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A Cross Comparative Analysis of Sustainable Alternatives for Traditional Roofing in Kerala

Dr. K. Thirumaran[1], Nabeela[2]
[1,2]*Department of Architecture, National Institute of Technology, Tiruchirappalli, India*

Abstract*: *Traditional architecture is not an architectural style. It is an attitude towards the culture of a society. Traditional architecture of Kerala is evolved overtime to meet the needs of the people (inhabitants) who live in and thereby the society. It is climate responsive. Properly installed roofing is vital to the structural integrity of a building. Roofing systems of traditional buildings in Kerala is evolved overtime in responsive to the climatic conditions and human comfort levels. It is an important feature of traditional architecture of Kerala. Timber is the main structural material available in Kerala in many varieties. The proficient choice of timber, artful assembly and exquisite carving of woodwork for roof frames are the unique features of traditional roofing systems of Kerala, using accurate fit of joints. However, the excessive use of timber is leading to depletion of many species and thus leading to environmental pollution and hazards due to deforestation. Increased demand needs increased need of supply. While sustainable development is the key need of the present, we have to take lead in initiating and promoting activities that would reduce the exploitation of our natural resources like timber resulting in their effective utilization and to explore alternate materials and methods for traditional roofing systems. The main aim of this research is to explore 'easy to install' alternate materials and methods for traditional roofing systems that are energy efficient, cost effective, climate responsive and sustainable that would aid the future constructions in Kerala. The study and research was carried out with the help of live case studies and literature case studies. The case studies were consolidated and analysed in detail to bring about inferences and conclusion. The scope of the study is to examine the significance and limitations of timber in traditional architecture of Kerala and to explore 'easy to install' alternate materials and methods for traditional roofing systems in Kerala focusing on residential buildings.

Keywords: Traditional Roofing, Timber, Sustainability, Kerala, Residential Building

I. INTRODUCTION

Kerala has a rich tradition and culture since time immemorial, which added to the opulence of her architectural beauty and heritage by the aid of suitable adaptation to the climate, building materials, and craft skills the place offered. Traditional Architecture of Kerala was evolved in response to the human comfort needs, the climatic conditions and the availability of materials conserving the tradition of the society (Manoj Kumar et al., 2009).

The traditional roof systems of Kerala complement in regulating the indoor environment through a well-articulated and complex arrangement as well as combination of material and construction system using timber as the prime material. Timber being the main structural material available in Kerala is of many varieties. The proficient choice of timber, artful assembly and exquisite carving of woodwork for roof frames using accurate fit of joints are the unique features of traditional roofing systems of Kerala (Nazma et al., 1981).

The best quality timber usually used for traditional roofing systems, on account of its remarkable physical and mechanical properties such as elasticity, strength and durability is being depleted due to over exploitation leading to directly and indirectly harming the environment. There has been a substantial gap between supply and demand. The major impact of depletion of resources as against the rising needs and the consequent ecological footprint is getting threateningly immense, unpredictable and completely unmanageable. That is why we have to enter into this kind of action program for efficient sustainable practices.

The idea of sustainability is to ensure that our decisions and actions of today do not inhibit the opportunities of future generations. Sustainable architecture explores to cut down the negative environmental impact of buildings by material performance and moderation, adequate growth and energy efficient. Sustainable architecture practices a conscious approach to energy and ecological conservation in the design of the built environment (Krishnan.A et al., 2001).

Architects has an inevitable responsibility in the creation of sustainable humane design, since they are the creators of built environment. While sustainable development is the need of the present, we have to take lead in initiating activities that would minimize the exploitation of our natural resources like timber resulting in their effective utilization and to explore alternate materials

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and methods for traditional roofing systems in Kerala.

II. METHODOLOGY

The study and research were carried out in a sequential format. Through the process of research, primary data collection was done mainly through observation and in-depth interviews with the experts. Secondary data collection was done by collecting related information from articles, books, e-books, e-projects, etc. Data collection through case studies is the inevitable part of this research. The study and research were carried out with the help of ten different case studies including live case studies and literature case studies in order to study and analyze different available materials and methods that can be used as an alternative for traditional timber framed roofing systems of Kerala houses. The case studies were consolidated and analysed in detail to bring about inferences and conclusion.

