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Thermal Performance Evaluation of Cool Roof in Different Climate Zones: A Review

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A b s t r a c t:

The roof is one of the most critical components of the building envelopes, and it achieved maximum heat flux in door building, and it covered nearly 20–25% of overall urban surface areas. In this paper, cool roofs are considered one of the environmental solutions to preserve thermal comfort in buildings, reduce emissivity and mitigation Urban Heat Island (UHI) effect, reduced greenhouse gases emission and reduced energy consumption. Many studies revealed from the literature review that cool roof application reduced energy use in the buildings and improves thermal performance. This paper summarizes cool roof thermal performance with different configuration of roof and different surface coatings materials in different climatic zones and different types of buildings, this benefits for engineers, researchers, and architectures to have make good decision of buildings, also cool roofs mitigate energy consumption demand in buildings as per the literature survey results.

Key word: cool roof, climate, thermal performance evaluation, energy consumption, temperature.

1. Introduction:

The roof is an essential component of the building envelope which is exposed direct solar radiation and contributes to the maximum load of the total cooling load of the building [1], and is an essential interface between the indoor and outdoor environments and to be strong enough to withstand all weather conditions. Also contribute nearly 50 to 60% load in a total cooling load of the building reaching inside form the outdoor in hot- dry, warm, and humid and composite climatic zones. Recently, many studies were revealed and showed that there can be different solutions to the excessive heat problem through the roof [2, 3, 4], passive cooling, cool roof, use of low emissivity material in the attic of a building and green roof these concepts were used to design the roofs for reducing the cooling load in buildings.

2.Cool roof working:

The cool roof building has the characteristic of high solar reflectance (ability to reflect solar radiation) and high infrared emittance (faster release of absorbed heat in the form of infrared radiation). It reduced the heat transfer to the building through the roofs as compared to the traditional roofs. The cool roof's basic working principle is given by the Cool Roof Rating Council (CRRC) shown Fig. 1.

The most of the solar radiation incidents on a cool roof surface reflected due to the higher reflectivity of the roof. This cool roof phenomenon makes it most convenient when solar radiation's intensity is very high, and maximum diurnal variation occurs. The flow chart of characteristics of cool roof had shown in Fig. 2 [5,6].

