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Thermal Energy Performance by providing Cool Roof and Solar Photovoltaic System to Enhance the Ambient Internal Temperature and Energy Saving Potential for Composite Tropical Climate

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Abstract: ***As the study proposed the thermal analysis by providing different concepts for cool roof depending upon different characteristics like material, passive cooling techniques, colours, radient barriers , different types of radiation control coatings, green building envelope with the help of solar PV system to enhance the power of technology and design thinking to implement cool roof for their buildings. As these charactistics gives the innovative and effective solution for improving the thermal energy performance of roof which has to be a key research, therefore its thermal performance has to be reduce by overheating roof and energy saving requirement for ambient temperature reduction. As we know the surrounding is rapidly changing and it affects us how anyway. So its important time to value, calculate and discuss on every aspect of design and technical consideration. So to study, for thermal energy performance by providing cool roof and Solar PV System to enhance the ambient internal temperature and energy saving potential for composite climate. The study include (case in AMROHA city) to collect proper data and analize the saving of electricity load and comfortable environment for humans by providing PV solar system , Green House and Tile Coating.***

Keywords: Cool Roof, Cool materials, Green building envelope, Solar PV system, Buildings, Thermal Energy Performance ,Use of Air Condition, Composite Tropical Climate

I. INTRODUCTION

Due to high temperatures around 40plus degrees during extreme months in between May to July of summer periods compared to other months of the year which also increase in energy consumption for cooling purposes (like the use of air conditioners) is up to 100% higher than the other months of the years, which generate heat – related mortality can be up to three times higher & also increase the peak electricity demand by almost 100% when temperature increasesfrom 20 to 40 degrees Celsius.

Cities are expected to facilitate quality of life for their inhabitants. However, city dwellers are increasingly facing heat stress in their built environment. In the context of continuous global warming, summer heatwaves are now a common occurrence worldwide. So people recommend covering the building outer layers like walls and roofs with some coatings, materials as well as pv panels to give the aesthetic look as well as to decreases the internal temperatures that comforts the human body temperature.

Maximum intensity always occurs during summer, except in cities with humid climates where the maximum occurs during the dry season. The peak local rise above ambient temperature varies in time; some cities near midday, others during the late afternoon. It will be critical for temperature peaks to be reduced to improve the thermal comfort for people living in such hot & humid areas. The combined use of coatings as a material and solar pv panel was found to be the most effective scenario to improve the microclimate of an areas, on average 2 °C reduction.

II. COOL ROOF

It is a system which is opaque in nature , these are highly reflective to reflects the rays coming from the sun i.e. the solar radiation absorbed and helps to radiate way. When the sun rays are at their peak it disturb the air and increase the temperature of the surrounding which affects the building envelope mainly the roof because it is directly in contact with the rays then it shows some reflections in roof performance . As traditional roof having temperature on hot days (as we are in composite tropical climate) in between (60-65 degree celcius) which increase the internal temperature of the building and disturb the human comfort .

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As we are in this composite climate range so most of the months are dry and hot , so if we have traditional roof and the days are hot and sunny the temperature itself pickup and rises the internal temperature which need the requirement of air conditioners on a full time use and it increase the electricity usage directly in electricity bill that is energy costs.

So the COOL ROOFS are great provisions as it is designed in such a way to decrease the temperature of the area upto (23-27 degrees celcius) . It helps to reflect more rays of sun and give comfort to the ambient environment. A cool roof is a low in technology, costing , easy to apply by locally available materials.

The definition of cool roof define by reflecting the higher solar rays and released absorbed heat, It helps to cool the planet too[1].

