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Exploring Feasibility of Passive Cooling Techniques in Residential Buildings in Kerala

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Abstract: ***The vernacular architecture of Kerala is perceived for giving agreeable indoor climatic conditions to its clients through normal and inactive cooling strategies. The modern residential buildings, with the use of present technology, results in higher rate of consumption of energy hence, it is necessary to conserve energy for sustainable economic development through adoption of passive cooling techniques. Traditional buildings focused on architectural features for attaining desired thermal comfort. But at present, while construction of residences, people are focusing on modernization rather than giving importance to climatic conditions of the area. Thus, this paper makes an effort to understand and analyses different passive cooling techniques of residential buildings in Kerala and exploring its feasibility.***

Keywords: Vernacular architecture, Kerala, Passive cooling

I. INTRODUCTION

Kerala is the southernmost state of India lying between the Arabian sea on the west and Western Ghats on the East and due to its geographical location Kerala is having warm-humid climate. On the basis of altitude Kerala is divided into 3 zones: the highland, midland & lowland. Kerala has mainly two seasons the monsoon season and non -monsoon season, in which winter and summer comes under non monsoon season. For a warm nation with a creating economy like India, roughly 8% of the nation's 249 million family units were cooled as of March 2018. It is relied upon to ascend to half by 2050, which would mean a huge increment in vitality needs. The incorporation of different passive cooling techniques is implemented in order to attain comfortable thermal conditions which has always been present in the vernacular architecture for a long time. Vernacular architecture was developed hundreds of years ago and was developed gradually over the years and has taken different factors into consideration like climate, region, culture, availability of materials, skills and tradition of local workers etc. Hence earlier buildings were more efficient in nature in terms of making use of locally available material for construction of buildings.

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In design Passive cooling refers to:
a) decrease of sun-powered warmth gains by utilizing sun oriented concealing gadgets, protection, suitable structure materials, and shading.
(b)the decline in warm warmth gains by lighting controls and so on.
(c) expulsion of overabundance heat from the structure by means of convection, evaporative cooling, air development, cool wind, earth coupling, an impression of radiation, and so forth.
Detached cooling thoughts help in channelizing the wind current and in this way expelling the abundance heat from the inside spaces.

Aim of the Research:
Exploring the feasibility of passive cooling techniques of vernacular architecture in residential buildings of Kerala.

Objective;
- Understanding & analyzing different passive cooling techniques in warm & humid climate.
- Exploring its feasibility in Vernacular architecture of Kerala.

Methodology:
The research methodology involves collection of relevant data through literature study and case studies for understanding the different types of passive cooling techniques adopted in residences in warm and humid climate. The detailed methodology to carry out the research has been summarized as follows (Fig-1).
The study shall shed light on the following aspects as a part of research methodology to accomplish the following objectives:

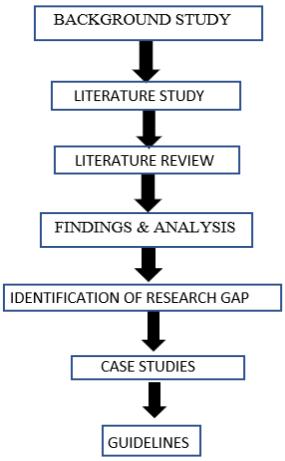


Figure 1: Methodology for Research

Scope

- The study focuses on different types of passive cooling techniques used in residential buildings in Kerala.
- The study is limited to vernacular architecture of Kerala.
- Focuses on various techniques in built form & influence of Vastushastra in vernacular architecture.

Limitation

- The study is confined to residential buildings in Kerala.
- The study is limited in analyzing the impact of passive cooling through demonstration using software skills.

II. LITERATURE STUDY

i. Kerala: Climate:

Kerala is having warm and humid climate, the average monthly climate of Kerala ranges from 21-34 °C and the relative humidity varies from 65-70%. The diffuse portion of sun-based radiation is very high because of overcast spread, and the radiation can be extraordinary on crisp mornings. Due to the presence of clouds the dissipation of the gathered heat from the earth to the sky at night is generally minor.

