Wind Engineering Joint Usage/Research Center
FY2018 Research Result Report

Research Field: outdoor environment field
Research Year: FY2018
Research Number: 183009
Research Theme: Actual condition investigation and optimization strategy study for thermal environment & air quality in bus stop of Guangzhou, China

Representative Researcher: Qiong Li
Budget [FY2018]: 200000JPY. It was mainly used for the travel fee for the communication meeting, buying experimental equipment and etc.

*There is no limitation of the number of pages of this report.
*Figures can be included to the report and they can also be colored.
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1. Research Aim

With the pace of reform and opening up for more than thirty years, China's urban construction has achieved unprecedented achievements, and the important element of urban life—public transport system has also received several major updates. The bus stop is an important part of the public transport system, with people's daily lives, is one of the important public environment of city life, its environmental design will directly affect the quality of the user's life. In the south of China, the climate is hot and humid, and the bus stops are in very simple form so that the thermal comfort in the bus stop is unsatisfied. In another hand, there is a large amount of exhaust gas emitted during the process of bus driving or parking than running at a steady speed. The passengers in the bus stop are exposed to the air with a high particle concentration. In order to improve the thermal environment and air quality in bus stop, the form of bus stop must be optimized. This project investigated the current conditions of the thermal environment and air quality in bus stop of Guangzhou, China, and discussed its optimal design strategy.

2. Research Method

The research methods in this study include filed investigation, questionnaire, field measurement and CFD simulation.

The purpose of field investigation is to know the design method of bus stop in Guangzhou, China. The field investigation covers 11 administrative regions of Guangzhou and adopts the methods of field observation, photo recording and video recording to observe and record the current design status of bus stops in Guangzhou, China. The design elements of the survey include five items: billboard, awning, station sign, seat and plane layout. The geometry characters of the investigated bus stops in Guangzhou were recorded using dimensional measurement and the standard geometry model of the bus stops in Guangzhou was made finally.

Questionnaire survey around 200 users and field measurements on 3 bus stops were made to understand the user demand and the actual condition of thermal environment and air quality of the bus stop in summer of Guangzhou. The following main problems were designed in the questionnaire:1) personal information of interviewees;2) the most commonly selected means of transport for respondents (multiple selection);3) average number of buses travelled per week by interviewees;4) the average length of time when an interviewee waits for a bus;5) overall satisfaction of interviewees with the current waiting environment;6) overall acceptance of the current waiting environment by respondents;7) aspects of respondents who are not satisfied with the current waiting environment (multiple selection);8) aspects of respondents who hope to improve the current waiting environment (multiple selection).

The thermal environments of bus stops under different design strategies were simulated using CFD method. And the optimized design strategy for the bus stops in Guangzhou, China was discussed.

3. Research Result

3.1. Characters of bus stops

The investigation find that although the various bus stops are different in shape, the basic structure is similar, and the difference is embodied in the material and morphology of each component. Therefore, the more common 27 component combinations are listed, as shown in Table 1.

Table1 Investigation photos on the design and use of bus stops in Guangzhou

 Type I	 Type 2	 Type 3	 Type 4	 Type 5	 Type 6
 Type 7	 Type 8	 Type 9	 Type 10	 Type 11	 Type 12
 Type 13	 Type 14	 Type 15	 Type 16	 Type 17	 Type 18
 Type 19	 Type 20	 Type 21	 Type 22	 Type 23	 Type 24
 Type 25	 Type 26	 Type 27			

The characters of bus stops are summarized as follows:

(1)Status of billboards: the city's billboards are basically metal pillar light box, some of them have no light box. The pillars are basically metal supports, of which the surface is green, blue or white painted, or stainless steel support without painting.

(2)Status of awning: there are flat roof, arch roof, wavy roof, curved roof, warped roof, and slope roof, among which flat roof is the most common. Material of them includes transparent glass, translucent colored glass, translucent blue plastic, opaque green plastic and opaque black PC board.

(3)Status of station: in some remote areas, bus stops do not have billboards, bus stop sign is the only sign of the station.

(4)Status of waiting seat: most bus stops have seats, but in remote areas or areas with less waiting space, there are no seats.

(5)Status of plane layout: generally linear, a few L - shaped

3.2. Need of users for bus stop

A total of 152 valid questionnaires were collected in the questionnaire, and the number of selected options for each option was counted as a percentage of the total number of valid

questionnaires, as shown in Table 2.