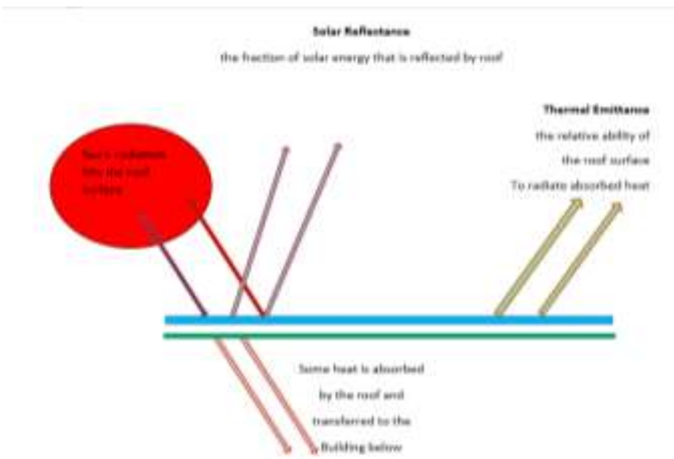


Fig1. 1Working principle of cool roof

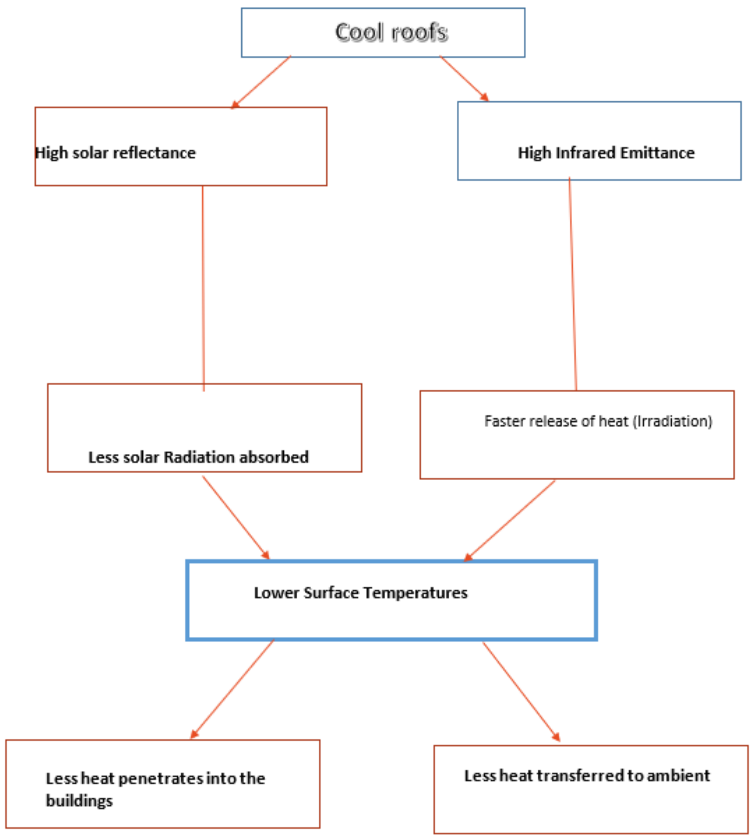


Fig. 2: The flow chart of characteristics of cool roof

3.Over view:

A basic calculator was created for cool rooftops (high albedo rooftops) and energy simulation was carried out for input parameters such as location, building type, roof type, and surface properties. This calculator performed comfort simulations for unconditioned buildings and a para-metric simulation between insulation thickness and roof albedo to discover ideal roof insulation. The result appeared that for New Delhi climate around 23 kWh/m 2 -year power may be spared with application of high albedo roof with 0.80 solar reflectance and most extreme temperature decrease watched was 3.9 °C in May for unconditioned buildings. The calculator moreover performed a simulation between insulation thickness and roof albedo. [7]. The examiners created show based on the Cool Roof Heat Transfer (CRHT) component in tropical climatic zone. The demonstrate was approved with exploratory information of two identical apartments of concrete roofs in Singapore. The study appeared that the cool coating with the reflectance of 0.74 on concrete roof decreased the top roof temperature by 14.1 °C, indoor reduced temperature by 2.4 °C, and daily heat gains by 0.66 kWh/m 2 (or 54%). Daily warm pick up decrease was moreover accomplished when cool coating connected on galvanized steel (metal) rooftops and this demonstrate indeed to roof and wall [8]. A study conducted for combination of efficient roof techniques (skylights and cool roof) in Commercial low-rise buildings using simulations in terms of impacts on energy demand and comfort in buildings. The study revealed that the impact of passive cooling within a 99.8% drop in degree-hours above the discomfort temperature in summer period. Beside saving energy-using cool roof was 33.8% in terms of cooling energy demand [9]. The study analyzed the impact of the passive cool roof on the cooling loads of air conditioning frameworks in a hot climate. An algorithm hybrid matrix was planned to simulate 37 rooftops with different shapes, materials, and construction to evaluate the saving energy in air conditioning frameworks. The comes about of simulation appeared that the vaulted roof with high albedo coating reduced 53% discomfort hours and saved 826 kWh in a year amid the summer season in comparison with an ordinary level roof. The study moreover suggested that the combined impact of cool roof and common ventilation expanded indoor thermal comfort [10]. The investigators used the numerical methods to validate the experimental results of the cool roof performance of a laboratory building in Greece. A TRNSYS simulation model was developed for the building and validated against real data with or without the cool coating. The analysis of the simulation results revealed that annual and peak energy savings in summer reported 19.8% and 27% from cool roof technology, respectively, and were found better than insulated roof [11]. The impact of cool rooftops examined non-conditioned, institutional building in a composite climate in India, and the observing period was six months (January to June 2012) on connecting areas of continuous concrete roof surface with the coated and uncoated surface. Measured solar reflectance was 0.28 and 0.57 respectively. In the event that reflectivity expanded at that point the seasonal normal indoor air temperature and heat flux decreased by 1.07 °C and 14.4 W m−2, respectively, with peak decreases of 1. 38 °C and 18.3 W m−2 in the month of April 2012. The number of adaptive comfort hours increased up to 8% compared to the dark roof which gives a significant enhancement in human comfort [12].Cool roof application treated on a 700 m2 roof of office/laboratory building having a place to a school campus in Trapani Sicily, Italy. The numerical and exploratory examinations revealed the surface temperature of the roof decreased up to 20 ˚C with profile amid the 24 h period cycle and a 54% reduction of the cooling energy demand accomplished using the cool roof. The roof painted with white double layer paint on primer finished with a washable gleam emulsion coating and calculated solar reflectance was 85.9% of the sphere. Study moreover suggested that insulation level have to be compelled to be decided accurately for climatic conditions as per demand of heating and cooling 13]TRNSYS software was used to evaluate the impact of the cool roof in term of thermal comfort, peak power, and surface temperature of a non-cooled school building in Athens, Greece. The solar reflectance of 0.89 of the roof resulted in a lower an air temperature of 2.8 °C and an annual cooling load by 40% [14] The experimental study has been carried out on room made of a concrete roof having a vertical cylindrical hole of 0.5 × 0.5 m and an array of 3 × 3 filled with phase change material (PCM) Chloride Hex hydrate (CaCl26H2O and low thermal conductivity, the purpose reduced the heat gain in a steady-state condition and control the indoor air temperature to achieve better thermal comfort level. Result proved that PCM decreased the indoor air temperature maximum by 4 °C with the reduction in indoor surface heat flux is about 51%. On the other hand, this developed model was useful for simulation when this PCM used in different wall structure with varying materials of buildings. [15]. A numerical model show created based on the limited volume strategy connected for six variations of a roof structure in Riyadh, Saudi Arabia. The consider reveals the temperature and heatf1ux varieties with time and the relative significance of the different heat-transfer components as well as every day found the middle value of roof heat-transfer stack. The result demonstrated that the 5 cm thick polystyrene layer diminishes the roof heat-transfer stack to one-third of its esteem in an indistinguishable roof area without separator [16]. In hot arid climate a vapor-reflective roof used to improve space cooling in buildings. The consist of roof design is composed of a concrete ceiling over which lies a bed of rocks in a water pool, an aluminum plate also covered over this bed, which improve an air gap to the external air and painted with a white titanium-based pigment to enhance the solar radiation reflection during day time. At night, the temperature of the aluminum sheet drops down the temperature of the rock bed mixed with water. Water vapor inside the roof condenses and falls by gravity. This effect carries heat outwards and cold inwards. Numerical calculations were carried out for a typical summer day of June for Laghouat in Algeria. It found the possibility of reducing the air temperature in buildings, and it was lowered by 2 to 3 °C if night natural ventilation is allowed. [17]. In tropical climates ,dwellings are made of cement-based materials like concrete . However, cement-based materials have low thermal conductivity and thermal diffusivity , a new passive cooling system consists of a corrugated aluminum sheet with insulation layer polyurethane is used to minimize heat transfer. Experimental show that the well-designed roof insulation system can reduce the typical thermal load by over 70%.[18].

