamboo strand lumber is depicted as a flow chart shown in figure 1.



Figure 1. Flow chart of the process for manufacturing bamboo strand lumber.

Properties of BSL in comparison with mass timber products

BSL and laminated veneer lumber are found to have comparable mechanical properties. Table 1 shows that physical and mechanical properties viz. water absorption, density, moisture content, modulus of

rupture in bending, modulus of elasticity in bending, compressive strength, and the screw withdrawal strength in face and edge of BSL. Compressive strength parallel to the grain value, modulus of rupture in bending, and modulus of elasticity in bending were on the higher side.

Table 1. Mechanical Properties of BSL

S.N.	Parameter	BSL Value	Laminated Veneer Lumber (IS 14616 1999)
1	Density (kg/m³)	1156.9	500 to 900 kg/m ³
2	Modulus of rupture (Mpa)	215.250	Minimum
3	Modulus of elasticity (Mpa)	232167500	Minimum
4	Moisture content (%)	9.68	5 to 15%
5	Compressive strength parallel to grain (Mpa)	38.4	35 Minimum
6	Screw withdrawal strength (N) a) Edge b) Face	1245 1985	2300 Minimum 2700 Minimum

However, the screw withdrawal strength tested in edge and face were observed to be 1245 N and 1985 N respectively. These were slightly lower than those recommended in IS 14616 (1999). Particularly, screw withdrawal strength was lower at edge and face, respectively, which may be due to inherent properties of bamboo, i.e., weak adhesion of longitudinal fibers and non-availability of radial fibers. This was attributed to the four-side compression of bamboo strands material in the hydraulic press during production, besides excellent adhesion quality of phenolic resin with



Figure 2. BSL prepared using crushed strands of B. bamboo bonded with PF adhesive.

bamboo stands. On top of that, MOR and MOE were observed to be 215.2 MPa and 23216 MPa respectively. These were also higher compared to those recommended in the standard for LVL. This can be credited mainly due to inherent material properties of bamboo. The results showed that the density of bamboo strand lumber is the primary factor responsible for better values of MOR, MOE, and compressive strength parallel to the grain.

Application and advantages of bamboo strand lumber

The bamboo based composites such as Bamboo Stands Lumber is considered more eco-friendly alternative compared to commonly used structural timbers. Also encouraging in-situ production of bamboo composites can provide numerous opportunities to ensure efficient utilization of bamboo resources available in the country. Bamboo composites are being utilised majorly for flooring tiles, panelling components, decorative crafts etc. The utilisation of bamboo composites in structural applications requires development of components with longer spans and larger cross sections compared to panel based industries. Through technological interventions, bamboo can be converted into various composites viz. Laminated bamboo lumber (LBL), Bamboo Strand Lumber (BSL), Bamboo Scrimber, Bamboo Plywood etc., which enhances the utilisation possibilities of the raw material as an alternative to commonly used timbers. Institute of Wood Science and Technology has developed Bamboo Stand lumber technology using crushed bamboo strands bonded with phenolic adhesive as an alternative to solid wood lumber for mass timber applications.

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Contact author @ chawlavp@icfre.org

Ensuring Fire Safety Robustness in Tall Timber Buildings by Means of Building Codes

Introduction

nternational building code (IBC) is a model building code which is developed by International Code Council. It is intended to protect public health, safety and welfare. The provisions of the code help in avoiding both unnecessary costs and encourage the use of new and smarter technological advances. From the environmental point of view, the building and construction sector has a significant impact on the environment. There are many materials that have a higher carbon footprint, and therefore, it is wiser to use non-polluting and recyclable materials, favouring the natural ones available and applying modern techniques and systems to address current environmental issues. Considerable studies have been carried out by the research community worldwide, in order to find alternative sustainable building materials and low-cost technology methods, which result in more sustainable and affordable construction needed today. Adopting green building materials is an excellent approach to meet this target. The selection of construction materials that have minimum environmental burdens is useful in the sustainable development of a country. Wood is one such material, which can be used in almost any building application. Studies show that wood products are associated with far fewer greenhouse gas emissions over their lifetime than other major building materials.

Wood is widely used for building construction for thousands of years. It is a preferred building construction material because of its properties such as high strength-to-weight ratio, light weight, good insulation and aesthetic appeal. However, the hygroscopic and anisotropic nature of wood restricts its use in structural applications. These limitations are mainly resolved by the development of engineered wood products such as cross-laminated timber (CLT), glue-laminated timber (Glulam), laminated veneer lumber (LVL), and dowel laminated timber (DLT). These engineered products offer enhanced dimensional stability, strength and design versatility for project detailing. They have also provided the opportunity to utilize even small girth logs from short rotation timbers in terms of high-value structural materials and the

Ritesh Kumar^{1,*}, Sanmitra Dan¹, Siddhartha Arya¹ and V. R. Ramkumar²

¹WPP Division,

ICFRE-Institute of Wood Science and Technology, Bangalore

² PPPT Division,

ICFRE-Institute of Wood Science and Technology,

IPIRTI Campus, Bangalore

*Email: ritesh@icfre.org

development of these engineered composites has made it feasible to construct tall buildings using completely wooden elements. The use of these products in multistory buildings has been increasing rapidly due to growing environmental concerns coupled with developments in international building codes. Further, in order to increase the use of mass timber elements in building construction, challenges such as strength quality, manufacturing standardization, and product durability are critically important to address.

1. Types of construction in IBC 2021

IBC refers timber building construction as a combustible type of construction, whereas, concrete and steel-based constructions are mentioned as noncombustible construction. In order to ensure the safety of inhabitants in the event of a fire, the IBC (2021) has systematically categorized building construction into five different types. This is based on the parameters such as the height of a building, occupant load, proximity to other buildings or structures, use fire resistant materials, use of water sprinklers, exit location, etc. Chapter-6 (sections 602.2 through 602.5) of IBC (2021), establishes five different types of constructions in which each building must be categorized. IBC (2015) has included nine construction type options: I-A, I-B, II-A, II-B, III-A, III-B, IV, V-A, and V-B, whereas, IBC (2021) has included three new construction types: IV-A, IV-B and IV-C. This chapter also looks into various materials (combustible or non-combustible) that are being used and the extent to which they can resist fire. Among these, Type 1 building construction is the most stringent one which provides the highest level of fire protection to its occupants, whereas, Type V, is the least stringent one in terms of use of types of building materials and practices followed. Each type of construction is further classified as "A" or "B", which means to say that a type "B" designation is basic and type "A" is enhanced. Based on the different types of constructions and the types of materials used, IBC (2021) chapter-6 is specified 1 to 3 hour fire resistivity. Timber construction has been categorized within Types III, IV and V construction. These types are also limited to low- and medium-rise buildings, with limited building area.

1.1. Type V construction

In this, the structure has inherently lower fire ratings. Types V-A have a 1-hour fire resistance rating (FRR) requirement for many structural elements, whereas, Type V-B has no FRR for most structural elements. In this type of construction, the walls, frames, roofs and floors are made partially or completely of wood. This type of construction also allows combustible exterior walls as well as combustible structural members on the interior. For such a reason these buildings are more challenging for fire fighters and requirs more fire barriers to protect neighbouring buildings. Singlefamily residential homes, car garage are the most common application, small commercial buildings such as restaurants, small office buildings, or even a small theatre might be wood-framed as well. Type V construction buildings are always smaller (<7000 sq. ft.) than a building of the same use built to a more stringent type (Type IV- 20,000 sq. ft.) construction. However, in this construction type, even if the building doesn't require sprinklers, the addition of sprinklers is always recommended to enhance fire safety.

1.2. Type IV construction

Under this the buildings are constructed using mass timber non-combustible materials which have fire-resistance ratings in accordance with Table 601 of IBC (2021). The use of thicker sections in this type provides resilience to the building against collapse and performs better under fire conditions due to the conversion of top wooden layer into char that protects the underlying wood against direct heat transfer due to flame. The very example of such type of construction is older churches, temples or barns where we can see thick structural beams that are fastened by metal plates and bolts. Type IV construction required its wooden elements (interior walls and framing etc.) to meet the minimum criteria of "heavy timber" or large size lumber. The beams and columns used in this type should be more than 8 inches thick, whereas the roof element should be around 6 inches. The maximum permissible height in Type IV construction is 85 ft, which is equal to the allowed height as in case of Type II-A and III-A construction type. Cross laminated timber (CLT) used as an exterior wall in Type IV construction shouldn't be less than 4 inches (10.2 cm) in thickness and it should be protected by fire retardant treated wood sheathing not less than 12mm in thickness, gypsum board not less than 1/2 inch (12.7 mm) thick.

Table 1: Fire-resistance Rating Requirements For Building Elements (hours) (IBC 2021- Table 601)*.

BUILDING ELEMENT		PE I	TYP	E II	TYP	E III		TYPE V				
BUILDING ELEMENT	A	В	A	В	A	В	A	В	C	HT	A	В
Primary structural frame ^f (see Section 202)	3 ^{a, b}	2a, b, c	1 ^{b, c}	0°	1 ^{b, c}	0	3ª	2ª	2ª	НТ	1 ^{b, c}	0
Bearing walls												
Exterior ^{e, f}	3	2	1	0	2	2	3	2	2	2	1	0
Interior	3ª	2ª	1	0	1	0	3	2	2	1/HT ^g	1	0
Non-bearing walls and partitions Exterior					See	Table 70)5.5					
Non-bearing walls and partitions-Interior ^d	0	0	0	0	0	0	0	0	0	Section 2 304.11.2	0	0
Floor construction and associated secondary structural members (see Section 202)	2	2	1	0	1	0	2	2	2	НТ	1	0
Roof construction and associated secondary structural members (see Section 202)	1 ¹ / ₂ ^b	1 ^{b,c}	1 ^{b,c}	0°	1 ^{b,c}	0	11/2	1	1	НТ	1 ^{b,c}	0

^{(*} Source https://codes.iccsafe.org/content/IBC2021P2/chapter-6-types-of-construction)

For SI: 1 foot = 304.8 mm

- a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.
- b. Except in Group F-1, H, M and S-1 occupancy, fire protection of structural members in roof construction shall not be required, including protection of primary structural frame members, roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.
- c. In all occupancy, heavy timber complying with section 2304.11 shall be allowed for roof construction, including primary structure frame members where a 1-hour or less fire-resistance rating is required
- d. Not less than the fire-resistance rating required by other sections of this code.
- e. Not less than the fire-resistance rating based on fire separation distance (see Table 705.5).
- f. Not less than the fire-resistance rating as referenced in Section 704.10.
- g. Heavy timber bearing walls supporting more than two floors or more than a floor and a roof shall have a fire resistance rating of not less than 1 hour.

