The Sustainable, Versatile, and Amazing Bamboo -The "Green Gold" for Civil Engineers!

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***Abstract*—Bamboo is a versatile, sustainable, and fastest-growing giant grass in the world and can grow about 90cm per day. The global bamboo coverage worldwide is 36 million hectares which is 3.2% of the total forest area. Bamboo has been widely used in the field of civil engineering for centuries due to its strength, flexibility, sustainability, and low environmental impact. Recently, bamboo has gained popularity due to its low carbon footprint and its unique ability to absorb CO2 (production of 1 Ton of bamboo absorbs about 1 ton of CO2) and release oxygen (35% more than average timber).**

The objective of this research is to study the life cycle of bamboo, the properties of different parts of bamboo, and its preservation techniques. And also the comparison of conventional concrete with supplementary cementitious material i.e. bamboo leaves ash and bamboo fiber-based concrete, and the possibility of use of bamboo as reinforcement in construction based on the research paper. The use of bamboo fiber gives optimum strength at 1% with a corresponding fiber aspect ratio of 40. The workability and mechanical properties of concrete goes on decreasing with an increase in the percentage of bamboo fiber. Similarly, replacing cement with BLA gives optimum strength at 5% replacement, strength, and workability go on decreasing on increasing BLA % in the concrete mix design. And to use bamboo as reinforcement is good for temporary construction work as it has less durability.

Overall the study has demonstrated that the use of bamboo fiber in concrete result in an increase in strength and toughness and the use of BLA improve the strength and durability properties of concrete. And the use of bamboo as reinforcement material is sustainable, environment-friendly, and economical but it has low durability, less capacity to bear the load, and resists the moment. So, the use of bamboo preservation techniques and treatment processes is beneficial in order to improve the quality and durability of bamboo.

KEYWORDS: Sustainable, Bamboo Species, Fiber, BLA (Bamboo leaf Ash), CO2 emissions

I. INTRODUCTION

The word ‘bamboo’ comes from the word mambu," which is the Malayan word for the plant. Bamboo is a colony plant belonging to the Poaceae family. There are more than 88 genera and more than 1400 species of bamboo available worldwide. It is one of the fastest-growing plants in the world and can be found mainly in China and other different parts of the world like Asia, America, and Africa.

1. History

Bamboo is mentioned in ancient Chinese texts dating back to the 7th century BC for a variety of purposes, including construction, food, medicine, etc. Since the 8th century, bamboo has been used in Japan for everything from baskets and paper to instruments and weapons. The spread of Buddhism throughout Asia in the 6th century AD resulted in the growth of bamboo forests around temples, which were used for building materials as well as a source of food. Bamboo became popular in the West in the 19th century as a decorative plant and as a material for furniture and other decorative objects. Because of its strength and durability, bamboo was used in the construction of bridges and other infrastructure in the South Pacific during World War II.

Bamboo is still used in a variety of applications today, including as a sustainable alternative to wood, a food source, and a material for furniture, scaffolding, textiles, and many other products.

Fig.1.1- Species of Bamboo, adapted from Kavitha S, Dr. T Felix kala, 2018

The new bamboo grows in the same way as its main bamboo. Within 60 days of its growth, new shoots emerge and develop into a stick with limbs and leaves. The diameter and height of bamboo remain the same after 2 months of growth its growth, new shoots emerge and develop into a stick with limbs and leaves. The diameter and height of

bamboo remain the same after 2 months of growth. Trees and most plants experience secondary growth, but bamboo does not. As it sprouts new leaves every year, and the lifespan of the bamboo culm is more than 10 years. The growth and growth rate of bamboo mainly depend on the rhizome and the types of species. Bamboo can grow about 1mm in height every 1-2 minutes and can reach up to 91cm within a day.

