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Urbanisation, Climate and the Phenomenon of Urban Heat Island

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Abstract: **-- Urbanization has a dynamic relationship with the physical environment Urban and rural environments differ substantially in their microclimate. These climatic differences are primarily caused by the alteration of the Earth's surface by human construction and the release of artificially created energy into the environment. Inadvertent climate changes induced by urbanization are well documented. Such changes are epitomized by the concept of `Urban Heat Island`(UHI) 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 the inevitable phenomena of the 21st century, hence there is a need to explore the causes and peculiarities of the Urban Heat Island Effect and propose solutions to the problem. This paper is a step towards proposing some solutions to the problem.**

Key Words**- Urbanization, Urban and Rural Environment, Air temperature variation, Urban Heat Island, Sky View Factor.**

I. INTRODUCTION

Traditionally, our culture has respected nature, ecology and sustainable living. However with increasing western influences and modern technology we are paving the way to environmental degradation and non-sustainable mode of development. In order to achieve sustainability, smooth amalgamations of traditional building practices and modern technologies must be developed and implemented. Urbanization has a significant impact on all elements of the atmosphere. Replacement of natural vegetation with artificial surfaces leads to alteration in the heat balance and hydrology of the local environment. The alteration of the Earth's surface by human construction and the release of artificially created energy into the environment cause climatic differences. The climate climate changes induced by urbanization are well documented through various studies and researchers. Such changes, are epitomized by the concept of `Urban Heat Island` (UHI) India is increasingly becoming urban. The 2001 Census record states that 27.8% of the urban population resides in cities as compared with 25.5% in 1990. Keeping in view this data it can be estimated that there will be a rise of approximately 40% in the Urban population by 2020. Urban development is an inevitable phenomenon, hence there is a need to explore the causes and peculiarities of the Urban Heat Island Effect and propose solutions to the problem. This paper is a step towards proposing some solutions to the problem. Urban areas are an example of the most dramatic anthropogenic land use changes where primarily the geometry and surface characteristics have been, and are constantly being, altered. climatic elements, such as solar radiation, wind speed and air temperature are affected by the urban forms urban forms. There are large differences in solar radiation and heat and water balances between urban and non-urban areas. Urbanization has a significant impact on all elements of the atmosphere. Replacing natural vegetation with artificial surfaces alters the heat balance and hydrology of the local environment. Urban canyons affect wind speed and increased particulate content affects the wind of a city. The urban atmosphere contains lots of pollution in the form of solid particles. These solid particles along with the strongly altered artificial urban surface significantly change the radiation balance in a city compared to non-urban areas. The radiation balance and the heat balance are closely correlated. The heat balance of an urban area is complex due to the large number of buildings and includes heat exchange through conduction by the ground, streets and walls as well as the heat from the combustion of fossil fuels. In a city, the water balance is also controlled by these same elements, but their proportions are significantly different. In urban areas, the amount of rainfall is higher than in non-urban areas.

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This paper explores the cause, and characteristics of Urban Heat Island Effect and proposes some solutions to the problem.

II. HISTORICAL BACKGROUND

Climatic factors played an important role in the growth of our civilizations. Climate is reflected in buildings and settlement planning. The designing and orienting of buildings with respect to climate is an old art. History provides many valuable lessons in which it is clearly seen that the intention was to take advantage of the surrounding environment and the average climatic conditions of the region and not to act against it.

Fig. 1 Typical house of Kerala

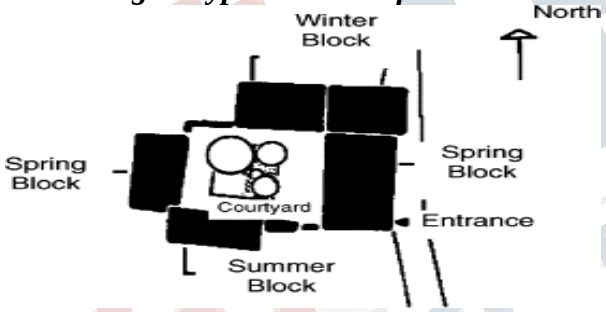

Fig. 2 Position of seasonal block around court typical house in Diyarbakir

Fig. 3 Typical House of Kerala-view of central courtyard and verandah building

Fig. 4 Jaisalmer-Jharokhas of a typical haveli Typical Jharokhas and \Chajjas shaded the building

The phenomenon of city- induced environmental change has been known for many centuries. The ancient Indian architectural manual ` Silpa Sastra`(translated by Acharya, 1979) laid out rules for siting of villages, towns and forts based on prevailing wind directions and solar orientation. Building and street layout, and massing, were prescribed so as to enhance street- level shade, air-pollution dispersal and storm-water drainage. Vitruvius`(75-25 BC) Book I of the Ten Books on Architecture (trans.Morgan,(1960) also considered city layout in relation to local environmental conditions.