Table 1 presents that there are several studies based on cool roof with in different method used in climates zone, the studies showed that the reflectivity of cool roof 57% to up 89% and reduction surface temperature 1.070 c to up 14.1C.

Ref.	Climate	Variables	Objectives	Methods	Result
[9]	Temperate	skylights and cool roof)	Enhance temperature Saving energy	simulations	energy saving 33.8% Reduction tem.
15	tropical	Chloride Hex hydrate (CaCl26H2O	decreased the top roof temperature indoor discuss temperature	experimental	Reduction indoor air temperature maximum by 4 °C
[17]	hot arid	Cool roof	Enhance temperature	Examinations	Reduction temp. 2 to up 3
[10]	Hot	shapes, materials, and construction	Reduce cooling loads of air conditioning	algorithm hybrid matrix	vaulted roof with high albedo coating diminished 53%
[18]	tropical	passive cooling	minimize heat transfer	Experimental	reduce the typical **thermal load** by over 70%
[7]	Temperate	reflective roof	Different reflective roof In three type buildings.	comparative study	0.63-0.83 Reflective 22-54 Energy Saving

[16]	Hot dry	cool coating+5 cm thick polystyrene layer	Reduced heat flex.	A numerical model	Reduce of heat-transfer stack to one-third of conventional roof
[8]	Tropical	Cool coating	Reduced heat gain	CRHT model	reduced indoor temperature 2.4 °C, reduced daily heat gains by 0.66 kWh/m 2
[11]	composite	with or without the cool coating	Reduced energy consumption	TRNSYS simulation model	27% from cool roof technology
[12]	composite	coated and uncoated surface	enhancement in human comfort	observation	reflectance was 0.28 and 0.57 respectively. heat flux decreased by 1.07 °C and 14.4 W m−2, respectively
[14]	composite	cool roof	Enhance thermal comfort	TRNSYS software	solar reflectance 0.89 of reduction air temperature of 2.8 °

Table 1 Summarized of details of the different types of cool roofs and different methods.