Hence, the daily variation in temperature is quite low. The nearness of high measure of dampness in the climate makes warm uneasiness the tenants for more often than not because of the less pace of vanishing and thus to maintain a strategic distance from dampness there ought to be ceaseless airflow/cross ventilation is recommended here. Shading should be provided for getting protection from direct solar radiation.

ii. Design Guidelines

OBJECTIVES	PHYSICAL MANIFESTATION
1)Resist heat gain	
• Decrease exposed surface area	Orientation and shape of building
• Increase thermal resistance	Roof insulation and wall insulation. Reflective surface of roof.
• Increase buffer spaces	Balconies and verandahs
• Increase shading	Walls, glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	Pale colour, glazed china mosaic tiles, etc.
2)Promote heat loss	
• Ventilation of appliances	Provide windows/ exhausts
• Increase air exchange rate (Ventilation throughout the day)	Ventilated roof construction. Courtyards, wind towers and arrangement of openings
• Decrease humidity levels	Dehumidifiers/ desiccant cooling

TABLE-1: Design guidelines for warm and humid climate Source: Koenigsberger O.H., Ingersoll T.G., Mayhew A. and Szokolay S.V., Manual of tropical housing and building.

A. Landform

if there's a contour site, it's better to have the building located in the windward side.

B. Waterbody

Waterbody is not necessary for warm and humid climate having high moisture present in the atmosphere.

C. Open spaces & built form

There should be proper spacing between buildings for not limiting the movement of air. (Fig-2).

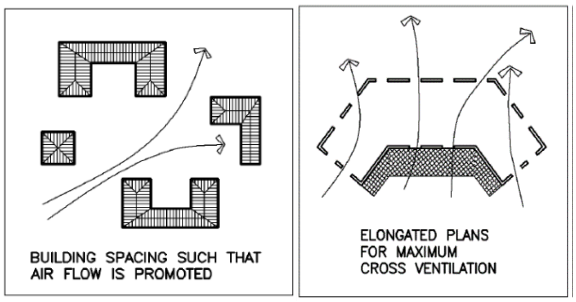


Figure 2: Koenigsberger O.H., Manual of tropical housing and building.

D. Spatial planning

Moisture and Heat generating areas of the house should be located separately and ventilated. In multistoried structure, a courtyard in center can helps in drawing out the hot air from the house.

E. Roof

The pitched roof is generally preferred a warm and humid climate. The Huge shades shield the dividers and openings from sun radiation and rainstorm. The rooftop must be made of materials that are lightweight with and high reflectivity and low warm limit. The type of rooftop ought to be planned in a manner to advance wind current. Vents gave at the housetop viably advance ventilation and draws hot air out (fig-3).

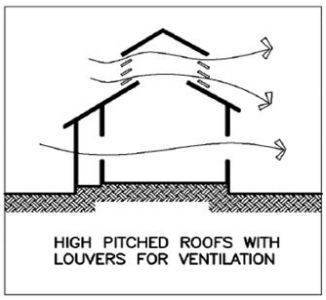


Figure 3: Air circulation

F. Walls

Walls should be constructed of materials with minimal heat storage capacity. There should be less obstruction in the airflow and walls should protected from the sun radiation.

G. Color & Texture

The walls must be coated with lighter shades or should be white washed and the roof surface can be of broken glazed tile.

H. Openings

Cross-ventilation is the principal objective in the warm and humid places. For getting ventilation every one of the entryways and windows is to be kept open for the most time. Openings of a relatively littler size can be put on the windward side, while the comparing openings on the leeward side possibly greater for encouraging a plume impact for regular ventilation (fig-4).

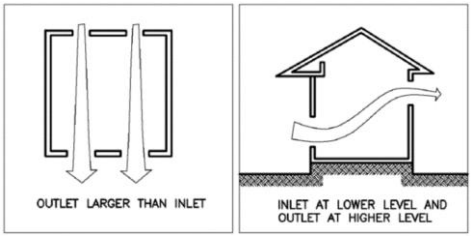


Figure 4: Position of the openings

iii. Kerala Vernacular Architecture

Vernacular architecture of Kerala was developed over hundreds of years ago and has taken different factors into consideration like climate, region, culture, availability of materials, skills etc.

Vernacular architecture of Kerala is built on the basis of 'Vastushastra', it is believed to be developed during the Bronze age of India (1500-500 B.C). It's based on culture, region, religion, climate etc.

A. Built form

In Kerala vernacular private structure is known as 'Nalukettu' with an open courtyard and four squares encompassing it, generally rectangular or squarish in arrangement in which all squares are topped with an inclining rooftop on every one of the four side. The courtyard is the wellspring of light and ventilation (Fig-5).