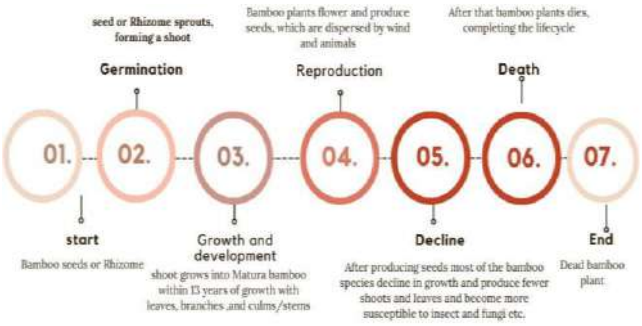

Fig.1.2-lifecycle of bamboo

2. TYPES OF BAMBOO

There are mainly two types of bamboo:

i) Running Bamboo (also known as Monopodial Bamboo)

ii) Clumping Bamboo (also Known as Sympodial Bamboo)

Running Bamboo

It is a type of bamboo that spreads quickly with respect to time through an underground network of roots known as rhizomes. This rhizome can grow quickly, send up new shoots, or culm some distance and become invasive if not properly managed. Running bamboo is well-known for its ability to form a dense grove and rapid growth rate. Some species of bamboo can grow several centimeter's per year and reach a height of more than 30 meter's. Running bamboo is frequently used in landscaping and can be grown for its ornamental value as well as for use in construction.

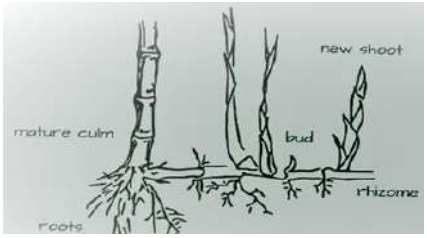

Fig.2.1-Running Bamboo

Clumping Bamboo

Clumping bamboo, unlike running bamboo, grows in dense, clumping clusters rather than spreading aggressively through rhizomes. Clumping bamboo grows in a dense clump of clubs in circular patterns, with growth appearing close to the parent plant. Clumping bamboo is easier to manage, as it grows slowly and steadily.

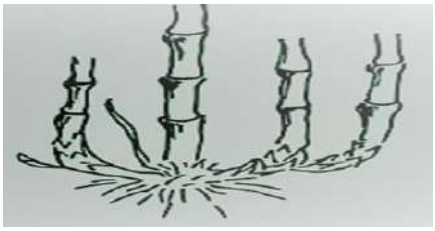

Fig.2.2-Clumping bamboo

3. BAMBOO ANATOMY, ECOLOGICAL BENEFITS, AND OPTIMAL GROWTH CONDITIONS

According to Gunnies world record, bamboo can grow 2.92 feet per day. That's why it is called the fastest-growing plant on Earth. Bamboo takes about three years to mature. Once it matured, the new shoots and sprouts in the summer and spring became larger. As there are different types of species available, based on the species' soil, sunlight, water condition, and climate in that area, bamboo attains its maximum size in a different number of years (4–15 years).

The favourable conditions for the effective growth of bamboo species are:

- The PH value should be around 7 or neutral for sandy loam with high organic content, but it won't grow in stagnant water.
- A minimum of 4 hours of sunlight is required.

So the use of fertilisers such as composted horse manure is the best choice in Asian countries. The bamboo has a shallow root system, so it gets most of its nutrients from the first 12 centimetres of soil.

The rhizome, which is lying 6–20 inches below the surface of the ground. The development of bamboo rhizomes takes place mostly between early autumn and late summer. As rhizomes grow, they become shoots, and later those shoots become culms. The newly grown shoots are breakable and can break with a little shock as well. If a good amount of sunlight is available for the bamboo for photosynthesis, then more energy is available for the growth of bamboo.

Fig.3.1-Bamboo Plant

Fig.3.2-Roots of bamboo

Fig.3.3-bamboo shoots

As we know, the culm is part of bamboo that grows above the ground surface. Bamboo has different parts such as culms or stems, nodes, internodes, and leaves. The inner and outer walls of bamboo are very tough, and most of the bamboo has hollowness inside, which makes it flexible and

not easy to break. The bamboo culm grows to a height of 10-20 meters, or even more depending on the species, and has a thickness of 4-10 cm. When bamboo is young, we can see narrow leaves growing from the stem of the bamboo. After this, the horizontal leaf-bearing branches start growing. Out of more than 1400 species of bamboo, most are hollow on the inside. The inside portion of the culm is divided by several diagrams, which are seen as rings on the outside.

These rings are called nodes, and the parts between the nodes are called internodes. Talking about nodes, they are the woody rings, and the portion between them is called a culm. The presence of nodes makes the bamboo stem stronger. The spacing of nodes, forms of nodes, and internodes vary from species to species. The distance between the nodes is shorter towards the base of the bamboo stem and goes on increasing towards the tip of the culm.