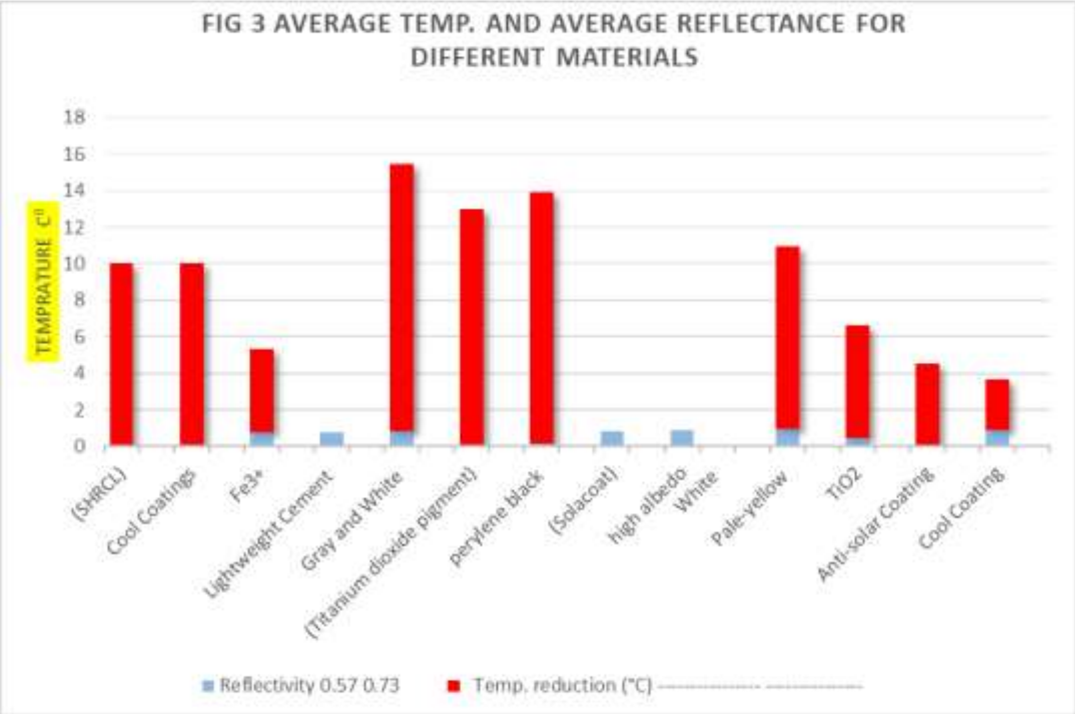
3.1 Materials applied on cool roof surfaces:

In North Australia, simple calculator carried out. The effect of light and dark-colored in roof surfaces. In term of heat gain and R-values, by integrating the equation for the steady-state downward heat transfer and an equation for the sunlit roof derived for the average daily downward heat flux. This studied revealed that a light-colored roof has reduced about 30% heat gains than a dark-colored one. [19] .Lightweight Cement Composite (LCC) using hollow ecospheres and a photocatalytic coating with Titanium Dioxide (TiO_2) and solar reflectance to reduce cooling energy consumption, study showed that a reduction of 80% in the thermal conductivity and increased in solar reflectance from 0.41 to 0.78 using a photocatalytic coating, also reduce heat gain up to 33% lower than concrete and coating combined heat gain reduced by 69% [20] Two procedures surface treatment and roof insulations were most useful for an energy-efficient roof, and these two procedures utilized for a single-story building of office building having 200 m2area have simulated for five climatic zones in India. Simulated results come about for five climatic zone of India and an add up to 88 diverse roof combinations utilized for each climatic zone to recognize appropriate roof thickness with tall albedo. The Optimized R-value for the roof in hot-dry climate and composite climate, warm and muggy climate, and mild climate and cold climate were 0.49 m2 K/W, 0.31 m2 K/W, and 1.02 m2 K/W individually [21]. On a metal roof, warm separator coating titanium dioxide shade with Chicken Egg Shell (CES) squander introduced and coordinates with an arrangement of aluminum tubes and reused aluminum cans orchestrated into tubes that act as a Moving-Air-Cavity (MAC). Four sorts of cool roofs designed with and exhibitions of the same carried out inside by utilizing halogen light bulbs taken after by a comparison of the roof and attic temperatures. The encompassing discuss temperature amid testing was around 27.5 °C and the lessening within the loft channel temperature up to 13 °C (from 42.4 °C to 29.6 °C) utilizing cool roof which was joined both Warm Cover Coating (TIC) and Moving-Air-Cavity (MAC) with comparison of customary roof [22]. Examine the potential of an urban roof by changing the reflectivity and utilizing green roof and recreation modeling performed to infer the results. In case the reflectivity of the roof expanded up to 0.45, at that point reduce the summer temperature by 0.25 °C within the thickly built-up environment, and it advance decreased up to 0.5 °C to improve the roof reflectance up to 0.7. In any case, more than 50% of the building rooftops of Vienna were not favorable for the planting of vegetation. So ideal arrangement found to provide consolation level in buildings was combining the green rooftops with high-reflective materials that offer distant better; a much better; a higher; a stronger; an improved">a higher arrangement to diminish urban heat load of buildings [23]. Warm execution of three rooftops, one ordinary red and two white reflective rooftops utilizing two open air test cells was carried out in Cuernavaca, Mexico. Result concluded that the white roof decreased the surface temperature between 10 °C and 14.6 °C compared with the gray roof. Moreover, the warm gains between 59 and 80% lower than the gray roof. The warm pick up of the ruddy roof was 22% higher than the white roof. So white roof