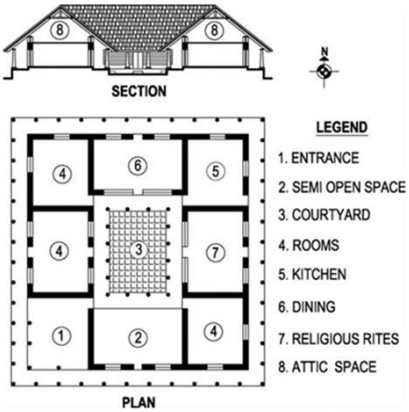


Figure 5: Basic form of Nalukettu

B. Materials used

Following are the materials used for the construction of vernacular buildings in Kerala which are mud, laterite and granite stone blocks, lime mortar, wood, bamboo, clay roofing tile and coconut palm leaves. The choice of materials used for the construction of houses varies for different regions based on factors like availability, region, culture, cost etc.

C. Spatial planning

Vastushastra has influenced in spatial planning of residential building in Kerala, with courtyard in the center surrounded by the verandahs for protection from rain and sun. The kitchen is situated at the North-East corner of the structure in Kerala as the breeze is significantly from South-West heading which aids in maintaining a strategic distance from the spread of hot air from kitchen to other parts of the house. Every other space including rooms are organized around the courtyard so as to allow sufficient air development in all seasons.

D. Internal courtyard

They offer occupants of the house a private open-air space, which is secure and usable for the duration of the day. With its normal ventilation, a yard enables the house to remain fittingly cool and dispensing with the need for forced air systems.

Research Findings:

1. Passive environment control system of Kerala vernacular residential architecture for a comfortable indoor environment: A qualitative and quantitative analyses (Year:2010). A.S. Dili, M.A. Naseer. T. Zacharia Varghese

Overview

A quantitative examination was done dependent on field analyses by account warm solace parameters in a chosen building.

Findings

The temperature recorded inside the room is seen as lower by around 4-degree C than that of semi open space around the yard during day time.

The lower some portion of the yard is seen as cooler by around 5-degree C from the most extreme outside temperature.

It acts as a large air space at the attic which acts as heat barrier.

2. Journal- Exploring passive cooling potentials in Indian vernacular architecture. (Year:2017). Neha Gupta.

Overview

This paper, endeavor to survey and explore diverse vernacular architecture of India and its structure components from India following the particular uninvolved cooling possibilities.

Findings

Characteristic ventilation ought to be the focal point of enthusiasm for any structure plan and results in a successful inactive cooling procedure

Utilize common sunlight in the structures helps in the decrease of counterfeit methods for lighting. Along these lines, the warmth created by the artificial lighting diminishes

Deciduous trees provide shading in summer.

3.Vasthushastram, Publisher: Sharon book (Year:2009). Aditya Varma.

Findings

Understanding the spatial planning.

Positioning of openings in a house.

Influence of wind and sun path in designing a house.

Site planning.

4. Essay: Cooling Your Home but Warming the Planet: How We Can Stop Air Conditioning from Worsening Climate change. (Year:2018). Christina Ospina.

Findings

Assessment of 20% of the all-out power utilized in structures the world over goes towards air conditioners and electric fans. Energy use for space cooling has been on the ascent for a considerable length of time.

5. Houses, how to reduce building costs Published by: Costford. (Year: 1993). Laurie Baker.

Overview

Rat Trap Bond.

Filler Slabs.

Jalis.

Findings

The air hole in the middle of the tiles make great warmth separator.

Cavity induced in walls provide better thermal insulation, resulting in cooler interiors in summer and warmer interiors in winter.

Jalis can effectively replace glass by controlling heat, glare and by allowing movement of air.

6. Construction Practices in Traditional Dwellings of Kerala, India. Jacob Joseph Koduveliparambil.

Findings

Laterite was used for the construction of walls.

When left exposed, undergo chemical change and becomes hard & durable with passage of time.

The main wind current was from the southwest kitchens were located to the north east corner, ensuring smoke free interiors.

7. Viya construction services in Kerala.

Findings

Tiling the roof: Concrete roof tiles/Clay tiles offer excellent warm protection, in this manner diminishing the warmth conductivity of the rooftop.

