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Review on Urban Heat Island Mitigation Strategy Through Vegetation and Pavements Characterization

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ABSTRACT

Urban heat island phenomenon is one of the main problems facing the 21st century and this happens due to increased urbanization, weaknesses in the urban design planning and deterioration of outdoor environment. This paper is prepared to review the basic concepts and strategies for mitigation of urban heat island. Approach through vegetation and pedestrian pavement in the process of urban planning and design as well as environmental engineering can be considered to address the problem of heat island towards achieving a balance in urban climate. The tree canopy function is to promote the occurrence latent heat evaporation and provide shade from the sun. The ability of the tree canopy function depends on its physical characteristics. Moreover, the use of pavement materials with high reflective surface on the structure of the city can reduce the absorption of solar radiation and this can reduce the incidence of heat islands. It is expected that the integration between shade trees and colored pavement coating in urban design could improve the external thermal comfort and reduce the heat island effect.

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INTRODUCTION

Among the causes of urban heat island occurrence is the lack of vegetation and high absorption of solar radiation on the surface of the city [1]. This phenomenon causes the ambient temperature to increased, especially in urban centers, that cause a serious impact on the demand for electricity for cooling and indirectly contribute to air pollution [2]. Previous studies conducted in selected cities in Malaysia noted the intensity of urban heat island from 2 °C to 7 °C [3]. Therefore, to address this phenomenon, then among the mitigation strategy is to increase tree planting and apply the use of materials that have a high albedo to buildings, open space and roads surface [1][2][4][5][6]. These steps can be realized by intensifying trees planting throughout the city [7]. Physical characteristics of shade tree such as foliage density, height and shape and the type of species also play an important role because it can affect the ability of climate modification around the city through the shade coverage, evapotranspiration, photosynthesis and wind protection. In addition there are two ways to producing high albedo pedestrian pavements which are to increase the reflection of the sun on the substance or enhance the evaporation and water storage in the pavement materials [8]. Pavement is considered cold if 25 percent or more of sun reflection occurs on the surface of the pavement by making the color of the grout lighter either by coating it with light-colored paint on the surface of the pavement or make a pavement with a mixture of light-colored materials. In addition, the brightness of the colors that are applied on the pavement should be controlled in order to avoid glare problems occur.

Heat Island Phenomenon:

Heat island with high temperatures occurs on the atmosphere and surface of urban areas compared to rural environment. Urban heat island is a condition in which unexpected climate changes occurs when there is rapid urbanization in urban centers [9]. Heat island phenomenon can occur in the daytime as well as night. Impact of this phenomenon causes the air temperature and the temperature of the external surface of urban areas to increase and become warmer and significantly more so in the late afternoon. However, the heat island is most intense at night, a few hours after sunset on clear sky conditions in the presence of wind [2]. There are several

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factors contributing to urban heat island like 'canyon geometry' which acts as a sunlight trap, building materials with high heat absorbers, the greenhouse effect, anthropogenic heat sources, less cooling by evaporation sources (plants, water body, etc.) and the pattern of wind movement [2][6].

Heat island pattern is determined by identifying the unique characteristics of each city [2][10]. Intensity of urban heat island is a difference of high temperature between in the urban areas compared to rural areas. Studies by Ilham Elsayed involving urban heat island in Malaysia revealed that the level of urbanization is directly proportional to the intensity of the urban heat island of the city[11]. In other words, the urban heat island intensity is directly proportional to the land use, population density and the number of vehicles. The study also saw a clear change in temperature occurs from weekdays to weekends. This is due to the impact of traffic, and other activities during working days. Figure 1 shows the profile of urban heat islands occur on steep temperature curve changes between urban and rural areas, which is the slope of the curve plateau weak increase of the temperature rise from the valley to the peak where the maximum temperature is found.

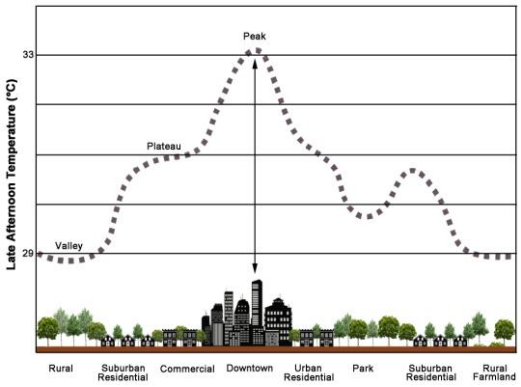

Fig. 1: Sketch of a typical heat island urban profile [10].