Table2 Statistical analysis of the results of questionnaire survey

Question item	Options (top three)	Other options
1. Common Travel modes (multiple selections)	Public transport (72.5%), Subway (66.7%), Cars (12.3%)	Taxis (11.6%), Electric vehicles (10.1%), Bicycles (9.4%)
2. Number of bus rides per week	2-5 Times (31.1%), 5-10 Times (28.3%), Less than 2 times (21%)	More than 10 times (19.6%)
3. Length of each waiting time	5-10 min (57.2%), 10-20 min (26.8%), Less than 5 minutes (10.1%)	20-30 min (4.3%), More than 30 minutes (1.6%)
4. Satisfaction and acceptance of the waiting environment (multiple selections):	General, barely acceptable (32.9%), Generally, more acceptable (24.5%), More satisfactory, more acceptable (16.1%)	A little dissatisfied, barely able to accept (9.8%), A little dissatisfied, a little unacceptable (4.9%), A little dissatisfied, more acceptable (3.5%), Remaining options (abbreviated)
5. Aspects of dissatisfaction with the waiting environment (multiple selections):	The sun is a little strong(53.8%), Lack of seats (38.5%), Temperature is too high (30.8%)	Too much dust, poor air quality (26.6%), The platform is too narrow and the waiting space is crowded (16.1%), Air Drying (13.3%), Small wind speed, non-circulation of air (11.9%) Poor roof shading effect (13.3%)
6. Recommendations for improvement of the waiting environment (multiple selections):	Increase the number of seats (44.8%), Increase the width of the awning (37.8%), Increase cooling device (32.9%)	Increase in humidification facilities (30.8%), Increase bus real-time arrival message board(29.4%), Use opaque awnings (26.6%), Increase the area of waiting space (16.1%), The shape of the shelter is more sense of design or endowed with regional cultural characteristics (13.3%), Added transparent board for wind and dust (11.2%)

It can be seen from the above data that:

(1)Bus and subway are the most commonly used modes of transportation for people waiting for buses. Bus is more commonly used and frequently used. It is used 2-5 times or even 5-10 times per week. Nowadays, the development of bus and bus stop are of great importance in the city to promote sustainable transportation mode.

(2)In most cases, the waiting time is 5-10 minutes, sometimes even 10-20 minutes. Under this background, it is necessary and necessary to provide a comfortable and healthy waiting environment for the waiting crowd.

(3)As far as the subjective feelings of the waiting crowd are concerned, most people think that

"the waiting environment is general, which is barely acceptable" or "general, which is relatively acceptable". The results show that although the waiting population is not very satisfied with the current situation of the bus waiting environment, but also know that the implementation of the bus waiting environment reconstruction project is difficult, high technical difficulties, large task, it is difficult to get a large degree of improvement in a short period of time.

(4)Most respondents are not satisfied with the waiting environment is the intensity of solar radiation, the number of seats and temperature. In addition, some interviewees are not satisfied with the air quality, waiting space, humidity, wind speed and rain shielding effect. Correspondingly, most interviewees hope to increase the number of seats, increase the width of awning to enhance the effect of sunshade and rain, increase the cooling and humidifying devices, use the opaque awning to enhance the effect of sunshade, increase the area of waiting room, and add transparent board to prevent wind and dust.

3.3. Design optimization recommendations for bus stop in Guangzhou

From this study, the design optimization recommendations for bus stop in Guangzhou are summarized as follows:

(1)Style: now too many advertising light boxes are crowding out the waiting space. Bus stops can be combined with the Lingnan cultural background of Guangzhou to improve from the selection and design of materials, colors, forms , do more cultural publicity display to create a unique bus waiting pavilion image characteristics in Guangzhou, and integration with the needs of urban development, so that bus stops can become the beautiful landscape of the city.

(2)Component design: the size, material and color of the awning, the material of seat, and the distance between the edge of awning and road, etc. Due to the unique regional climate conditions in Guangzhou, sunny and hot weather is more common, so the awning should choose materials with lower light transmittance to provide better shading effect. Seats are not required to a certain extent, taking into account street level, sidewalk width, platform size and other issues. Under the condition of allowing, the seat setting is necessary, but still should consider that the size of seat should not be too large, the number of seat should not be too much, and they should be placed in a reasonable position.

(3)Plane layout: in the L-shaped shelter, when the station sign and the billboard are close to or even integrated, it can form a small space with strong shading effect and have certain shading, rain and wind effect. A U-shaped shelter can be more effective, but it can also hinder air flow and hinder cooling. As to which form is more practical, it should be adapted to local conditions. It is worth mentioning that software numerical simulation can be used for quantitative analysis when necessary.

3.4. Prospect

The above problems and suggestions for improvement are mainly analyzed qualitatively from a theoretical perspective, but it is still difficult to implement them in practice. For example, although sunshade and billboard can provide shade for the waiting crowd to a great extent, their material, size, street orientation and street aspect ratio all have an impact on the shading effect. At this time, we need to start from a quantitative point of view, to discuss in what kind of street orientation, street aspect ratio of the combination of background, that shadows of the awnings and billboards play the biggest contribution on the shelter effect of waiting space.

This result will guide us to carry on the unified upgrade transformation to the city bus stop specifically, and can save the manpower and material resources greatly. Therefore, in the follow-up research, the importance of quantitative research to practical application should be paid attention to, and more specific and feasible optimization suggestions should be put forward.

