A Study on the Effects of Underlying Surface on the Microclimate of Campus in Wintertime

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Abstract. The winter temperature of campus in north China is generally low, and different underlying surfaces have different characteristics in different environments in winter. In this paper, three different underlying surfaces on campus: hard pavement, vegetation and water surface, were selected for a quantitative study. From December 21 to 25, 2019, the temperature and relative humidity of 6 measuring points in Chang’an campus of Northwest Polytechnic University were measured every 0.5h per day. The results show that the temperatures of hard pavement surface were generally higher than that of grassland and water body in the wintertime. Detailed process and results of the research are introduced in this paper, and some suggestions for the future campus planning in consideration of winter environmental factors are provided accordingly.

1. Introduction

The winter temperature of campus in north China is generally low, we should do the investigation and research on the existing environment and the different characteristics of the thermal environment of different underlying surface are summarized and it can guide the construction and development of the campus in the future.

The underlying surface has a significant impact on the air temperature and relative humidity of the microenvironment, which can further affect the microclimate of the environment, and then affect the experience in the living environment. The flow of people in colleges and universities has the characteristics of centralization and strong regularity. Therefore, it is necessary to study the influence of different underlying surfaces on the regulation of temperature and humidity in the environment. Different underlying surfaces affect the temperature and relative humidity of the environment through their own characteristics. Zhou Lichen (2006) found that the branches and leaves of plants in the green space can effectively block the solar radiation of the external environment, so as to avoid the rapid temperature rise in the green space under the same environmental conditions. [1] Che Sheng Quan (2001) concluded that the transpiration of plants is like the release of water vapour in the green space environment. At the same time, due to the coverage of plants, the water vapour inside a green space is not easy to be lost to the outside environment, thus increasing the relative humidity in the green space environment in many ways. [2] From the perspective of water lands cape layout, different layout of water landscape will affect the surrounding microclimate regulation effect.
The underlying surface of the campus is equipped with green water and hard paving. The research has confirmed that the cooling capacity of different underlying surfaces is Arbor > grassland > water surface > hard paving, among which the research on the microclimate of greening is more, The research on the influence of water body layout on microclimate is more than that on surrounding microclimate. However, the research on Microclimate of small water landscape is still lacking. [3]

Based on the above research on different underlying surfaces, this paper mainly tests three types of typical underlying surfaces that were identified in the campus environment, and studies the different effects of such surfaces on the outdoor thermal environment in winter.

2. Collection of meteorological data of typical underlying surfaces in a university

2.1. Experimental design

Six experimental measurement points of hard pavement, grassland and water surface with visible and invisible sunlight were selected in the campus, and the air temperatures at 1.5m height were selected as the control measurement point; the instrument was placed at the measuring points with ensured air circulation and without direct sunlight. Shelter was set to reduce the unexpected impact on the experiment as much as possible. All the instruments were installed on Dec. 20th, 2019 and started at the same time for the first count, so as to ensure that the measurement results of all the six points could be caught at the same time.

2.2. Selection of measurement points

According to the feasibility of the investigation and study, six experimental measurement points were selected on campus. They located in the hard paved ground, grassland and water surface with visible and invisible sunlight, which were respectively recorded as HS, HWS, GS, GWS, WS, WWS and set the control point as CP. (the location of measurement points is shown in the distribution map of measurement points in Figure 1).

![Figure 1. Distribution of measuring points](image)

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WMCAUS 2020
IOP Conf. Series: Materials Science and Engineering 960 (2020) 042059
doi:10.1088/1757-899X/960/4/042059
2.3. Selection, installation and precautions of experimental instruments
In the experiment, 7 HOBO temperature and humidity recorders (model: mx1101, ux100-003) was used to record the temperature; they were placed in the radiation-proof cover wrapped with tin foil to ensure normal air circulation and avoid direct sunlight. The temperature and humidity recorders at the measuring point and the control point, and debug the recorders, set the measurement frequency as 30min / time, and use the unit of centigrade; select 21, 22, 23, 24, including December 22, winter solstice as the measurement date; place the instrument before 14:00 on December 20, 2019, and start the measurement at 16:00.