Due to lack in proper treatment to cool the buildings for better living style, increase the level of Energy consumption which evolved the concepts of higher demand in supply of air contioning which effectively contribute in energy consumption. Human body feel uncomfortable when the outdoor temperature reaches 35-40 degrees celcius whereas indoor temperature should be in between 28-32 degree celcius. the difference is about 5-8 degree celcius which is quite high. Due to increase in demand of air conditioners also increase the carbon emissions in our areas.In India the public places also felt warmer than comfort level of humans allow .So the demand for comfort zone increases as people want their living and working places to be in [2] .As India is a developing country which is running incredibly fast. Therefore , it makes India the third largest contributer of CO2 emissions in the world. Moreover, the nature of human environment changed into habitual behaviour which means it becomes status symbol more than necessity for the use of air conditioners. In addition, it also helps the governments and institutions in evaluating the thermal comfort for locals to improve laws and directives concerning energy use. The production of CO2 and pollution harms the environment, so the use of air conditioners may become uncontrolled use of energy. As the buildings with air conditioners emit 2–3 times the CO2 compared to mixed mode and naturally ventilated buildings without comfort [3].

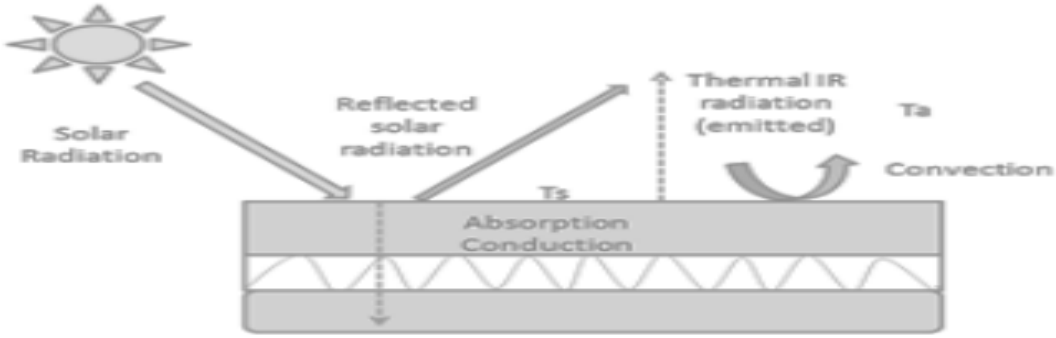


Fig: 1 Energy Balance of a roof exposed to solar radiation [4]

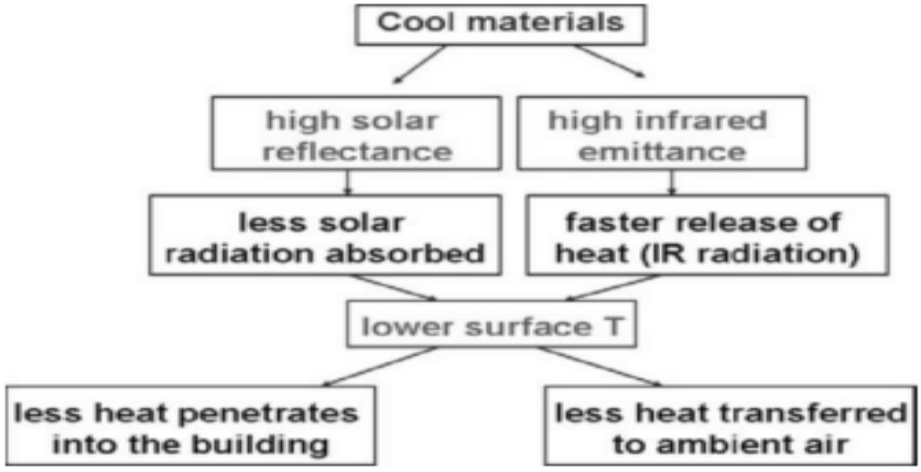


Fig:2 basics principle of cool materials [5]

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III. DIFFERENT MATERIALS / TECHNIQUES TO PROVIDE COOL ROOF:

A. *Ballasted Roofing Systems*

In this system a layer of stones and cement is laid on the top of the roof surface, which provides an insulating barrier against the solar heat . It is quite thick works like any old building with thick wall to give cool internal environment . It is low cost , durable if combined with terrace green gardens[1].

