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Hygrothermal Regulation of Brick Masonry of Nanjing City Wall by Plants

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1 Introduction

Nanjing City Wall is one of the most important cultural heritages in China. With the influence of climatic variations such as the solar radiation and rainfall, Nanjing City Wall was deteriorated due to efflorescence, peeling and cracking. As the plant can be a potential regulator of the micro-environment mitigating the adverse effect of local climate to cultural heritage, this paper aims at evaluating the potential of plant to buffer the microclimate of Nanjing City Wall.

2 Method

The influence of trees on the microclimate of the Nanjing City Wall was studied through field measurements and simulation. Firstly, two shaded walls (Sites 1 and 2) and two unshaded walls (Site 3 and 4) were been monitored from Apr. 2019 to Dec. 2019. Air temperature and relative humidity under the canopy, surface temperatures and water content of the wall were measured. Then a coupled two–dimensional hygrothermal 'City Wall–plant' model was developed and set up in FORTRAN language to simulate the trees and City Wall at Site 2. In this study, the coupled hygrothermal transfer model by Matsumoto (1978) was adopted to simulate the City Wall, and the tree model was based on Kondou (1996).

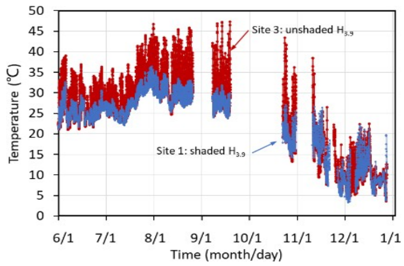
3 Results and Discussion

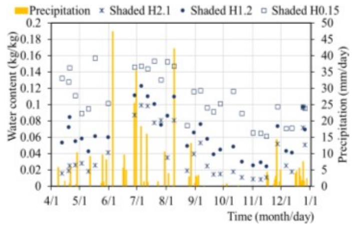
3.1 Measured Results

Figure 1a shows that almost the same daily minimum values and large differences in the maximum values were seen at the shaded (Site 1) and unshaded (Site 3) surfaces. It means that the trees can mitigate temperature stress in summer. Figure 1b shows average water content of 10 bricks at Site 2 (shaded) and Site 4 (unshaded). The measured water content decreased with the measured height. In Site 4, the water content at $H_{2.1}$ was higher than that at $H_{1.2}$, which may be due to different water absorption and storage capacity of bricks and herbaceous plant at $H_{2.1}$.

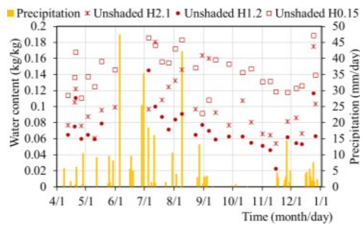
3.2 Comparison Between Measured and Calculated Results

A two-dimensional 'City Wall–plant' model was set up in FORTRAN language to simulate the shaded wall at Site 2. The measured and simulated surface temperatures at three points $H_{1.2}$, $H_{3.9}$, and $H_{5.4}$ of the south facade (Site 2) were compared. A linear regression analysis was performed, and a good correlation was obtained with slopes 1.00, 0.98, and 0.97 and goodnessof-fit 0.99, 0.98, and 0.96 at $H_{1.2}$, $H_{3.9}$, and $H_{5.4}$, respectively. Figure 2 shows that the calculated water content reproduced the time profile of the measured results at heights $H_{0.15}$, $H_{1.2}$, and $H_{2.1}$. Due to the evaporation on the wall surface and water movement in the wall, the water content assumed a peak value during rainfall, then gradually decreased. The ability of the model to respond to diurnal and seasonal variations proved the validity of the model.





Site 2 (shaded)

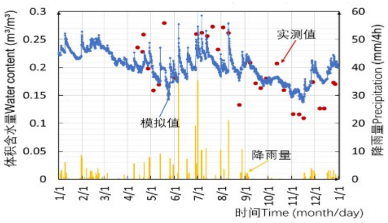


Site 4 (unshaded)

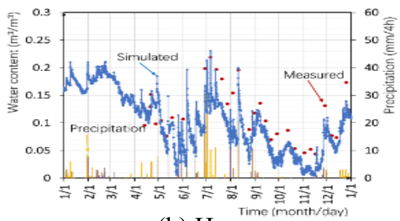
(a) Measured surface temperatures at Site 1 and Site 3 (Jun. 2019-Dec. 2019)

(b) Average water content of 10 bricks located at Site 2 and Site 4 (Apr. 2019-Dec. 2019)

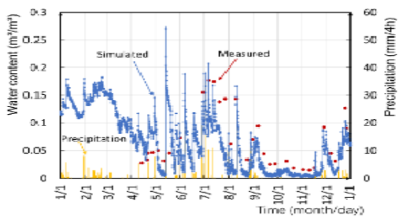
Figure 1. Measured surface temperatures and water content at Sites.



(a) $H_{0.15}$



(b) $H_{1.2}$



(c) $H_{2.1}$

Figure 2. Comparison of measured and simulated water content at three heights.

4 Conclusion

This paper investigated the influence of trees on hygrothermal performance of Nanjing City Wall. The results showed that the trees can reduce the temperature stress on the wall, and the measured water content decreased with height. Then a proposed 'City Wall–plant' model was validated, and the validated model can be applied to analyse the trees' impact on the microclimate and surface weathering of Nanjing City Wall.

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