Table 2 Different types of materials using coat on roofs

Climate	Material	Reflectivity	Reduction in surface Temp. (°C)	Reference
Berkeley, CA, USA, Temperate	White base coat with mono color topcoats Tiles	0.26-0.57	————	[28]
Berkeley, CA, USA, Temperate	High-albedo Coatings	0.18-0.73	————	[27]
Xian, China, Warm and Temperate	Solar Heating Reflective Coating Layer (SHRCL)		10	[32]
La Rochelle, France Warm and Temperate	Cool Selective Coatings		10	[35]
Nanjing, China, Tropical	Color coatings of Fe3+ doped La2Mo2O7 pigment	0.61-0.75	4.6	[31]
Singapore Tropical	Lightweight Cement Composite and Photocatalytic Coating with Titanium dioxide (TiO2)	0.41-0.78	————	[20]
Tabasco, Mexico Tropical	Gray and White Reflective Coating	0.84	10-14.6	[24]
Kuala Lumpur, Tropical	Thermal insulation coating (Titanium dioxide pigment)	————	13	[22]
Beijing, China Tropical	NIR-transmitting perylene black and dioxazine purple colorants and addition of chrome titanium yellow black coating	0.12-0.13	10.2-13.8	[25]
Townsville, Australia, , Hot	White highly reflective paint (Solacoat)	0.80	————	[19]
Hot-Dry, Composite, Warm and Humid, Temperate and cold	Roof insulation with high albedo coating combination of radiant barriers	0.70-0.90	————	[21]
Arizona, USA Warm	White Roof Coating,			[26]
Karaikudi, Tamilnadu, India Warm-Humid	Pale-yellow color nano pigment Bi4Ti3O12 (BTO) and conventional infrared reflective white pigment TiO2	**0.95**	**7-10**	[34]
Athens, Greece, Composite	Thermochromatic coating with and withoutTiO2	0.43	4.3-6.2	[33]
Islamabad, Pakistan, Composite	Anti-solar Coating		4.5	[29]

With tall reflectivity was a cost-effective technique to reduce building vitality utilization [24]. In Shanghai, China, dark coating color with NIR-transmitting perylene dark and dioxazine purple colorants and expansion of chrome titanium yellow dark coating created. Assessed surface temperature decrease and yearly cooling vitality reserve funds were 13.8 °C and 3.9 kWh $m^{-2}yr^{-1}$ with perylene dark colorant and 10.2 °C and 2.24 kWh $m^{-2}yr^{-1}$ with dioxazine purple colorant separately [25] The sunbased intelligent roof innovations were analyzed utilizing the farther detecting image information combined with building vitality computer simulation. For this reason, 932 government and commercials, buildings roofs examined in an urbanized zone of Arizona State College, USA. This cool roof innovation essentially improved the vitality efficiencies in buildings and decreased crest electrical demand up to 555 kW. This study has been evaluated the natural benefits and the evaluated (GHG mission diminishments almost 3823 tons of carbon dioxide (CO_2), 5.29 tons of nitrogen oxide (NO_x), and 3.52 tons of sulfur dioxide (SO_2) emissions annually [26]. The high albedo coatings connected on the rooftops of one house and two school buildings in Sacramento, California. The impact of changing roof albedo from 0.18 to 0.73 analyzed in terms of top control and cooling energy savings. The test and recreation comes about surveyed that the regular cooling vitality investment funds achieved approximately 2.2 kWh/d and estimated about 264 kWh for the complete season. The top peak was also reduced to 0.6 kW during the summer period [27]. The examiners created and considered the impact of models of roofing materials. The 24 cool colored model tiles and 24 cool colored models shingles were arranged by white basecoat with mono-color topcoats. The cool colored of different shades of ruddy, brown, green, and blue tiles and shingles was tried and found the reflectance from 0.26 to 0.57 and 0.18 to 0.34, individually [28]. The anti-solar coating on the protects roof was analyzed to survey the decrease of energy consumption in an air-conditioning room and gas warming machines. The exploratory comes about of roof area 20.8 m^2 appeared the Vitality sparing in air conditioning was found about 45 kWh/day in expansion to the decrease in heat loss in winters [29] analyze the changes in heat gain and R-values. An equation for the sunlit roof derived for the average daily downward heat flow by integrating the equation for the steady-state downward heat transfer for north Australia. This equation suggested that a light-colored roof has about 30% lower heat gains than a dark-colored one [30]. The color coatings of Fe3+ doped a2Mo2O7 colors with cubic fluorite colors created in shinning yellow color with high Near Infrared Reflectance (NIR). The warm execution of this created reflective color coating found in a higher run of 61–75% compared with a customary coating of the same color. The tests performed within the control environment in boxes with the coatings painted roofs. The recreated tests appeared the difference of more than 4.5 °C in indoor temperatures in comparison to conventional coating [31]



The solar reflectance of 0.89 of the roof resulted in a lower air temperature of 2.8 °C and an annual cooling load by 40% [35].