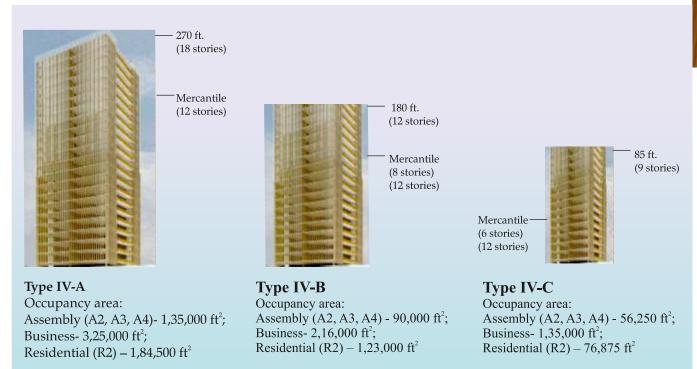


Figure 1. Illustrative building size for residential (ICB 2021 Table 504.3) and office occupancy area (ICB 2021 Table 506.2)

1.2.1. Type IV-A:

Figure 1 illustrates the building size and area of occupancy for Type IV constructions. Type I-A as well as Type IV-A construction has similar fire-resistance rating. The outside face of exterior walls of mass timber construction shall be protected with non-combustible protection with a minimum assigned time of 40 minutes, as specified in Table 722.7.1(1). In this the mass timber elements are completely covered with noncombustible materials such as multiple layers of 5/8 inches of gypsum boards as described in section (IBC 2021: 722.7). The flooring on both sides, walls on sides, roof surface, shafts etc., should be fully covered with fire retardant materials. The floor assembly shall contain a non-combustible material covering not less than 1 inch (25 mm) in thickness above the mass timber (IBC-2021). Type IV-A also requires dual water supplies for buildings more than 120 feet in height to ensure automatic and manual suppression provisions (sprinklers). Concealed spaces shall not include combustibles other than electrical, mechanical, plumbing, and fire protection equipment as allowed in the building code. The requirement from noncombustible protection material used in this type shall contribute a time equal to or greater than the times assigned in Table 722.7 1(1), but not less than 80 minutes. The use of materials and their respective protection contributions specified in Table 722.7.1(2) shall be permitted to be used for compliance with Section 722.7.1 (IBC 2021).

1.2.2. Type IV-B:

Type IV-B as well as Type I-B construction must meet the same fire-resistance requirements. However, the present allowance in IBC Section 403.2.1.1, to reduce I-B construction to one-hour structural elements has not been included for Type IV-B construction. As such, twohour structural elements are still required for Type IV-B construction. As with Type IV-A construction, Type IV-B also requires dual water supplies for buildings exceeding 120 feet in height. This redundant water supply, coupled with the two-hour passively protected structural frame, provides a conservative approach to fire protection. The outside face of exterior walls shall have non-combustible protection with a minimum assigned fire-resisting time of 40 min. The noncombustible material barriers (as per ASTM E1354) should have a peak heat release rate of less than 150kW/m2, a total heat release of less than 20 MJ/m² and an effective heat of combustion of less than 18 MJ/kg; when the samples are tested in horizontal condition and at an incident radiant heat flux of 50 kW/m². Interior faces of all mass timber elements, including the inside faces of exterior mass timber walls and mass timber roofs, shall be protected with materials tested in accordance with ASTM E136. Alternately, materials required to be non-combustible shall be tested in accordance with ASTM E2652 using the acceptance criteria prescribed by ASTM E136 (IBC-2021).

1.2.3. Type IV-C:

This type of construction doesn't require having non-combustible surface covering for interior elements of the building, however, the concealed spaces, shafts, elevators, stairways, and interior exit stairway enclosures are

Table 2. Protection required from non-combustible protection material [IBC 2021- Table 722.7.1 (1)]

Required fire resistance rating of building element as per Table 601 and Table 705.5 (hours)	Minimum protection required from non-combustible protection (min)
1	40
2	80
3	120

required to be fully protected with non-combustible materials. The exterior walls or faces in this construction Type are required to have full covering with non-combustible material with a minimum assigned time of 40 minutes, as

Table 3. Protection provided by non-combustible protection material [IBC 2021- Table 722.7.1 (2)]

Non-combustible protection material	Protection contribution (min)
1/2-inch Type X gypsum board	25
5/8-inch Type X gypsum board	40

determined in Table 722 7.1(1). Components of the exterior wall covering shall be of non-combustible material except water-resistive barriers. The non-combustible material as tested in the horizontal orientation and at an incident radiant heat flux of 50 kW/m^2 and according to ASTM E1354 should have peak heat release rate of less than 150 kW/m^2 , a total heat release of less than 20 MJ/m^2 and an effective heat of combustion of less than 18 MJ/kg. The flame spread index of this material should be 25 or less and a smoke-developed index of 450 or less as determined in accordance with ASTM E84 or UL 723 (IBC 2021).

1.2.4. Type IV-HT (Heavy Timber):

Type IV (HT) construction demands the exterior walls to be of non-combustible materials, whereas, the interior walls of the building are made of solid wood or mass timber elements. In this type, concealed spaces are not permitted. In case the concealed spaces are provided in the building it has to comply with Section 602.4.4.3 of IBM 2021 which says that such spaces shall not include combustible materials other than electrical, mechanical, plumbing, and fire protection equipments as allowed in building code. Also, the concealed spaces are required to be fully protected by providing a complete covering of non-combustible insulation (5/8 inches thick gypsum board). This construction type is also required to have sprinkler systems with a provision of both manual as well as automatic systems. Section 2304.11 (IBC 2021) has tabulated the minimum permitted dimensions of materials like CLT, GLT, solid timber etc. that the construction shall comply with. For example, exterior walls are permitted to be of CLT with thickness not less than 4 inches (102 mm), roof and floor are permitted to be of CLT with thickness not less than 3 inches (76 mm) and 4 inches (102 mm), respectively; interior walls and partitions are required to be of solid wood construction prepared by using two layers of 1-inch (25 mm) matched boards or laminated construction 4 inches (102 mm) thick, roof and floors shall be without concealed spaces or with concealed spaces without any combustibles materials other than electrical, mechanical, plumbing, and fire protection equipment's as allowed in building code and should be properly insulated.

1.3 Type III

Type III construction requires the exterior walls of the building to be of non-combustible materials. Exterior walls of Type III construction are built with brick, masonry, concrete block, precast panels, or other non-combustible materials. However, interior structures and the roof can be of wood as permitted by the code. The fire retardant wood used is tested in accordance with ASTM E84 or UL 723, a listed flame spread index of 25 or less. Additionally, the ASTM E84 or UL 723 test shall be continued for a 20-minute period and the flame front shall not progress more than 10/2 feet (3200 mm) beyond the centre line of the burners at any time during the test.

		Minimum solid sav	nominal n size	Minimui Iaminat	•	Minimum composite size	
SUPPORTING	HEAVY TIMBER STRUCTURAL ELEMENTS	Width, Inch	Depth, Inch	Width, Inch	Depth, Inch	Width, Inch	Depth, Inch
Floor loads only or combined floor and roof loads	Columns; Framed sawn or glued-laminated timber arches that spring from the floor line; Framed timber trusses Wood beams and girders	8	8 10	6³/₄ 5	8 ¹ / ₄ 10 ¹ / ₂	7 5¹/₄	7 ¹ / ₂ 9 ¹ / ₂
	Columns (roof and ceiling loads); Lower half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	8	5	8 ¹ / ₄	5 ¹ / ₄	71/2
Roof loads only	Upper half of: wood-frame or glued-laminated arches that spring from the floor line or from grade	6	6	5	6	5 ¹ / ₄	5 ¹ / ₂
	Framed timber trusses and other roof framing; Framed or glued-laminated arches that spring from the top of walls or wall abutments	4 ^b	6	3⁵	6 ⁷ / ₈	3 ¹ / ₂ ^b	5 ¹ / ₂

Table 4: Minimum dimensions of heavy timber structural members (IBC 2021- Table 2304.11)*.

- * (Source: IBC 2021 https://codes.iccsafe.org/content/IBC2021P2/ chapter-23-wood) For SI: 1 inch = 25.4 mm.
- a. Spaced members shall be permitted to be composed of two or more pieces not less than 3 inches nominal in thickness where blocked solidly throughout their intervening spaces or where spaces are tightly closed by a continuous wood cover plate of not less than 2 inches nominal in thickness secured to the underside of the members. Splice plates shall be not less than 3 inches nominal in thickness.
- b. Where protected by approved automatic sprinklers under the roof deck, framing members shall be not less than 3 inches nominal in width.

2. Fire and life safety provisions in National Building Code India (2016)

The National Building Code of India, 2016 (NBCI) is a model code intended to protect the safety of the public with regard to structural sufficiency, fire hazards and health aspects of buildings. NBCI is a national standard for local governments, public works departments, and other government construction departments and agencies to follow. It is published by the Bureau of Indian Standards (BIS), which is part of the Ministry of Consumer Affairs, Food and Public Distribution, Consumer Affairs. In 1970, the NBCI was first published. In 2016, the NBCI underwent its third revision. It is divided into 12 parts that cover administrative provisions, control rules and general building requirements, fire safety requirements, material and structural design requirements, construction management, building service, plumbing service, landscape development, sustainability, and asset and facility management. The NBCI 2016 specifies minimum requirements for public safety in terms of structural sufficiency, fire hazards, and health aspects of buildings.

Part 4 of NBCI (2016) covers all necessary requirements with regards to preventing occurrence of fire in a building and thereby saving life. The code specifies occupancy-wise classification, constructional aspects, egress requirements and protection features that are necessary to minimize danger to life and property from fire. Fire prevention is accomplished by categorizing and limiting buildings based on

- 1. Occupancy (Classifications and subdivisions of occupancy (as per NBCI 4:3.1).
- 2. Building construction types based on fire resistance of structural and non-structural components.
- 3. Fire zones (as per NBCI 4:3.2.2.2).
- 4. Maximum height, floor area, and open areas of the building.

2.1. Classifications and subdivisions of buildings based on occupancy (as per NBCI 4:3.1):

For the prevention of fire, the general classification of buildings is done on the basis of occupancy in article 3.1.1 (General Classification) of Part 4 of NBCI, 2016. All buildings, whether existing or hereafter erect is said to be classified according to the provisions of this clause as mentioned in Table 5.

