URBAN HEAT ISLAND INTENSITY-STUDY OF ENERGY BALANCE IN URBAN ENVIRONMENT, A CASE OF PUNE

Ar. Pradnya Patki
STES's Sinhgad College of Architecture
Pune, India

Abstract— In urban areas temperature is the function of solar radiation as well as emission of energy from different objects, surfaces and materials. The energy emitted by any object of any material is function of its absolute temperature. Characteristics of urban materials, in challenging solar reflectance, thermal emissivity, and heat capacity, also influence urban heat island development. The aim of the paper is to calculate energy emitted for a case in Pune & compare with the proposed case materials. Objectives of paper are to study Intensity of UHI, to study properties of urban materials, calculate the energy emitted for a case in Pune & compare with the proposed case materials. The method used is quantitative comparative analysis by taking a case of commercial (office) building is Pune. The proposed outcome of the paper is to prove that retrofitting the existing materials of buildings that absorb low solar energy work better in urban areas to cater problems regarding UHI. Therefore, this paper recommends using reflective materials on external surface of buildings and surroundings to reduce UHI effects and improve the urban environment.

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION

Urbanization has a dynamic relationship with the physical environment. Urbanization has direct impact on the spatial structure of the city, which in turn results in the dramatic change of the overall immediate environment. Rapid urbanization, often neglecting design issues related to urban climate are likely to increase levels of discomfort in cities. The cities are becoming complex character consisting of different surface materials of low albedo and with lack of vegetative cover.

A. The Urban Heat Island-UHI

An Urban Heat Island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas, i.e. urban air and surface temperatures that are higher than nearby rural areas. (Oke T, 1987) The heat island sketch pictured here shows a city's heat island profile. It demonstrates how urban temperatures are typically lower at the urban-rural border than in dense downtown areas. The concentration of human activities in urban areas creates an "island" of heat surrounded by a "sea" of cooler rural areas called the "urban heat island".

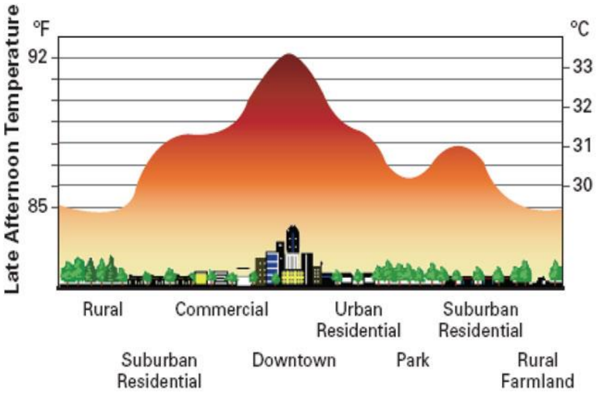

Fig 1: UHI profile (Heat island Group)

The main cause of the UHI is modification of the land surface by urban development which uses materials which effectively retain heat. An UHI is created when naturally vegetated surfaces – e.g. grass and trees are replaced with non-reflective, impervious surfaces that absorb a high percentage of incoming solar radiation (Taha, 1997). UHI has become more and more significant during the last 50 years, due to urban growth and increase in energy consumption in urban areas. Urban centres with large populations tend to create microclimates different from that of the surrounding region. This can lead to the formation of local 'hot spots', which may shift in space with diurnal and seasonal cycles, under particular meteorological conditions, and with landuse changes (Unwin, 1980).

B. Significance of topic

Approximately half of the world's population lives in cities, and this value is expected to increase to 61% by 2030. City growth and urban development are inevitable; this means more number of people will be exposed to consequences resulting from heat islands in the future. India is increasingly becoming urban. According to the 2001 Census, 27.8% of the urban population resides in cities, compared with 25.5% in 1990. The Urban population is expected to rise to around 40% by 2020. City growth and urban development are inevitable phenomenon of the 21st century, hence there is a need to explore the causes and peculiarities of the UHIE and propose solutions to the problem. This paper is a step towards proposing some solutions to the problem.

