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A climate analysis tool for passive heating and cooling strategies in hot humid climate based on Typical Meteorological Year data sets

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ABSTRACT

Through a newly developed climate analysis tool, this paper examines the potential of improving thermal comfort under the climates of Vietnam thanks to passive strategies. A building climatic chart for Vietnamese was proposed based on Fanger's theory [1] and the comfort zone of this chart was then extended by calculating the effects of passive heating and cooling strategies. Typical Meteorological Year weather data are used for extracting and graphically printing of hourly environmental parameters on the psychrometric chart and for climate analysis, subsequently. The limitation and the scope of this method are also specified. The climates of three climatic regions in Vietnam have been used as case studies using all year, seasonal and monthly analysis. The results show that natural ventilation is an effective cooling solution as thermal comfort improvement varies with the climatic zones, increasing from 24.8% in Hanoi, 22.1% in Danang to 32.0% in Hochiminh city. Meanwhile, passive solar heating is only effective under the climate of Hanoi. Direct evaporative cooling also shows great cooling potential for comfort improvement but probable elevated humidity is not expected. Total possible comfort in a year of each location indicates that further climate modification methods are inevitable to achieve comfort during extreme weather conditions, especially in Hanoi.

1. Introduction

A full understanding of local climate is the main requirement for the designs of climate responsive architecture towards sustainable development. This requirement indicates that designer should be supported by suitable weather-analysis tool rather than relying completely on statistical climatic data from other providers. However, application of environmental support tool among design community in hot humid climate seems rather limited. Wong et al. [2] conducted a survey on the application of environmental design tools among designers in Singapore. The results revealed that almost architects examined did not employ such tools in their works and that consultations with building scientists are rare. This means that designers are likely hesitant to use sophisticated tools or commercial tools, which may impose a burden on their time and budget. Therefore, a simple tool for climate analysis used in preliminary design is essential. Recently there has been some weather tools developed for climate analysis [3,4]. Due to the criteria implemented, they are design support tools aimed to apply in temperate and cold climates where occupant tends to use HVAC systems more frequently. Under hot humid climate, naturally ventilated buildings are very common and thus occupant's comfort criteria may differ significantly. This paper proposes a simple method for climate analysis by which the potential of comfort improvement by using passive cooling and heating strategies could be derived. As being presented in detail, this method also allows user to modify the thermal comfort model and algorithms to meet specific requirements or conditions of a climate.

The method proposed will be carried out through three steps: (1) proposal of an appropriate comfort zone on building psychrometric chart for people living in hot humid climate; (2) extracting and printing of climate data on this chart; and (3) quantitative analysis and assessment of thermal comfort, heating and cooling potential of passive strategies. Three climatic regions in Vietnam are investigated as case studies.

Vietnam generally has tropical monsoon climate [5]. Whole territory of Vietnam is located in the tropics, in the Southeast edge of the Asian continent, bordering the East Sea (part of the Pacific Ocean). The climate of Vietnam is strongly influenced by trade winds, which often blows at low latitudes. As the territory of Vietnam largely spreads from the North to the South, in this analysis 3 typical sites, including Hanoi (21 North), Danang (16 North) and Hochiminh city (10 N) which represent 3 climatic regions in the North, Centre and South of Vietnam, have been selected (see Fig. 1).

Fig. 2 summarizes main statistical climatic data of the 3 sites from Ref. [5]. Differences in geographical characteristics and

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Fig. 1. Map of Vietnam, which shows selected sites of the present study.

latitudes of the three climatic regions cause some climatic distinctions. Hanoi has 4 separated seasons with a fairly cold winter, but the lowest temperature hardly falls below 5 °C. The highest temperature can reach 40 °C. In Danang, the climate is basically tropical monsoon. There is no cold winter. Lowest temperatures is often well above 15 °C. The highest temperature may sometimes exceed 40 °C. Hochiminh city has typical hot and humid climate with monsoon all year round. There are annual dry hot and rainy warm seasons corresponding to two inhomogeneous monsoons in the region. Rainfall is quite large. High average air temperature and solar radiation during the year indicate that cooling demand would be dominant. Abundant wind around the year offers a great potential for passive cooling and indoor air quality improvement.

In Vietnam, air relative humidity is always high and reaches around 90% at night. The daily amplitudes to temperature variation are quite small and almost below 7 °C, even in summer. This is because high relative humidity and cloudy sky act as a "blanket" preventing radiation loss from the earth and prevent air temperature from dropping much further.

