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Building Affordable Homes with Mass Timber Construction

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Abstract: ***With the explosion in increased population migration to metro cities, housing infrastructure poses to be one of the biggest challenges in India as well as other countries. Housing in-equality, affordability and homelessness are persistent and complex challenges in our society. United Nations in the year 2015 has adopted Sustainable Development Goals or Global Goals to facilitate people to enjoy peace and prosperity, allow balanced social, economic and environmental sustainability. The need for a safe space to live which transforms the quality of life of individuals and families is a basic necessity. Thus, providing sustainable cities and communities along with good health and well-being of the citizens are priorities which needs to be addressed along with providing affordable clean energy, furthering actions to mitigate climate change. According to a United Nations report, (17) by 2050, more than 7 billion people will move to cities. The rapid growth of cities due to rising population has resulted in increased number of slums which are becoming a feature of urban life. To accommodate the rising urban poor, affordable homes have to be envisioned and built faster. The delay in construction time required by conventional construction methods is resulting in squatter, un- organized settlements as well as contributing largely to global carbon emissions. The need to provide affordable, sustainable homes with healthy benefits using better construction technology is the need of the day. Conventional method of construction which involves concrete and steel are a disastrous method of construction as they are dependent on energy generated from fossil fuels to process materials. As per a United Nations report (17), globally our cities occupy 3 percent of Earth's land but account for 60 to 80 percent of energy consumption and 70 percent of carbon emissions. Hence, the need for alternative sustainable method of construction which can be built in the smallest amount of time, is a necessity. The technology adopted must be a big leap in reducing the carbon emissions, reducing the construction time and providing a healthy environment for the habitants. Presently in India, to reduce the construction time of mass housing, the Government is adopting 'light gauge steel frame' structures in which constructions are faster compared to the conventional buildings. However, this method is still dependent on burning of fossil fuels and other non-renewable resources still resulting in a sizeable carbon footprint. The need to adopt sustainable ways of construction, with less environmental disruption, while ensuring quality and to build faster, led to study of various construction practices adopted globally. Amongst the various solutions, Mass Timber Construction is believed to be one of the most effective solution, characterized by pre-fabricated components manufactured off-site and assembled on site in a shorter period of time and reduced dependency on workers, all the while using a renewable resource, timber [1].***

To move towards accomplishing the Sustainable Development Goals set by the United Nations, our future cities have be built to be safe, sustainable and inclusive. For achieving this we have to change and relook the way we build.

Key words: Carbon neutral buildings. Cross laminated timber, Sustainable Construction, Build with speed

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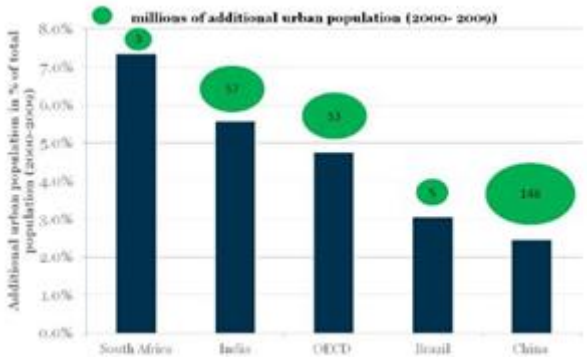
AIM

To change the way we build, adopting emerging construction technology in building faster and providing a better standard quality home transforming the life of individuals and at the same time making it economically affordable. The materials used for construction have to be manufactured using low energy, renewable resources. Mass timber technology construction is an emerging method being adopted globally to build homes faster, cleaner, and being carbon neutral, many countries in Canada, Australia, Europe, Asia, etc., are building multi-storeyed structures in a very short span of time adopting Mass Timber construction. My aim is to bring this mode of construction to India [2].