Table2 is present different types of materials using coat on roofs, figure3 show Average temperature and Compression study carried out between Solar Heating Reflective Coating Layer (SHRCL and asphalt pavement surface SHRCLs and standard pavements for their cooling performance, study revealed. SHRCL reduced the temperature around 10 °C in comparison to the regular pavement. Also temperature difference was 5 °C not only in SHRCLs but also in normal pavements. [32]. The thermos chromatic coating was developed and tested experimentally to analyze the effect of highly reflective, cool, and standard coatings on roof surface temperatures. The color-changing temperature was kept constant at 30 °C in samples of eleven thermochromics layers. The maximum solar reflectance reached 43% during the colored to colorless phase. The two groups of these coatings were developed without TiO2 and with TiO2 to examine the properties of thermochromics pigments. Mean daily surface temperatures were found the variation from 23.8 to 38.4 °C for the thermochromics samples and surface temperatures from 28.1 °C to 44.6 °C for the cool and from 29.8 °C to 48.5 °C for the typical samples respectively [33]. Acomparitive study between A pale-yellow color Nano pigment Bi4Ti3O12 (BTO 0) and conventional infrared-reflective white pigment TiO2 demonstrated in term of thermal study using the IR lamp exposure by coating on to the steel substrate to reduced energy consumption, BTO coated steel substrate reduces the interior temperature by almost 10 °C while the TiO2 coated steel reduces the internal temperature of nearly 7 °C respectively [34].TRNSYS software was used to evaluate the impact of the cool roof on thermal comfort, peak power, and surface temperature of a non-cooled school building in Athens, Greece.

Table 3 Solar reflectance and infrared emissivity properties of typical roof types

Roof surface type	**Solar reflectance**	**Infrared emissivity**	**Roof surface temperature rise (°C)**
Ethylene propylene diene monomer (EPDM)–black	0.06	0.85	46.1
EPDM White	0.69	0.87	13.9
Thermoplastic polyolefin (TPO)–white	0.83	0.92	6.11
Bitumen–smooth surface	0.06	0.86	46.1
Bitumen–white granules	0.26	0.92	35.0
Built-up roof (BUR)–dark gravel	0.12	0.90	42.2
BUR–light gravel	0.34	0.90	31.7
Asphalt shingles–generic black granules	0.05	0.91	45.6
Asphalt shingles–generic white granules	0.25	0.91	35.6
Shingles–white elastomeric coating	0.71	0.91	12.2

Shingles–aluminum coating	0.54	0.42	28.6
Steel–new, bare, galvanized	0.61	0.04	30.6
Aluminum	0.61	0.20	26.7
Siliconized polyester–white	0.59	0.85	20.6

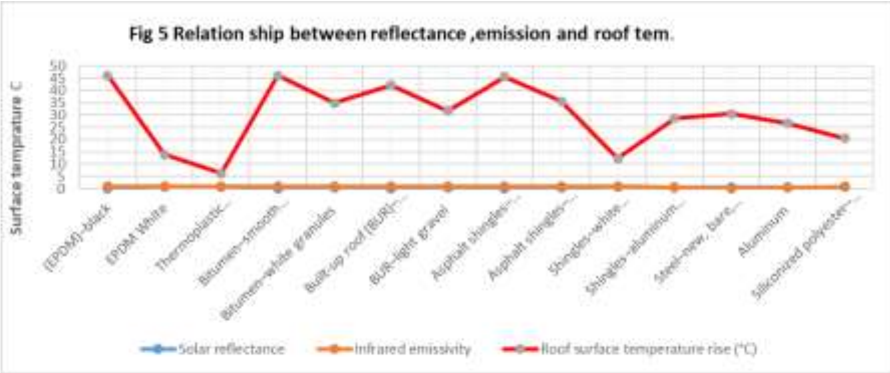


Fig 5 Relation ship between reflectance ,emission and roof tem.