Fig3.4-Bamboo Culm


Fig.3.5-Bamboo bottom culm


Fig.3.6-Bamboo diaphragm

Every stem has two nodes, with two rings on the upper part and two rings on the lower part. The lower ring on the bamboo stem is called the sheath ring, which is formed after the sheath leaf falls off, and the upper ring is called the stem ring, which is the scar formed after the growth of the inter-nodal tissue ceases. Bamboo is different from other trees in that it has more than 35% more oxygen than other hardwoods, which are spread over an equal area. It is antifungal and antibacterial. The bamboo Kun present in the bamboo increases its resistance against destructive bacteria and fungi. As a rough estimate, a mature bamboo may shed about 50 to 500g of leaves per day during the growing season.


Fig 3.7-Bamboo Culm-length


Fig 3.8-bamboo sheath with culm


Fig.3.9-bamboo seeds

With no seeds, the likelihood of flowering is extremely low. Bamboo flowers typically grow at different intervals depending on the species, with some species flowering every year and others only flowering every 20–120 years. When a bamboo plant flowers, it usually means that it has reached the end of its life cycle. While not all bamboo species flower at the end of their life cycle, some do, which is referred to as "gregarious flowering." This phenomenon occurs when all of the bamboo plants of a specific species in a given area flower at roughly the same time, often after a long period of dormancy. Usually bamboo dies after flowering because seed production required an enormous amount of energy which stresses the bamboo to such an extent that it will die. After bamboo flowers, it will produce seeds and then the plant will start to decline. This is because the energy that the plant once used for growth and producing new culms is now being redirected towards producing seeds. As a result, the culms may become weaker and thinner, and the plant may start to look less healthy. Once the seeds have been produced, the plant may die back entirely or it may continue to produce new shoots and culms, but at a slower rate than before. The exact lifespan of a bamboo plant after flowering can vary depending on the species and growing conditions, but it is typically several years. It's worth noting that not all bamboo species will flower and die back in this way - some species will continue to grow and produce new culms for many years without ever flowering.

As we know, there are more than 1400 species of bamboo. Identifying the bamboo species is very difficult, but I will be explaining some basic tips to know more about bamboo, its different parts, and how one bamboo differs from another. I think it will be helpful for other researchers and students to understand more about bamboo.

Among different parts of bamboo, bamboo roots can be used as one factor in identifying bamboo species, but they are not always reliable or definitive on their own. The root systems of different bamboo species can vary in size, shape, and structure and can also be affected by environmental factors such as soil type, moisture levels, and temperature. However, some species of bamboo are known to have distinct root characteristics that can be used to identify them.

Some people may think that there are more than 1400 species of bamboo, all of which may differ from each other, so how do you identify the species? Identifying the species of bamboo directly is a challenging task as it requires expertise. However, I have explained some properties and differences between bamboo and its parts.

a. Colour

The colour of bamboo can vary from species to species. There is also a chance that two different species of bamboo culm have the same colour. Some bamboo culms may have green culms, yellow culms, green culms, etc. It can be one of the properties used to identify the species of bamboo.

b.Bamboo sheath

There are two rings on each node of bamboo. The distance between the nodes and the node is called the internode. The relation between the culm sheath and the internode is whether it is smaller than the internode, longer than the internode, falling off, or attaching to the culm. The presence

of tiny hairs on the culm sheath—are they black or reddish; do they have a specific pattern, or are they randomly placed? We have to see the size, colour, and texture, too. And they are dense at the bottom or top. And how are the branches coming off? Is it tearing the sheath or pushing the sheath? How is the shape there? They are in a bifurcated shear, and the leaf blades begin from the bottom or heirs. In fig 3.10 you can see the presence of reddish hair on the sheath.

Fig.3.10 Bamboo Sheath

Fig.3.11 Bamboo culm and culm sheath

The important thing about leaves is what the size and shape are. If we know about this, then we can try to identify the bamboo species. Apply the rule of elimination to identify bamboo. Now talking about bamboo leaves, they may look similar. So the thing is, how can we differentiate it? How can we identify its varieties? So here are some tips.