III.TRADITIONAL ROOFING SYSTEM

The roof is a system that separates the top floor of a building from the outdoor environment (Punmia B.C et al., 2011). The traditional roof of Kerala consists of steep overhanging eaves that protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation. The attic level ventilation controls heat gain by the superstructure (Ashalatha Thampuran, 2001). The geometry of the roof, profile of the rafter, projections of the eaves of the porch, gable, intersections of roof planes and the variety of coverings etc. distinguish the house forms in different sub regions of Kerala. Fig. 1 shows the typical roof frame of Kerala.

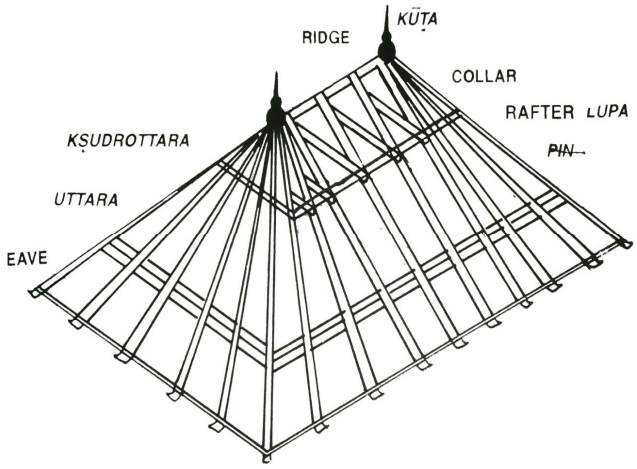

Fig. 1 Typical Roof Frame (Source: Manushyalayachandrika)

Ten different case studies were conducted in order to study and analyse various available materials and methods for roofing in Kerala. The main case studies are discussed here in detail whereas the study and analysis of other case studies are consolidated in the table 1.

A. Case study 1: Asarmulla- Residence of Mr.Humayun Kabeer, Malappuram

'Asarmulla', residence of Mr. Humayun Kabeer is located in Parappanangadi in Malappuram. The building covers an area of 1840sq.ft of plot area. This cost effective residence is constructed of eco-friendly and locally available materials using techniques by Habitat Technology, Parappanangadi. The site experiences an average annual temperature ranging from 25o C to 35o Celsius. Summer lasts from March to May, whereas the monsoon begins by June and ends by August. Malappuram receives around 2,700mm annual average rainfall.

1) *Roof System:* Being an expert in the construction field, the owner himself is confident in the technologies adopted for the construction of his own residence. Above the two storied mud plastered wall structure is the steel framed sloping roof structure with Mangalore tiles laid in two layers. The air between the two tiles act as a thermal insulator, which controls the heat gained by the super structure to an extent. The gable windows also contribute in controlling the heat gain by means of cross ventilation. The roof consists of steep overhanging eaves that protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation. Along with these features, Fig. 2 shows that the courtyard also plays an important role in regulating human comfort levels in the interiors.

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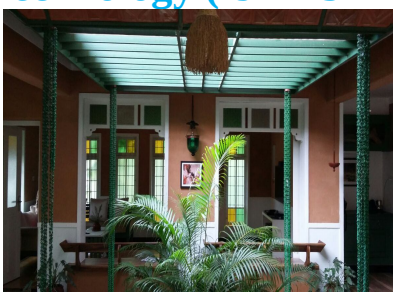

Fig. 2 Courtyard providing natural light and ventilation.

Fig. 3 Mangalore tiles laid exposed to the interior.