Table 5. General classification of building in groups and subgroups as per Part 4- NBCI 3.1.1 and fire zone as per Part 4- NBCI 3.2.2.2.

		and me zone as per rart 4- NDC1 3.2.2.2.	
Occupancy		Sub-division	Fire Zone
Group A	Residential	A1 - Lodging and rooming houses A2 - One or two family private dwellings A3 - Dormitories	1 1 1
		A4 - Apartment houses A5 - Hotels A6 - Starred hotels1	1 1 1
Group B	Educational	B1 - Schools up to senior secondary level B2 - All others/training institutions	1 1
Group C	Institutional	C1 - Hospitals and sanatoria C2 - Custodial institutions C3 - Penal and mental institutions	1 1 1
Group D	Assembly	D1 - Buildings having a theatrical or motion picture or any other stage and fixed seats for over 1,000 persons D2 - Buildings having a theatrical or motion picture or any other stage and fixed seats for up to 1,000 persons	1
		D3 - Buildings without a permanent stage having accommodation for 300 or more persons but no permanent seating arrangement D4 - Buildings without a permanent stage having accommodation	1
		for less than 300 persons but no permanent seating arrangement D5 - All other structures including temporary structures designed	1
		for assembly of people not covered by D-1 to D-4, at ground level	1
		D6 - Buildings having mixed occupancy of assembly and mercantile D7 - Underground and elevated mass rapid transit system	1 1
Group E	Business	E1 - Offices, banks, professional establishments, like offices of architects, engineers, doctors, lawyers and police stations	
		E2 - Laboratories, research establishments, libraries and test houses	$\frac{1}{2}$
		E3 - Computer installations	2
		E4 - Telephone exchanges	2
		E5 - Broadcasting stations and T.V. stations1	2
Group F	Mercantile	F1 - Shops, stores, departmental stores markets with area up to 500 m ²	1
		F2 - Shops, stores, departmental stores markets with area more than 500 m ²	1
		F3 - Underground shopping centres. Storage and service facilities incidental to the sale of merchandise and located in the same building shall be included under this group	1
Group G	Industrial	G1 - Buildings used for low hazard industrie	2
		G2 - Buildings used for moderate hazard industries	2
C 11	Ci	G3 - Buildings used for high hazard industries	3
Group H	Storage	-	3
Group J	Hazardous		3

2.2. Fire prevention via fire zones:

For the purpose of the code, the city or area under the jurisdiction of authority has been demarcated into distinct fire zones as mentioned in Part 4- NBCI 3.2.2.2. These zones are designated as follows

- a) Fire Zone No.1: This zone comprises of areas having residential (Group A), educational (Group B), institutional (Group C), and assembly (Group D), small business (Sub- divisions E-1) and retail mercantile (Group F) buildings, or areas which are under development for such occupancies.
- b) Fire Zone No. 2: This zone comprises of areas having a business (Sub-divisions E-2 to E-5) and industrial buildings (Sub-division G-1 and G-2), except high hazard industrial buildings (Sub-division G-3) or areas which are under development for such occupancies.
- c) Fire Zone No. 3: This zone comprises of areas having high-hazard industrial buildings (Sub

division G-3), storage buildings (Group H) and buildings for hazardous used (Group J).

2.3. Fire safety based on type of construction:

The rapidness of the fire spreading and the amount of smoke generated at the time of combustion depends upon the design of the building and the type of materials used in its construction. The fire resistance of a building or its structural and non-structural elements is expressed in hours against a specified fire load which is expressed in kcal/m², and against a certain intensity of the fire. For the purpose of code, the building construction is classified into four types based on the fire resistance ratings of structural and non-structural elements, according to clause 3.3.1 of Part 4 in NBCI, 2016. The fire-resistance rating of various types of construction for structural and non-structural members is specified in clause 3.3.1 of Part 4 in NBCI, 2016 and here in this article as Table 6.

Table 6: Fire resistance ratings of structural and non-structural elements (in minutes) [Part 4, Clause 3.3.1 and 3.3.2 in NBCI 2016].

SI. No.	Structural element		stance Rating onstruction	gs (min) for	diff.
		Type 1	Type 2	Type 3	Type 4
1	Exterior walls: a) Fire separation less than 3.7 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	120	60	60	60
	b) Fire separation of 3.7 m or more but less than 9 m:				
	1) Bearing	240	90	90	60
	2) Non-bearing	90	60	60	60
	c) Fire separation of 9 m or more:				
	1) Bearing	240	120	120	60
	2) Non-bearing	60	60	60	60
2	Fire separation assemblies (like fire check doors)	120	120	120	120
3	Fire enclosures of exits	120	120	120	120
4	Shafts for services, lift hoist way and refuse chutes	120	120	120	120
5	Vertical separation between adjacent tenant spaces	60	60	60	60
6	Dwelling unit separation:				
	1) Bearing	120	120	60	60
	2) Non-bearing	60	60	60	60
7	Interior bearing walls, bearing partitions, columns, beams, girders, trusses (other than roof trusses) and framing:				
	a) Supporting more than one floor	240	120	120	120
	b) Supporting one floor only	180	90	60	60
	c) Supporting a roof only	180	90	60	60
8	Walls supporting structural members	180	90	60	60
9	Floor construction	120	90	60	60
10	Roof construction:				
	a) 5 m or less in height to lowest member	120	90	60	60
	b) More than 5 m but less than 6.7 m in height to lowest member	60	60	60	60
	c) 6.7 m or more in height to lowest member	0	0	0	0
Note:	1. The above fire resistance rating shall be required to achieve the	respective	type of cons	truction unl	ess

Note

- 1. The above fire resistance rating shall be required to achieve the respective type of construction unless otherwise specified in the respective clauses for different applications/use.
- 2. In case of lift bank, the partition wall, if any, need not be of fire rating specified in this table.

2.4. Fire prevention based on maximum height, floor area, and open areas of the building:

Clause 3.3.1 Part 4 in NBCI (2016) requires (for buildings that are 15 m or more in height) the use of non-combustible materials for construction. The internal walls of staircase enclosures should be of brickwork or reinforced concrete or any other material of construction with a minimum of 2 hr rating. As per clause 3.4.4 of Part 4, the maximum permissible height of a building should be based on its occupancy and the type of construction as suggested in Part 3 of NBCI 2016. The important determining factors are related to the width of street fronting the building, or floor area ratios (FAR) and the local fire-fighting facilities available. FAR is defined in Article 2.36 as "the quotient obtained by dividing the total covered areas (plinth area) on all floors by the area of the plot".

Conclusion

Significant differences have been observed between NBCI 2016 and IBC 2021. Although Part 4, article 2.7, has defined Combustible Material, no specific definition of non-combustible material was prescribed in NBC 2016. Furthermore, Article 1.2 defines the scope of application of the Part 4 requirements, but there is no guidance on what to do with buildings that do not fall within the scope. Low-rise residential buildings which are less than 15 metres in height, as a result, it is unclear whether small residential buildings must comply with fire safety regulations. However, IBC 2021 clearly indicates the difference between combustible and non-combustible construction. Different requirements are clearly given for combustible and non-combustible constructions for fire-safety performances in IBC 2021. In India, buildings are preferably made of concrete and other noncombustible materials which provide 3 hr fire resistance rating in Type 1 and Type 2 construction (as shown in NBC 2016, Part 4, Table 1 clause 3.3.1 and 3.3.2 of Part 4). Similar performance can be achieved through mass timber construction using combustible and noncombustible construction materials without compromising on safety and serviceability standards. Construction Type III, IV and V can withstand the fires for the highest level of fire protection similar to Type I and Type II in IBC 2021 (IBC 2021- Table 601). Stringent safety standards are followed in IBC 2021 using engineered wood products along with combustible and non-combustible materials, which shows the potential of using mass timber construction and buildings. Part 4 of the NBCI, 2016 in case of Type IV construction type required most structural elements to have a 1-hour fire resistance rating. But for load-bearing walls supporting more than one floor, their required fire-resistance rating is 2-hour. The 2-hour rating is much more stringent than the requirement for the same type of building in the IBC 2021. This comparative review shows that the minimum requirements designed to protect the safety with regard to structural sufficiency, fire hazards and health aspects of buildings in India, need to be revived if mass timber buildings are to be constructed.

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Implementation of Fire Safety Design in Tall Timber Buildings

Wood: immense possibility and potential

ood is a natural entity, which is being utilized by mankind as a construction material since prehistoric ages. In the past, wood was utilized for building applications but now it is being replaced by other constructional materials like steel, concrete, aluminium, etc. Production of these new age construction materials is very energy-intensive process. The greenhouse gases emitted from the production of these construction materials play a significant role in global climate change. Therefore, there arises a need to search for some alternate energy efficient and green building materials which can mitigate the problem of global carbon emissions as well as help in developing the global housing infrastructure.

Wood has the potential to be utilized as a green building material and as an alternative raw material for the construction sector because of its structural properties and associated environmental benefits. The benefit associated includes low carbon footprint, renewability and lesser pollution during production process in comparison with other building materials such as steel or cement. Other important parameters such as good strength properties, high strength to weight ratio and aesthetic appearance provide multiple avenues towards using wood as a building material. Nowadays mass timber products such as cross laminated timber (CLT), glue laminated timber (GLT), etc. are being developed and utilized for mass timber buildings.

One of the key benefits of mass timber is that it is a renewable resource, unlike steel and concrete, which are made up of non-renewable materials. Wood is a natural and abundant resource that can be replenished relatively quickly. Additionally, mass timber can be produced and transported with a relatively low carbon footprint, making it a more sustainable option than traditional building materials. Another advantage of mass timber is that it can be prefabricated off-site, which can save time and money during construction. This also means that mass timber buildings can be constructed more quickly and with less disruption to the surrounding area.

Atul Kumar*, Kamal Mishra, and Sanmitra Dan

ICFRE - Institute of Wood Science and Technology, Bengaluru

*E-mail: atulktamta@gmail.com

Despite the many benefits of mass timber, it is not yet widely used in construction. This is partly due to the lack of awareness and understanding of the material, as well as a lack of regulations and codes that allow for its use in tall buildings. Also, the presence of defects, variability in different wood properties, dimensional instability, dimension limitations and fire hazards limit the utilization of wood as a constructional material. Fire performance is of immense importance as far as the use of wood as a building material is concerned.

Fire safety design in tall timber buildings

In Indian context, the National Building Code of India (NBCI) provides guideline for fire safety in buildings. In India, the NBCI is a set of guidelines for the design, construction, and maintenance of buildings. It was first published in 1970 and has since been updated periodically. The NBCI covers a wide range of topics, including building materials, fire safety, environmental protection, and energy efficiency, among others. The code serves as a reference for architects, engineers, builders, and building owners to ensure that buildings are designed and constructed in a safe, sustainable, and environmentally responsible manner. The NBCI includes provisions for fire safety in wood construction, including requirements for fire resistance, fire protection systems, and evacuation plans. According to the NBCI, wooden buildings must have a fire resistance rating of at least 1 h for the structural elements. This means that the wooden structural elements of the building must be able to withstand a fire for at least 1 h without collapsing.

Additionally, the NBCI requires that the wooden buildings have fire protection systems such as smoke alarms and sprinklers installed. The NBCI also includes provision for evacuation plans in wooden buildings. This includes the installation of clearly marked exit signs and the provision of multiple exits to ensure that occupants can safely evacuate the building in the event of a fire. It is worth mentioning that there are different fire safety regulations for different types of buildings

and structures, such as residential, commercial, and industrial buildings (BIS 2016 National Building Code of India 2016, Volume 1 & 2).

Fundamentals of fire development process

A time–temperature curve can be used to show how a typical fire develops. Figure 1 summarizes the key phases of fire development in relation to the active or passive design elements that may be used.

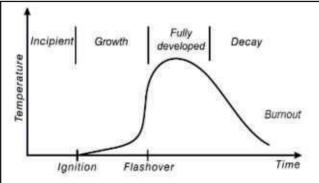


Figure 1: Time–temperature curve depicting process of fire development (Buchanan et al., 2022)

Heating of potential fuel occurs in the early stages of fire formation, with the heating zone staying constrained, tiny, and often undetectable. The beginning of fiery combustion, which ushers in the growth stage, is known as ignition.