2. Comfort zone for people living in hot humid climate of Vietnam

The comfort zone on building psychrometric chart is well known as an important indicator using in climatic analysis and establishing of climatic design strategies. The earliest efforts to establish the comfort zone and the building climatic chart could be found in some publications [6–8]. However, it is still an *argument* that under a specific condition the comfort zone for different climatic regions is unchanged. Based on steady-state heat balance theory of Fanger [1], ASHRAE [9] reported that under steady-state condition, "*people cannot physiologically adapt to preferring warmer or colder environments, and therefore the same comfort conditions can likely be applied throughout the world*". However, the conventional comfort zone proposed by ASHRAE standard 55 [10] seems inappropriate for Vietnamese because of the fact that it omits the effect of humidity adaptation of people living in hot humid climate. In this standard the upper comfort limit of 0.012 $kg_{water}/kg_{dry\ air}$ is rather stringent because this requirement is hardly satisfied in hot humid climate where relative humidity usually exceeds 80%.

Some computer weather tools have failed in predicting comfortable period of the climates of Vietnam because they used inappropriate comfort boundaries. The comfort zone for Hanoi proposed by Climate consultant software [4] using comfort model of ASHRAE standard 55 [10] indicates that only 4.9% of total time of a year should be comfortable. Also in Hanoi, Fig. 3 shows the comfort prediction of another weather tool [3] in which Szokolay's method [11] was adopted. The significant weakness of this method is that a 'steady-state' condition was imposed (clothing = 0.57 clo, metabolic rate = 1.25 met, wind speed was not mentioned), but the 'adaptive comfort model' of Auliciems [12] ($T_n = 17.6 + 0.31 \times T_{o.av}$) was employed to find neutral temperature. According to this

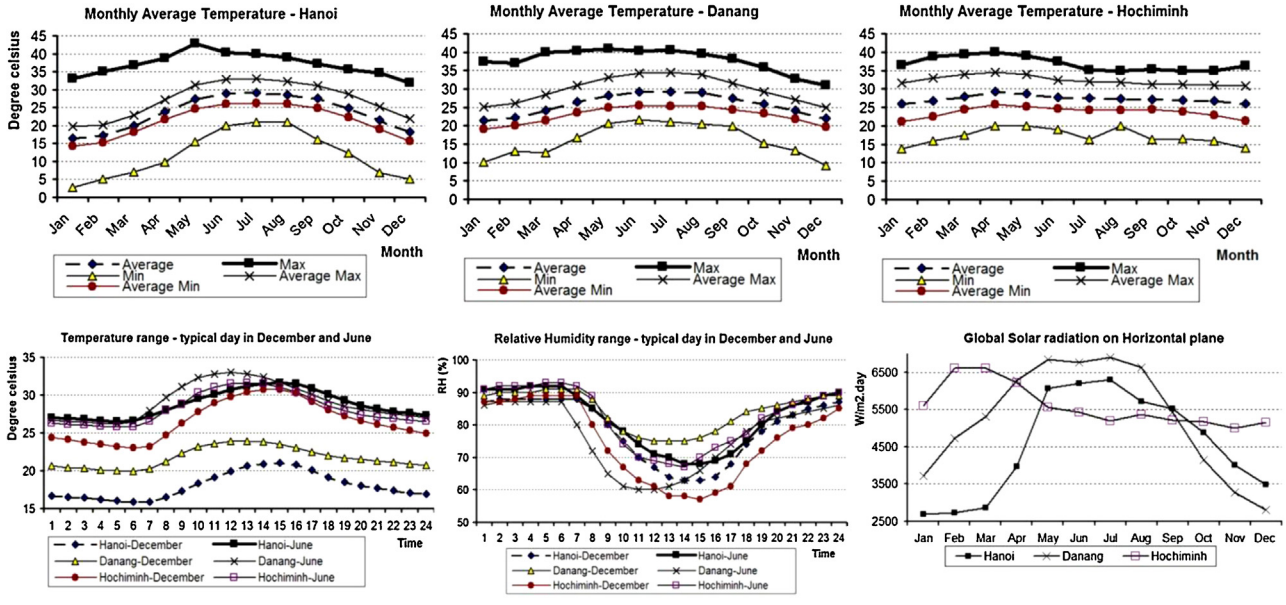

Fig. 2. Statistical data of temperature, relative humidity and solar radiation in Hanoi, Danang and Hochiminh city.