Fig. 4 Overhanging eaves covered by tiles laid in two layers

2) *Roofing Materials:* The steel frame consists of rectangular tubes of 2"-3". 18kg. G.I. pipe is used for the roof structure. The recyclable, light weight steel is painted green to prevent corrosion as well as to blend with the design. The transportation cost is very less as the steel is locally available which is bought from Kottakkal, Malappuram. Therefore, it is material efficient, cost effective and energy efficient to an extent compared to the traditional timber framed structures. The steel members of the framed are joined by welding. The Mangalore tiles laid exposed to the exterior is of size 10"x16" and which is laid below is of size 7"x9" as shown in the Fig. 3. The tiles acts similar to the traditional roofing tiles in maintaining the human thermal comfort.
3) *Installation and Maintenance:* Less labour is required for the installation of the roofing system compared to the traditional roofing systems. Steel framed structure is constructed first where the members are joined by welding. The members are painted to prevent corrosion. Then the tiles are laid in two layers as like in the Fig. 4. It took about 4 - 5 days for installation including welding and laying tiles. Painting of the steel frame periodically (once in two years) is the only maintenance needed.

B. Case Study 2: Residence of Ar. Sajan, Thiruvananthapuram

'Visala', residence of Ar.Sajan, who helms the affairs at Costford, the organisation that promotes Master Architect Laurie Baker's architectural theories, blended his personal and professional tastes well enough to come up with a model for green building in the outskirts of the city. Bamboo, casuarina poles and coconut tree trunks holding a house built in mud, covering 2,700 square feet, using recycled and renewable items are the main features of the structure. That too, at just Rs 750 per square feet covering the labour expenses, electrification and water connection charges. This eco-friendly house is located atop a hill a few kilometres from

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Powdikonam, in the suburbs of Thiruvanthapuram. The region is prone to strong winds as it is on hill top. This house was Costford's presentation at the recently-concluded Green Building Congress at Hyderabad and won much appreciation.

1) *Roof System:* The roof system consists of bamboo and Casuarina framed sloping roof structure and bamboo ply or Mangalore tiles laid on top appropriately. The steep overhanging eaves protects the wall and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation. Fig. 5 exhibits that the gable windows also contribute in controlling the heat gain by means of cross ventilation.

Fig. 5 Bamboo ply on Casuarina framework and gable windows promoting ventilation

Fig. 6 Tiled roofing on Casuarina framed structure

2) *Roofing Material:* Bamboos and Casuarina are used for making the roof-framed structure, which are taken from the plot itself. The members are joined using metallic (galvanised iron threads) threads and natural coir's, nails and special timber joinery techniques The bamboo and casuarina wood structure is strengthened by a chemical treatment using a solution of borax and boric acid, an effective mechanism to ward off moisture and sustain the bark for many years. No transportation cost. Therefore, it is cost effective as well as energy efficient compared to the traditional timber roofing systems in the present scenario. Fig. 6 shows that the Mangalore tiles laid on top of the framed structure is of size 10"x16". The tiles acts similar to the traditional roofing tiles in maintaining the human thermal comfort. The transportation cost is very less-only for bringing the tiles into the site.

3) *Installation and Maintenance:* Less labour is required for the installation of the roofing system compared to the traditional roofing systems. Framed structure is constructed using the treated bamboo and casuarina. Coconut trunk is also used as a structural element. Then the bamboo ply and tiles are laid on top appropriately. The building construction materials used for the whole structure increases the resistance of the structure to environmental hazards such as strong winds. No termite attack or any other damages since constructed.

C. Case Study 3: Residence of Mr.Mohammed, Malappuram

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The 27 year old river side residence of Mr. Mohammed is located 1 km away from Kakkad near Chaliyar river in Malappuram. The plot is away from main roads and no vehicular access to the site except by two-wheelers. The region is prone to environmental hazards such as flooding and strong winds. This cost effective residence is constructed of eco-friendly and locally available materials. The roof system is installed using traditional techniques. The site experiences an average annual temperature ranging from 25o C to 35o Celsius. Summer lasts from March to May, whereas the monsoon begins by June and ends by August. Malappuram receives around 2,700mm annual average rainfall.

1) *Roof System:* The roof system consists of coconut framed sloping roof structure and Mangalore tiles laid on top as like in the Fig. 7. Roof consists of steep overhanging eaves that protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation, thus maintaining human comfort to an extent.
2) *Roofing Material:* Coconut trees are used for making the roof framed structure which are taken from the plot itself. Fig. 8 shows that the members are joined using traditional techniques. Rafters are of size 1"x2", Purlin are of size 1.5"x4.7", Central strut is of size 4.3"x2.4", Collar tie is of 2.7"x4.7". No transportation cost. Therefore, it is cost effective as well as energy efficient compared to the traditional timber roofing systems in the present scenario. Mangalore tiles laid on top of the framed structure is of size 10"x16". The tiles acts similar to the traditional roofing tiles in maintaining the human thermal comfort. The transportation cost is very less-only for bringing the tiles into the site.