I. INTRODUCTION

The urban poor in India *(18)* who have migrated to the mega cities are constantly in need of homes which enhance their living spirit. The homes need to be designed such that they are flexible enough to accommodate their simple needs, some additional space to accommodate a guest and to fulfil the requirement and happiness of having a home with efficient space utilization and have a

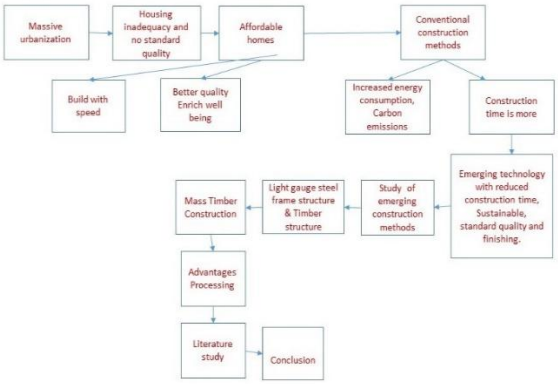


Source: OECD (2011), OECD Regions at a Glance 2011

standard quality finish. Presently, the construction industry is the major contributor for carbon emissions across the globe as well as enormous energy is consumed to manufacture and process various construction products. To create a powerful impact to mitigate global warming, a big leap in adapting sustainable methods of construction is the need of the day.

Various innovations are happening to make greener construction materials, but some of these are processed from non-renewable resources, causing the depletion of natural resources. The energy required to manufacture these products are also high. These factors have been contributing to the global carbon emissions massively. As per the UN study, though our cities occupy a smaller percent of Planet's land, we are guzzling around 60% to 70% of *(17)* energy and are constantly adding to the carbon emissions. The conventional practice of concrete and masonry structures being constructed take longer duration for completion. The huge gap created between demand and supply is one

reason for squatter un-organized growth, slums and illegal encroachments. There are many individual structures being constructed using sustainable practices, these structures needs to be crafted by skilled labours on site working for longer duration to construct it. These structures are a step in inching towards sustainability, but to have the big leap and meet the Sustainable Development Goals, we need a bigger effort to make our buildings better and have clean environment. In the present time of rapid urbanization, according to the United Nations, by 2050, our cities will have about two-thirds of the total population. Amidst escalating land prices in the urban fabric, crafting individual sustainable houses are a luxurious venture. The world needs to build enough homes for the urban poor to accommodate more than 2.9 billion people. Constructing homes in the old conventional way that is using a lot of concrete and steel will be a disastrous venture. Hence, the need to move vertically using alternate sustainable construction methods is an immediate and urgent need of the day.



The Ministry of Housing and Urban affairs in India are building affordable homes using conventional *(18)* 'Concrete and Steel' structure and the other widely used construction method is 'light gauge steel frame' structure. In recent times many affordable homes are being constructed using 'light gauge steel frame' structures. These materials are processed from non-renewable resources which are depleting on a large scale. To reverse our dependency on the depleting non-renewable resources, we need to adopt emerging technology of construction which uses more of renewable natural resources on a large scale. Timber has been a building material since many years in India as well as globally [3]. Various forms of Timber can be used for construction due to its structural rigidity *(1),* environmental sustainability, reduced energy consumption, reduced CO2 emissions and healthier spaces. It further leads to a renewable nature through which we can have sustainable forests. Previously, matured timbers have been used for construction of palaces, temples, houses (few dating back to 1000BC), globally as it has both tensile as well as compressive strength, a high strength to weight ratio and ease of working [4]. Timber is a renewable material which can be easily replenished and re-grown in huge areas while they provide us clean air and absorbs carbon-dioxide which remains trapped inside forever. To manufacture and process Timber products *(4),* less energy is needed when compared to steel and concrete constructions. By increasing the use of Timber products in our structures we will reduce the carbon impact of construction which are the major contributors for carbon emissions. A sustainable forestry sector can be developed in large areas which in-turn will contribute to the non-urban economy, reducing urbanisation. Various research and innovations in the timber industry has resulted in increase of mass timber products like Cross laminated timber, Glue-lam, etc. The engineered lumber of newly grown trees are joined together by various means to achieve the required strength and thickness to form columns, beams, wall panels. The use of engineered wood, beams and CLT panels for building is termed as Mass Timber Construction. This is considered as one of the most sustainable method globally for the following features: *(1)*

- Environmentally friendly product- as the wood used in Mass timber comes from young trees which are from sustainably managed forests.
- Global CO2 emissions of around 14% to 30% can be saved and also reduces the fossil fuel consumption usage by around 12% to 19%
- Mass timber retains CO2 and the manufacturing process uses less carbon than either concrete or steel.
- It contributes towards health and aesthetic benefits.
- It is lighter in weight compared to Steel and Concrete structures, which reduces the dead load and allows us to use this as a material to add extra floor over the existing buildings wherever permissible.
- Majority of the work happens at factory to a high level of precision, and there is a considerable limit of on-site work, ensuring faster assembly, thereby reducing overall cost.