By means of convection, heated gases will rise to the ceiling and expand; creating a hot upper layer that radiates heat to feed lower-lying compartmentalized objects. The fuel at the ground level will ignite quickly if the upper-layer temperatures rise above about 500–600°C, leading to a rapidly spreading fire that eventually flashes over which is a stage of transition from the growth stage to the fully developed stage.

In contrast to the fully formed stage, where the intensity of the fire is typically regulated by the ventilated conditions, the rate of burning in the growth stage is typically determined by the nature and arrangement of the burning fuel surfaces. Structures and compartment boundaries are typically affected when a fire has fully developed. The ventilation and fuel load, including any input from the burning timber structure to the fuel load, determine how long the fully evolved stage withstands. The amount of ventilation available will determine how much the gas temperatures are reduced throughout the decay phase. If charring keeps reducing the strength of structural elements throughout this time, structural failure may occur during the decay stage. The end of an uncontrolled fire in a compartment is referred to as a 'burnout', after all the fuel has been used up and the temperature in the compartment continues to drop until it is close to ambient.

Process of combustion of wood

Cellulose, hemicellulose, and lignin are the three primary components of wood, along with smaller amounts of extractives and inorganic minerals that leads to the creation of ash following a fire. The thermal decomposition of different wood constituent, namely hemicellulose, cellulose and lignin take place in temperature ranges of 200260°C, 240-350°C and 280-500°C, respectively (Wade et al. 2022). Wood will degrade when heated from the outside, producing a mixture of volatiles and solid carbonaceous residue termed as char. Depending on the intensity of the

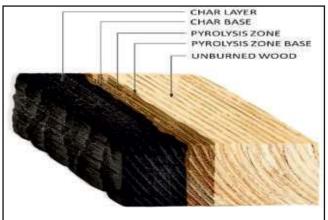


Figure 2: Degradation zone in a section of burnt wood (Le and Tsai., 2019)

external heat flux, wood combustion can be either flaming or smouldering. The four primary temperature-based zones are shown in figure 2 (Ha Truong Di Le and Mengting Tsai 2019) and can be summarised as follows (Browne 1958):

Zone A: Dehydration occurs at temperatures up to 200°C, creating water vapour, trace amounts of carbon dioxide, formic and acetic acids, and other substances. Between temperature range of 100°C and 200°C, there may be a significant reduction of strength.

Zone B: There is some gradual pyrolysis takes place between 200°C and 280°C, yielding the same water vapour, carbon dioxide, formic and acetic acids. Along with the gradual transformation of the wood into char, some carbon monoxide may also be formed. The start of pyrolysis is accompanied with a dark brown colour.

Zone C: The pyrolysis rate accelerates quickly at temperatures between 280°C and 500°C, producing modest amounts of various gases and compounds as well as flammable gases such as carbon monoxide, methane, formaldehyde, and formic and acetic acids.

Zone D: Carbon dioxide and water vapour react with carbon to produce combustible products such as carbon

monoxide, hydrogen, and formaldehyde when heated to temperatures exceeding 500°C.

Fire retardants: application, mode of action and types

Wood fire retardants are chemicals or compounds that are applied to wood products to slow down or prevent the spread of fire. These products can be applied in a variety of ways, such as dipping, spraying or brushing.

Application of fire retardants

Fire retardant chemicals can be applied to wood to reduce its flammability and slow the spread of fire. The most common application method for fire retardants is spraying, which is used either as a liquid or as a foam. Some fire retardants also come in the form of a paste or gel that can be brushed or rolled onto the wood surface. The application of fire retardant to wood is typically done before construction, but it can also be applied to existing structures during renovations or retrofits. The specific application process will depend on the type of fire retardant being used and the condition of the wood. It is important to understand that fire retardants are not fireproof, they only slow down the ignition and spread of fire. Therefore, only certified fire-retardant products, applied by certified applicators, can be used on building materials.

Mode of action

To be as effective as possible, most retardants combine a few of the following methods of action. The amount of oxygen and combustible material that actually ignites can be reduced by a fire retardant's discharge of an inert gas that dilutes the mixture of previously flammable gases. On the other hand, an ejected gas may be quite reactive and capable of suppressing the activities occurring in the gaseous phase. In some cases, the endothermic degradation of the retardant, which lowers the temperature and decreases the number of combustible components, results in the generation of this gas. The naturally occurring char layer serves as a fire retardant by preventing heat transmission, oxygen diffusion to the area of breakdown, and the entry of combustibles into the flame zone. Therefore, chemicals that hasten the char formation by causing dehydration can also increase fire retardancy.

There are several types of wood fire retardants available, each with their own properties and advantages. Some of the most common types include:

Boron-based fire retardants: These have been

employed as preservation and fire-retardant chemicals for many years. The two substances that are most frequently used are borax and boric acid, maybe in conjunction with different additional nitrogen, phosphorus, or inorganic salt retardants. The mode of operation relies on the formation of a shield that reduces the transfer of heat, oxygen, and flammable gases.

Nitrogen-based fire retardants: They decompose and release incombustible gases that dilutes the otherwise flammable gas that is necessary to sustain a flame, while also lowering the temperature due to its endothermic decomposition. The potential of nitrogen-based fire retardant is mostly used in combination with phosphorus chemicals (in particular phosphorus acid and its salts), which are efficient catalysts for cellulose dehydration. As a result, they quicken the charring and give the wood a layer of protection. The breakdown of phosphoric acid is also endothermic. The phosphor compound's effectiveness is inversely related to how acidic it is. It is important to keep in mind, nevertheless, that greater acidity may also drastically diminish mechanical stability.

Hydroxides and carbonates (such as magnesium or aluminium): They have been investigated in the past. In addition to cooling the wood and slowing the burning process, the endothermic decomposition of this material class also releases CO₂ or water to saturate the flammable gases. The leftover oxide residues also create a layer of protection. Despite being inexpensive, their low efficiency would require a high load, which would restrict their use.

Silicates: Silicates provide fire retardancy effects by filling the lumens with incombustible material and in some cases being intumescent and therefore forming a protective layer in case of elevated temperatures.

Fire-retardant coatings: These are coatings that are applied to the surface of the wood to create a barrier against fire. They can be used as a standalone fire protection method or in combination with other fire-retardant treatments.

Measures to improve fire performance of timber building

1. Sprinklers

Automatic fire sprinkler frameworks are the best approach towards developing the fire wellbeing in all structures. As shown in figures 3 and 4, sprinklers are especially advised for tall timber buildings as the fire will be put out or bought under control before the timber structure is in danger of catching fire.

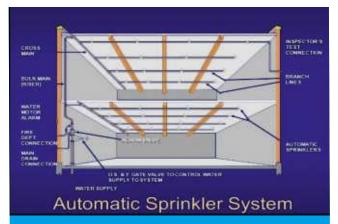


Figure 3. Wet sprinkler system (https://www.shiramafiretex.com/automatic-sprinkler-systems/).

Future scope of work

Fire performance is of immense importance as far as the use of wood as a building material is concerned. Future studies could be undertaken to assess the stability and integrity of wooden elements of buildings during fire. The future of fire safety of mass timber is a topic of ongoing research and development. Here are a few key trends and considerations:

- I Increased use: The use of mass timber in construction is growing due to its sustainability, affordability, and design flexibility.
- II. Improved fire resistance: Mass timber products are being developed with improved fire resistance through the use of fire-retardant treatments or fire

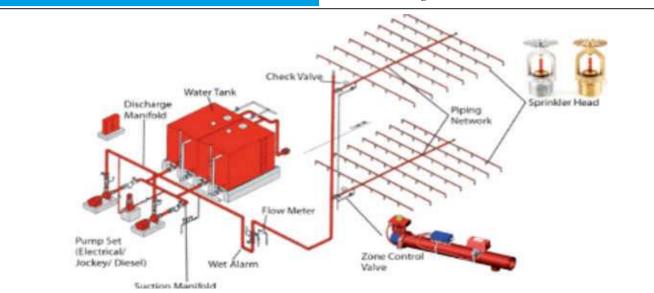


Figure 4. Sprinkler system for multiple storey building (https://www.fireknock.com/products/sprinkler-system.jpg).

Encapsulation

Encapsulation's main goals are to prevent structural wood from adding to the fire load and to stop the fire from spreading after it has been contained. Encapsulation can be done either completely or partially. Figure 5 shows two types of encapsulations based on concrete and gypsum.

Complete encapsulation offers the same level of fire resistance as a completely non-combustible material by giving a layer of gypsum plasterboard or another material that is thick enough to prevent any charring of the wood in a complete burnout. On the other hand, limited encapsulation is a more cost-effective option that will keep structural wood from being involved in the fire until it is well into the burning phase, but it may not ensure total burnout without the commencement of charring.

resistant coatings.

- III. Code changes: Building codes and standards are being updated to reflect the increased use of mass timber and to ensure that fire safety requirements are met.
- IV. Research and testing: Ongoing research and testing is being conducted to better understand the fire behaviour of mass timber and to develop new fire protection strategies.

Overall, the future of fire safety of mass timber woods is likely to see continued advancements in fire resistance technologies, building codes and standards, and research and testing.

References Contact author at atulktamta@gmail.com

Selection of Wood for Frames of Fire-rated Door Sets

Introduction

uilding occupants are always at risk of fire. Understanding and applying the code requirements enhances occupant safety. With the increasing building activities and stringent building regulations, the behaviour of building components from various panel products or in combination with the other materials against fire and to ensure occupants safety is the need of the hour.

Wood is one of the most used natural building materials worldwide. A number of valuable properties such as low heat conductivity, low bulk density, relatively high strength, amenability to mechanical working, etc. makes wood a popular building material. The often inevitable hazards of fire make wood a very desirable material for further investigation. It is necessary to take great care to adequately reduce the risk of fire. The usage of wood as an interior material is strictly controlled by the building codes, thus in the design stage it is necessary to thoroughly consider the resistance of these materials to fire.

When exposed to the fire, the wood goes through a process of thermal breakdown into combustible gases. In brief, the wood undergoes different stages of combustion such as evaporation of moisture, vaporization of hydrocarbon compounds, gas vapour ignition and combustion followed by char burning. During this process, a layer of charcoal forms on the burning surface of the timber and this charred layer is the key contributing factor for the timber's fire resistance. The layer acts as an insulator protecting the inner core of the timber, making it resist heat penetration and thus burn more gradually. During this process, the temperature of inner, uncharred core remains low, enabling it to continue to carry its load. Initially the rate of charring is fast but as the char depth increases it provides a stronger protective layer to the timber, decreasing the overall combustion rate. The rate at which timber chars varies between species and is predominately depends on the density and moisture content.