III. URBAN HEAT ISLAND : THE PHENOMENON

It is often warmer in the city than in surrounding rural areas during hot fine weather, especially at night. This phenomenon is referred to as the 'Urban Heat Island' (UHI). This describes the increased temperature of urban air compared to its rural surroundings.

The term 'heat island' is used because warmer city air lies in a 'sea' of cooler rural air. The figure below shows an ideal heat island profile for a city, showing temperatures rising from the rural fringe and peaking in the city centre. The profile also demonstrates how temperatures can vary across a city depending on the nature of the land cover, such that urban parks and lakes are cooler than adjacent areas covered by buildings.

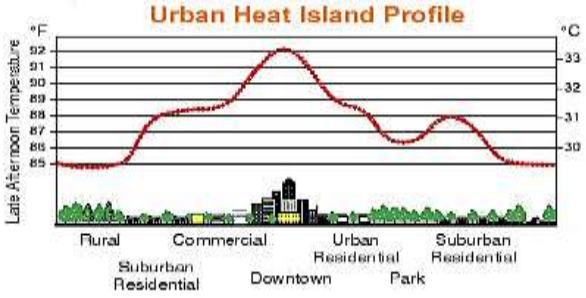

Fig. 5 Urban Heat Island Profile Source: Heat Island Group

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The urban heat island is caused by the storage of solar energy in the urban fabric during the day and release of this energy into the atmosphere at night. The process of urbanisation and development alters the balance between the energy from the sun used for raising the air temperature (heating process) and that used for evaporation (cooling process), because the cooling effect of vegetated surfaces is replaced by impervious engineered surfaces. The UHI phenomenon was.first noticed by meteorologists more than a century ago (Howard, 1833). Since then, the UHI effect has been well explored worldwide (Oke, 1978; Landsberg, 1981 Santamoouris, 2002; Akbari, Rosenfeld, & Taha, 1990; Tso, 1996). Some of the most important factors which may in.uence the UHI effect include canyon geometry, thermal properties of materials, anthropogenic heat, the urban greenhouse effect, and evaporation surfaces (Santamoouris, 2002). According to Landsberg (1981), UHI, as the most obvious climatic manifestation of urbanization, can be observed in every town and city.

As mentioned by EPA : Heat island are formed when vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb - rather than reflect - the sun's heat, causing surface temperatures and overall ambient temperatures to rise.

IV. WHAT ARE THE OPTIONS FOR MANAGING THE URBAN HEAT ISLAND ?

Researches have unearthed a series of causal relationships between a wide range of urban factors and climate.Policies designed to reduce the UHI may need to balance the need to manage heat at the building, neighbourhood and city scales, taking into account the nature of development (new versus existing) and be conscious of what is achievable in reality. The principal causes of the urban heat island are the storage of solar energy in the urban fabric during daytime and release of this energy into the atmosphere at night, and the fact that the process of urbanisation alters the balance between the energy from the sun used for raising the air temperature (heating process) and that used for evaporation (cooling process) because vegetated surfaces are replaced by impervious engineered ones. Hence we see that the strategies for tackling the root causes of the UHI need to focus on controlling the absorption and release/escape of heat from the urban fabric and maintaining the balance between the available natural energy between heating and cooling of the urban atmosphere.

From a practical point of view managing climates at the street canyon to neighbourhood scale will be a better option to control the phenomenon of Urban Heat Island. The various steps that can be taken in this direction can include-

4.1 Cool roofs: Roofs store and release a considerable amount of energy back into the atmosphere. the deterioration of roof materials will be accelerated because of high roof temperatures and the buildings with poor roof insulation leads to increased demand for cooling energy and a decrease in indoor thermal comfort on upper floors. In contrast cool roofs built from materials with high solar reflectance or albedo and high thermal emittance may reach temperatures considerably lower than their low reflectance counterparts. This is because they absorb and store less solar energy during the day and thus are not major emitters of heat into the urban atmosphere at night. Apart from their reduced contribution to the development of the nocturnal heat island, cool roofs have obvious benefits for the lifetime of roofs as excessive contraction and expansion is avoided through a damped daily temperature range and absorption of ultraviolet radiation is reduced. Also there will be gains in terms of indoor thermal comfort through the reduced transfer of heat through roofs to the upper floors of buildings and reduced demand for active cooling systems.