II. REVIEW OF LITERATURE

A. Properties of Urban Materials

Materials contribute to absorption of solar energy, causing surfaces, & the air above them to be warmer in urban areas than those in rural areas. Thermal properties of fabric- there is increased absorption of solar radiation by built mass and hard surfaces, due to their excessive storage capacity. Building materials like brick and asphalt have high heat conductivity. Properties of urban materials, in particular solar reflectance, thermal emissivity, and heat capacity, also influence urban heat island development, as they determine how the sun's energy is reflected, emitted, and absorbed. Stone, brick, concrete, and asphalt surfaces that are impervious to water can trap the Sun's heat. Urban surface roughness reduces sensible heat loss due to the obstruction of airflow by buildings and other large structures. Various concrete structures including the high rise buildings in urban areas absorb and release heat energy and cause a significant climate change in cities and may result in global climate effects.

B. Albedo

All cities of world have witnessed rapid urbanization, which causes the natural landscape having predominantly vegetation cover and pervious areas, converted into built up and impervious area. This impervious area is largely contributed by use of materials like concrete, bricks, tiles etc for buildings and bitumen etc. for roads and parking lots. The introduction of new surface materials coupled with emission of heat, moisture and pollutants dramatically change radiative, thermal, moisture, roughness and emission properties of the surface and the atmosphere above (Roth, 2002). Climatic differences are primarily caused by the alteration on the surface of earth by human constructions and the release of artificially created energy into the environment.

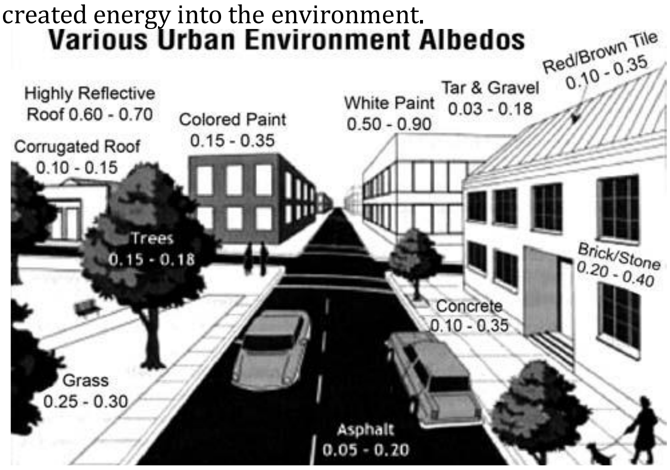

Fig 2: Various Urban Environment Albedos (EPA, U.S.)

As a city grows and develops, new factors modify the local climate of a city and, have a complex character consisting of a mosaic of different surface materials. Artificial surfaces with low albedo absorb much insolation, heating the surface more than if it were a natural surface like grass. This is manifested by higher temperatures as a result of modification of the reflective (albedo), absorptive, storage and emissive characteristics of surface components in cities (Adebay, 1991). Albedo changes the short-wave portion of the radiation balance by the presence of higher energy absorbing surfaces, structures with high thermal capacity and buildings of complex three dimensional geometry. Each surface material has a different albedo, a measure of the amount of solar radiation reflected back into space. For a city as a whole, the albedo can be as low as 10-15%, which means that a lot of the incoming solar radiation is absorbed by the city. Additionally, most of the building materials used in the construction is characterized by a high heat capacity and high heat conductivity. The Fig 10 gives the albedo in urban environment. The tendency of materials to store heat is one of the reasons for the discomfort experienced in the early evenings when walls and ground surfaces that have received solar radiation during the day have temperatures above the air temperature.