Anand Nandanwar*, M.C. Kiran, Narsimha Murthy and B.S. Mamatha

ICFRE - Institute of wood Science and Technology, IPIRTI Campus, Bengaluru

*E-mail: nandanwaran@icfre.org

A fire-rated door set consisting of shutter, hardware and frame, is a door with afire-resistance rating (sometimes referred to as a fire protection rating for closures) used as part of a passive fire protection system to reduce the spread of fire or smoke between compartments and to enable safe egress from a building or structure. Fire rating has to be specified prior to the installation of a timber door in any high-rise buildings, shopping complexes, hotels, condominiums, etc. Fire doors are 'rated' by time (in minutes or hours) that a door can withstand when exposed to fire test conditions. Fire ratings include 30, 60, 90, 120 min, etc., with the maximum rating required of any swinging type fire door being 180 min. Fire doors are made up of a combination of materials, such as timber, steel, gypsum (as an endothermic fill), vermiculite boards, glass sections, etc. The door frame includes the fire or smoke seals, door hardware, and the structure that holds the fire door assembly in place. Together, these components form an assembly, typically called a 'door-set' which holds a numerical rating, quantified in hours of resistance to a test fire. It is reasonable to assume that all fire doors and frames manufactured to the same specification as the two specimen doors and frames will achieve the same fire resisting properties. During the fire resistance tests, the failure of the door is analyzed by impermeability/integrity (fire visible on unexposed face) and insulation (unexposed surface temperature increases specified limits).

During the designing of the fire-rated doors, a lot of importance is given to the construction of door shutter to withstand a given fire rating. The frame used in firerated door shutters is generally neglected during designing fire-rated door assemblies. On the contrary, It is observed that even if the fire-rated door resists fire for said duration, the failure occurs because of wrong selection of door frame, resulting in non-conformity of door for given fire rating.

Throughout the world, various standards and codes

describe fire resistance of materials in different ways. Various types of test methods are available for

evaluating fire resistance of wood and panel products internationally.

The performance of timber doors is analysed by subjecting them to the standard test procedure specified in BS 476 Part 22 (1987), BS EN 1634-1 (2000), IS 3614 (1992), ISO 3008 (2007), etc. As shown in figure 1, tests are made on complete door



Figure 1. Fire door testing setup.

assemblies, fire door and frame with all the necessary hardware. Whereas, the Indian standard IS 1734 (Part

3)-1983 describes the test method for determining fire resistance of plywood by conducting three tests, namely flammability, flame penetration and rate of burning.

A study was carried out at the institute to find the effect of dimensions, density and species of wooden frames used in fire-rated doors to resist fire.

Evaluation

The frames of the fire-rated doors received for testing from different agencies were taken for testing and evaluation (Figure 2). After testing fire-rated doors as per BS 476 part 20 & 22/ IS 3614, the frames from 13 door ruminants were taken.







Figure 2. Samples of wood frame for evaluation.

The species of the samples was verified in situ. The most commonly used species for use in frames of firerated doors used in India were identified. Samples of different species of various densities were collected for the study as given below:

Red meranti (*Shorea acuminata*) Sal (*Shorea robusta*), Birch (*Betula pendula*) Padauk (*Pterocarpus spp.*) White Meranti (*Shorea spp.*) Specimens were prepared from door frames for evaluation of properties, namely density, moisture content and rate of burning as per relevant Indian standards (figure 3). Since, during the testing of firerated doors, the flame travels and charring takes place along one direction, i.e. thickness (depth) similar to the pattern of rate of burning test in longitudinal direction, as per IS 1734 (part 3) (figure 4),the rate of burning test was selected, as it relates to the actual burning of wood used in door frames, in case of fire. A typical failure pattern of fire-rated door during fire rated door testing is shown in figure 5.



Figure 3. Specimens prepared from door frames.

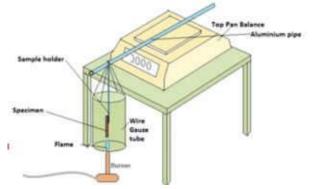


Figure 4. Test setup for rate of burning.

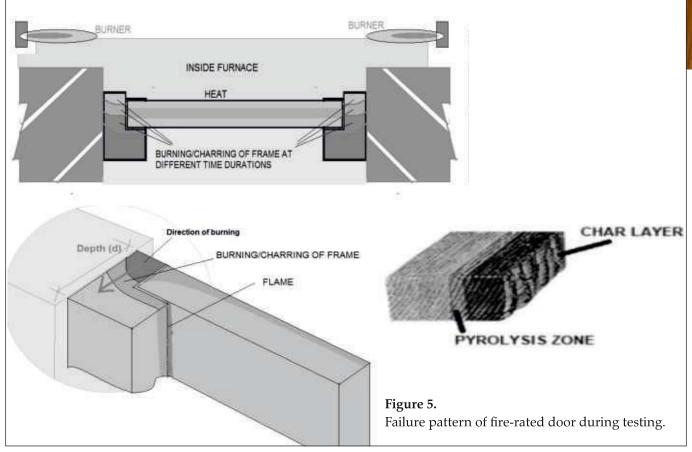
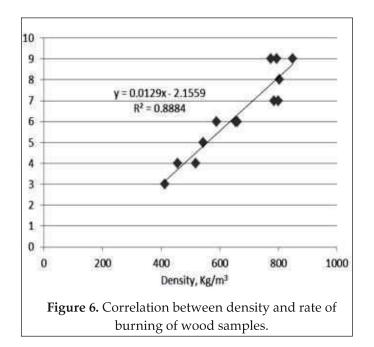


	Table 1. Results of ra	U	
	Species	Average density (kg/m³)	Rate of burning (min)
1.	S. robusta	85	7
2.	S. robusta	800	7
3.	S. robusta	804	8
4.	S. robusta	849	9
5.	Betula pendula	518	4
6.	B. pendula	590	6
7.	S.acuminata	412	3
8.	S. acuminata	456	4
9.	Shorea spp.	544	5
10.	S.acuminata	794	9
11.	Pterocarpus spp.	654	6
12.	Pterocarpus spp.	660	6
13.	Pterocarpus spp.	774	9



Results of rate of burning tests of samples drawn from frames are given in table 1 and the correlation between density and rate of burning of wood samples is given in Figure 6. From figure 6, it is observed that the fire resistance increases with increase in the density of wood, and also from the correlation it is observed that the fire resistance of wood increases with increase in the density. Although timber is said to be a combustible material, a properly designed timber structure performs very well in fire. Heavy timber has a good inherent fire resistance, because a char layer is formed that retards the heat penetration. When heavy timber members are exposed to fire, the temperature of the exposed surface of the member is close to the fire temperature. When the outer layer of wood reaches its burning point, the wood ignites and burns rapidly. The burned wood becomes a layer of char which loses all its strength but retains a role as an insulating layer preventing excessive temperature rise in the core.

The rate of time for burning of sample *G* (*Shorea acuminate*) having density of 412 kg/m³ was observed as 3 min, whereas a high rate of burning,i.e. 9 min was observed for sample D (*Shorea robusta*) having density of 849 kg/m³. The average density of 13 samples taken for the study was computed as 665 kg/m³. The low

conductivity of char will cause a steep thermal gradient across the char layer. Underneath the char layer, there is a layer of heated wood with a temperature of above 200°C, which is known as the pyrolysis zone, shown in figure 5. This part of wood is undergoing irreversible chemical decomposition caused solely by a rise in temperature, accompanied by loss of weight and discolouration.

Conclusion

The density of the wood plays an important role in selecting frames for fire-rated door shutters. High rate of burning is observed for *Shorea acuminate* sample having density of 412 kg/m³, whereas lowest rate of burning was observed for *Shorea robusta* sample having density of 849 kg/m³. The average density of 13 samples taken for the study was computed as 665 kg/m³. This indicates the resistance to burning increases with density of the wood. The fire rating increases with density of wood used in fire-rated door shutters. Also, the depth of door frame and area of cross section also plays an important role in achieving desired fire rating.

References Contact author at and anwar an @icfre.org

Trade Statistics- Wood and Wood Products (HS-Code-44)

V. K. Upadhyay

ICFRE - Institute of Wood Science and Technology, Bengaluru E-mail: upadhyayvk@icfre.org

Statistics of Import and Export of Wood and Wood Products in India During Oct-Dec 2022

(Value in US\$ Million)

_	No I USCodo I Commodify												
S.No.	HSCode	Commodity	(Imp)	Export (Exp)	Trade Balance (Exp_Imp)								
1	4401	FUEL WOOD, IN LOGS, IN BILLETS, IN TWIGS, IN FAGGOTS OR IN SIMILAR FORMS; WOOD IN CHIPS OR PARTICLES; SAWDUST AND WOOD	0.33	0.04	-0.29								
2	4402	WOD CHRCL(INCL SHL/NUT CHRCL) W/N AGLOMRTD	1.85	12.31	10.46								
3	4403	WOOD IN THE ROUGH, WHETHER OR NOT STRIPPED OF BARK OR SAPWOOD, OR ROUGHLY SQUARED	258	3.32	-254.68								
4	4404	HOOPWOOD SPLIT POLES PILES PICKETS AND STACKOF WOOD POINTED BUT NOT CUT TO LENGTHWSE WOODEN STICKS CHIPWOOD	0.09	0.02	-0.07								
5	4405	WOOD WOOL; WOOD FLOUR	0.51	0	-0.51								
6	4407	WOOD SAWN OR CHIPPED LENGTHWISE, SLICED OR PEELED, WHETHER OR NOT PLANED, SANDED OR ENDJOINTED, OF A THICKNESS EXCEEDING	147.75	2.11	-145.64								
7	4408	VENER SHET AND SHETS FOR PLWD (W/N SPLICD)AND OTHR WOOD SAWN IN LENTH SLICD/PEELD W/N PLANED OR FINGR JTD THIKNES <= 6MM	57.22	8.02	-49.2								
8	4409	WOOD(INCL STRIPS,FRIZS FOR PARQT FLORNG NT ASEMBLD) CONTINUSLY SHAPED(TONGD GROVD V-JTD ETC) ALONG ANY EDGS/FACS W/N P	8.19	3.28	-4.91								
9	4410	PARTCLE BORD AND SMLR BORD OF WOOD OTHER LIGNUS MATRLS W/N AGLOMRTD WITH RESIN OR OTHR ORGNIC BINDG SUBSTS	7.64	1.76	-5.88								
10	4411	FIBR BORD OF WOOD OR OTHR LIGNEUS MATRLS W/N BONDED WITH RESIN/OTHR ORGNIC SUBSTS	21.92	13.32	-8.6								
11	4412	PLYWOOD, VENEERED PANELS AND SIMILAR LAMINATED WOOD	36.94	19.52	-17.42								
12	4413	DENSIFIED WOOD, IN BLOCKS, PLATES, STRIPS, OR PROFILE SHAPES	0.97	0.15	-0.82								
13	4414	WOODEN FRAMES FOR PAINTINGS, PHOTOGRAPHS, MIRRORS OR SIMILAR OBJECTS	0.29	3.29	3								
14	4415	PCKNG CASES,BXES,CRTS,DRMS AND SMLR PCKNGS OF WOOD; CBLE DRMS OF WOOD; PALLET, BOX PALLETS AND OTHR LOAD BOARDS OF WO	3.17	3.15	-0.02								
15	4416	CASKS, BARRELS, VATS, TUBS AND OTHER COOPERSPRODUCTS AND PARTS THEREOF, OF WOOD, INCLUDING STAVES	0.98	0	-0.98								
16	4417	TOOLS, TOOL BODIES, TOOL HANDLES, BROOM OR BRUSH BODIES AND HANDLES, OF WOOD; BOOT OR SHOE LASTS AND TREES, OF WOOD	0.54	3.8	3.26								
17	4418	BUILDERS JOINERY AND CARPENTRY OF WOOD, INCLUDING CELLULAR WOOD PANELS, ASSEMBLED FLOORING PANELS, SHINGLES AND SHAKES	13.26	8.34	-4.92								
18	4419	TABLEWARE AND KITCHENWARE, OF WOOD	6.63	14.36	7.73								
19	4420	MARQUTY AND INLAID WOOD;CASKETS/CASES FOR JWELRY/CTLRY AND SMLR ARTCLS STATUETS AND OTHR ORNAMTS OF WOOD NT FALLNG I	0.95	3.69	2.74								
20	4421	OTHER ARTICLES OF WOOD	9.23	48.62	39.39								
Total	44	WOOD AND ARTICLES OF WOOD; WOOD CHARCOAL.	576.46	149.1	-427.36								