Fig.3.12 Bamboo Leaves

Fig.3.13 Bamboo front view

Fig.3.14 Bamboo back view

The most important thing about leaves is their size and shape. If we know about this, then we can try to identify the bamboo species. If you look at Fig. 3.13, the shape and colour of the leaves from the front look similar, but if you look at Fig. 3.14, the colour of the bamboo leaves are different. The first leaf is a whitish-green colour, while the second is green. There are some factors that help to differentiate the bamboo species with the help of bamboo leaves, which are given below.

i) Colour
The colour of the leaves can vary widely; the leaves are green, whitish green, and bright green. It varies from species to species of bamboo.

ii) The shape of the leaves
Most bamboo leaves are long and narrow in shape and size. Some species of bamboo have wider leaves, while others have lance-shaped leaves.

iii) Vein of the bamboo
The vein in the bamboo leaf also helps to identify the species of bamboo. Most bamboo leaves have three main veins, and golden bamboo has five veins.

iv) Hairs
Some of the bamboo has very tiny hair on the stems, which is very small but can be visible to the naked eye.

So with the help of these characteristics of bamboo leaves, you can start to identify different species of bamboo. However, identifying the bamboo species is difficult and tricky, so you can give it a try, but for confirmation, it's best to consult with an expert. If you are not sure about it.

4. ENVIRONMENTAL IMPACT/BENEFIT OF BAMBOO

Bamboo has the ability to absorb CO2 from the atmosphere. Because bamboo sequesters the most carbon, it cleans the atmosphere of carbon dioxide produced by the combustion of non-renewable energy resources such as coal and oil for the benefit of humanity. Bamboo is the fastest-growing plant, absorbing massive amounts of CO2 through photosynthesis. As a result of carbon sequestration, bamboo contains 50% carbon in all its parts. Fully matured Beema bamboo sequesters over 450 kg of CO2 per tree per year, lowering CO2 levels in an environmentally sustainable way.

Bamboo sequesters carbon dioxide at a rate of over 450 kg per tree. Bamboo releases up to 320 kg of oxygen per tree in a year, which is sufficient for human beings' breath for the whole year. According to research, 'one hectare of bamboo absorbs about 17 tonnes of carbon per year. 'Bamboo" is a fast-growing and higher biomass-producing species that showed oxygen production of 27.38 metric tonnes per year.

Total carbon dioxide emissions in India as per 2021 data: 260 crore metric tonnes.
Bamboo cultivation in India covers about 1.4 million hectares and includes more than 148 species.
Total carbon absorbed by bamboo: 17 tonnes *1.4 crore
=17* 14000000
= 238000000
=23.8 crore tonnes of carbon
= 215909970 metric tonnes of carbon.
Percentage reduction in CO2 due to bamboo
= (215909970/2600000000)*100
= 8.3%

Total oxygen produced = 24.83 tonnes * 14000,000.
= 347620000 tonnes per year

The total amount of oxygen they would breathe in a day

would be between 16 and 2,304 litres.
Range of 735,840 (260 tonnes) to 841,920 litres (298 tonnes) of oxygen per year.
The number of people who breathe the oxygen produced by bamboo per year
= 347620000/ ((260+298)/2)
=1245950
= 12 lakhs 45 thousand, 9 hundred, and 50 persons.

5. "IS BAMBOO A BAHUBALI AND A FUTURE GOLD?"

The statement "bamboo is the Bahubali and future gold" has been used to describe the immense potential and importance of bamboo as a natural resource. The justification for the above statements is given below:

The strength and durability properties of bamboo make it a good material for the construction of buildings, as scaffolding, and many other purposes. The strength-to-weight ratio of bamboo is high compared to steel, which makes it stronger than steel in some cases. The talk about bamboo growth rate and sustainability the future of bamboo as "gold" is related to sustainability and a higher growth rate. Bamboo can grow up to several feet (metres) within a year. So it is one of the good renewable resources. The ability of bamboo to grow in different climatic conditions makes it a versatile resource.

And bamboo has tremendous economic potential as a source of income and livelihood for a lot of people and communities. Bamboo can be used to make a variety of products, ranging from construction materials to furniture to textiles, and it can also be processed into bamboo charcoal, bamboo fibre, and bamboo vinegar. Bamboo's versatility and economic potential make it a valuable natural resource for communities all over the world.
At last, the statement "bamboo is the Bahubali and future gold" emphasises bamboo's enormous potential as a natural resource for sustainable development, economic growth, and environmental conservation.