4.2 Green Roofs: Green roofs, which consist of a growing small/medium plants over a waterproof membrane, can have a marked impact on the climate of the upper floors of buildings and their immediate environs.

Planting Trees and Vegetation: ‘Urban Greening’ can be a cost effective way of ameliorating harsh urban climates at the individual building to neighbourhood scale. Trees and vegetation are good modifiers of climate, as they not only provide shade (surface peak temperature reductions of 5-20degree C may be possible) but are natural cooling systems as they consume large amounts of available energy in the atmosphere through the process of evapotranspiration; the energy is used to convert water contained in the vegetation into water vapour which is transpired through leaves to the atmosphere.

4.3 Use of high albedo materials: Artificial surfaces with low albedo absorb much insolation, heating the surface more than if it were a natural surface like grass.

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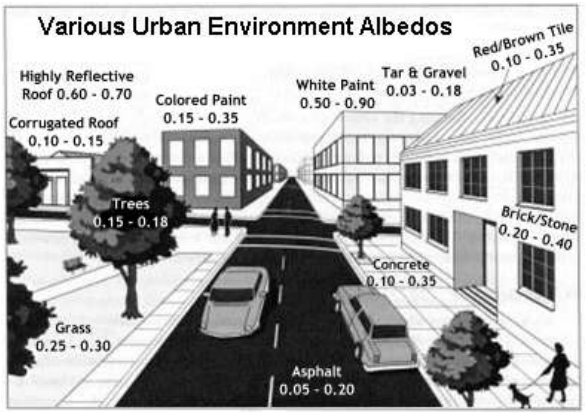

Figure 6 Typical albedos.-Courtesy NASA (Source)

The additional heat can create differences in air temperature between the city and countryside of 10o C (18o F) or more. Because of presence of reflective surfaces in the urban canyon the sunlight is trapped.

Building materials like brick and asphalt have high heat conductivity. Heat loss in the evening can compensate for that which has been gained during the day.

Because of the warm city surface convection is induced and that draws the urban air upwards which is in turn then replaced by cool air from the countryside. This rural-urban circulation is more likely to occur when synoptic-scale winds are light. The rising air transports dust and other particulates upward, gathering as a dust dome. If winds are strong enough, the pollutants spill over the city boundary and stretch downwind over the countryside as a pollution plume. Particulates concentrated in the urban atmosphere serve as nuclei for the condensation of water.

4.4 Sky view Factor: An important determinant of the rate of release of heat from the urban environment at night and thus the rate of urban cooling is sky view. This describes the relative openness between buildings. A restricted sky view, as found for narrow streets and tall buildings, will prevent the free escape of heat emitted from street and building surfaces. This will contribute to the accumulation of heat within 'street canyons' and thus the elevation of air temperatures. In addition, if streets are oriented at an angle that is perpendicular to the prevailing wind, during intense urban heat island events this will reduce the chances of ventilation of the street canyon and removal of heat and pollutants that accumulate between buildings. For this reason new developments should optimise sky view and consider street orientation.

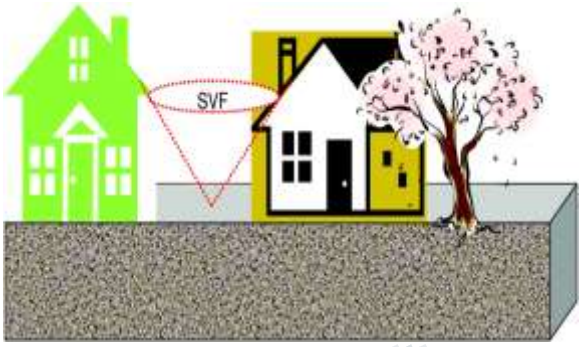

Fig.6:The sky view factor

V. CONCLUSIONS

Some of the aspects of the causes and effects of heat islands were examined. The study shows that proper understanding of the influence of these parameters can help in managing the negative impacts of Urbanisation on climate and thus add to the comfort of the inhabitants. Awareness of such principles and moreover its application is yet to percolate into Architectural practice and to achieve this students pursuing architectural education and young practicing architects must be given sufficient knowledge about these issues and any work done in this direction must be given proper recognition and Professional bodies must design awards for such works .

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