Mass Timber is*(2)* a composite wood system, integrating multiple layers of solids and sawn lumber such as Cross-laminated timber (CLT), glue laminated timber, nail laminated timber and Dowel-laminated timber. This method of construction has been in practice since 1990 in Germany and Austria.

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CLT is an engineered wood made of dimensioned lumber orienting the grains at right angles to one another and then fixed by adhesive to form structural panels. By fixing layers at right angles the CLT panel exhibits great structural rigidity in both directions.

Mass timber products are designed to achieve the same strength ratings as concrete and steel while having a much lighter weight. These structures are pre-fabricated multi-layer engineered wood panel product with a minimum of three layers of parallel boards, by fixing their surfaces together with an adhesive under pressure to various sizes for columns and beams as per the structural requirement, and covered with CLT panels for walls and roof.*(3)* The lumber is not sourced from old matured trees, but from newly grown trees or even from waste wood [5]. Mass Timber and Heavy Timber exhibit few similarities but they are not the same. Mass Timber is manufactured using specific engineered materials like NLT and CLT, whereas Heavy Timber is used in traditional construction method where heavy sawn beams sourced from mature timbers were used. Mass Timber is a strong, effective and efficient low- carbon alternative to concrete and steel. If we consider the products lifetime from the harvest of raw materials through manufacturing, transportation, construction and disposal or recycling- Mass Timber outweighs the cement and steel products in having less embodied energy. Mass Timber has a smaller environmental foot print than other structural materials. CLT has a building system is flexible, suitable for long spans in floors, walls and roofs. As this construction can be panellised or developed in a modular system it is suited for additions to existing buildings also. The lightness, flexibility, ease of working and structural rigidity allows Mass Timber construction to be designed for larger spans [6]. As the weight of the structure is reduced and multi-storeyed floors can be assembled on site very efficiently and with much precision cutting down on co-ordination, pollution, on- site disturbances, wastages, and cost. This construction technology is the most relevant, efficient, Sustainable, affordable, stronger, lighter, aesthetically very pleasing with lot of health benefits [7]. As these structures tread lightly on ground, multi-storied structures can be planned on brown-field sites, where the conventional buildings are restricted to lesser floors.

II. BENEFITS OF MASS TIMBER

A. Structural Stability (6)

Cross laminated timber is a large scale pre-fabricated solid engineered wood panel, light weight yet very strong [8]. Despite being five times lighter than concrete, it carries the same strength as concrete. CLT attains its strength as dimensioned lumber of alternate grains (i.e. Parallel and perpendicular) directions are glued together which enables it to attain strength and stiffness in both directions which enables it to be used in making of columns, beams -primary structural material in multi- storey construction also for two- way spanning slabs, and walls. CLT panels are manufactured by pressing dimensioned lumber in many layers like 3, 5, 7 or more. The thickness can be around 500 mm and the length can vary between 16-20m and width of more than 3m.

B. Earth quake resistance (7)

Mass Timber has the strength equal to steel and concrete. It is lighter in weight compared to conventional building materials. Compared to concrete buildings, this weighs around $1/5^{th}$ of the overall weight. The lightness of the material accompanied by the strength of timber makes it the best building materials for earthquake prone areas [9]. Cross Laminated or Glue Laminated Mass Timber beams are very ductile i.e., they are able to withstand the bending and distortion without breaking. Mass Timber structures are very much suitable for areas with frequent earth quakes as any earthquake activity puts more pressure on structures [10]. A steel and concrete structure in a seismic zone can crack and this may need demolishing it or replacing it, wood buildings can be repaired. These structures being lighter can be constructed on brown field's land which are not suitable for heavy concrete construction.