As we know, when cement reacts with water, a hydration reaction takes place, and some amount of heat is generated during this process called heat of hydration. It produces the sulphur compounds C3S and C2S during the hydration process.C3A, and C4AF, as major compounds, and K2O, TiO2, and other alkali materials a minor compounds. When C3S and C2S come in contact with carbon dioxide, they get carbonised into silica gel and calcium carbonate.
Every year, the use of concrete-making material increases, resulting in larger amounts of greenhouse emissions. According to the research for 2019, 2020, and 2021

The amount of CO2 emissions from fossil fuels is
2019: about 36.8 Gt of CO2
2020: about 34.6 Gt of CO2 (reduced due to the COVID-19 pandemic) &
2021: about 37.0 Gt of CO2 respectively
And according to various reports and studies, CO2 emissions from the cement industry are 2019-2.8 billion metric tonnes2020-CO2 emissions declined by about 7% due to COVID-19.And in 2021, the CO2 emissions will be around 2.8 billion metric tonnes as the industry recovers from the COVID-19 era.

So in order to reduce CO2 emissions, the production of cement should be reduced, and alternative materials should be examined. Much research about sustainable, environmentally friendly materials to replace cement has been done. There are many cementitious materials like bamboo leaf ash, rice husk ash, steel slag, and much more that can replace cement by a certain amount. Materials like fly ash and GGBS can replace cement by more than 50%. But still, the use of this material in construction is limited. There is much research going on in order to reduce CO2 in the environment. Among them, carbonation curing is one. There are two types of carbonation curing.
Curing with CO2, &
Weathering by CO2

Weathering by CO2 occurs naturally in hardened concrete, which decreases the PH value and results in the consumption of steel. And due to the carbonation curing by CO2, the amount of CO2 available in the environment is reduced by a certain amount, and it also increases the strength of the concrete. This is due to the complete depletion of the calcium hydroxide, which is a by-product formed during the hydration reaction.
There are many natural fibres that have been used in order to increase the tensile strength and flexural strength of concrete, among them bamboo fibre.

6. DIFFERENT USE OF BAMBOO TREES

1. Bamboo as a fibre.
2. Bamboo as a reinforcement
3. Bamboo leaf ash as a cementitious material

6.1. Bamboo as a fibre.

A crack in concrete is due to its low strength against tensile loads. As we know, cracks in structural members start in the tension zone. In order to increase the tensile strength of the concrete, different types of fibre, like synthetic fibre, steel fibre, and natural fibre, can be used. However, in comparison to natural fibre, concrete is more economical and environmentally friendly, and its overall carbon

footprint is reduced.

As per the research, the use of 1% of bamboo fibre with an aspect ratio of 40 has given concrete its maximum strength. The aspect ratio of bamboo fibre is defined as the ratio of the length of the bamboo to the diameter of the bamboo fibre.

It has been found that the workability of concrete has decreased with an increase in bamboo fibre percentage and aspect ratio. The use of an optimum percentage of bamboo fibre has also increased the Compressive strength, split tensile strength, and flexural strength of the concrete specimen.

According to research done by S. Kavitha, the optimum replacement of concrete with bamboo fibre does not emit carbon and absorbs carbon from the environment. When the compressive strength of carbon-cured concrete was compared to that of water-cured concrete, the compressive strength of carbon-cured concrete was found to be 9.9% greater than that of water-cured conventional concrete. As they have used the optimum percentage of bamboo fibre (1%) in concrete, from the tests it has been found that the compressive and tensile strengths of carbon-cured concrete are, respectively, 14% and 9.9% higher than those of conventional water-cured concrete.

6.2. Bamboo as a reinforcement

Bamboo is one of the oldest building materials that has been used for various purposes like bridge house furniture, tools, and equipment.

Bamboo is a sustainable building material that has good strength, is lightweight, and is flexible. There are more than 1400 species of bamboo available around the world. The properties—shape, size, and strength—of bamboo vary from species to species. It has been found that some species of bamboo have very good ultimate tensile strength, similar to mild steel at the yield point. The ultimate tensile strength of bamboo varies from 140 to 250) N/mm2. It has a high strength-to-weight ratio but low natural durability. So it will be good to treat bamboo chemically to enhance its durability property. The natural durability of bamboo is about 1–3 years against insects and fungi, depending on the species.