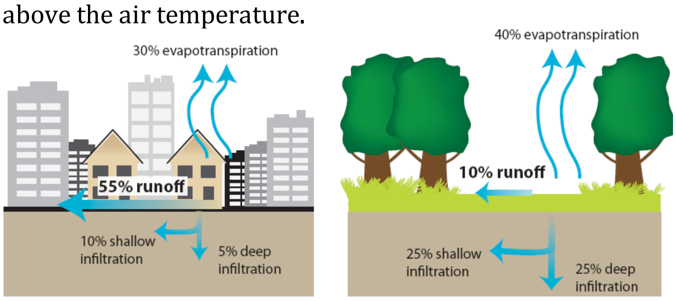

Fig 3: Urban & rural land surfaces (FISRWG)

III. METHODOLOGY

The flow chart shows the method followed to calculate the intensity of urban heat island effective. Energy emitted by different materials.

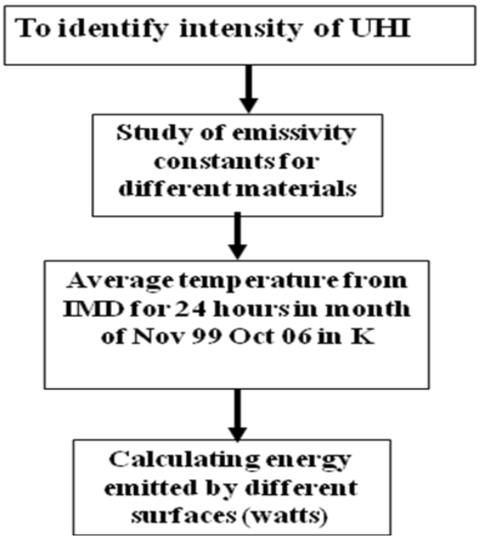

Fig 4: Procedure (Raykar P, 2005)

The method used is case study based where one commercial building materials of building façade and surface landscape materials are studied. Energy emitted by these materials is calculated and then it is replaced by other materials or the percentage of area which it covers is modified to reduce the UHIE. In urban areas temperature is the function of solar radiation as well as emission of energy from different objects, surfaces and materials. The energy emitted by any object of any material is function of its absolute temperature.

This is proved by Stefan-Boltzmann.

$$q = \varepsilon \sigma T^4 A$$

Where, q = heat transfer (W)

σ = 5.6703 10^{-8} ($W/m^2.K^4$) - The Stefan-Boltzmann Constant

T = absolute temperature Kelvin (K)

A = area of the emitting body (m^2)

ε = emissivity of the object (= 1 for a black body)

A Site is located in Hinjewadi, there are other buildings surrounding the site are also mostly IT buildings. The Persistent Commercial buildings are designed as different blocks with major material used as glass for façade.

A. Energy emitted by existing & proposed case

UHI Intensity-Indicator of UHI is the (Solar) Energy re-radiated (emitted) by the objects like buildings and different surfaces. The UHI intensity at Hinjewadi is 20,100,000 W. From the table below it is clear that if we convert concrete roof into green roof & reduce hard paving & glass area only by 10 % then energy emitted can be reduced to 20%

