STUDY OF PEDESTRIAN ROAD ON EXTERIOR LIGHT-THERMAL ENVIRONMENT IN URBAN CENTRAL DISTRICT
The Case of Guangzhou

by

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Taking the greenbelt environment of pedestrian ways in urban center as the research area, compare the ecological benefits of each greenbelt with the measurement of four ecological energy indexes, such as temperature, relative humidity and illuminance of three representative roads' greenbelt environment in Tianhe District, Guangzhou to prove that except the hard paved road, the three roads with different plant compositions all can improve city's microclimate, especially the road with arbors planted on both sides is an effective, active way for thermal insulation and energy saving, thus producing good comprehensive benefits for energy saving. With analysis and discussion in this paper, some design thoughts and suggestions are offered to provide a theoretical basis for the study of greenbelt environment of urban walkways.

Key words: *walking environment, air temperature, relative humidity, illuminance*

Introduction

Almost all cities pay more attention automobile traffic than individual's walking scale [1]. *High-rise buildings and open spaces* constitute the majority of the urban space, which not only reduces the possibility of walking as a form of transportation, but also deprives vitality of the city and decreases the city space for living and walking.

Pedestrian ways mainly serve as passages and spaces. The transportation function is the most important one of walkways. Passages allow pedestrians to safely and comfortably arrive at the destinations. The function of passage refers to arriving easily and accurately at the destination places and buildings by way of roads. The walking road is not only a traffic space, but also an open space of the city which connects buildings, squares, gardens and roadways. It represents the city's look, presenting a unique walkway landscape [2-4]. In order to create favorable urban living conditions, the slow traffic on the street should be given attention and roads based on the walking width of the pedestrians and linking two places should be built to create a charming street landscape, thus promoting a walking habit. As the main public areas in the city, the street and its sidewalk are the most important organs of a city. A course concering landscape ecology [5, 6]. Streets, sidewalks or plant belts of small size may seem make no difference, but once placed in a street of miles subdivided into hundreds of sections where millions of people dwell in, they will effect a huge impact on community's appearance, people's feelings and environmental benefits. As social commentators, sociologists and city designers agree, the

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walkway is a comprehensive social space [7-9]. There are different researches for walkways, including space design, road plant design, road physical environment research [10], as well as distance, scale and attraction study [11, 12]. The street landscape is a basic element for forming a walking space. The walkway is an important place for public life, a part of the city's green space, and walkways in the commercial area can improve the area's economic value. The pedestrian way plays a big role in improving road landscape and increasing city's vitality. Roads with plants can reduce air pollution by 60% compared with those with less or no plant [13], and pedestrian ways can be studied for comprehensive ecological service research and others [14, 15].

At present, building an ecological city has become a new concept and method. It is of practical significance to study the ecological benefits of walkways to lower urban heat island effect, achieve the harmony between human and environment and the sustainable development of the city, as well as realize ecological civilization. In this paper, by studying the use condition, temperature and humidity difference, and illuminance difference of different types of walkway greenbelts in the most representative residential area in urban center, the quantitative conclusion about the ecological effect of the road landscape in winter is obtained, and corresponding suggestions about walkways which are suitable for the climate and human use are put forward to provide a theoretical basis for expanding walkway greening modes and creating diversified urban pedestrian ways.

The environment profile and status quo of the research area

The environmental profile of the research area

The research object is located at 113° 35′ east longitude and 23° 12′ north latitude in Zhujiang New Town, Tianhe District, Guangzhou. Figure 1 is a main part of Tianhe CBD in Guangzhou, is the place in China with most over-300-meter skyscrapers. It has a complete walkway planning system, a rich greening environment and perfect public facilities. In some commercial and residential areas, streets nearby, shops with gardens, art devices designed at the traffic nodes and nightscape lighting all have perfected walkways. The research area is a commercial and residential one where road greening between buildings is concentrated. The walkways chosen, besides serving as passages and spaces, have a stronger overall sense in terms of road pavement and garden greening. The walkways in this area can well represent the space environment of the ones in urban center.