Urban Heat Island Mitigation Strategies:

(i) Cooling Through Vegetation:

Shade tree has great potential as a cooling element to overcome problems such as heat stress experienced by the urban environment [12]. Most studies touching on the physical characteristics of trees (foliage density, height, shape) and the type species is a factor to be considered during the implimentation of mitigation to improve comfort in the urban environment and to the consumer. Many studies conducted to evaluate and assess how the tree works to improve the performance of the climate around the city, controlling temperature, adaptation to climate change and reducing the use of power [7].

Tropical hot and humid climate and rainfall experienced throughout the year provide the most suitable enviroment for the growth of plants to thrive in the tropical rain forest and evergreen trees are the majority in this area. The trees of this type have a high density of foliage and have the same thermal performance throughout the year. The performance of the tree is also influenced by climatic conditions such as the angle of sunlight, cloud conditions, location and soil conditions. Production of the total area of shading dependents on the shape of trees, foliage density and angle of the sunlight [12]. In the tropics, shades by tree cover is very important especially during the day because it can enhance the exterior of human thermal comfort and the surrounding area.

Leaf area index (LAI) and Leaf area density (LAD) is an indicator used to study the thermal conversion of the trees with its environment [13]. LAI is used to evaluate and compare the trees canopy of various species, and it can be done manually or using an instrument. LAD is a key parameter needed to see the interaction model of radiation through the canopy of trees with its surrounding areas [13]. When the LAI and LAD occurred modification then it can affect some of which, such as climatic factors (air temperature, relative humidity, surface temperature and wind speed), building energy performance, thermal comfort and heat island mitigation around the city [13][12].

(ii) Cooling Through Pavement:

One contributor to the formation of heat islands is the layers on pavement surface. The 'cooling' nature of pavement materials is determined by their physical characteristics such as color, surface texture and material. There are few studies that have been conducted to identify the benefits to be gained when the colored pavement surface material is used [14][15]. Figure 2 show pavement surface of a dark, rough and materials from gravel, asphalt and pave stone will be hotter because it tends to absorb more sunlight rather than light-colored surface, smooth and materials of marble, mosaic and stone [14]. Moreover, the physical properties of the material on the soil surface or road is a major concern for the city to promote optimum cooling effect.

Through observation, most of the colors used in paving materials around the city are black, white, gray, brown, red and green. The colors of the materials have reflection effect and the performance depends on the ability of its reflection depends on range of colors from bright to dark. Thus, the color of pavement surface play an important role in reducing the surface temperature by high degree in the vicinity of the city. Studies by L. Doulos, M. Santamouris and I. Livada shows that the light-colored pavement materials have the lowest impact to the surface temperature in the range of temperatures between 21 °C to 38 °C, while the surface of the pavement with dark colors are between 26 °C to 53 °C [14].

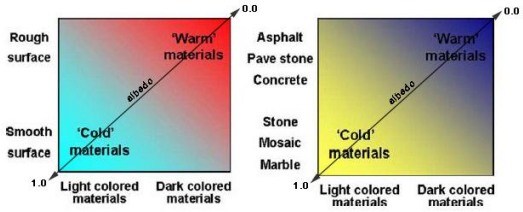

Fig. 2: Definition 'cool' and 'warm' material based on physical characteristics (color, surface texture and material) and albedo value [14].

Conclusion:

This paper discusses the urban heat island phenomenon by focusing on heat island mitigation strategies through characteristics of vegetation and pavement to improve thermal comfort around the cities with hot and humid climates. Naturally, shade trees may modify the temperature of our surroundings and shades are dependent on the physical characteristics of the tree canopy, especially in terms of the density of foliage and its shape structure. Else, the use of pavement materials also contribute to the reduction of air temperature and surface temperature through the physical characteristics of the pavement materials such as color, surface texture and material because it affects the albedo. Thus, the dark pavement with rough surface will absorb more sunlight than light-colored pavement with smooth surfaces. The remaining question is; how the characteristics of shade trees and pavements can be synergized to promote optimum heat reduction effect towards urban heat island mitigation.

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