B. *Building Rooftops*

It also helps to reduce the stormwater , its a vegetative rooftop that helps to to reduce the both temerature internally and externally surrounding with the help of two processes evaporation and transpiration, which removes water from the soil and leaves emit through itself. According to Environmental Protection Agency (EPA) it helps to reduce upto 15degree celcius , surrounding of city's ambient temperature[1].The best thing to building rooftops is that it covers almost 20% of the urban surfaces in cities. Rooftops are generally more exposed to direct sunlight compared with any other outdoor space. In composite climate we have all types of climates that includes sunny days most of the times that absorbs the more heat in the roof as compared to any other façade. By providing greeneryover the surface of the roof it may help in reducing the inside temperature at least just below the floor of that area. And also helpful for aesthetics as well as for fresh air too. It helps to increased indoor thermal comfort, decreased cooling energy demand, increased outdoor thermal comfort. Cool roofs can be applied on both flat and pitched surfaces.

C. *High Albedo*

The roof surfaces, shading by textured surfaces, cool walls all help to reduce the inside temperature of the building to give the comfort human. The cool walls can reflect a higher fraction of incoming sunlight than average exterior walls – and high thermal emittance, meaning they can efficiently release absorbed heat. “Cool walls provide energy cost savings and emission reductions cool walls can save as much or more energy than the same size cool roof. Also said that cool paints with light colored should reflect at least 40% of solar energy, while higher- performance cool walls should reflect at least 60%. The study assumed that an average wall that is not cool reflects 25% of sunlight.

D. *Broken China Mosaic Terracing*

In this type of roofing small pieces of glossy glazed tiles broken into smaller pieces . It is low cost experiment type of coating. the tiles are white or light color prefered, which added into slurry of cement to make a smooth surface. The combination of waterproofing material and cement mortar fill up into the joint that were made[6].

E. *Asphalt coating*

It is a type of coaching which is made by modifying into bitumen after combine with plastic and combine with the layer of reinforced materials . After this layer material is applied on the surface to give the final touch . It is inexpensive coating which helps to achieve a higher solar reflectance[6].

F. *Agricultural Roofing*

It helps in many different ways like unemployment, food insecurity, human health and mitigating poverty. In developed countries, these termed as urban practices that help an agriculture world as a short lived activity for areas with vacant space before any use for living after it becomes profitable for commercial, residential and industrial landuse. This include rice husk ash and cocopeat. Combination of these material form a tile which is in many sort of ways like flat , teluga, roman, pantile, mission Interlocking roof tile etc[7].

G. *Green Roof*

A green roof itself defines the greenery itself, means fresh, pure, organic and mostly loved. Some benefits are extracted from it like it gives fresh air by purifying it, rainwater buffer, obviously reduce ambient temperature , encourages biodivercity and save energy and electricity[7].

H. *Reinforced Cement Concrete(RCC) and Slate Tiles*

It is commonly used roof both in commercial and residential buildings . The surface of it covered with elastomatic cool roof coating or covered with glazed tiles which is in broken pieces.

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I. Metal

It is one of the best materials to reflect back for about 65% of solar raays. It is further painted with white coating to increase its emittance. These are come in a form of tiles.

J. Cool Colours

Cool colours are those roofing materials that can reflect the infrared energy by integratin pigments, these colours absorb some visible spectrum too. 'Cool color' roofing materials are created by integrating cool and dark colour. It can be in form of tile, metal and coatings that can be applicable.[7]

K. Roof Ponds

This is one of the most important measure of passive technique. As we know that roof is the most exposd part of the building with the outdoor environment, so to provide the coolness at the roof by increasing the thickness of the roof , shades, insulation, drop ceiling , agriculturing the roof by planting more trees , blue spaces by pools, ponds etc for thermal comfort to the surrounding . It can reduce the temperature upto 5-7 degree celcius[8].