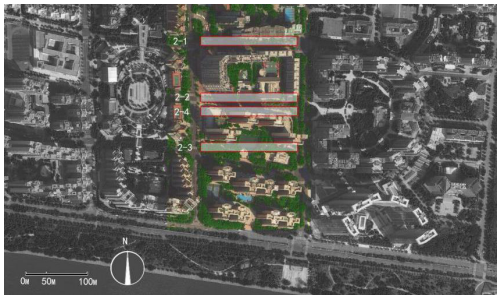

Figure 1. Site distribution of Pedestrian road in Zhujiang New Town

The construction status quo of the research area

The walkway greenbelts in downtown Guangzhou were surveyed in the field in December 2016. According to the principles of representativeness and typicalness, the greening and surrounding environment of the walkways in the residential area were analyzed, and such factors as the road trend and structure were considered. At last, the walkway space between the communities with small high-rise residential buildings, besides the one-way roadways and of higher utilization rate was chosen as the research object. Four road sections with similar exterior environment, relatively homogeneous materials and different greening structures were selected as sample areas to conduct research. They are four walkways with the width of 6 m

and the length of 230 m within the road red line. The study is divided into factors analysis of the site itself and measurement of the site's ecological effects. According to the requirements of the test target, the *Shangzhulunan* walkway nearby was used as a control area for simultaneous measurement. See the general situation of the sample areas in tab 1.

Table 1. Bacic information of the selected plots

Number	Name	Width	Length	Orientation	Structure
2-1	Haiminglu	6 m	230 m	East and west	2 Roadways + 2 Pedestrian ways
2-2	Shangzhulubei	6 m	230 m	East and west	2 Roadways + 2 Pedestrian ways
2-3	Haiyuelu	6 m	230 m	East and west	2 Roadways + 2 Pedestrian ways
2-4	Shangzhulunan	6 m	230 m	East and west	2 roadways + 2 Pedestrian ways

Materials and methods

Method

In the specific experiment, taking data 's representativeness and continuity into account, the 3-point observation method was adopted. There are altogether three observation points. The first one was set in the middle of the road (about 115 m away), and the last two were set at 5 meters away from the first in east and west, respectively. The observation height is 1.5 m above the ground, a height for the standard weather blind to measure temperature and humidity. It can represent well the microclimate within the scope of human activity.

The measurement was done in the daytime when life was relatively active. On a sunny day in January 2017, temperature, relative humidity and illuminance were measured continuously for three days (26, 27, and 28) at 8:00 a. m. to 18:00 p. m., once per 2 hours. Each time they were measured and analyzed synchronously, and their test values for four sample areas in winter were thus obtained for comparison and analysis.

Collection of the experimental data

- The data of temperature and relative humidity were collected with the use of AS847 integrated temperature and humidity meter produced by Dongguan Wan Chuang electronics. The technical parameters: the temperature measurement range is –10~50 ℃, K-TYPE: 20~1000 ℃, and the humidity measurement range 10~95%.
- The data of illuminance was measured by TES-1339 illuminometer. The technical parameter is 0.01Lx and the resolution /9999 digit reading value.

Results and analysis

The influence of walkways with different interiors on temperature

It can be seen from fig. 2 that the trend of overall temperature change is similar to that of environment temperature of the four walkways. The change of daily temperature difference in the Shangzhulunan walkway which has no greening is the most obvious, temperature low at 8:00~10:00 a. m. and at 24.6 ℃ in the high-temperature period of 14:00 p. m., 2.4 ℃ higher than that of the arbor-small arbor-shrub road at the same time, 2.3 ℃ higher than that of the road with arbors on single side, and 1.6 ℃ higher than that of the road with arbors on both sides. This is mainly because that the ground materials of the hard paved road with no tree shading have a high reflectivity, and thus receive more sunlight during the day, causing temperature rise quickly. However, the heat loss speed of the ground in the evening is faster than that of

the roads with greening, and the change of daily temperature difference is the biggest. On the whole, walkways with greening change relatively less in temperature in the daytime, and thus can reduce the influence of midday temperature on the pedestrian environment, serving the role of regulating the microclimate.

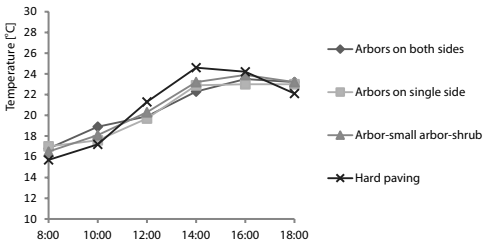

Figure 2. Average temperature changes of Pedestrian road green space on three days

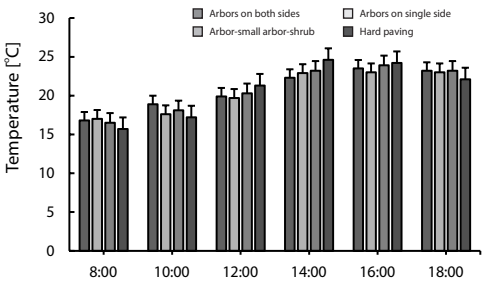

Figure 3. Average temperature difference analysis of Pedestrian road green space on three days

As shown in fig. 2, among the four walkways with different greenbelts, the highest temperature of the hard paved Shangzhulunan walkway is higher than that of the other three roads with greening, and the l+ owest temperature lower than that of the three roads with greening. As for the daily temperature difference, temperature of the road with arbors on both sides was 6.7 ℃, road with arbors on single side 6 ℃, and small arbor-arbor-shrub road 7.4 ℃.