Fig. 7 Tiled roofing on coconut-framed structure

Fig. 8 Wall plate and rafter-purlin joinery

3) Coconut timber framed structure is constructed using traditional timber roofing techniques and joineries. Then the tiles are laid on top. 4 carpenters for the wood work. Installation of framework took 3 days and laying of tiles took 1 day. Therefore, total days for installation took 4 days. The building construction materials used for the whole structure increase the resistance of this low income household to environmental hazards such as heavy rainfall, flooding and strong winds. No termite attack since constructed.

D. Case Study 4: Residence of Mr.Abdusamad, Malappuram

The 10 year old river side residence of Mr. Abdusamad is located 1 km away from Kakkad near Chaliyar River in Malappuram. The plot is away from main roads and no vehicular access to the site except by two-wheelers. The region is prone to environmental hazards such as flooding and strong winds. This cost effective residence is constructed of eco-friendly and locally available materials. The roof system is installed using simple techniques. The site experiences an average annual temperature ranging from

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25o C to 35o Celsius. Summer lasts from March to May, whereas the monsoon begins by June and ends by August. Malappuram receives around 2,700mm annual average rainfall.

1) *Roof System:* The roof system consists of bamboo and areca framed sloping roof structure and asphalt sheets laid on top (Figure.10). The steep overhanging eaves protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation.
2) *Roofing Material:* 8 areca trees, 18 large bamboos of 4" dia. and 22 small bamboos of 2" dia. are used for making the roof framed structure which are taken from the plot itself (See Fig. 9). The members are joined using metallic (galvanised iron threads) threads and natural coir's, refer Fig. 10. The bamboos are treated by flowing water technique. The transportation cost is very less - only for bringing the sheets into the site. Therefore, it is material efficient, cost effective and energy efficient to an extent compared to the traditional timber roofing systems. 40 asphalt sheets which costs Rs. 250 per sheet is the roof cover used. The exposed surface of the sheets are painted.

Fig. 9 Sheet roofing on bamboo-areca framed structure

Fig. 10 Joinery using coir

3) *Installation and Maintenance:* Less labour is required for the installation of the roofing system compared to the traditional roofing systems. Rs. 400 per day as labour cost. Easy to install due to simple techniques. User participation present in the installation of the roofing system. Framed structure is constructed first using bamboo and areca wood where the members are connected using GI threads and coir (Figure.11). The asphalt sheets are then fixed with a frame work above the sheets, to secure them to the frame. First frame work took 7 days, Sheet laying and second framework took 7 days. Therefore, it took 2 weeks for the complete installation of the roofing system. The building construction materials used for the whole structure increase the resistance of this low income household to environmental hazards such as heavy rainfall, flooding and strong winds. No termite attack or any other damages since constructed.

E. Case Study 5: Residence of Mr.Shihab, Malappuram

The 7 year old river side residence of Mr. Shihab is located 1 km away from Kakkad near Chaliyar river in Malappuram. The plot is away from main roads and no vehicular access to the site except by two-wheelers. The region is prone to environmental hazards such as flooding and strong winds. This cost effective residence is constructed of eco-friendly and locally available materials. The roof system is installed using simple techniques. The site experiences an average annual temperature ranging from 25o C to 35o Celsius. Summer lasts from March to May, whereas the monsoon begins by June and ends by August. Malappuram receives around 2,700mm annual average rainfall.

1) *Roof System:* The roof system consists of areca framed structure and asphalt sheets laid on top (Figure). The overhanging eaves protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation.

2) *Roofing Materials:* 8 areca trees are used for making the roof framed structure which are taken from the plot itself. In the Fig. 11 shows that the members are joined using metallic (galvanised iron threads) threads. The transportation cost is very less - only for bringing the sheets into the site. Therefore, it is cost effective as well as energy efficient to an extent compared to the traditional timber roofing systems. The asphalt sheet which costs Rs. 750 per sheet is the roof cover used. The exposed surface of the sheets are painted.