1.Tiling the roof: Concrete roof tiles/Clay tiles offer excellent warm protection, in this manner diminishing the warmth conductivity of the rooftop.

2.Reflecting sunlight with cool roof: The useful utilization of the heat safe coatings increments the solace of the insides by lessening the indoor temperature.

3.False ceiling: The Buffer space made via air between two layers of roofs chills the room off.

4.Roof Garden; The mud acts as an insulator which is used to grow plants, absorbing the solar radiation, thereby keeping the slab cool.

5.Avoid using too much hard paving:

They absorb sun-oriented radiation and the reflected warmth created is consumed by the encompassing structure surfaces hence expanding the warmth gain

6.Flooring material: Flooring tiles must be made of natural materials which are responsive to the climate like red oxide, Athangudi tiles are ideal for heat reduction in houses in Kerala.

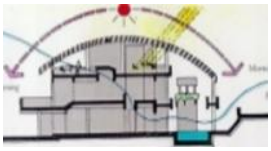
8. KenYeang– Eco architecture: Projects, Theory, Ideas, Subsystems. Ken Yeang.

Overview

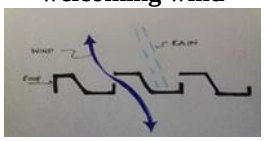
Deals with green structure and ace arranging as a biology driven methodology concentrated on biodiversity and planning structures as 'constructed ecosystems'.

Findings

Huge conc. Louvered roof which act as umbrella roof which act as solar filter.



Use of Z – shaped roof for keeping out rain and welcoming wind



Helps in directing wind

9.The Living Culture and Typo-Morphology of Vernacular-Traditional Houses in Kerala. (Year :2005).

Overview

This paper is a record of observations by the author on vernacular residences of Kerala.

Findings

Fundamental structure with the single lobby, the hipped, shingle rooftop, the mukhapu, and the three displayed room course of action.

Utilization of grilled windows and permeable walls as reaction to tropical sun glare.

Open lay-out living spaces.

10. Eco housing Assessment Criteria (Year: 2009).

Findings

Orient longer axis of the building in the N-S direction to minimize solar gain.

Light weight walls with lower thermal mass heat is preferred.

Orient longer axis of the building in the N-S direction to minimize solar gain.

Light weight walls with lower thermal mass heat is preferred.

Total area of the window openings should be about 30% of total floor area.

Place majority of the windows on the Northern side for the diffused daylight.

11. A review of passive cooling architectural design interventions for thermal comfort in residential buildings. c.v. subramaniana1, n. ramachandranb and s. senthamil kumarc ab.

Overview

Formal appraisal on different strategies for inactive cooling methods taken up in various customary structures and examination of conventional and current structures for thermal comfort.

Findings

Laying Hollow Clay Tiles (HCT) over RCC rooftop rather than traditional Weathering Course (WC). is discovered that 38-63% of vitality reserve funds can be accomplished than the traditional WC rooftop by this technique.

Warmth transmitted through the uncovered top of single or two story private structures is around 50-70%.

III. CASE STUDIES

The concept of passive cooling will be applicable when there is a positive response from people in terms of choice in materials, roof preference and cooling preference.

To understand the passive cooling techniques in residential buildings different case studies are taken from different parts of Kerala and Malaysia for understanding the type of roofing they adopted and to understand current trends in construction of residential buildings etc.

Case Study 1: The Hamlet, Trivandrum

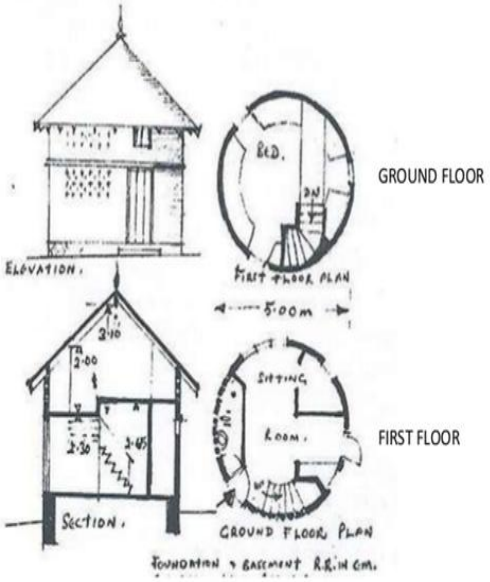


Figure 6: Floor Plan Details.