3. Analysis of meteorological data of typical underlying surface

3.1. Data characteristics of each measuring point of hard pavement

3.1.1. Temperature conditions in shaded areas of hard pavements. It can be seen from Figure 2 that the temperature in the hard paved shadow area is corresponding to the weather conditions of the day. When the weather is fine, the daily minimum temperature at this point is higher than the daily minimum temperature at the control point and appears earlier; the daily maximum temperature of the measurement point is slightly higher than the daily maximum temperature of the control point, and the peak arrival time is obviously earlier than the control point; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and daily minimum temperature is delayed, and the daily maximum temperature and daily minimum temperature of the control point.

![Figure 2. Comparison of temperature in the shadow area of hard pavement](image)

3.1.2. Temperature conditions in hard paved sunny areas. Figure 3 shows that the temperature in the hard paved sunshine area is corresponding to the weather conditions of the day. When the weather is fine, the daily minimum temperature of the point is higher than the daily minimum temperature of the control point, and the peak time is slightly earlier than the control point; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and daily minimum temperature occurs the temperature difference with the control point gradually decreased, even lower than the daily maximum temperature and daily minimum temperature of the control point.
3.1.3. The temperature in shaded areas of grassland. Figure 4 shows that the temperature in the shade area of grassland is corresponding to the weather conditions of the day. When the weather is fine, the daily minimum temperature of the point is lower than the minimum temperature of the control point and appears earlier; the daily maximum temperature of the measurement point is also lower than the daily maximum temperature of the control point, and the peak arrival time is earlier than the control point; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and daily minimum temperature is delayed, and It is worth mentioning that the daily minimum temperature is from the afternoon to the night of that day. It is speculated that the rapid decrease in temperature may be caused by the weather change and high humidity.

3.1.4. The temperature in the sunny area of grassland. Figure 5 shows that the temperature in the sunshine area of grassland is corresponding to the weather conditions of the day. When the weather is fine, the daily minimum temperature of the point is lower than the minimum temperature of the control point and appears earlier; the daily maximum temperature of the measurement point is also lower than the daily maximum temperature of the control point, and the peak arrival time is earlier than the control point; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and daily minimum temperature is delayed, and It is worth mentioning that the daily minimum temperature is from the afternoon to the night of that day. It is speculated that the rapid decrease in temperature may be caused by the weather change and high humidity.
temperature and daily minimum temperature is delayed, and at the same time, because the humidity of grassland is higher, the influence of wind increases, so the temperature changes greatly at night.

Figure 5. Comparison of temperature in the sunshine area of grassland

3.1.5. The temperature in the shadow area of the water surface. Figure 6 shows that the temperature in the shadow area of the water surface is corresponding to the weather conditions of the day. When the weather is fine, the daily minimum temperature of the point is higher than the minimum temperature of the control point and appears earlier; the daily maximum temperature of the measurement point is also higher than the daily maximum temperature of the control point, and the peak time is earlier than the contrast point; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and daily minimum temperature is delayed, and the temperature difference with the control point decreased gradually, and the degree of delay of daily minimum temperature was greater than that of daily maximum temperature.

Figure 6. Comparison of temperature in the shadow area of water surface

3.1.6. The temperature in the sunny area of the water surface. Figure 7 shows that the temperature in the sunshine area on the water surface is corresponding to the weather conditions of the day. When the
weather is fine, the daily minimum temperature is higher than the daily minimum temperature of the control point, and the daily maximum temperature is lower than the daily maximum temperature of the control point, and the peak appears earlier; with the deterioration of the weather conditions, the occurrence time of the daily maximum temperature and the daily minimum temperature is delayed, and the temperature difference with the control point is gradually reduced. The delay of the minimum temperature is less than the daily maximum temperature.

![Figure 7. Comparison of temperature in the sunshine area of water surface](image)

4. Analysis of overall characteristics

4.1. Dec. 21 and 22 were sunny days
It can be seen from the Figure 8 that for hard pavement when there is no sunshine at night, the temperature of the measuring point with available sunlight is slightly higher than that of the measuring point without sunlight, and when the sun comes out, the temperature of the two measuring points will increase significantly; however, the temperature of the measuring point with available sunlight will decline, and then it will continue to rise to the highest temperature point. In the cooling stage, the cooling rate of the measuring points with non-available sunlight is faster than that of the measuring points with available sunlight, and the difference is about 1 ℃ at the lowest temperature.