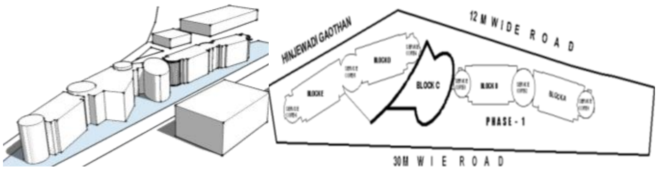

Fig 4: 3D view & Plan of Persistant Building at Hinjewadi

IV. ANALYSIS

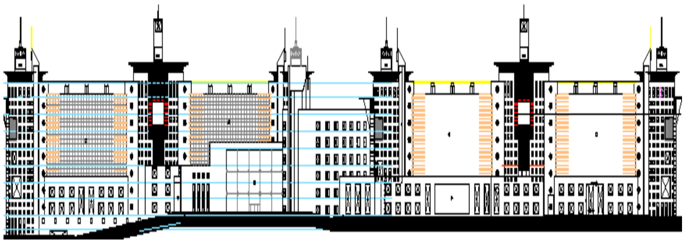

Fig 5: Facade of Persistant Building at Hinjewadi

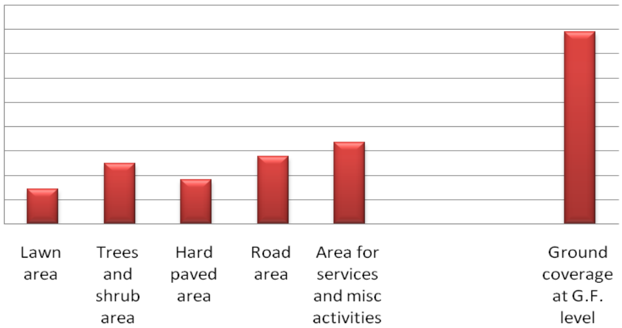

Fig 6: Percentage of Materials used on site landscape

Fig 7: Site plan showing landscaping

Table 1: Energy emitted by existing & proposed case at Persistent Systems, Hinjewadi

Material Of LC	Area Existing (sq m)	Area %	Emissivity Coefficient ε	Area Proposed (sq m)	Air Temperature (⁰C)	Air Temperature (⁰K)	Constant Σ (W/m².K⁴)	Energy Existing (watts)	Energy Proposed (watts)
Concrete surface (Roof Top)	8448	43	0.9	**0**	31.4	304.55	5.6703E-08	3,710,000	0
Hard Paving	3935	20	0.87	3541.5	31.4	304.55	5.6703E-08	1,670,000	1,50,000
Tar surfaces (roads)	3395	17	0.94	3395	31.4	304.55	5.6703E-08	1,560,000	1,560,000
Vegetation-trees & shrubs & lawn	3972	20	0	12813.5	31.4	304.55	5.6703E-08	0	0
Plastered surfaces (vertical faces)	21070	73	0.91	21884.26	31.4	304.55	5.6703E-08	9,350,000	9,710,000
Glass (vertical faces)	8142.67	27	0.95	7328.41	31.4	304.55	5.6703E-08	3,770,000	3,400,000
Total	489622.7							20,100,000	16,200,000

V. CONCLUSION & SUGGESTIONS

A. Using High-Albedo Materials on Building Surfaces

Because the urban ambient temperature is associated with the surface temperatures of the building facade, lower surface temperature can obviously decrease the ambient air temperature and eventually contribute to better urban thermal environment. Therefore, this paper recommends using reflective materials on external surface of building to reduce UHI effects and improve the urban environment. **Vertical Green Spaces-**Green spaces in some parts of buildings that provide natural ventilation or appropriate landscapes in different layers or floors of buildings.

B. Cool Roofs

Dark surfaces, such as black roofs on buildings, absorb much more heat than light surfaces, which reflect sunlight.

Cool roofs reduce building heat gain, create saving AC expenditures, enhance the life expectancy of both the roof membrane and the building's cooling equipment, improve thermal efficiency of the roof insulation, reduce the demand for electric power, reduce resulting air pollution and greenhouse gas emissions, provide energy savings, and mitigate UHI effects. **Horizontal Green Spaces-**Green spaces on roofs absorb heat, decrease the tendency towards thermal air movement, and filter air movement. Vegetation in and around buildings as well as on the roof tops and hanging creepers can be effectively used to achieve better comfort conditions. Therefore, this paper recommends using green spaces in vertical and horizontal layers.

C. Cool pavements

The simplest way to reduce solar absorption is to replace dark surfaces that strongly absorb sunlight, with light-colored surfaces that reflect sunlight. Lower surface temperatures contribute to decreasing the temperature of the ambient air because the heat convection intensity from a cooler surface is lower. Such temperature reductions have a significant impact on cooling energy consumption in urban areas. Lighter-colored pavements are more reflective, which cools the surface temperature during hot summer days. By increasing the albedo, or solar reflectance (SR), of surfaces such as roofs, pavements, the surfaces absorb less solar heat and thus transmit less heat back into the environment. This process, called "negative radiative forcing," effectively cools the environment and offsets substantial quantities of greenhouse CO_2.

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