L. Photovoltaic Roof Tiles

These tiles are used over the wooden battens , having thickess of min 75mm. These can be run in all the direction with the help of nails. It provides extra waterproof barrier , air and dust prevention. [9]

M. Shading by textured surfaces

These textured surfaces are helpful to create shades to building element. Highly textured walls and partitions like bamboo have a portion of their surface in shade which can increase the outer surface coefficient, which permits the facade surface to stay cooler as well as to cool down faster at night[10]



Fig: 3 use of bamboo sticks as a shading

N. Aluminium roof coatings

It is also consider into cool coating material. It is a combination of pigment flakes of alluminium metal and asphalt. It has spectral curves which can tend to increase wavelength about 800mm. It is high solar reflectance range compared with white or light color coatings. These are characterised into values with range 0.3-0.6 [11,12]

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Material	Solar reflectance	Infrared emittance	Solar reflectance Index	T surface max (C)
Coatings				
White	0.7 -0.85	0.8 -0.9	84-113	51 – 42
Aluminum	0.2 -0.65	0.25-0.65	-25 – 72	55 – 92
Black	0.04-0.05	0.8 -0.9	-7 – 0	82 – 85
Asphalt shingles				
White (grey) asphalt shingle	0.2-0.3	0.8-0.90	15 – 28	70 -77
Black	0.04	0.8-0.90	-7 - -1	83 – 85
Tiles				
Terracotta ceramic tile	0.25-0.4	0.85-0.9	23 – 45	65 -74
White clay or concrete tile	0.6-0.75	0.85-0.9	71 -93	47– 56
Grey concrete tile	0.18 -0.25	0.85-0.9	14 - 25	73 – 77
Membranes				
White membrane	0.65-0.85	0.8 -0.9	76 – 107	42-53
Black	0.04- 0.05	0.8-0.9	-7 – 0	83-85
Metal roof				
unpainted	0.2-0.6	0.05-0.35	-48 – 53	63-101
Painted white	0.6-0.75	0.8-0.9	69 – 93	47-56
Dark conventionally coloured	0.05-0.1	0.8-0.9	-6 – 6	80-85
Built-up roof				
With asphalt	0.04	0.8-0.9	-4 - -1	83-85
With dark gravel	0.08.-0.2	0.8-0.9	-2 – 19	75-83
With white gravel	0.3-0.5	0.8-0.9	27 – 58	60-72
With white coating	0.75-0.85	0.8-0.9	93 – 113	42-48
Modified bitumen				
With mineral surface capsheet	0.10-0.2	0.85-0.95	4 – 21	74 - 81
White coating over mineral surface	0.6 – 0.75	0.85-0.95	71 – 94	47-55

Fig:4 Different material with different solar reflectance [15]

O. Metamaterials and 2D-3D photonic structures

A number of metamaterials and 2D-3D photonic structures,
such as metamaterial structures based on multilayer all-dielectric micro-pyramid structures, dielectric resonator metasurfaces ,2D metal-dielectric photonic structure have been developed, which have very high solar reflectance cinsidering with atmospheric window close to it. But it can not be considered for residencial buildings due to expensive way. [15]

P. Phase Change Material

Good in durability and reduction in surface temperature. It plays a good role when come to be a part of building envelope , it can reduce the peak load of heat transfer into the building and reduce the fluctuation of the room temperature which helps to improve the internal and external thermal comforts and cool the area around degree celcius. [15].
The PCM has a melting point of 24°C that means it can absorb heat from the ambient air at this temperature, provide coolness inside the building by preventing from heating up. It can be helpful in providing pleasant working conditions with comfortable temperature to live and work, and also help to maintain the temperature so that it doesn't increase further. It is economical with an advantage of comfort levels. The best & recommended example of a phase change material at 0°C is ice. We need 1kg of ice at 0°C to melt in a form of liquid that is water with the help of 333 kilojoules of energy & the same energy is required to raise the temperature of 1 kg of water from 0 to 80°C. PCMs can store a large amount of energy at a constant temperature. In building applications, the main focus is on temperature maintenance and not on the heat supplied through external parameters. This ensures pleasant working conditions and an agreeable temperature to live and work. Apart from enhancing comfort, a large reduction in costs can also be achieved by using PCM. It helps to decrease the rate of heat i.e. temperature between the building and the environment. They can only maintain the temperature for a longer duration. The PCM is best way to make the temperature comfortable & remain maintained during both times for human requirements.