Fig. 11 Joinery using metallic threads-areca framed structure

3) *Installation and Maintenance:* No labour is required for the installation of the roofing system compared to the traditional roofing systems. Here the user himself installed the whole roofing system. Areca framed structure is constructed first where the members are joined by metallic threads. Then the asphalt sheets are laid on top. The total cost for roofing took about Rs.10000. The building construction materials used for the whole structure increase the resistance of this low income household to environmental hazards such as heavy rainfall, flooding and strong winds. No termite attack or any other damages since constructed.

F. Case Study 6: Residence of Mr. Hameed

This 7 year old residence of Mr. Hameed is located 1 km away from Kakkad near Chaliyar river in Malappuram. The plot is away from main roads and no vehicular access to the site except by two-wheelers. The region is prone to environmental hazards such as flooding and strong winds. in Kakkad in Malappuram. The site experiences an average annual temperature ranging from 25o C to 35o Celsius. Summer lasts from March to May, whereas the monsoon begins by June and ends by August. Malappuram receives around 2,700mm annual average rainfall.

1) *Roof System:* Above the double storied mud plastered wall structure is the steel framed sloping roof structure with Mangalore tiles laid on top as shown in the Fig. 12. The roof consists of steep overhanging eaves that protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation.

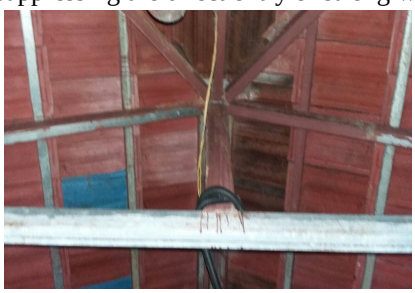

Fig. 12 Steel central strut

2) *Roofing Material:* The steel frame consists of rectangular tubes of 2"-3". The recyclable, lightweight steel painted brown to prevent corrosion as well as to blend with the whole design of the structure. The transportation cost is very less as the steel is locally available which is bought from Kottakkal, Malappuram. Therefore, it is material efficient, cost effective and energy efficient to an extent compared to the traditional timber framed structures. The steel members of the framed structure joined by welding. The Mangalore tiles laid on top of the steel frame is of size 10"x16". The tiles acts similar to the traditional roofing tiles in maintaining the human thermal comfort.

3) *Installation and Maintenance:* Less labour is required for the installation of the roofing system compared to the traditional roofing systems. Steel framed structure is constructed first where the members are joined by welding. The members are painted to prevent corrosion. Then the tiles are laid on top. Painting of the steel frame periodically (once in two years) is the only maintenance needed. The building construction materials used for the whole structure increase the resistance of this low income household to environmental hazards such as heavy rainfall, flooding and strong winds.

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IV. DISCUSSION

Steel seems to be more light weight and material efficient compared to all other framing materials. Steel framed structures requires less labour and is easy to handle and install compared to traditional timber framing. Material cost is less compared to high quality timber used for traditional roofing. Not vulnerable to termites, therefore termite proofing is not required. Less probability of damage in an earthquake or in other environmental hazards like strong winds, etc. Dimensionally stable- does not expand or contract with moisture content. Periodic maintenance needed to prevent corrosion.

Bamboo pole is an environment friendly and locally available material which can be replaced and replenished easily. Light weight, high strength structural material which can withstand earthquakes, strong winds and floods. Bamboo framed roof structure is Material efficient, Cost effective, Energy efficient and eco-friendly. Less labour and is easy to handle and install compared to traditional timber framing. Skilled labour or special tools are not required, user himself can install the structure. Bamboo is very efficient in carbon sequestration and helps in reducing greenhouse gas emissions. Fast growing, highly productive and self-renewing resource, accessible to poor. Cheap to buy, process and maintain.

Areca wood is an environment friendly and locally available material which can be replaced and replenished easily. Untreated areca wood structures are durable for 15 years were as treated areca wood are durable for about 75 years. Areca framed roof structure is Cost effective, Energy efficient and eco-friendly. Less labour and is easy to handle and install compared to traditional timber framing. Skilled labour or special tools are not required, user himself can install the structure.