The mechanical properties of bamboo are due to the presence of cellulose. Compared to steel, bamboo is abundant, economical, sustainable, and environmentally friendly. The amount of energy required to produce steel is about 45–50 times that required to produce natural products, and the production of steel produces a huge amount of CO2. According to the IEA, 1 tonne of steel production produces approximately 1.4 tonnes of CO2. So in order to overcome the cost, scarcity, and environmental effects caused by the steel industry, it is necessary to do research on alternative materials. It has been found that bamboo has similar properties as compared to steel, but it may not be suitable for use in buildings as reinforcement due to the following reasons:

According to the research, the MOE of bamboo is 1/10th that of steel and has low durability. So bamboo has higher deflection cracks with a higher width but less capacity to bear a load and resist a moment than steel.

The use of bamboo as reinforcement swells and pushes the concrete due to the ability of bamboo to absorb water when curing begins. As concrete is a porous material, it creates a damp environment around it, resulting in the fungal growth and decay of the bamboo. In order to increase the bonding of bamboo with concrete, suitable epoxy should be used, which is expensive and time-consuming. Also, it has less durability, so different preservation techniques should be used before using it as a reinforcement.

At last, there is much research going on about bamboo and how it uses reinforcement; perhaps in the future, we as an engineer have to develop effective methods and treatments for bamboo so that we can utilize this amazing bamboo as a reinforcement.

6.3. Bamboo leaf ash as a cementitious material

Bamboo is the fastest-growing giant grass in the world. Every year, large amounts of bamboo leaves fall to the ground and go to waste in the same place where they grow.

It has been found that the bamboo leaf ash that is produced by burning the bamboo has good cementitious properties. The BLA is prepared by collecting dried bamboo leaves and burning them completely to ash in the open air, then heating them in a muffle furnace at 600–650 degrees Celsius for 2-3 hours. After this, the produced bamboo leaf ash is allowed to cool for about 1 hour, and then it is sieved through a 90-micron sieve to be used as a partial replicant for cement. The ash should be kept in a polythene bag or an airtight bag to prevent moisture absorption; otherwise, it will lose its strength when it comes into contact with water. The burned bamboo leaves are treated in a muffle furnace in order to remove the carbon content, remove the organic matter, activate the amorphous silica, and increase the pozzolanic property. According to the research done by Er. Suhaib Firdous and Er. Anzar Hamid (2018), bamboo leaf ash is amorphous in nature and activates pozzolanic properties after calcination.

If we heat burned bamboo leaves in a furnace for a longer time at high temperatures, then the amorphous silica becomes crystalline and the ash loses its pozzolanic property. After the ash is prepared, the chemical composition test is done by XRF analysis. The main Constituents of BLA are oxides of silicon, aluminium, and iron. The carbohydrate content of bamboo helps to enhance the durability property of bamboo against fungal and other external attacks and increases the service life.

From the research paper, it has been found that a 5% replacement of BLA gives optimum strength in concrete. The workability of concrete decreases with an increase in the amount of bamboo leaf ash.

As the specific gravity of bamboo leaf ash is lower than that of cement, a smaller amount of BLA occupies more space, and the water absorption capacity is also higher than that of cement. So while casting, the mix becomes stiff as BLA decreases workability, so the optimal amount of water is added to the concrete to make it workable.

7. TYPES OF PRESERVATION TECHNIQUES

In the extraction method of fibre, you can learn how to make bamboo fibre. First, the diaphragm and node must be removed, and the hollow portion is used. There are three general methods, which are listed below. Mechanical extraction method Alkali treatment method Stem explosion method, these methods enhance the strength of bamboo and also use the mechanical method to extract the fibre. First, bamboo young (2-8 months old) are harvested. Cleave the bamboo vertically, roll it using a roller, and boil it for 10 hours at 900 degrees Celsius. Dry the strip, and a small piece of fibre is extracted. Another method is similar to the above, but in this method, first cut the bamboo into small pieces as shown in the figure. Submerge the bamboo piece for 7 days to make it easier to handle. The fibre is extracted after it is mechanically rolled.

7.1 Bamboo Preservation and treatment process

As bamboo has a lower natural durability, it requires chemical treatment for a longer life. Low natural durability of about 1–3 years. Against fungi and insects, the outer and inner parts of the bamboo are impermeable, so it is difficult to treat bamboo using normal preservation techniques. So it should be carried in green conditions.