C. Fire resistance

CLT have inherent fire resistance properties and meets all the requisite fire safety norms as in steel or concrete structures. It is observed that CLT panels retains the structural integrity and its structural stability when subjected to high temperature. CLT members achieve the Fire resistance through charring.*(9)* When the surface of the CLT is subjected to a high temperature fire it is observed that the face of the timber panel gets charred and forms a black layer which prevents the excessive rise in temperature with un-burnt core [11]. CLT performs better in case of fire compared to structural steel. When steel is exposed to high temperature it can lose its strength allowing the building to fail structurally. The CLT panels are manufactured in various thickness to offer a fire resistance of up to 90 minutes.

D. Lighter in Weight

Mass Timber structures are lighter in weight compared to conventional structures *(4)*, though they are structurally equal in strength as steel and concrete. This property of mass timber allows for designing larger spans, enabling large uninterrupted space [12][13][14]. These structures being lighter in weight can be an integral part of urban densification. Densification *(4)* means building taller, buildings on brown- field sites where previously the conventional structures couldn't have been constructed. Number of floors can be increased in existing buildings, as well as new structures. The density of Mass Timber are around 20% the density of concrete allowing for the maximum number of extra floors which can be added. Typically the load of timber building weighs around two thirds of conventional concrete structure.

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Lateral design loads for earthquakes are reduced in timber due to its lightness.

This property of Mass timber enables for construction of structures in challenging sites where the SBC remains very low, coastal areas, low-lying, swampy areas at a lesser cost compared to conventional structure. There will be a considerable savings in foundation design loads and thus development of these structures will be more commercially beneficial.

E. Eco- Friendly

Timber has been used as a construction material dating back to 1000 BC. It is considered one of the most sustainable materials to manufacture as very little energy is consumed compared to other materials like cement and steel*(9)*. Timber can be regrown, thus, it is a renewable resource and it is a sustainable material which grows naturally, CLT is a renewable, green and sustainable material [15]. Huge areas of timber can be cultivated adding to the sustainable forestry, these sustainable forestry are considered to be one of the main additions in mitigating climate change as wood is a carbon neutral material which absorbs CO2 from the atmosphere to grow. By using more of timber products in constructing our buildings, the structure's carbon footprint is reduced. Various studies across the world shows that Mass Timber buildings are the most environmentally friendly structures and they are carbon neutral buildings. CLT structures are prefabricated offsite and installed in shorter time with less labour force requirement on site and work can be carried on in all seasons year round [16].

F. Economical

Many properties of the Mass timber structures makes it more economical*(13)* when we consider the overall cost of the project, the significant feature being the reduced time taken to construct and deliver a multi-storey project. The faster delivery time allows for faster occupancy. As most of the Mass Timber components are pre-fabricated at factory with precision, reduced number of workers are sufficient at site to assemble these components [17]. Better utilization of workers and materials optimises the wastage and number of workers required. The study has shown that the construction time can be reduced by 61% by building with Mass timber and the overall construction cost can be reduced by 5%. Being lighter in weight, the foundation cost and cost of transportation is significantly reduced. It's been observed that on a single day, CLT panels up to 1300 sqmt can be installed easily, significantly cutting the construction schedule. An 18 storey residential structure has been completed in 8 weeks.

G. Wood and Well-being

The warmth of wood has proved to enhance the emotional well-being of the inhabitants. It has proved to reduce stress and increase the physical, mental, emotional health, and increase positive feelings. The indoor environmental quality is enhanced. The aesthetics of natural wood attracts most of the people as it exhibits a positive atmosphere and it is a natural resource.

H. Durability

Timber has been used for construction since ancient times which are existing till now. There are many structures older than 200 years existing globally and in good shape. Mass Timber products are engineered lumber which are stronger than the natural heavy timber.

III. CLIMATE RESPONSE

India has many timber structures in various parts of the Sub-Continent. We have huge timber palaces, houses, temples, etc., *(11)* Mass Timber construction is being widely adopted in many countries like Canada, US, Australia, Europe, etc., In Asian countries, Singapore, Japan and China have started using Mass Timber technology in their buildings [18]. Malaysia is beginning construction using this technology and a lot of research has been done in using the domestic species of wood for manufacturing CLT panels and structural elements.