Top 10 country wise Import and Export of Wood and Wood Products in India During Oct-Dec 2022

(Value in US\$ Million)

HS- Code	1077					70	けせ			£0	ナセ			70	ナ ナ		9	50tt	7
Rank	Country (8)	Import	Country (2)	Export	Country (7)	Import	Country (15)	Export	Country (59)	Import	Country (7)	Export	Country (1)	Import	Country (1)	Export	Country (4)	Import	Country
-	VIETNAM SOC REP	0.14	FRANCE	0.02	SRI LANKA DSR	89.0	BHUTAN	11.52	ECUADOR	37.55	CHINA P RP	1.82	CHINA P RP	0.09	QATAR	0.02	CHINA P RP	0.1	
2	CHINA P RP	90:0	SAUDI ARAB	0.02	INDONESIA	0.59	SRI LANKA DSR	0.35	MALAYSIA	32.74	U ARAB EMTS	1.07					GERMANY	0.01	
က	GERMANY	0.03			CHINA PRP	0.34	U ARAB EMTS	0.21	URUGUAY	28.74	QATAR	0.32					PERU	0.01	
4	NETHERLAND	0.03			BHUTAN	0.18	IRAN	0.03	GHANA	19.7	MALDIVES	0.07					VIETNAM SOC REP	0.39	
S	USA	0.03			HONGKONG	0.04	MALDIVES	0.03	USA	18.38	JAPAN	0.02							
9	ITALY	0.02			SEYCHEL LES	0.01	USA	0.03	PAPUA N GNA	16.45	MALAYSIA	0.01							
7	FRANCE	0.01			UNSPECIFIED	0.01	BELGIUM	0.02	BRAZIL	16.15	USA	0.01							
∞	SINGAPORE	0.01					DOMINIC REP	0.02	ARGENTINA	15.18									
6							NEPAL	0.02	SOLOMON IS	12.53									
10							NETHERL AND	0.02	AUSTRALIA	10.19									
Top 10		0.33		0.04		1.85		12.25		207.61		3.32		0.09		0.02		0.51	
%@		100.0		100.0		100.0		5.66		80.5		100.0		100.0		100.0		100.0	
Others		0.0		0.0		0.0		0.1		50.4		0.0		0.0		0.0		0.0	

		147.75		2.11		57.22		8.02		8.19		3.28		7.64		1.76		21.92		13.32		36.94
0.0		50.5		0.1		31.6		0.2		0.4		0.0		0.2		0.1		1.6		12.5		1.0
		8:59		95.7		44.7		97.3		95.1		99.1		6.76		93.2		92.6		6.1		97.2
0		97.25		2.02		25.58		7.8		62.7		3.25		7.48		1.64		20.3		0.81		35.9
	SWEDEN	5.38	MALDIVES PHILIPPINES	90:0	GABON	15.91	SWEDEN	90:0	MYANMAR	60:0	BHUTAN	0.01	AUSTRIA	0.04	MOZAMBI QUE	0.03	BELGIUM	0.37	COLOMBIA	0.05	IRAN	0.21
	AUSTRIA	5.46	MALDIVES	90.0	FINLAND	0.01	SPAIN	90.0	RUSSIA	0.1	JAPAN	0.02	SOUTH AFRICA	0.07	TANZANIA REP	0.05	TURKEY	0.38	CHILE	0.04	ITALY	0.21
	TOGO	5.69	LITHUANIA	0.1	ESTONIA	0.11	GERMANY	0.11	ROMANIA	0.13	GUATEMALA	0.02	TURKEY	0.1	KUWAIT	0.05	INDONESIA	9.0	CANADA	0.22	U ARAB EMTS	1.07
	SINGAPORE	6.28	USA	0.14	EQUTL GUINEA	0.1	FRANCE	0.14	LITHUANIA	0.15	NEPAL	0.03	ROMANIA	0.19	BHUTAN	0.05	BRAZIL	69:0	BRAZIL	0.02	MYANMAR	2.05
	USA	68'9	IRAQ	0.15	CZECH REPUBLIC	0.03	CANADA	0.25	SWEDEN	0.24	U ARAB EMTS	90.0	BANGLADESH PR	0.19	BAHARAIN IS	0.05	NEW ZEALAND	0.71	BHUTAN	60'0	VIETNAM SOC REP	2.85
	BRAZIL	6.91	OMAN	0.17	COTE D' IVOIRE	1.09	MEXICO	0.45	BRAZIL	0.78	QATAR	0.11	CHINA PRP	0.33	SINGAPORE	80.0	GERMANY	0.72	BANGLA DESH PR	0.05	MALAYSI A	3.53
	MALAYSIA	8.04	QATAR	0.24	CHINA P RP	7.89	USA	1.05	SINGAPORE	1.15	UK	0.15	BHUTAN	0.45	USA	0.17	THAILAND	3.4	BAHARAIN IS	0.18	RUSSIA	4.31
	INDONESI A	8.09	U ARAB EMTS	0.28	CANADA	0.14	CHINA PRP	1.24	CHINA PRP	1.25	GERMANY	0.45	GERMANY	0.47	SRI LANKA DSR	0.24	CHINA PRP	3.63	AUSTRALI A	0.07	INDONESIA	6.55
	BENIN	9.05	KUWAIT	0.33	BRAZIL	0.27	BANGLAD ESH PR	1.45	INDONESIA	1.86	ITALY	0.76	MALAYSIA	1.52	NEPAL	0.43	VIETNAM SOC REP	4.75	ANGOLA	0.01	CHINA P RP	7.46
	GERMANY	35.46	ITALY	0.49	AUSTRIA	0.03	NEPAL	2.99	ESTONIA	2.04	USA	1.64	THAILAND	4.12	SAUDI ARAB	0.49	MALAYSIA	5.05	ALGERIA	80.0	NEPAL	79.7
Export	Country (64)	Import	Country (15)	Export	Country (35)	Import	Country (18)	Export	Country (20)	Import	Country (13)	Export	Country (18)	Import	Country (17)	Export	Country (29)	Import	Country (47)	Export	Country (25)	Import
	<u>L077</u>						tt				ナナ				*				tt		71	

	19.52		0.97		0.15		0.29		3.29		3.17		3.15		96.0				0.54		3.8	
	16.6		0.0		0.0		0.0		0.2		0.2		0.7		0.0				0.0		6.5	
	14.8		100.0		100.0		100.0		93.0		95.3		79.4		100.0				100.0		87.4	
	2.89		0.97		0.15		0.29		3.06		3.02		2.5		86.0				0.54		3.32	
CYPRUS	0.07							NETHERL ANDANTI L	0.04	UK	0.05	SPAIN	0.1							CANADA	0.1	VIETNAM SOC REP
CONGO D. REP.	0.12							JAPAN	0.04	BAHARAI N IS	0.09	GERMANY	0.11							NORWAY	0.11	TURKEY
CHINA PRP	0.03	USA	0.01			USA	0.01	ITALY	50.0	SWEDEN	0.19	FRANCE	0.12							CHINA PRP	0.11	FINLAND
CANADA	0.17	LATVIA	0.03	VIETNAM SOC REP	0.01	UK	0.01	CANADA	60.0	VIETNAM SOC REP	0.21	CHINA P RP	0.12							FINLAND	0.19	ITALY
BRUNEI	0.01	NETHERL AND	0.04	UK	0.02	THAILAND	0.01	FRANCE	0.12	LITHUANIA	0.22	BELGIUM	0.12							NETHERL AND	0.21	SLOVAK REP
BHUTAN	1.82	POLAND	0.05	SENEGAL	0.02	BELGIUM	0.01	AUSTRALIA	0.12	LATVIA	0.27	TAIWAN	0.18	CHINA PRP	0.02					UK	0.22	THAILAND
BELGIUM	0.03	SRI LANKA DSR	90.0	NEPAL	0.02	PORTUGAL	0.02	UK	0.15	GERMANY	0.27	NETHERLAND	0.19	UK	0.07					DENMARK	0.24	MALAYSIA
BANGLAD ESH PR	0.19	CHINA PRP	60.0	KUWAIT	90.0	U ARAB EMTS	0.03	SPAIN	0.2	SOUTH AFRICA	0.37	SAUDI ARAB	0.23	FRANCE	0.12					KOREA RP	0.24	INDONESIA
BAHARAIN IS	0.3	GERMANY	0.2	CONGO D. REP.	0.01	CHINA PRP	0.09	NETHERLA ND	0.21	POLAND	0.62	UK	0.38	SPAIN	0.14			VIETNAM SOC REP	0.43	USA	0.89	GERMANY
AUSTRALIA	0.15	ITALY	0.49	BAHARAIN IS	0.01	MALAYSIA	0.11	USA	2.04	THAILAND	0.73	USA	0.95	USA	0.63			CHINA P RP	0.11	GERMANY	1.01	CHINA P RP
Country (49)	Export	Country (8)	Import	Country (7)	Export	Country (8)	Import	Country (23)	Export	Country (16)	Import	Country (38)	Export	Country (5)	Import	Country	Export	Country (2)	Import	Country (29)	Export	Country (30)
	EItt					Þ	Itt			SI				91				LI	ナ ナ		† †	