Why does bamboo need to be preserved? As we know, the bamboo culm is natural, and it will decay with respect to time. And as time passes, it will be susceptible to insects and fungi. Which ultimately decreases the durability and lifespan of the bamboo. So in order to maintain its quality and increase its life, bamboo preservation is very important.

How is bamboo preserved? There are bamboo preservation methods that may be economical, costly, easy, or difficult. Mainly, they can be divided into two types:

Pressure method

Non-pressure method

A) Pressurised method

It is one of the most important and reliable methods of bamboo preservation. In this method, controlling the quality of bamboo is possible as this method uses a vessel in which pressure is applied at the control rate.

After putting bamboo in the vessel, pressure is applied, which opens up the capillaries, which were closed. Preserving the bamboo should start within 2–3 days of harvesting. The pressure treatment plant consists of a vessel in which bamboo is inserted and closed. Then a vacuum is created inside it, and in this condition, introduce a water-based preservative inside the chamber, which creates a pressure of about 7–8.5 kg/sq. cm. In this condition, the capillary opens up. If the capillaries collapse, then the preservative will go inside, and again, for this bamboo, make a 3mm hole in one internodal section.

B) Non-pressurised method

It is the traditional method of preserving bamboo. In this method, bamboo is dipped in water. The water contains a mixture of starch and sugar. Bamboo can be preserved using chemicals. So based on chemical use, the preservation method is divided into two types:

Hazardous chemical

Non-hazardous chemical

In hazardous chemicals, the bamboo is treated with or without a fixing agent. A fixing agent is a chemical in hazardous chemicals, the bamboo is treated with or without a fixing agent. A fixing agent is a chemical that is used to stabilise the preservative within the bamboo. The preservative and fixing agent are used in the bamboo, which will be used in exterior conditions. The fixing agent helps to bind preservatives with the bamboo fibre for a longer period of time in order to increase the lifespan.

Borax is a very popular wood preservative; it does not have any fixing agent, and the bamboo treated with it will be suitable for interior purposes. The most widely used chemicals are CCA (copper, chrome, and arsenic) and CCB (copper, chrome, and boric acid). Both chemicals contain chrome as a fixing agent.

Bamboo contains bundles of capillaries. Capillaries start collapsing within 72 hours of harvesting. So the dipping method is used within 72 hours. As we know, bamboo has a strong outer covering. Which consists of lots of silica and lignin. Penetrating chemicals is difficult. So put a 3mm hole within the internode portion on the opposite side so that the chemical will enter through one hole and air comes out through another hole.

The bamboo should be preserved for 21 days with chemicals having a concentration of 4–8%. After 21 days, the bamboo should properly remove and drain the chemical. Then dry the bamboo in the shade, not in the direct sun,

because the presence of sunlight causes chemical breakdown and also reduces their effectiveness.

8. THE HOT AND COLD CREOSOTE METHOD

In this method, creosote preservative is used to treat bamboo. The method involves keeping the bamboo in a tank fitted with a heating arrangement and filled with a creosote-fuel oil mixture. Then boil the bamboo at a temperature slightly below the boiling point for three to six hours, then cool the sample. The creosote will go inside the capillaries, and the bamboo will become even more water-repellent. As creosote is hydrophobic in nature, this will create a barrier in bamboo that helps it to protect from insects, fungi, moisture, and water damage.

II. CONCLUSION

Hence bamboo is a very good construction material. Actually, it is the future of gold. As of now, there is very little research about bamboo and its different parts more research should be done so that we can take maximum benefit from it. Most of the parts of the bamboo are crucial from the civil engineering point of view. The stem of the bamboo can be used as fibre in the concrete, the leaves after burning can be used as a partial replacement for the cement and the culm of bamboo can be used as coarse aggregate, scaffolding and other purposes.

In conclusion, bamboo is a sustainable, versatile, and amazing resource with great potential as "green gold" for civil engineers. It is a superior alternative to traditional building materials due to its rapid growth rate, low environmental impact, economical nature, high strength-to-weight ratio, and the fact that it is locally available in most Asian countries like China, India, and Nepal. So bamboo is an excellent choice for creating an environmentally friendly, innovative, and resilient structure that meets the demands of today's construction industry due to its numerous benefits.

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