Any housing project has to address the physical, social *(1)* and emotional needs along with providing thermal comfort for the inhabitants. The thermal performance of CLT is higher as it absorbs CO2 and enables in providing airtight building envelope as well provides very good thermal insulation. CLT exhibits good thermal insulation and lower heat conductivity, making it a right material for constructing homes. It is observed that the thermal conductivity of CLT is lesser compared to concrete and brick. India has a tropical climate with hot-dry areas, hot-humid zones and temperate zone *(11)*.

It is observed that timber is suitable for construction in hot-humid climate as it is characterized by high relative humidity, low diurnal temperature variations and low annual variation. Hot-humid climates call for materials which can breathe, light in colour, light in weight. Timber has low density having air in its cells. It is a breathable natural material with good resistance to heat flow. All of these features make Mass timber a suitable material for building in hot-humid climate [19]. It is a good material to be used in temperate climates as well as we need protection from cold. Mass timber technology is suitable for construction in Indian sub-continent.

Also, India is native to many species of timber which can be used in manufacturing CLT. As young wood is used, we can grow trees on huge acres of land and replenish them after felling. We can promote the farmers to grow these trees as an added income along with their agricultural crops. The trees used for CLT are to be between 5-10 years of age. By adopting this method of construction, we will be expanding huge areas of green cover, creating more sustainably managed forests and further contributing to farmer well-being. We will be creating a cleaner, happier, healthier, inclusive atmosphere. The technology is fireproof, mould proof and termite proof and the wood solution contributes to the well-being and health benefits for the occupants. Various studies and the occupant's feedback show that Mass Timber construction is the most relevant affordable housing solution. Presently the Indian government is developing lot of housing schemes using 'light gauge steel frame' structures, but compared with this technology, mass timber construction proves to be more advantageous.

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A. Advantages over 'light gauge steel frame' structures (1)

The majority of low to mid-rise multi-storey housing is built with light frame construction in the recent times. The embodied energy of the steel structure is more compared to timber for the following reasons:

- Reduced components- Mass Timber has fewer pre-fabricated components which can be assembled on site with less effort.
- Taller structures – with light frame lesser number of floors can be constructed around 5 floors whereas with Mass timber we can build more than 18 to 20 floors.
- Reduced site work- Mass timber requires reduced transportation and reduced traffic implication.
- Efficient Labour management- light frame construction requires around 20-30 people on site for assembling, whereas for Mass timber we need around 6 people working on site.
- More climate friendly lift and stair core walls- In light frame structures, these elements are constructed with concrete or concrete blocks, we can use CLT panels in Mass Timber construction.
- Better Waste management- Light frame involves certain on-site works which generates waste- this is eliminated in Mass Timber construction.
- Speed- Light frame construction requires more time for construction compared with buildings using Mass Timber products.
- Thermal Performance- CLT fares better than light frame structure
- Health- Exposed wood has shown provide better physical and mental health. It reduces stress and increases positivity.
- The shorter construction time of Mass Timber buildings yields in quicker occupancy. It creates a healthy, durable, high quality housing for all.

IV. IMPLEMENTAITON

Globally many countries have revised their policy to adopt Mass Timber as one of the emerging sustainable construction practice. Many incentives are being provided for building with timber like addition of extra floors which makes it more commercially attractive for builders. Mass Timber meets all the *required* safety norms as well as many parameters of building construction to be the emerging construction technology. Policies are formulated and revised to build large projects across all markets.

This has been considered as the crucial step to mitigate climate change and meet the UN SDG's. Globally there has been a huge awareness and demand to build more environmentally friendly buildings which are carbon neutral or carbon negative. *(16)* The Mass Timber construction has to be popularised in urgency to mitigate the climatic change and meet the demand of providing standard better quality homes at affordable cost. The building codes need to be revised to include Mass Timber construction. To make it more viable and affordable many new *manufacturers* and suppliers need to enter the market.