Casuarina pole is an environment friendly and locally available material which can be replaced and replenished easily. High strength structural material which can withstand vulnerability caused due to environmental hazards like strong winds. Treated casuarina structures are durable for about 60 years. Areca framed roof structure is Cost effective, Energy efficient and eco-friendly. Less labour and is easy to handle and install compared to traditional timber framing. Termite proofing is required.

Coconut trunk is an environment friendly and locally available material which can be replaced and replenished easily. Its high strength helps in reducing the vulnerability caused due to environmental hazards like strong winds, floods and earthquakes. It can withstand dampness and heavy rainfall. Coconut framed roof structure is Cost effective, Energy efficient and eco-friendly. It is similar to the traditional roofing system in its method of installation and the techniques for the joineries adopted. Skilled labour is required. Highly durable even without any treatments. Highly productive and renewable resource, accessible to all class, the rich as well as the poor. No maintenance required. Not easily attacked by termites.

From the case studies conducted, it is inferred that these materials are environment friendly, energy efficient, cost effective, and climate responsive and sustainable. In addition, these materials are suitable as an alternate to the traditional roof structures of Kerala.

V. CONCLUSION

The basic technique, form and material used in Kerala houses are the same for all economic levels as well as classes. Only the size or the addition of more buildings to a compound separates the rich from poor. Considering the roofing systems of residential buildings in Kerala, we can see that Traditional Kerala houses have sloping roof that consists of steep overhanging eaves that protects the walls and the openings on the walls from heat and rainfall, while suppressing the direct entry of strong winds, thereby optimizing ventilation. The attic level ventilation controls heat gain by the building. In traditional architecture of Kerala, roof systems complement the space system of planning through a complex and well-articulated arrangement as well as combination of material and construction system using timber as the prime material.

The complex in labour, intensive construction methods, scarcity of traditionally used best quality timber, the increasing gap between supply and demand, the rising cost of such timbers due to high demand, the increasing transportation cost for importing such timbers has risen the need for exploring new sustainable alternate materials for traditional roof structures for houses in Kerala.

From the case studies conducted, it is clear that the Steel gains importance because it is easy to make and only a lesser amount of unsustainable material is exploited. Thus, it can be used as an alternate material for the traditional roofing systems in Kerala. It is highly durable and can withstand vulnerability caused due to environmental hazards such as heavy winds, heavy rainfall, earthquakes, floods, etc. These materials in combination with traditional roof form characterised by sloping roofs, steep overhanging eaves and attic level ventilation will function as similar to the traditional roofing systems in controlling thermal gain and maintaining human comfort at low cost and with less damage to the environment.

The recently developed alternate such as concrete has proven to contribute to the damage caused by construction building materials to the environment. However, the materials such as bamboo is very efficient in carbon sequestration and helps in reducing greenhouse gas emissions. Thus reducing the previously caused damages. The use of Steel gains importance in the present scenario as it is easy to make, light weight and material efficiency is maintained along with energy efficiency and cost effectiveness