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Some characteristics of PCM are

1) Chemical compatibility of wall;
2) Thickness of the wall to ensure tightness;
3) Suitability of the thermal characteristics of the material in application; and
4) It is able to cope up with the mechanical stress acting on the walls caused by the volume change of the PCM.[13]

Benefits of installation

a) Economical as it saves huge amount on diesel cost (for the generator) and HVAC running cost,
b) It can be helpful to give cold backup for about 8 hours without additional power source or maintenance,
c) It is a passive system which is automatic PCM battery without manpower. [14]

Q. Star Cool Shied (SRI-130) Heat Resistant Paint

Paint for both Interiors as well as Exteriors. It is estimated at Rs12.31 / Square Feet, with a water proof and anti-corrosion quality that have covering area of about 25-30 sq.feet/litre. it can be easily applied witha roller. it may be applied with 3simple steps-

1) Scrub & Clean the surface
2) Apply first coat
3) Apply final coat after 4 hours

R. Star Cool Shied (SRI-130) Solar heat reflective & Insulating Cool Coating for Roof

It is estimated at Rs12.31 / Square Feet, with a water proof and anti-corrosion quality that have covering area of about 26-30 sq. Feet/Litre. It gives a protection from Heat, Water & Dust. It is a Nano-modified ceramic coating, containing Nano reflectors & Insulation additives. It is also Elastomeric Flexible that Expands and contracts in summers & winters both. Good to fills up the hairline cracks on your roof surface. Also formulated with Non- yellowish & UV Block Technology. With a good Adhesion to multiple substrates & clings well to the surface at all temperatures. High resistance to dirt pick-up for long-term solar reflectivity. One of the best input is that it doesn't get affected by mild acid rain, soapy water & other liquids and doesn,t requires any primer.

S. Site Application of Cool Roof Coating

The procedure of application of any product of coating to the roof surface depend upon product to product - As the roof surface must be properly clean , swept and well prepared. Any broken area or crack area must be reinforced with caulk and polyster fabric strips. Then the coating must be applied with a roller , another coat must apply after the first one fully dried up after all set the cool roof coating will be applied.[15]

IV. HUMAN COMFORT

Solar radiation is the best way for air conditioning energy consumption, and it almost 40% of the electrical peak load in large cities. In summer, for single-story buildings, cooling load through the roof is 36.7% of the load of the entire building envelop, while in a multi-story building it can reach 8-10% (16).

But in today's building lacking of thermal storage capacity with older buildings for cool interiors. The room temperature quickly rises to a level that is equal to or even higher than the ambient. People suggest air conditioners for this purpose but they affect the pocket by its cost. Human Comfort Requirement: The range of comfort parameters that needs to be addressed. Thermal insulation on wall & roof in form of tiling's, panelling, painting & through different glasses, features like green & blue spaces (landscape & ponds). These coatings sometimes also help in aesthetics also. Now a days green building concept also in practice that helps in natural way for making the environment comfortable.

V. SOLAR PHOTOVOLTAIC SYSTEM

In this system, modules of photovoltaic having a liquid with roof profiles to enhance the building envelope. The panels are so designed to elevate according to the orientation of the building with the sun and the most important thing is to select the materials with light dispersing properties and thermal mass, so that it is desgned in such a way it naturally transfer the air .Now it is available in light weight panels without any effect on both building and environment. The modules of photovoltaic system can easily convert light of sun into heat. Depending upon the location of the poles it varies from an angle of (45-70)degree and can easily heatup the water.