4. Configuration of different cool roof:

Acomparitive experimental was obtained between Reinforced Cement Concrete (RCC) roof with and without cool paint in term of thermal comfort for indoor temperature room, out surface roof temperature, inner surface roof temperature, the study was conducted on residential buildings located in composite, Indore, Madhya Pradesh, India. The study revealed that the roof's interior and exterior surface temperature reduced about 4.1 C and 9.2 C, respectively, while indoor room temperature reduced about 2.4 C [36]. In India, concrete buildings have 150 mm thick Reinforced Cement Concrete (RCC) with Weathering Course (WC) having 75–100 mm thick lime brick mortar used. Heat transmitted into the buildings about 40–75%, that increased energy consumption, so the alternate concept was used Hollow Clay Tiles (HCT) laid over RCC instead of weathering course (WC) proposed. The study has been conducted four types of roof structures and typical Indian climatic conditions found that energy savings obtained with the use of the HCT roof was 38-63% compared with conventional WC roof. [37]. For the study, the effect of cavity ventilation in the occupied zone of the factory and a computer program developed for comparison between the cavity roof and a single roof in the Japanese climate. The study proved that the cavity roof was much more effective as compared to a single roof for lower the operative temperature by about 4.4 °C and when air condoning system used with an operative temperature of 26 °C in the factory cooling load reduction achieved approximately 50% during the summer using cavity roof. So the result proved [67] [45] [38]. A simple calculator was developed for cool paint applied on roofs and energy simulation was carried out in three countries, around equator Jamaica, Northeast Brazil (Recife) and Ghana, and a single-story home in Jamaica analyzed before and after cool paint applied on roofs. Internal ceiling surface temperature and indoor air temperature reduced by 6.8 °C and 2.3 °C respectively, Energy Plus software model used to develop similar models for Northeast Brazil (Recife) and Ghana. The results indicate that air temperature reduced to 3.2–5.5 °C and 0.75–1.2 °C respectively. The application of cool paint on roofs improved thermal comfort in building and energy saving, and reduction achieved up to 22-26kWh/m2/Year. [39]. In a warm and humid tropical climate, concrete slabs roof unbearably hot during summer and very cold during winter to cut down this problem, robust roof slab insulation system is the perfect solution, Experimental study sing small and large-scale models was investigated and found The poor thermal performance of concrete slab can be significantly improved in a tropical climate using an insulation thickness of only 25 mm, and it reduced the slab soffit temperature. On the other hand, the study proved that insulated rooftop slabs with robust insulation can be good method to provide thermal comfort in buildings [40]. The investigators developed a model based on the Cool Roof Heat Transfer (CRHT) mechanism

in tropical climatic zone. The model was validated with experimental data of two identical apartments of concrete roofs in Singapore. The results showed that the cool coating with the reflectance of 0.74 on concrete roof reduced the peak roof temperature by 14.1 °C, indoor air temperature by 2.4 °C, and daily heat gain by 0.66 kWh/m2 (or 54%). Daily heat gain reduction was also achieved when cool coating applied on galvanized steel (metal) roofs and this model even to roofs and walls [41]. A Cool Roof Heat Transfer (CRHT) model was used to compare the performance of a double skin roof and a double-skin roof combined with a cool roof on two identical configured naturally ventilated apartments in the tropical climate of Singapore. The roof temperature difference between test rooms without the coating and with coating was found to be 15 °C. White coatings applied on double skin roof reduced daily heat gain by 0.21 kWh/m2 (or 51%) with peak indoor temperature decrease it up to 2.4 °C. It was also found that the double-skin roof is about 6% more effective than a cool roof for reducing annual heat gain. The experimental results proved that the purposed CRHT model is generally applicable to any climatic zones of the world rather than tropical climate [42]. A study carried out for the roof switch the small-sized-thickness duct in which the airflow is laminar (micro ventilation), and turbulent and performance of terracotta roofs compared with copper ones with same thermal resistance for a no ventilated air gap. 30% energy saving achieved using ventilated roofs in summer concerning the non-ventilated structure in the case of small thicknesses of the air duct, and airflow is laminar [43].