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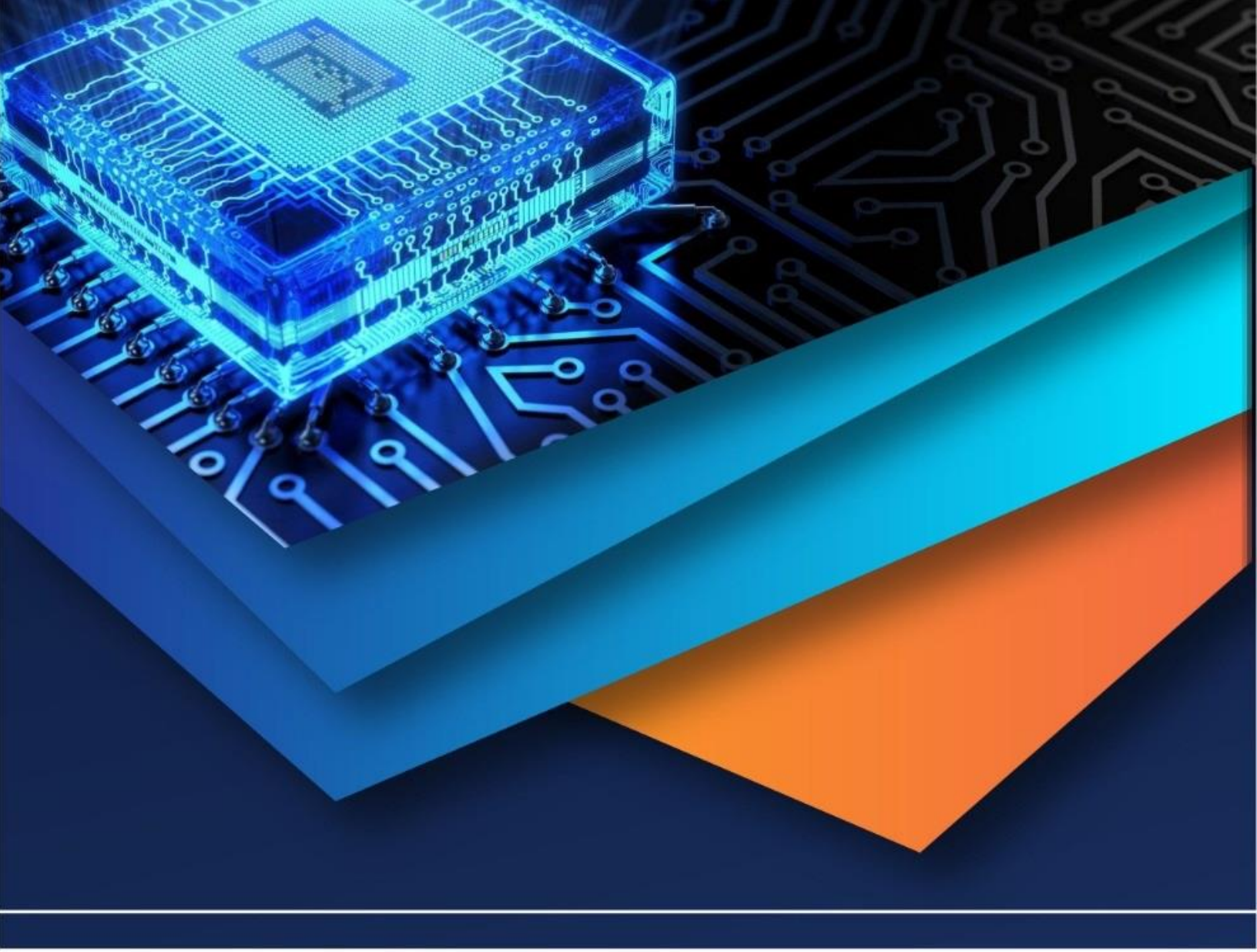
compared to heavy timber roof structures and less damage to the environment as it can be recycled and reused. The use of such alternates ensure that our decisions and actions of today do not inhibit the opportunities of future generations. Thus promoting to a sustainable future.

REFERENCES

[1] Manoj Kumar Singh, Sadhan Mahapatra, S.K. Atreya, "Bioclimatism and vernacular architecture of northeast India", Building and Environment, 44, 2009, 878–888.
[2] Krishnan, A, et al., Climate Responsive Architecture- A design handbook for energy efficient buildings. New Delhi:Tata Mcgraw – Hill Publishing Co. Ltd., 2001.
[3] Nazma, P.M.Ganapathy, K.M.Bhat, N.Sasidharan, R.Gnanaharan, A handbook of Kerala timbers, Kerala Forest Research Institute Peechi, Thrissur, 1981.
[4] Punmia B.C, Ashok Kumar Jain, Arun Kumar Jain, Building Construction, 10th edition, Laxmi Publications (P) Ltd.,2011.
[5] Ashalatha Thampuran, Traditional Architectural Forms of Malabar Coast, Vastuvidyapratishthanam, Calicut, Kerala 2001. Tirumangalat Nilakandan mussath, Manushyalaya Chandrika, Muscut, 16th Century.



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