13.26		8.34		6.63		14.36		0.95		3.69		9.23		48.62
1.1		0.5		0.0		1.6		0.0		0.7		0.1		7.1
92.0		94.0		8.66		89.0		100.0		80.8		0.66		85.4
12.2		7.84		6.62		12.78		0.95		2.98		9.14		41.54
0.17	TANZANI A REP	0.07	UK	0.01	CANADA	0.17			NETHERLAND	0.07	ESTONIA	0.07	SPAIN	0.73
0.24	NETHERL AND	80:0	THAILAND	0.01	POLAND	0.19			CANADA	80.0	CANADA	0.07	CANADA	1.13
0.26	VIETNAM SOC REP	60.0	ROMANIA	0.01	ISRAEL	0.22			AUSTRALIA	60.0	VIETNAM SOC REP	80.0	FRANCE	1.18
0.45	UK	0.17	KOREA RP	0.02	U ARAB EMTS	0.3	SWITZERLAND	0.02	TURKEY	0.1	U ARAB EMTS	80.0	KENYA	1.18
0.5	GREECE	0.44	INDONESIA	0.02	SAUDI ARAB	0.37	CANADA	0.03	UK	0.13	INDONESIA	0.1	SAUDI ARAB	1.25
1.46	BHUTAN	0.45	HONG	0.03	SWEDEN	0.43	MALAYSIA	0.05	SPAIN	0.18	GERMANY	0.11	AUSTRALIA	1.75
1.73	USA	0.49	MALAYSIA	90.0	AUSTRALIA	0.49	THAILAND	0.07	FRANCE	0.18	POLAND	0.11	UK	2.11
1.81	U ARAB EMTS	0.62	NETHERLA NDANTIL	80.0	UK	0.71	HONG	0.15	U ARAB EMTS	0.19	RUSSIA	0.18	GERMANY	2.25
1.97	NEPAL	1.03	RUSSIA	0.11	NETHERLAND	1.74	INDONESIA	0.29	GERMANY	0.2	MALAYSIA	0.29	NETHERLAND	3.45
3.61	MALDIVES	4.4	CHINA P RP	6.27	USA	8.16	CHINA P RP	0.34	USA	1.76	CHINA P RP	8.05	USA	26.51
Import	Country (30)	Export	Country (11)	Import	Country (41)	Export	Country (7)	Import	Country (39)	Export	Country (15)	Import	Country (76)	Export
				61	tt			07	tt			17	たけ	

(Within parenthesis showed that total number of involved countries), @ i.e. percentage share of top 10 countries in total



THE INDIAN ACADEMY OF WOOD SCIENCE

Working Office: Institute of Wood Science & Technology Campus, P.O. Malleswaram, Bengaluru-560 003 (India)

The Indian Academy of Wood Science was founded in 1968 to advance the knowledge of wood science & technology and covers in its activities all the aspects related to wood, cellulose and their products such as logging, saw milling, wood working, plywood, fibre boards, particle boards, improved and composite woods, cellulose and cellulose based sciences and industries and allied fields. The Academy runs a Journal called "Journal of the Indian Academy of Wood Science". In addition to this, it also organises seminars and workshops. During some annual meetings, lectures from eminent scientists are also arranged. The Academy has joined hands with Springer, an internationally reputed publishing house, for bringing out the journal fully online for wider international readership. Authors may submit the manuscript of their research papers online following the Springer publication link http://www.editorialmanager.com/jiaw



APPLICATION FOR MEMBERSHIP

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The General Secretary Indian Academy of Wood Science Institute of Wood Science & Technology Campus P.O. Malleswaram, Bangalore-560 003 (India)

Sir,

I wish to become a member of the Indian Academy of Wood Science and give below the necessary particulars for enrolling as "Corporate Member/Institutional Member/Individual Member" (as the case may be). Necessary remittance of Rs.* is made by a Demand Draft/Cash, which may please be acknowledged. I agree to abide by the constitution of the academy and agree to the code of ethics contained therein.

Place	e:	(Signature of the Applicant)
Date	:	
1.	Name of applicant in full (in block capitals)	
2.	(a) Date of Birth, (b) Age (in case of individuals only)	
3.	Academic and professional qualifications (in case of individuals only)	
4.	Present employment/how engaged and brief history of previous career in case of individuals (separate sheet may be attached, if necessary)	
5.	Brief description of general activities in case of Corporate, Institutional Members	
6.	Address to which communications should be sent including phone, fax & e-mail	

^{*} Demand Draft should be drawn in favour of 'Indian Academy of Wood Science' and payable at Bangalore.

Membership Type	Annual Fee	Life Time Fee				
Indian :						
Corporate	N. A.	Rs. 100,000				
Institutional	Rs. 2,000	N.A.				
Individual	Rs. 500	Rs. 5,000				
Foreign :						
Corporate	N. A.	US \$ 2,500				
Institutional	US \$ 50	N.A.				
Individual	US \$ 20	US \$ 200				

SHORT TERM TRAINING COURSES

(2023 - 2024)

1. Sandalwood: Farming and Management of its Health

Course Director : Dr. R. Sundararaj

Contact : 080-22190154, 9740433959, rsundararaj@icfre.org

Dates : 10 – 14 April 2023 (5 days)

: Rs.15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Seed and nursery technology of sandalwood with hands on training; management of pests and diseases in sandalwood nursery and plantations with special focus on good silvicultural practices for best health of sandalwood; sandalwood trade; economics; protection; utilization and assessment of oil content and demonstration of oil extraction; policy and schemes of Forest Department for encouraging raising of sandalwood plantations; visit to relevant laboratories and sandalwood plantations.

2. Saw Doctoring

Course Director : Mr. V. Prakash

Contact : 080-30534009, 9886202680, vijayp@icfre.org

Dates : 05-07 June, 2023 (3 days)

Fees : Rs. 9,000/- (With boarding and lodging) + 18% GST

Rs. 6,000/- (Without lodging facility) + 18% GST

Course content: Preventive maintenance of saw blades (Band saw cracks); Saw tensioning; Swaging and spring setting; straining methods of band saws; saw tooth profile; cutting speed; Ordinary spring set saws and TCT saws; saws for ripping; cross cutting; Levelling and tensioning; Spring setting; Fabrication of setting gauges and straight edges; Carbide tip brazing and brazing by electrical and oxy-acetylene methods; Face and side grinding of TCT saws; Plate saw sharpening by grinding machine; Plate saw sharpening and gulleting by manual grinder; Sharpening of planer knives and cutters; Levelling; tensioning and back gauging; Joining by oxy-acetylene welding and brazing

3. Micropropagation of Bamboo

Course Director : Ms. Tresa Hamalton

Contact : 080-22190137, 9360473165, <u>tresa@icfre.org</u>

Dates : 19-23 June 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Preparation of media; Aseptic techniques; Explant collection, processing and surface sterilization; Inoculation techniques for shoot initiation; In vitro shoot multiplication; In vitro and ex vitro rooting; Clonal fidelity testing; Potting mixture preparation; Methods of hardening of in vitro and ex vitro rooted plants at mist chamber.

4. Analysis of Raw Materials for Resin Manufacture

Course Director : Dr. Mamatha B. S.

Contact : 080-30534039, 8971160881,

sheshagirimb@icfre.org, mamathabs888@gmail.com

Dates : 03 – 05 July, 2023 (3 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 12,000/- (Without lodging facility) + 18% GST

Course content: Analytical procedure involved in estimation of Phenol, Formalin, and Urea;

Standardization of solutions required for analysis.

5. Testing of Plywood and Block Board as per IS:303, IS:710, IS:1328, IS:4990 & IS:1659

Course Director: Mr. Anand Nandanwar

Contact : 080 30534016, 9845464716, nandanawaran@icfre.org

Dates : 10-14 July, 2023 (5 days)

Fees: Rs. 29,000/- (With boarding and lodging) + 18% GST

Rs. 24,000/- (Without lodging facility) + 18% GST

Course content: Testing and evaluation of Plywood and Block board as per relevant Indian Standards; Evaluation of Physical and Mechanical properties as per IS 1734 of - General purpose plywood - IS 303, Marine Plywood - IS 710, Shuttering Plywood - IS 4990 and Block Board - IS 1659

6. Bamboo Processing and Bamboo Composites

Course Director : Dr. Vipin Chawla and Dr. Pradeep Kumar Kushwaha

Contact : 080-22190173, 9342890100, vipinkumarchawla@icfre.org;

080-22190169, 8095367557, kushwahapk@icfre.org

Dates : 07 – 11 August, 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Preliminary Bamboo Processing; Bamboo Round Stick making; Bamboo preservation; Bamboo Composites Technology (Mat & Strip based products -Viz. Bamboo Mat Board, Bamboo Mat Tray & Bamboo Wood at Lab scale)

7. Bamboo Based Housing System

Course Director : Mr. V.R. Ramkumar

Contact : 080-30534007, 6363071012, vrramkumar@icfre.org,

ramce37@gmail.com

Dates : 07 – 11 August, 2023 (5 days)

Fees : Rs. 30,000/- (With boarding and lodging) + 18% GST

Rs. 25,000/- (Without lodging facility) + 18% GST

Course content: Introduction to Green Building Materials; Selection and Treatment of Bamboo; Testing of Bamboo and its Connection Detailing; Model Making 12ft 10 ft; Composite connections and future trends

8. Testing Of Door Shutters As Per IS: 2202, IS:1003 & IS: 4020

Course Director : Mr. Anand Nandanwar

Contact : 080 30534016, 9845464716, nandanwaran@icfre.org

Dates : 21 – 23 August, 2023 (3 days)

Fees : Rs. 21,000/- (With boarding and lodging) + 18% GST

Rs. 18,000/- (Without lodging facility) + 18% GST

Course content : Testing and evaluation of Door Shutter as per IS 4020 for Flush Door - IS 2202

and Panel Door - IS 1003

9. Bamboo: Propagation and Management

Course Director : Dr. T.N. Manohara

Contact : 080-22190156, 9435351304, manoharatn@icfre.org

Dates : 21 – 25 August, 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GS

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content : Bamboo distribution; taxonomy; identification; nursery and propagation

methods; precision farming and sustainable management of bamboo

plantations; methods of bamboo harvesting.

10.Sandalwood Farming and Management of its health

Course Director : Dr. Narasimha Murthy

Contact : 080-30534210, 9945897100, murthy@ipirti.gov.in

Dates : 11 – 15 September, 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Seed and nursery technology of sandalwood with hands on training; management of pests and diseases in sandalwood nursery and plantations with special focus on good silvicultural practices for best health of sandalwood; sandalwood trade; economics; protection; utilization and assessment of oil content and demonstration of oil extraction; policy and schemes of Forest Department for encouraging raising of sandalwood plantations; visit to relevant laboratories and sandalwood plantations.

11. Plywood Manufacturing- II (Adhesives for Plywood and Plywood Manufacturing-Resin Preparation, Gluing, Hot Pressing)

Course Director : Ms. Sujatha. D

Contact : 080-30534005, 9880005284,

sujathad@icfre.org, sujathad1@gmail.com

Dates : 11 – 15 September, 2023 (5 days)

Fees : Rs. 23,000 /- (With boarding and lodging) + 18% GST

Rs. 18,000/- (Without lodging facility) + 18% GST

Course content : Phenol & Urea formaldehyde resin manufacturing; Working properties of

resin; Formulation of adhesives and spreading; Hot pressing

12. Epoxy Resin Table Top Manufacturing

Course Director : Mr. V.R. Ramkumar

Contact : 080-30534007, 6363071012,

vrramkumar@icfre.org, ramace37@gmail.com

Dates : 13 – 15 September, 2023 (3 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 12,000/- (Without lodging facility) + 18% GST

Course content: Selection of raw materials (Resin, Wood and steel legs or others); Processing of

wood and other materials; Epoxy pouring and curing; Sanding and finishing;

Fixing of accessories and Model Making

13. Resin Manufacturing

Course Director : Ms. Sujatha. D

Contact : 80-30534005, 9880005284,

sujathad@icfre.org, sujathad1@gmail.com

Dates : 04 - 06 October, 2023 (3 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 12,000/- (Without lodging facility) + 18% GST

Course content : General aspects of raw materials used in resin manufacturing; Preparation of

Phenol Formaldehyde Resin; Preparation of Urea Formaldehyde Resin.;

Characterization of resin preparation.