From comparison and analysis of fig. 3, temperature adjustment of the three roads with different plants is slightly better than that of the hard paved road, which is related to greening crown breadth and tree height. The study shows that evaporation of soil water and water loss of plant leaf are the main causes of plants' temperature drop [16]. As physiological metabolism and consumption of plants in winter are lower than that in summer, cooling and humidifying range in winter is lower than in summer [17]. In general, cooling range is relatively small and the difference is not great.

The influence of walkways with different interiors on relative humidity

The trend of relative humidity change at different time periods for the roads with greening and the hard paved road without greening is shown in fig. 4. Relative humidity of each measure point is generally opposite to daily temperature variation. The higher the temperature is, the lower the relative humidity is. On the whole, relative humidity of the roads with greening is slightly higher than that of the hard paved road, indicating that the roads with greening have a humidifying effect. The reason is that an interface like an isolated layer is formed in the roads with greening, which has a slow exchange and convection with air, is less affected by atmosphere humidity, and can prevent the rapid evaporation of water to the outside. However, the hard paved road without greening is more open, exchanging air frequently with the outside world. And its water evaporation and consumption is faster and humidity relatively is low.

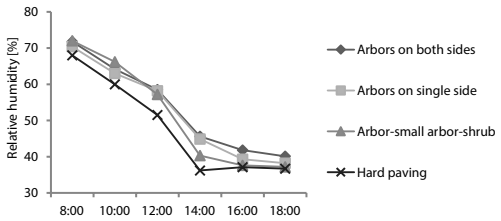

Figure 4. Average observation relative humidity changes of Pedestrian road on three days

As shown in fig. 4, the highest observed values of relative humidity for the four roads are close to each other, with that of the hard

paved road a little bit lower. This is because the highest relative humidity occurred at 8:00 a. m. when temperature was low and light less, therefore, plants had little impact on it. According to the highest and lowest relative humidity values, the order of the humidification range is small arbor-arbor-shrub road > road with arbors on both sides > road with arbors on single side > hard paved road.

The comparison and analysis of fig. 5 show that the relative humidity difference of the greenbelt in each walkway is not obvious. It may be because that the road space is relatively open, and air exchange and convection with the outside world are fast, therefore, no enclosure is formed to cause significant difference in air humidity. Although relative humidity varies little, the humidifying effect does exist in the road spaces planted with plants.

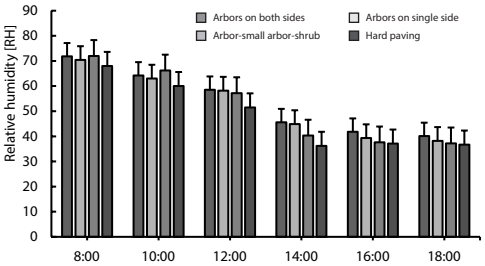

Figure 5. Relative humidity difference analysis of Pedestrian road on three days

The influence of walkways with different interiors on light environment

As shown in fig. 6, the sunlight is relatively weak at 8:00 a. m. and 18:00 p. m. With rising temperature, the difference between illuminance increases and the illuminance value of the hard paved Sahngzhulunan walkway reaches its peak at 14:00 p. m. The light difference between morning and evening of the three roads with greening is small, slightly higher at 12:00, and relatively stable at other time periods. Through observation and a comparative study, it can be known that the ecological effects of a space is determined by both the community itself and the total amount of solar energy received. Compared with the hard paved road, the roads with greening can effectively absorb and block sunlight. The blocking effect on solar illumination changes road temperature, provides shading for pedestrians, as well as balances plant growth and improves the environment.

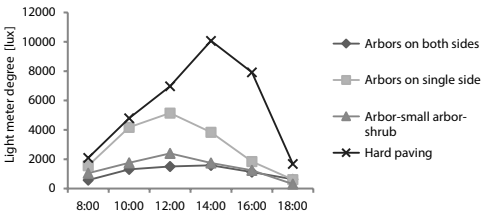

Figure 6. Average illuminance changes of Pedestrian road on three days

The highest and lowest illuminance values of the four walkways with different interiors are shown in fig. 6. The illuminance of the roads with greening is obviously lower than that of the hard paved road without greening. The observed highest illuminance values of the small arbor-arbor-shrub road, the road with arbors on single side and the road with arbors on both sides are 2396 lux, 5148 lux, 1603 lux, and their light blocking ranges reached 76%, 49%, and 84%, respectively, compared with the Shangzhulunan walkway. The minimum illumination values of the roads with and without greening show that both kinds of roads have an obvious light blocking effect.