Architect: Laurie Baker

Residence is built up on a contour site having rocky hillside with very little vegetation when Baker started constructing. “make low-cost a habit and a way of life” by reusing everything, from brick to glass bottles, as building materials All the walls are made of mud bricks.

Concrete roof embedded with chipped or broken terra cotta roofing tiles into the mixture for better thermal insulation (Fig-6).

Pitched roof with Mangalore tiles is used for the roofing.

Clerestory arches used for getting natural sunlight also promotes passive cooling (Fig-7)

Gables had punctures through which hot air rises from the house and go out through the gable on top (Fig-8).

Jalis are used for boosting ventilation in the house.

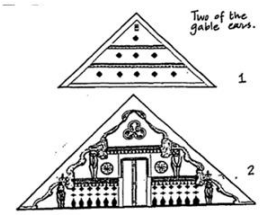


Figure 7: Gable punctures

Figure 8: Clerestory arches

Use of filler slab in the interior which acts as good heat insulator.

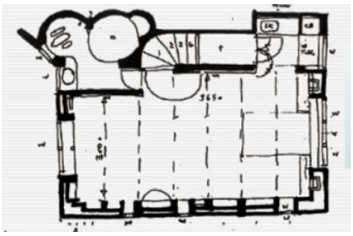


Figure 9: Plan

Use of less partition in the interior. Arches are provided in places of doors in the interior ensuring air circulation(Fig-9).

Case Study 2: The Walls And Vault House, Kottayam

Architects: Lijo Reny Architects

Design responds to the region’s contrasting climatic conditions, which feature long heavy monsoons and periods of hot sun. Built area: 3190ft.sq Land: 37 cents

Figure 10: Planning of the house

Sunlight doesn’t fall evenly on the roof due to its curvilinear form which helps in controlling the heat gain on slab. Flat slab is connected with courtyard so even if the flat slab gets heated up it will be dissipated through courtyard(Fig-10).

The stone walls that encloses the open to sky landscape courts acts as thermal barrier as well as providing privacy to the desired space(Fig-11).

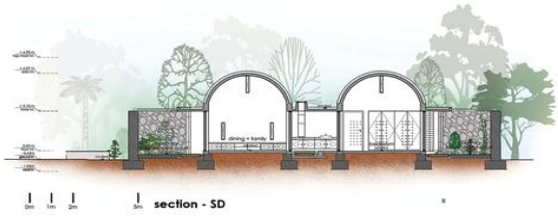


Figure 11: Section

Figure 12: Section

The layout consists of 2 primarily linear bays vaulted room that are separated by a path open to sky landscape courtyard in center. Barrel vault is provided over living and bedroom and vent is provided on the vault which helps for hot air to escape. Grill is provided on top of courtyard for safety aspect and source of light and ventilation for the house(Fig-12,13&14).

Figure 13: Section

Figure 14: Section

Case Study 3: The Safari Roof House, Malaysia

Figure 15: View of the safari house

This house is arranged in blocks around a garden, similar to the vernacular architecture of Malaysia. Arranged in blocks around a densely planted garden, the building is experienced from the inside out. An open settlement pattern is used to improve sufficient air circulation(fig-15).

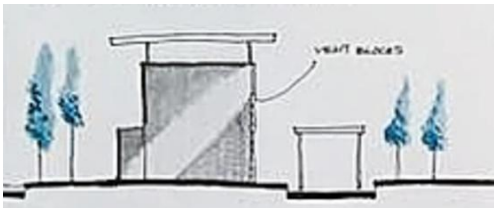


Figure 16: Conceptual Sketch

The roof is raised from the body of the house to providing air flow, which was inspired from Land rover from which it takes Its name. large walls of Precast cement vent blocks are used for shading the West side of the house which helps in reduce afternoon heat from the west and also promote the movement of wind(Fig-16).

Many researchers have concluded that the warmth going into the structure through rooftop is the significant reason for inconvenience if there should be an occurrence of non-cooled fabricating or the significant burden for the cooled structure. About 55% of the undesirable warmth that develops in residences comes in through the rooftop. This is difficult to control with customary roofing materials. For instance, not at all like most light-shaded surfaces, even white black-top and fiberglass shingles retain 70% of the sun-based radiation.

