Strategies and validations on mitigation of urban heat island in hot and humid regions

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Abstract

The phenomenon of urban heat island effect (UHI), i.e. air temperature in the downtown area higher than that in the suburb, is typically contributed by anthropogenic heat, ground surface covering, and radiation emitted from the man-made objects. The rising air temperature not only increases the energy use for indoor air conditioning but decrease the thermal comfort levels of outdoor occupants as well. Therefore, this paper integrates the UHI mitigation strategies into four categories, which are land use, greenery, street geometry, material application, establishing relevant practices for mitigating the UHI effect in Taiwan. This paper is based on the project entitled “Strategy on mitigation of urban heat island (SOMHI),” supported by the Architecture and Building Research Institute (ABRI), Ministry of the Interior, Taiwan. The SOMHI project tends to be the basis of popularizing the improvement of the urban heat island and transacting the improvement strategy for the future implementation.

Keywords

urban heat island, mitigation strategy, outdoor thermal comfort

1. Introduction

As the concentration of CO_2 in the atmosphere is gradually increased day by day with industry development and worldwide environment destruction, the problem of global

warming is more serious in recent years. The air temperature in the downtown area is higher than that in the suburb, i.e. urban heat island effect (UHI), contributed by artificial structure, high thermal storage coefficient pavement, machines heat in extremely high population density area of cities. The influence of the increasing urban temperature not only results in the increasing of indoor air conditioning energy cost and reducing of outdoor thermal comfort, but also causes urban ecological problems. Therefore, the Taiwan government has currently implemented the “Eco-City and Green Building Promotion Program” and the mitigation measure of the heat island effect is labeled as one of the most important projects, in order to mitigate the impact and the challenge of the heat island effect.

It has to execute “the competitive mitigation measures plan of the urban heat island effect” in order to mitigate the heat island effect effectively, via choosing the case which has potential by competition way and enforcing the transformation of heat island effect project. In addition to promoting the awareness of the heat island effect and strategy and strengthening discussion and realization of the mitigation strategy by the way of setting up demonstrative cases.

The paper is based on the project entitled “Strategy on mitigation of urban heat island (SOMHI)”, supported by the Architecture and Building Research Institute (ABRI), Ministry of the Interior, Taiwan. The SOMHI project aimed to be the basis of promoting the improvement of the urban heat island and transacting the improvement strategy for the future implementation.

2. Previous studies on urban heat island or outdoor microclimate

The study on urban heat island (UHI) is always an important issue related to urban studies, meteorology, geography, landscape and building research. Due to the climate change and global warming, people have been more concerned on the UHI effect. As early in 1970, Luke Howard and Oke [1, 2] validate the significant air temperature differences between the downtown and the suburb. Later on, there are several studies focused on UHI from different scale, method, temporal-spatial distribution, mitigation measures [3-7] .

Studies on urban thermal environment mainly focus on two subjects. The first subject observes the UHI effect, discusses how the distribution of UHI is affected by green spaces, land zoning, and population from a macro perspective. The intensity of UHI is

also compared among different cities, countries, or climatic zones [6, 8, 9]. The second subject focuses on urban microclimate, such as street geometry [10-12], land coverage [5, 13], roof materials [14, 15], and anthropogenic heat [5, 16] from a micro perspective.

It has been confirmed in previous studies that shading has a significant effect on outdoor thermal environment. Street orientation and height/width ratio (H/W) represent the shading level in some studies [10-12], while SVF represents shading level in others [9, 17, 18]. In terms of utilization behaviors in hot-humid Taiwan, 93% people in a urban square would choose to stay in shade under trees or buildings [19], which also demonstrates the importance of shade in outdoor environment.

However, the intensity of heat island as high as above 10℃ in the foreign dry area, which is not easily occurred in Taiwan with a hot and humid subtropical climate, and their improvement strategy also is not necessarily suitable in Taiwan. Moreover, Köppen climatic classification system shows that the strategy and methods used is limited because of the diverse characteristic of the Taiwan climate and the extremely high construction density condition of the urban sites, so that we have to solve the urban heat island problems with the viewpoint of Taiwan climate and urban sites and the result of the native field measurement.

3. Outdoor thermal comfort in hot-humid regions

Thermal comfort is people’s subjective thermal perception on the current thermal environment, which is combined with air temperature, relative humidity, wind speed and mean radiant temperature, and also the clothing and activity of human body. Lin [20] indicated that “Some studies have examined thermal comfort in outdoor environments. Compared with indoor thermal comfort, outdoor thermal comfort and thermal acceptable range should differ due to psychological and behavioral factors [21, 22], i.e., thermal adaptation. Adaptation is the gradual decrease in an organism’s response to repeated environmental stimulation, such that an organism adapts to survive in a given environment [23].Thermal adaptation has become an important issue in studies of indoor and outdoor thermal environments. Many studies have indicated that occupant perceptions and preferences for thermal environments vary markedly due to differences in behavioral adjustments, physiological adaptation to a climate, and psychological habituation or expectations. Physiological adaptation to a climate is generally slow and has not been a focus of thermal comfort studies. Conversely, the impacts of psychological adaptation and behavioral adjustment on thermal comfort are significant

[23, 24].” Therefore, the outdoor thermal comfort is especially important for local use. For Taiwan, there existed thermal comfort range and thermal perception scales that are 26-30°C PET [25] and 23.0-33.1°C SET* [21].

4. Strategies and validations on mitigation of urban heat island in hot and humid regions

The ways of coordination are divided into four parts. “Site description” shows the basic characteristic data. “Environment factor” represents the characteristics of the environmental design. “Field measurement” indicates that the measurement time and how to obtain the meteorological element. Main results lists the most important observation, and the improvement strategy of researcher’s suggestion, and the anticipated effect in the process.

The strategy of heat island effect adaptable Taiwan are divided into four categories, which are land use, greenery, street geometry, material application, according to the strategy of mitigating heat island effect of the previous literature, and the Taiwan native climatic characteristics and the range of the Taiwan inhabitant's heat comfort.

5. Conclusions

The paper suggests that the estimation of thermal comfort in the outdoor space is not only necessary economically, but also helpful in the energy saving and environmental protection in the human living environment. Therefore, this paper proposes the scope of Taiwan outdoor thermal comfort, and describes the outdoor comfort by a variety of indices. The result of the study can be applied to the standard of further outdoors thermal environmental assessments.

In the four categories of the Taiwan's strategies of mitigating heat island effect, “material application” is the realistic method to be executed, but the effect would be significantly limited with the characteristics of the Taiwan urban concentrated. Therefore, the improvement aiming at “greenery” and “street geometry” in the intermediate stage can be carried out. The “land use” strategy can be adopted in the future, in order to mitigate effectively the urban heat island problem.

At present, the information archives should be first systematically established because the materials character about outdoors thermal environment is relatively limited in

Taiwan, such as the radiance emissivity, transmissivity, the reflection rate, the leaf area index, etc, so as to put reasonable design into practice in terms of the Taiwan climatic condition.

As the results of executing strategy mitigating heat island effect before and after, a reasonable pattern of testing and verifying improvements and effects should be established, including reduction algorithm, value simulation, and field measurement to confirm the improvement effect, in order to be the basis of policy promotion in the future.

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