According to fig. 7, the difference between lighting values is also obvious, most significant in the 14:00-16:00 p. m. period. Although there is no fixed proportion of illumi-

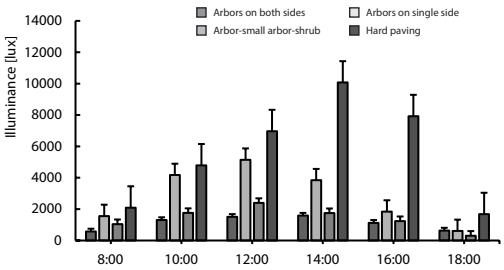

Figure 7 . Illuminance difference analysis of Pedestrian road on three days

nance to plant photosynthesis, it is necessary for plants to receive a certain amount of sunlight in a certain illuminance range to ensure production quantity [18].

Discussion

In this paper, site and environment factors are studied, respectively. Individual walking activities are only a form, and the walking road space is a carrier. Only when the individual, the site and the environment combine, can the walking road be more valuable, representing a city public space full of vitality and humanity.

The site factors of walkway greenbelts

Through the site observation of the four roads, the main objective of the study is to discuss their spatial form and plant composition. In terms of the space form, the four roads are in a linear shape, connecting the community, the school and the intersection. Compact and evenly distributed, they meet the walking needs of pedestrians and have improved walking efficiency. In terms of the plant composition, the landscape and functional advantages of the big arbors are fully played, which not only make the city greener, but also strengthen the enclosure sense of the walking space, thus improving the quality of the walking environment and creating a relatively safe and open space. According to the walkway comfort indexes-the three comfort indexes of continuity, space identification degree and street crossing safety, the site environment of the four roads basically meets the requirements.

The environmental and ecological factors of walkway greenbelts

The walkway spaces of different structures have an influence on the temperature and humidity effect. The temperature and humidity effect of the roads with greening is influenced by both the canopy density and the permeability of the greenbelt. The test results show that the daily temperature variation of the three roads with different greening environment is smaller than that of the hard paved road. In winter, the temperature and humidity effect of the road space is mainly influenced by the stability of local microclimate. The results further prove the rationality of cooling-humidifying ecological effect evaluation of walkway greenbelts in winter. As for illuminance, the roads with greening can effectively absorb and block sunlight, provide shading for pedestrians as well as balance plant growth and improve the environment; under the same external environment, among the four roads, the one with more plants has greater canopy density and higher aero-anion concentration. The comparison of the observed data shows that illuminance in this area can satisfy the need of plants' normal growth. In the design of walkway greening, reasonable plant arrangement cannot only prolong the growth period of plants, but also increase the yield of more organic substances in the plants.

Conclusions

By comparing and analyzing the climatic factors of temperature, relative humidity and illuminance on the Pedestrian road with the aforeementioned methods, we can quantitatively grasp the influence of cooling and humidification on the illuminance effect of Pedestrian road, and comprehensively analyze the characteristics of light and heat environment of various walking roads, which shows the positive role of light and heat environment. In addition, the light intensity has a great influence on the growth and development of plants, which directly affects the intensity of plant photosynthesis.

The walkway is not just a passageway for pedestrians. The road space should be made more comfortable and pleasing with diversified facilities and detail design [19]. In particular, the ecological environment of the site should be considered in the first place. In the design of pedestrian ways, it is necessary to refer to tab 5. Environmental ecology is fundamental to greenbelt construction in urban central area.