14. Testing of Plywood and Block Board as Per IS:303, IS:710, IS:1328, IS:4990 & IS:1659

Course Director : Mr. Kiran M. C.

Contact : 080-30534012, 9620196858, kiranmc@icfre.org

Dates : 09 – 13 October, 2023

Fees : Rs. 29,000/- (With boarding and lodging) + 18% GST

Rs. 24,000/- (Without lodging facility) + 18% GST

Course content : Testing and evaluation of Plywood and Block board as per relevant Indian

Standards IS 1734; General purpose plywood - IS 303; Marine Plywood - IS

710; Shuttering Plywood - IS 4990; Block Board - IS 1659

15. Plant Molecular Biology Techniques

Course Director : Ms. Tresa Hamalton

Contact : 080-22190137, 9360473165, tresa@icfre.org

Dates : 06 – 10 November, 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content : Handling of equipments used in molecular biology; DNA extraction from

different plant tissues and its quantification; DNA separation by AGE and PAGE; Demonstration of PCR and its application in genetic diversity analysis,

DNA barcoding for species identification

16. Wood Seasoning and Preservation

Course Director : Mr. Ritesh D. Ram and Ms. C. N. Vani

Contact : 080-22190178, 9449056230, ritesh@icfre.org

080-22190174, 9448505140, cnvani@icfre.org

Dates : 20 – 24 November, 2023 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Wood seasoning and preservation, basic concepts of wood seasoning; methods of wood seasoning; seasoning schedules; drying defects and their control; different types of wood preservatives; methods of wood treatment and safety measures i.e. handing issues, wood degradation by different kinds of bio-organisms (fungi, termites, borers etc

18. Veneering

Course Director : Mr. Uday D. Nagammanavar

Contact : 080-30534011, 9845616385, udaydn@icfre.org

Dates : 11 – 13 December, 2023 (3 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 12,000/- (Without lodging facility) + 18% GST

Log storage (Need for storage, dry storage, wet storage, precautions in storage); **Course content** Steaming and boiling (Effect of heating on properties of wood, advantages and disadvantages of heating); Preparation of logs for peeling (Cross cutting, debarking and cleaning); Log centering (Purpose and economic importance of centering, centering errors and their influence on veneer yield, methods of centering); Veneer peeling lathe (Machine parts, cutting action, undesirable movement of wood on lathe, play in lathe machine parts, spindle overhanging, dynamic equilibrium and slackness. Peeling lathe settings- setting of knife, setting of pressure bar, setting of the gap); Rotary cutting of veneer (Lathe settings and veneer quality, mechanism of veneer formation, type A and B veneer, effect of pressure bar compression and temperature on veneer yield. Peeling defects, their cause and control - thickness variation, roughness, loose veneer corrugation, raised grain, torn grain, bump formation, wooliness, knife and pressure bar marks); Veneer Clipping (Functions, types, clipping efficiency, clipping allowance, veneer yield, dry clipping); Veneer drying (Purpose, drying variables, moisture movement in veneers during drying, special measures for controlling Final moisture content, drying defects and their control, types of dryers); Knife grinding machine and grinding wheels (Knives, grinding machines, composition, abrasives, grain size, grade, structure, bond, wheel selection, grinding head, grinding bed, coolant, grinding procedures, maintenance. Jointing and splicing of veneers. Demonstration on Media preparation; Explant collection; Surface sterilization and inoculation; Shoot multiplication and rooting; Potting mixture preparation and hardening in mist chamber)

19. Wood Identification

Course Director : Dr. Anil Kumar Sethy and Ms. S. Shashikala

Contact : 080-22190172, 8971074462, aksethy@icfre.org

080-22190215, 9964534875, sshashikala@icfre.org

Dates : 08 –12 January 2024 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content : Field Identification of 25 commercial timbers; method of identification

(Physical properties and internal structural features).

20. Seed handling, Nursery and Plantation Technology

Course Director : Dr. N. Ravi

Contact : 080-2290155, 9435524070, nravi@icfre.org

Dates : 05 – 09 February, 2024 (5 days)

Fees : Rs. 15,000/- (With boarding and lodging) + 18% GST

Rs. 10,000/- (Without lodging facility) + 18% GST

Course content: Components of nursery; propagation techniques; composting; concept of root trainers based seedling production; seed technology; supplementary nutrition; bio-fertilizers; pest management in nursery and quality assessment of seedlings (includes one day field tour and half day field visit to KSDL).

21. Wood Polymer composites

Course Director : Dr. S. S. Chauhan

Contact : 080-2210145, 9980125862, shakti@icfre.org

Dates : 14 – 16 February, 2024 (3 days)

Fees: Rs. 9000/- (With boarding and lodging) + 18% GST

Rs. 6000/- (Without lodging facility) + 18% GST

Course content: Basics of wood, polymers and wood polymer composites; Manufacturing WPC; Physical and mechanical characterization of the composite; Additives for WPC; Degradation of WPC (moisture, biodegradation and weathering); Biodegradable composites; Current trends and market potential. hands-on-experience on compounding, injection molding and mechanical testing of the composites

Note: The above courses can be customized and scheduled to any mutually convenient period on request based on number of participants. For students/research scholars, a concessional fee of Rs.4000/- and Rs.7000/- (without lodging facility) will be charged for 3 days training and 5 days training respectively.

REGISTRATION

The application/nomination letter should be sent to the respective Course Director, Institute of Wood Science and Technology, 18th Cross, Malleswaram, Bangalore-560 003 at least 15 days before the commencement of the respective course. The requisite course fee can be paid either in cash or through Demand Draft drawn in favour of "The Director, IWST-Training" payable at Bangalore. The fee can also be remitted by online transfer to the following bank account.

Account Name: The Director, IWST-Training Account

Number : 392002010007384

Bank Name : Union Bank of India, Malleswaram, Bangalore

IFSC Code : UBIN0539201

Note: Participants are advised to commence their journey for the training only after receiving confirmation about the course. If adequate response for a particular course is not received, the same is liable to be cancelled. In such a case, the entire course fee will be refunded to the concerned.

TRAINING CALENDAR (2023- 2024)

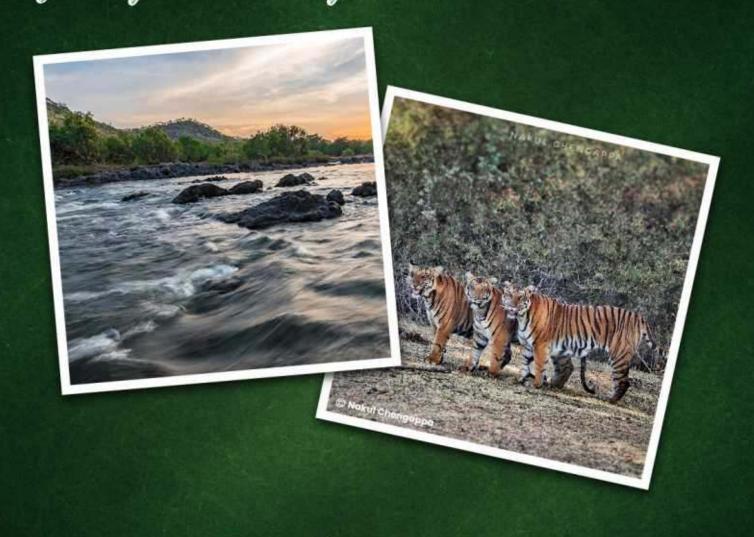
Sl No.	Name of Course	Course Director Particulars	Apr 2023	May 2023	Jun 2023	Jul 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024
1	Sandalwood: Farming and Management of its Health	Dr. R. Sundararaj FP Division Ph: 080-22190154	10-14	भी	च	गि	की	1/2/	70					
2	Saw Doctoring	Mr. V. Prakash: PPPT Division Ph: 080-30534009			05 07				47		7.			
3	Micropropagation of Bamboo	Ms. Tresa Hamalton SFM Division Ph: 080-22190137			19-23						3			
4	Analysis of Raw Materials for Resin Manufacture	Dr. Mamatha B. S. PPPT Division Ph: 080-30534039				03-05								
5	Testing of Plywood and Block Board as per IS:303, IS:710, IS:1328, IS:4990 & IS:1659	Mr. Anand Nandanwar PPPT Division Ph: 080-30534016				10-14						× Hai		
6	Bamboo Processing and Bamboo Composites	Dr. Vipin Kumar Chawla WPP Division Ph 080-22190193					07-11					SAII		
7	Bamboo Based Housing System	Mr. V.R. Ramkumar PPPT Division Ph: 080-30534007					07-11				70	W.5.		
8	Testing Of Door Shutters As Per IS: 2202, IS:1003 & IS: 4020	Mr. Anand Nandanwar PPPT Division Ph: 080-30534016					21-23				3		7	
9	Bamboo: Propagation and Management	Dr. T. N. Manohara SFM Division Ph: 080-22190156					21-25	CH	MC					
10	Sandalwood Farming and Management of its health	Dr. Narasimha Murthy FP Division Ph: 080-30534210				čκ		11-15						
11	Plywood Manufacturing- II (Adhesives for Plywood and Plywood Manufacturing- Resin Preparation, Gluing, Hot Pressing)	Ms. Sujatha. D PPPT Division Ph: 080-30534005						11-15						
12	Epoxy Resin Table Top Manufacturing	Mr. V.R. Ramkumar PPPT Division Ph: 080-30534007						13-15						

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SI No.	Name of Course	Course Director Particulars	Apr 2023	May 2023	Jun 2023	Jul 2023	Aug 2023	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024
13	Resin Manufacturing	Ms. Sujatha. D PPPT Division Ph: 080-30534005							04-06					
14	Testing of Plywood and Block Board as Per IS:303, IS:710, IS:1328, IS:4990 & IS:1659	Mr. Kiran M. C. PPPT Division Ph: 080-30534012							09-13					
15	Plant Molecular Biology Techniques	Ms. Tresa Hamalton SFM Division Ph: 080-22190137		2			5 ///			06-10				
17	Wood Seasoning and Preservation	Mr. Ritesh D. Ram Ms. C. N. Vani WP Division Ph: 080-22190175 080-22190174	15		घा	141	<u> </u>	1.34.	-60	20-24				
16	Testing of Door Shutters as Per IS: 2202, IS:1003, IS: 4020	Mr. Kiran M. C. PPPT Division Ph: 080-30534012								0	06-08			
18	Veneering	Mr. Uday D. Nagammanavar PPPT Division Ph 080-30534011									11-13	51		
19	Wood Identification	Dr. Anil Kumar Sethy Ms. S. Shashikala WPP Division Ph: 080-22190172, 080 22190215										08-12		
20	Seed handling, Nursery and Plantation Technology	Dr. N. Ravi SFM Division Ph: 080 22190155										BAII	05-09	
21	Wood Polymer composites	Dr. S. S. Chauhan WPP Division Ph: 080-22190145											14-16	

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