Creating awareness and educating the Architects, Engineers and Contractors about the benefits of Mass Timber construction needs to be taken up in a bigger way. Sequestering carbon leading to forest carbon stocks which can be tradeable are also looked by many countries to popularise Mass Timber construction. Sustainable forestry *(4)* have to be promoted and cultivated in huge areas allowing massive green cover of timber. Managed forests with *the* right kind of harvesting can deliver higher CO2 mitigation. The managed forests are much beneficial than mere conservation of forests. Forest based communities as *well* as agriculturists can benefit from growing timber through sustainably managed forests. Sustainable managed forestry programs can also be a factor in reducing the migration to urban cities as they add to the economy of the farming community. With the emerging sustainable construction process, a significant amount of work in revising the guidelines to include timber as a construction material needs to be done immediately along with the development of sustainably managed forestry.*(15)* These two together helps us in meeting the UN's sustainable development goals, thus making this planet a better place to live in.

Globally, many countries are adopting Mass Timber construction for building affordable homes along with passive designs to make the structures carbon neutral. The habitants of the built structures are reaping the benefits of having a healthy positive environment, a better finished environment. India is moving ahead in all fields and has many innovations in the field of technology and research. The pollution and the climate *change* makes it a necessity to adopt this emerging sustainable construction practice of Mass Timber to be adapted in building larger structures as well as affordable homes. This helps us in having a clean pollution free environment. India being the leading developing country with a huge population is being looked by many other countries. We can set an example and lead other countries in adapting the sustainable construction practice.

A. Few affordable homes built across the world

1. A 13 floor residential unit built in Quebec City in the year 2017 stands tall as an example of popularising this technology. This has 92 units and passing all the necessary safety test. This building stands safe providing a strong resistance to seismic activity as well as fire resistance. It can be accessed at https://www.nordic.ca/en/projects/structures/origine
2. A 470 residential units of around 60000 sft of built up area in 3 blocks of 8 story building constructed entirely with Mass Timber in Arbora. Its unique selling feature is its exposed wooden post and beam built with glue laminated wood and the walls with CLT. The sheer volume of wood used in this project of this size delivers significant carbon-lock in benefits as well has lowered embodied energy compared to steel and concrete. This was completed in 2019. It can be accessed at https://www.nordic.ca/en/project/structures/arbora.
3. A large timber-built affordable housing complex is designed in Netherlands. The building is designed such that it can be demounted and reassembled elsewhere as needed. It can be accessed at https://largest-clt-affordable-housing-complex-in-the-netherlands/.

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4. Australian Government is promoting Mass Timber construction in a huge way. An affordable housing development in Campbell town is the largest residential engineered timber building. This is named as The Gardens- which comprises of 3 towers with 101 apartment. Built with about 22000 sqmt or 962 tonnes of CLT. It can be accessed at https://australias-largest-residential-timber-building-is-an-affordable-housing-project/.
5. Seattle affordable homes- one of the taller buildings being constructed using Mass Timber. This has 126 apartments with 8 floors being constructed with CLT panels and warm aesthetics of wood.
6. The Australian software company Atlassian is constructing a 40 storey structure at 180 mtrs tall with mass timber and glass and steel façade. It can be accessed at https://atlassian-sydney-headquarters-to-be-worlds-tallest-hybrid-timber-building/.

V. CONCLUSION

The current situation of rapid urbanisation, inadequate and substandard affordable housing is a critical, social, economic and cultural challenge. This makes it clear that it is expedient to have a very strong agenda on building buildings with better standards, accelerated construction process and to move towards a repeatable, stronger, resilient, durable, energy efficient and natural housing solution. In the 21st century to tackle the challenge of rising urban population we should adopt modern emerging technology to construct. We need to reduce the use of building materials which consume huge energy to manufacture it. Mass Timber construction technology is a big leap to mitigate the climate change, provide affordable, sustainable housing for masses in lesser time. We can renew the green cover by growing huge areas of sustainably managed forest. By creating these green covers, it contributes to cleaner air.

Benefits from growing timber forests are innumerable, sustainable and creates a positive environment. Mass Timber construction reduces waste generation. Implementing this technology results in manufacturing of Pre-fabricated components off site and thus enabling standard quality space. Using engineered new-growth lumber makes it an emerging sustainable material. Building Mass Timber homes will be a major contributor to address the issue of providing homes and also reducing illegal settlements, slums, temporary shelter, and homelessness. This material provides holistic performance with economic advantages and reduced environmental impact of high-performance. Mass Timber construction is very much suitable to build in Indian climatic conditions as well as these products can be manufactured using the regional timber. The use of regional timber boosts the local rural economy.

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