Dec. 23 and 24 were fog and overcast respectively. It can be seen from Figure 8 that when there is no difference in solar irradiance, the temperature changes of the two measuring points are almost the same.

For hard paving, the temperature range is -2℃ ~ 9℃, the highest temperature in non-sunny days is lower than that in sunny days, and the lowest temperature in non-sunny days is higher than that in sunny days.
4.2. Dec. 21 and 22 were sunny days

It can be seen from the Figure 9 that, for grassland, when there was no sunshine at night, the temperature of the measuring point with available sunlight was slightly lower than that of the measuring point where sunlight is not available. However, when the sun comes out, the temperature of the two measuring points increases significantly, and the temperature of the measuring point with available sunlight increases more sharply, gradually reducing the temperature difference between the measuring point and the measuring point with unavailable sunlight. In the cooling stage, the cooling rate of the measuring points with no available sunlight is slower than that of the measuring points with available sunlight, and the difference is about 1 ℃ when the lowest temperature is reached.

Dec. 23 and 24 were fog and overcast respectively. It can be seen from the Figure 9 that when there was no difference in solar irradiance, the temperature changes of the two measuring points were almost the same, but the highest temperature of the measuring point with available sunlight is higher than that of the measuring point with no available sunlight, and the lowest temperature is lower than that of the measuring point with no available sunlight.

For grassland, the range of temperatures was – 6 ℃ ~ 9 ℃. The highest temperature in non-sunny days was similar to that on sunny days, but the lowest temperature in non-sunny days was higher than that on sunny days.
Figure 9. Comparison of the temperature of grassland

4.3. Dec. 21 and 22 are sunny days
It can be seen from the Figure 10 that, for the water body, when there is no sunlight at night, the temperature of the measuring point with available sunlight is slightly lower than that of the measuring point where the sunlight is not available. However, when the sun comes out, the temperature of the two measuring points increases obviously, and the temperature of the measuring point with no sunlight increases more sharply, which is far higher than that of the measuring point of the unavailable sunlight, and then gradually falls back. In the cooling stage, the cooling rate of the measuring point of the non-available sunlight is gradually equal to the temperature change rate of the measuring point of the available sunlight.

Dec. 23 and 24 were fog and overcast respectively. It can be seen from Figure 10 that when there is no difference in solar irradiance, the temperature changes of the two measuring points are almost the same.

For water body, the temperature range is from -1°C to 11°C. The maximum temperature in non-sunny days is lower than that on sunny days, and the minimum temperature in non-sunny days is higher than that on sunny days, and the temperature difference is small.

To sum up, the surface temperature of campus water is higher than that of hard pavement in winter in North China. If only considering the need for high ambient temperature in winter, water or hard pavement can be selected as the more ideal underlying surface type. For the temperature characteristics of the same underlying surface under different conditions, it can be seen from Figure 8, figure 9 and figure 10 that for hard pavement with less water content, the temperature in the area under sunshine is higher than that in the shadow area; in the area with large water content, such as grassland and water surface, the temperature in the sunshine area is lower than that in the shadow area.
5. Conclusion

For the winter of Chang'an campus of Northwest Polytechnic University. The temperature of the water body and the hard pavement is generally higher than that of grassland. The reason may be that humidity and wind lead to the change of temperature, which is shown in the following aspects: 1. The direct sunlight increases the evaporation and heat dissipation of water, resulting in the temperature drop. 2. The shadow area is mostly covered by other objects, which virtually forms a windless area. The air velocity is small, and the evaporation and heat dissipation reduces, which makes the temperature of the shadow area higher. Therefore, it is recommended to set more underlying surface designs that can be converted into hard paving in winter, such as grass planting brick paving.

In the investigation and research design stage, the interval between the selected points is far, and the influencing factors of each point are not well controlled; at the same time, the measurement frequency is too small in the phase of temperature peak appearance, and the time when the peak value appears is not well grasped.

Acknowledgment(s)
The research of this paper was supported by the Shaanxi Provincial Key R&D Program - International Science and Technology Cooperation Program (2020KW-066), the Training Program of Innovation and Entrepreneurship for University Students (CX2020114) of China, and the Fundamental Research Funds for the Central Universities (3102018xyzzlz002).

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