Table 4 Details of the different configuration of cool roofs

Table 5 Thermo-physical properties of roofs in different climatic zones

Location and Climatic Zone		Thickness (m)	Thermal Conductivity (W/m K)	Density (kg/m3)	Specific Heat (J/kg K)	U-value (W/m2 K)	Reference
Madhya Pradesh India composite climate	Cool Paint	0.002	0.09	800	1.053	-----	36
	Laminated Ply	0.0513	0.11	545	1.214		
	Plaster	0.012	0.72	840	1.762		
	Reinforced	0.150	1.58	846	2.288		
	Cement Concrete (RCC						
Laghouat Algeria, Hot and Semi-Arid	Concrete slab	NA	1.8	2400	1080	-----	17
	Rocks	NA	2.3	2600	800		
	Water	NA	0.613	1000	4175		
	Aluminum	NA	0.026	1.22	1008		
Perundurai, Tamilnadu, India, Warm and Humid	Reinforced cement concrete (RCC)	0.15	1.28	1130	NA		37
	Weathering course (WC)						
	Hollow Clay Tile	0.075	0.25	800	NA		
	Air Gap						
		0.075	0.25	800	NA		
		NA	.O26	1005	NA		
Toyohashi, Japan Warm and Temperate	Tiles	0.014	0.96	NA	1450	1.26	38
	Board	0.012	0.15	NA	700		
	Roof	0.37	NA	NA	NA		
Moratuwa, Tropical, hot dry	Concrete	0.125	1.7	NA	NA	1.01	40
	Polyethylene insulation	0.025-.050	0.035	NA	NA		
Jamaica, Tropical	White reflective paint	0.004	NA	NA	NA	0.618	39
Riyadh, Saudi Arabia, Hot-Dry	Tiles	0.025	1.73	2243	920	------------	16
	Mortar bed	0.02	0.72	1858	837		
	Sand	0.05	0.33	1515			
	Water proofing membrane	0.04	0.19	1121	800		
	Reinforced concrete	0.15	1.73	2243	1675		
	Cement plaster	0.015	0.72	1858	837		
	Foam Concrete-I	0.075	0.52	1600	837		
	Foam Concrete-II	0.075	0.08	300	837		
	Extruded polystyrene	0.05	0.029	35	1213		
	Molded polystyrene	0.05	0.036	24	1213		
	Poly Urethane	0.05	0.022	32	1590		
Catania, Italy, Warm and Temperate	Clay shingle	0.012	0.72	1800	840		34
	Mortar	0.02	1.4	2000	840		
	Sand	0.02	0.6	1700	840		
	Polyester membrane	0.008	0.16	1120	1460		
	Light cement screed	0.1	0.65	1600	880		
	Mineral wool	0.03	0.044	35	840		
	Reinforced base	0.06	1.14	2000	840		
	Prefabricated slab	0.06	1.16	2000	840		
	Air gap	0.3	NA	1.2	1000		
	False ceiling	0.02	0.21	900	840		
Catania, Italy, Warm and Temperate	Brick tiles	0.04	0.75	1800	NA		33
	Wooden planking	0.01	0.12	450	NA		
	Air (ventilation layer)	0.80	0.025		NA		
	Rigid fiberglass panels	0.04	0.038	100	NA		
	Cement mortar	0.02	1.40	2000	NA		
	Brick and concrete floor slab	0.30	0.81	1600	NA		
	Lime mortar and cement plastering	0.02	0.90	1800	NA		
Singapore, Tropical	Air	NA	0.025	1.28	1008		42
	Plaster	0.001	1.5	600	750		
	Polystyrene	NA	0.09	1050	1300		
	Concrete	0.100	0.85	2350	675		
	Galvanized Steel	0.008	15.3	4800	500		
	Cool Coating	0.0005	0.045	1053	0		
Pisa, Italy, Warm and Temperate	Copper plates	0.006	380	8900	NA		43
	Polyethylene sheet	0.001	0.35	950	NA		
	Fir boarding	0.040	0.12	450	NA		
	Brick tiles	0.025	0.90	2000	NA		
	Tile-lintel floor	0.180	0.60	1800	NA		
	Lime plaster coat	0.015	0.70	1400	NA		
Singapore, Tropical	Concrete	0.1	0.65	2450	840		41
	Cool Coating	0.0005	0.05	1053			
	Glazing	0.0035	0.7	NA	NA		
	Plaster concrete block	0.125	1.1	800	920		
	Plaster	0.001	0.25	850	1000		

Conclusion:

According to literature review, it is clear that 50-60% of the total heat gain indoor building comes from the roof, Therefore, heat flux enters in buildings through the roof, so, the suitable design of the roof would decrease the thermal load and energy consumption in the different climates. The used of cool roofs technology in buildings encourage sustainable and attracts energy scientists, architects, and urban planners to make better decision toward thermal comfort conditions and energy conservation and urban quality improvement. According to the literature review outlined, the research can be achieved:

- The roof surface treatments with different coatings also a useful technique to achieve comfort level in buildings and energy efficiency measures in different climatic zones.
- Cool roof applications do not require complex maintenance in building roofs and easily applied on the existing roofs by conventional methods with low cost as per the requirement of users.
- The average roof surface temperature reductions are 4.7 ˚C, 2.4 ˚C, 2.3, and 1.4 ˚C for temperate, tropical, hot-dry, and composite climatic zones, respectively.
- The study shows that average energy saving achieved using the cool roof for temperate, tropical, hot-dry, and composite climatic zones are 32.8%, 35.7%, 15.0%, and 25.01%, respectively.

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