IV. DESIGN GUIDELINES FOR ROOF

A climate tight rooftop is fundamental in the protection of a structure. The rooftop sheds the downpour, conceals from the unforgiving sun, and cradles the climate. In warm and humid climate, it's smarter to go for sloping roof rather than flat roof which absorbs more heat, but the choice of roof also depends upon the choice and requirement of the client.

Most significant factors that influence the roofing temperature of your home are

- Type of roofing and attic
- Color of the roof
- Roofing material

The most generally utilized parameters for rooftop warm assessments are the thermal transmittance (U), It is viewed as that lesser the U the better the warm action. According to Indian Standard I.S. code 3792 – 1978, the most extreme estimation of in general thermal transmittance (U-value) of a rooftop ought not surpass 2.33 W/m2-K in warm and muggy atmospheres.

V. DIFFERENT ROOF STYLES

Flat Roof

Photovoltaic or PV rooftop shingles catch and divert sun-based power into power. Sunlight based electric boards and shingles come in customary shingle shapes and sizes which are growing in the market rapidly. It requires initial investment in the start but can be compensated in few years. To understand the PV energy production on roof of sloping roof Software 'insight' is used to analyses it with setting Kochi as the geographical location for the house. Which gave the following report on energy saving. (fig-17) But Providing P.V panels on the entire roof is costly.

A downside to a level rooftop on house is its propensity to trap heat. A few techniques to lessen heat assimilation by level rooftops have been created and demonstrated, which can bring about recognizable cost reserve funds on cooling in the home through choice of materials, coatings applied or by providing green roof.

1.Application of two layers of splendid white elastomeric paint to your level rooftop to expand the sun-oriented reflectivity. Trial of warmth decrease with elastomeric paint demonstrates a 60 to 70 percent improvement in the amount it reflects daylight and warmth.

2. Earthen pots are put on the solid R.C.C roof slab, accordingly part of the air pocket framed within the pot. Air hole is consistently warmth protecting. Inside air is lighter and will, in general, go upwards accordingly contact the surface of the rooftop ought to be free from air and no warmth can be in contact with the surface of solid rooftop. Consequently, no warmth can reach the rooftop surface and keep the temperature in the room comfortable. U- value for mud pots as roof covering is 2.03 W/m2K.

3. Green rooftops conceal the structures beneath from direct daylight and lessen both surface temperatures and encompassing air temperatures through vanishing and transpiration, the procedure by which plants expel dampness from the dirt and produce it through their leaves. But it's expensive.

4.Tiling the roof top with tiles having good solar reflectance helps in reducing the temperature by 1degree.

5.Use of filler slab in place of concrete helps in reducing the temperature as concrete absorbs more heat compared to filler materials like Mangalore tiles.

6.By providing false ceiling of plywood which sandwiches 5o mm thick polystyrene with an aluminum foil pasted on top and it should be hung 25 mm below the concrete slab creating air cavity. The aluminum foil will radiate the reflected heat from the concrete slab

Sloping Roof

Building structures having pitched rooftops are roughly 10-15 percent smaller than the ones with level rooftops. This profound decrease brings about higher warm protection by simply off-putting the size of the surface presented to the outsides. Its more durable compared to levelled roof.

Higher the ceiling height of the room better the better the indoor thermal comfort.

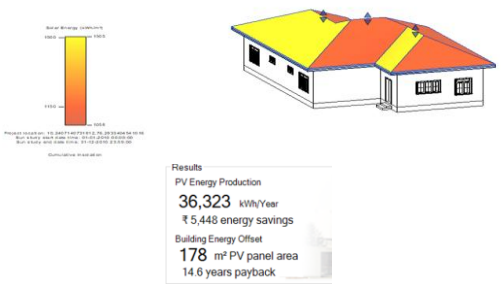


Figure 17: Analysis of PV energy on sloping roof through software

Avoid materials which absorb heat.
Provide attic under the roof which can be used as a heat barrier.

VI. CONCLUSION

The decision of roofing material relies on the climatic state of the zone and dependent on the decision of the customer on premise of his necessity.
As warmth goes into the structure through rooftop it is essential to shield the structure from the warm the of the sun, which can be cultivated by the utilization of passive rooftop design. Selection of new innovations like P.V shingles for material aides in changing over the sun-based warmth into power and further aides in cleaving down the vitality bills.
Arrangement of false roof under rooftop helps in decreasing the temperature. The rules will be valuable for developing houses in warm and muggy atmosphere.

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