Table 5. Suggestion on design of Pedestrian road in site, environmental and ecological factors

	Site characteristics or research findings	Conclusion	Design suggestion
Site factors	Greenbelt of the arbor-small arbor-shrub road	Increase humidity and lower temperature, adjust the microclimate, purify air, decrease noise, reduce runoff, windproof and provide a more enclosed space	Natural green barriers, design activities based on wind direction and sunshine time
	Greenbelt of the road planted with arbors	Lower temperature, increase humidity, adjust the microclimate, purify air, conserve water and provide a more open sight	Dust-free, introduce fresh air
	Greenbelt of the hard paved road	Absorb and accumulate a large amount of thermal radiation, raise ground temperature, influence rainfall infiltration, provide year-round use, hard, durable and low maintenance costs	Design that can be used more quickly without water after rain and for special purposes (ultra-high-density communities, large population flow, space constraints)
Ecologogical factors	Temperature efficiency	Hard paved road > road with arbors on both sides > road with arbors on single side > small arbor-arbor-shrub road	Choose plant composition according to temperature drop range
	Relative humidity efficiency	hard paved road > road with arbors on both sides > small arbor-arbor-shrub road > road with arbors on single side	Determine whether to moisten or keep dry according to climatic conditions
	Illuminance efficiency	hard paved road > road with arbors on single side > road with arbors on both sides > small arbor-arbor-shrub road	Consider occlusion or introduction of sunlight according to plant needs and spatial functions

Reference

[1] Jan, G., *Humanized City*, China Construction Industry Press, Beijing, 2013
[2] Giulio, M. D., *et al*., Effects of Habitat and Landscape Framentation on Humans and Biodiversity in Densely Populated Landscapes, *Journal of Environmental Management*, *90* (2009), 10, pp. 2959-2968
[3] Trombulak, S., Frissell, C., Review of Ecological Effects of Roads on Terrestrial and Aquatic Communities, *Conservation Physiology*, *14* (2000), 1, pp. 18-30
[4] Hawbaker, T., *et al.*, Road Density and Landscape Pattern in Relation to Housing Density, Land Ownership, Land Cover and Soils, *Landscape Ecol*, *20* (2004), 5, pp. 609-625
[5] Dawson, K. J. A., Comprehensive Conservation Strategy for Georgia's Greenways, *Landscape and Urban Planning*, *33* (1995), 1-3, pp. 22-43
[6] Walmsley, A., Greenways and the Making of Urban Form, *Landscape and Urban Planning*, 33 (1995), 1-3, pp. 81-127
[7] Mohammad, J. K., *et al*., Effects of Access to Public Open Spaces on Walking: Is Proximity Enough, *Landscape and Urban Planning*, *117* (2013), Sept., pp. 92- 99
[8] Xu, L. Y., *et al*., The Landscape Design of Roads Afforestaion of Jiangnan New District in Mudanjing Municipality, *Agricultural Sclence and Technology*, *15* (2014), 7, pp. 1290-1212

[9] Kaczynski, A. T., Henderson, K. A., Parks and Recreation Settings and Activeliving: A Review of Associations with Physical Activity Function and Intensity, *Journal of Physical Activity and Health*, *5* (2008), 4, pp. 619-632
[10] Zhu, C. Y., Effects of the Different Width of Urban Green Belts on the Temperature and Humidity, *Acta Ecologica Sinica*, *31* (2011), 2, pp. 383-394
[11] Aspinall, P. A., *et al*., Preference and Relative Importance for Environmental Attributes Ofneighbourhood Open Space in Older People, *Environment and Planning B: Planningand Design*, *37* (2010), 6, pp. 1022-1039
[12] Coombes, E., *et al.*, The Relationship of Physical Activityand Overweight to Objectively Measured Green Space Accessibility and Use, *SocialScience and Medicine*, *70* (2010), 6, pp. 816-822
[13] Abbas, M. Y., *et al*., Asia Pacific International Conference on Environment-Behaviour Studies, *Procedia – Social and Behavioral Sciences, 168* (2015), Jan., pp. 1-7
[14] Georgia, S. S., Mainstreaming the Environmental Benefits of Street Trees, *Urban Forestry and Urban Greening*, *12* (2013), 1, pp. 2-11
[15] ***, TEEB, The Economics of Ecosystems and Biodiversity, TEEB Manual for Cities: Ecosystem Services in Urban Management, United Nations Environment Program, Geneva, 2011
[16] Perry, J. H., Ryan. R. J., The Effect of Urban Leaf Area on Summertime Urban Surface Kinetic Temperaturest A Terre FIaute Case Study, *Urban Forestry and Urban Greening*, *6* (2007), 2, pp. 63-72
[17] Ji, P., *et al*., Selected Vertical Structures of Green Belts Along Urban Rivers Affect Seasonal Temperature and Humidity, *Journal of Grassland*, *20* (2012), 3, pp. 456-463
[18] Chang, N., Li, D. W., Ecological Wall on Exterior Light –Thermal Environment of a Building, *Journal of South China University of technology (Nature Science Edition)*, *45* (2017), 8, pp. 146-152
[19] Carmona, M., *Public Laces – Urban Space*: *The Dimensions of Urban Design,* Architectural Press, Oxford, UK, 2003

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