The solar heat system like parabolic trough, compound parabolic and tubes . Those who want more amount of heat or energy for large quantity they will require solar parabola. The module of photovoltaic can easily convert light into electricity. Earlier modules of silicon solar came with less efficiency and cannot be fixed on curves but later thin film modules came like photovoltaic tiles . It has a rule to fix on the roof surface by placing the panels facing the cardinal point with equal latitude angle to the surface which is horizontal. eg. if the house is oriented 33 degree north then the photovoltaic surface should face south with 33 degree to the horizontal surface. This is important as a rule to fix the panelsystem. As the system is placed in a style grid manner . With the help of practical knowledge in solar system, power can contribute a clean and renewable energy . After its application you can realize that it is an one time investment for almost 25 years of working . So the investment at early stage is high but after sometime there is nothing to pay [17].

As it has several designed batteries like working on different grids like ongrid, offgrid and hybrid grid generation . In ongrid and offgrid it provides dim working conservation but with hybrid generation it mixup and can provide the load for about 24x7. It has a battery backup for atleast about 12 hours .

VI. CASE STUDY

Residence of two storey building at **Amroha city** with solar photovoltaic system , green house and tile coating.



The PV panel that is used there is about 5.5kw in area for about 200sqft. It is designed and alligned towards the south at 35 degree on the roof. As it start working from after sunrise to sunset i.e. from 6a.m to 6p.m . Around 12 hours of production provides for about 4kw and the peak hours to store heat and convert it into energy it takes about 4 hours i.e. from 11a.m to 3p.m. It generates about 15-20 units per day. As it is a thumb rule for using solar generation it requires the power setup for all 5 star rating appliances like Air Conditioner, Induction, Geyser, Refrigerator, Washing machine, Fan, Cooler, LEDs etc. It is less consumer of Energy. The global warming has already been a cause of several problems in our environment mainly thermal fluctuation, uncomfort living, high energy cost, species extinction, building deteroition, health issues etc.

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Since the owners of the house planned this solar panel system 5 years back . So they also export the netmitring for about 3 months of storage . Overall they invest 5 lacs in total in this system with 1 lakh for green house and cool roofing tiles. Total they spect around 6 lacs. As they told us their monthly electricity bill was around 8-10 thousand . But after 5 years bill cost is around only 200 rupees monthly. After 5 years they are utilising free electricity with air conditioner utilization of 8-10 hours. Due to green house and tiles coating the temperaure is almost 9-10 degree less compared with 5 years ago scenario. Green plants gives soothing and refreshing effect to the eyes . It also needs cleaning requirement i.e. wear and tear , from bird beat etc. Cleaning is easy with water so that it can enhance its efficiency. At starting in its first year an efficiency decreases about 10% then another for next continous years it decreases 2,1,1,2 like wise but thankfully resist in between 70-72% , because it has high conductor. So cleaning and caring is must. Watering plants , cleaning tiles enhance the level and working of roof. So now happily and confidently , they call their roof as COOL ROOF.