4. Published Paper etc.

[Underline the representative researcher and collaborate researchers]

[Published papers]

1. Zhenhao Pan, Qinglin Meng, Qiong Li, Jingchao Xie, Jiaping Liu. Evaporative cooling of porous tiles with seawater in a tropical climate with salty humid air. Construction and Building Materials, 2019, 204(4):727-739.
2. Zhihong Tang, Jiejin Cai, Qiong Li, Jiyun Zhao. The regional scale atmospheric dispersion of radionuclide 131I: A simulation method based on WRF-Chen model. Radiation Physics and Chemistry, 2019, 156(3):81-93.
3. Qiong Li, Zhongliang Luo, Junsong Wang, Qinglin Meng. Field measurement on the climatic effect

of watering on asphalt road in hot and humid area. Proceedings of International Workshop on Wind-Related Disasters and Mitigation, March 11-14, 2018, Sendai, Japan.
4. Lingling Li, Lei Zhang, Qiong Li, Peng Ren, Lihua Zhao, Yufeng Zhang, Qinglin Meng. CFD study on the characteristics of temperature and velocity in an Environmental wind tunnel. Proceedings of the 4th International Conference on Building Energy Environment, Feb.5-9, 2018, Melbourne, Australia.
5. Qiong Li, Xi Yu, Qi Nie, Qinglin Meng. Influence of vehicle on thermal environment in urban street canyon. Proceedings of the 13th Building Physics Conference of China, November 13-14, 2019, Xi'an, China.
6. Qiong Li, Xi Yu, Qi Nie. A case study of thermal environment in urban street canyon in hot and humid climate city based on vehicle effect. Proceedings of Sustainable built Environment Conference 2019, August 6-7, 2019, Tokyo, Japan.

[Presentations at academic societies]
1. Speaker: Qiong Li. Title: Study on evaporative cooling performance of unglazed porous ceramic material in extreme hot-humid climatic environment. Conference: 2018 Workshop on Energy & Environment of Residential Buildings in China, 2018, Lawrence Berkeley National Lab (LBNL), USA.
2. Speaker: Qiong Li. Title: Evaporative cooling of porous tiles with sea water in tropical climate and salty humid air. Conference: 2018 China-UK Workshop on Renewable Energy Systems in Zero Carbon Villages, Tibet, China.
3. Speaker: Qiong Li. Title: Study on passive evaporation cooling of island reef buildings in South China Sea. Conference: Tenth Youth Green Building Technology Forum and 2018 Annual Meeting of the Youth Committee of the Green Construction Committee of the China Urban Science Association, August 30-31, 2018, Beijing, China.
4. Speaker: Qiong Li. Title: Influence of vehicle on thermal environment in urban street canyon. Conference: The 13th Building Physics Conference of China, November 13-14, 2019, Xi'an, China.
5. Speaker: Qiong Li, Peijie Tang. Title: Verification of vehicle canopy model in the thermal environment of urban street canyon. Conference: International Workshop on Wind Effects on Buildings and Urban Environment, March 10-12, 2019, Tokyo, Japan.
6. Speaker: Peijie Tang. Title: Investigation of indoor thermal environment in homes and health status of elderly people in Guangzhou, China. Conference: International Workshop on Wind Effects on Buildings and Urban Environment, March 10-12, 2019, Tokyo, Japan.
7. Speaker: Qiong Li. Title: Regulation mechanism and design method of modern urban thermal environment. Conference: Fifteenth International Green Building and Building Energy Conservation Conference, April 3-4, 2019, Shenzhen, China.

[Other]
1. Best Paper Award. The 13th Building Physics Conference of China, November 13-14, 2019, Xi'an, China.
2. Best Paper Award. Tenth Youth Green Building Technology Forum and 2018 Annual Meeting of the Youth Committee of the Green Construction Committee of the China Urban Science Association, August 30-31, 2018, Beijing, China.

5. Research Group

1. Representative Researcher:

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2. Collaborate Researchers

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6. Abstract (half page)

Research Theme: Actual condition investigation and optimization strategy study for thermal environment & air quality in bus stop of Guangzhou, China

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Summary·Figures

The high density of urban development poses challenges to human health. In order to promote the construction of healthy China, sustainable modes of transport should be encouraged, and measures should be taken to optimize the design of bus stop and improve the bus waiting environment. In this research, the design status and application status of bus stop in 11 administrative regions of Guangzhou, China were investigated, and the questionnaire survey around 200 users and field measurements on 3 typical bus stops were made to understand the user demand and the actual condition of thermal environment and air quality of bus stops in summer of Guangzhou. The CFD simulation was used to analyze the thermal environment and optimize the design schemes for the bus stops in Guangzhou, China. The results show that the structure of bus stop in Guangzhou is open, and the basic components have developed into 27 combination forms. The waiting crowds think that the waiting environment is so-so and barely acceptable. Most people think the solar radiation is a bit strong and not satisfied with the lack of seats. They also think the temperature in the bus stop is too high. The bus stops in Guangzhou, China are advised to add cooling and humidification device in summer, and increase the area of awning.

Fig.1 Photography

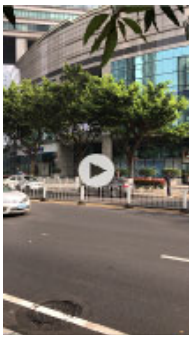

Fig.2 Video

Fig.3 Dimensional measurement

Fig.4 Software modeling