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Application of human thermal load into unsteady condition for improvement of outdoor thermal comfort

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ABSTRACT

Human thermal comfort is studied as a countermeasure to the thermal stress in outdoor urban space. Outdoors, people experience the strong impact of solar radiation in states that are unsteady and non-uniform. The feeling of comfort is a mixed sensation that can be easier to improve overall, as compared with a global large-scale effort, and can lead to improved ways of saving energy and reducing costs. Moreover, this can be directly beneficial to human experience and fulfill natural human desires. Since a thermal comfort index is a useful tool for understanding the present state and evaluating the impact of countermeasures, we examine the effects of the human thermal load, which is a thermal comfort index based on the energy balance of the human body. In a steady state, and even in an unsteady state with its variations in weather and human factors, thermal comfort values can generally be obtained by using the overall human thermal load. The reason for this is that the human thermal load takes physiological factors in account as well as weather parameters. This leads to the idea that thermal sensations follow from the human thermal load, which can then well describe a given human environment. As a result, human sensations as expressed by the human thermal load pave the way to the creation of comfortable urban spaces that require minimum expense and energy as an example of simple heat transport model focusing on urban outer structure.

1. Introduction

Challenges to environment are now a theme that is common to the entire world. The global rise in temperature is well known as 'Global Warming' and environmental measures are attracting increasing attention [1–4]. Moreover, people, products and energy are concentrated in urban areas, which causes specifically urban problems such as thermal stress, which can produce what are referred to as 'Urban Heat Islands' [5–7]. Many researches have been carried out not only for UHI but also for general urban climate. In order to mitigate the burden of the urban thermal environment, and urban heat islands as an example, a number of plans have been proposed, such as tree planting and highly reflective surface coatings, among others [8–11]. The present urban thermal environment, however, will not be fundamentally improved by these plans alone, as complex, large-scale urban planning projects are required. This is because direct improvements of air temperature, humidity, radiant temperature, or wind speed may be not possible without large-scale effort such as urban restructuring or planning, and this takes time and is costly. The countermeasure of our approach regards improvement of the human experience of temperature in urban space. In general, how one feels the temperature or experiences thermal comfort is determined by six dominant factors: air temperature, humidity, radiant temperature, wind speed, metabolism, and clothing. Since comfort is a mixed sensation, that is, humans do not feel only one isolated component, so it is difficult to establish a better thermal environment by improving just one component. The feeling temperatures that we experience, however, can be easier to improve overall, and this may lead to improved ways of saving energy and expense.

The history of thermal comfort study goes back to the concept of Effective Temperature, which was advanced by Houghten and Yaglou in 1923 [12]. This work was based on subject experiments and assumed an indoor environment in which the three factors of air temperature, relative humidity, and wind speed went into the calculations. Later, CET was proposed, which also considered

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