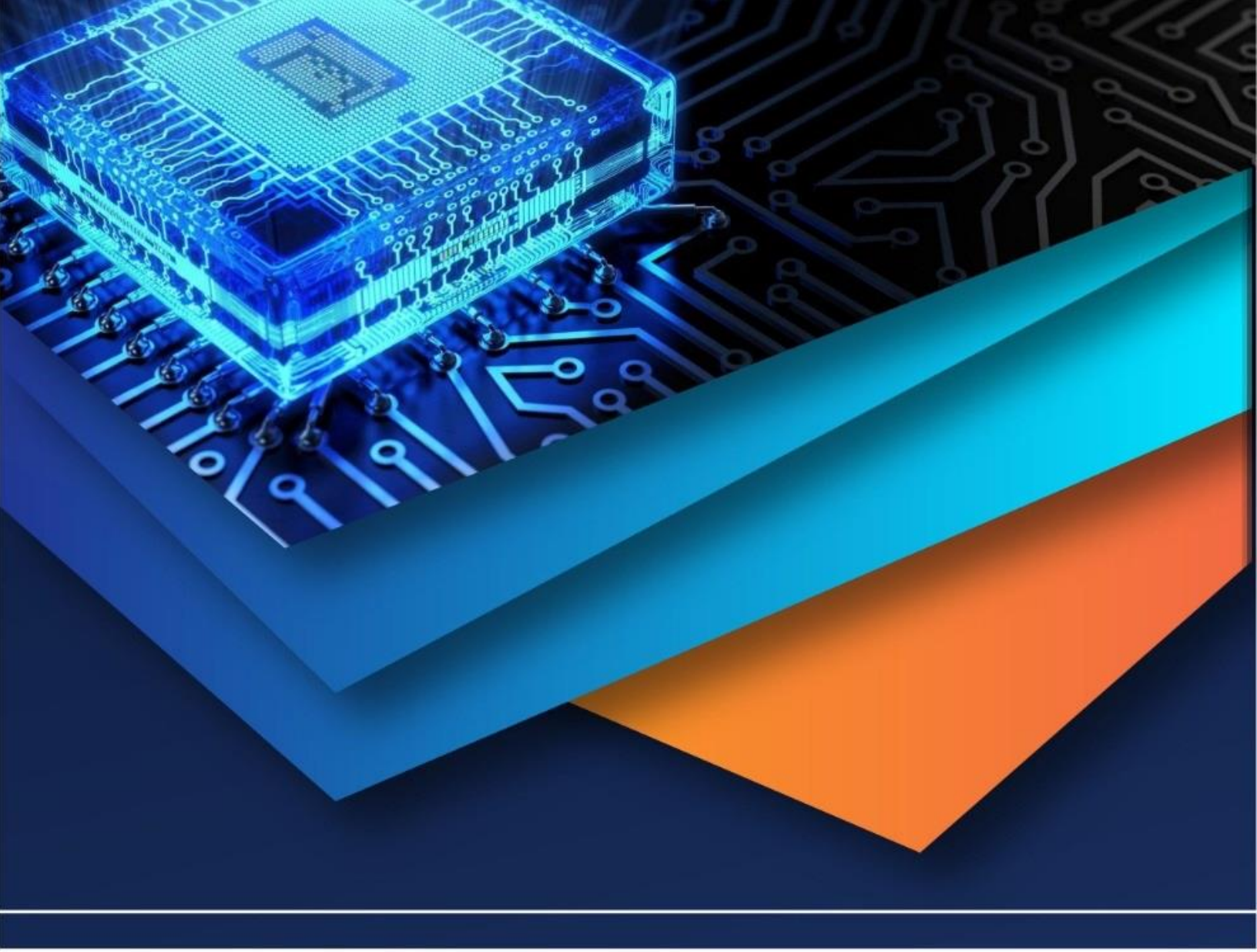
VII. CONCLUSION

Architects just want to develop attractive buildings to create a special object with material, form , colour and textures but construction of house itself a big challenge due to its cost . So after completion of building many people avoid to go for intelligent and energy efficient building. As a building owner Solar system is not a first choice due to its cost and aesthetics. But as an architect with investor mind it is one time investment phenomena. That help you personally, balancing indoor and ambient thermal comfort with energy saving and cost, at the end it becomes benefitial decision. As case studies are the most significant way to understand how the cool roofs work in practice through different materials and application. In this study , it help in understanding that cool roofs that include solar photovoltaic system and their electricity generation and saving with tiles coating and green house have been justified to be as Thermal energy performance for composite climate. With this study , the quantified benefits have been extended to other applications for cool roof extension. All this can be considered an effection solar technique which can be implemented for new buildings as well as retrofitting of existing building structure. Their mechanism is based on the application of such materials that has a coating with high reflectivity and high emissivity. So that thermal comfort , increasing energy efficiency, impove the surrounding ambient environment, life span of roof at global level.

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