

# Wind Engineering Joint Usage/Research Center FY2019 Research Result Report

Research Field: outdoor environment field  
Research Year: FY2019  
Research Number:  
Research Theme: Study on the regulation mechanism of pavement-watering on the thermal environment of urban street block in hot and humid area  
  
Representative Researcher: Qiong Li  
  
Budget [FY2019]: 450000JPY

- \*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.
- \*Submitted reports will be uploaded to the JURC Homepage.

## 1. Research Aim

For the existing hardened pavement in the city, water cooling is an effective way to alleviate the urban heat island and reduce energy consumption. For the hot and humid cities in china, they normally have heavy rainfall, high temperature and strong solar radiation. It has the potential to use passive evaporative cooling technology to alleviate heat island.

This project is to analyze the mechanism of water cooling in urban hardened pavement, explore its influence mechanism on the thermal environment of urban street block and put forward a watering method for road surface cooling in hot and humid area of China.

## 2. Research Method

Theoretical analysis and field measurement on watering of asphalt road pavement were used to study the thermal performance of asphalt road and air above road before and after watering. And different cases with different watering frequency, watering rate and starting time were compared to get the optimal method for watering on asphalt pavement in Guangzhou, China.

## 3. Research Result

This study made a heat balance analysis on the asphalt road with and without watering. The analysis shows that the factors affecting the road heat balance contain longwave radiation, shortwave radiation, heat convection between road and air, and heat conduction from asphalt surface to deeper material under the road. From the analysis on how water receive energy, we found that the cooling effect of watering contained two parts such as heat conduction between liquid water and road, and latent heat. The evaporation rate were calculated from the comparison analysis of the heat balance on the asphalt road with and without watering.

In an open asphalt road of South China University of Technology located in Guangzhou, China, a water drenching system was installed in the two sides of road. The different experimental cases with different watering frequency, watering rate and starting time were done in summer day and compared.

For each experimental case, the surface temperature, heat flux and solar radiation on the road, and the air temperature, humidity, mean radiation temperature and etc. above the road were measured. The experimental cases are shown in Table 1.

Table 1 Description of experimental cases

Case	Date	Water drenching scheme	Water drenching rate(mm/h)
1	July 25th	Non-drenching water	—
2	August 29th	Non-drenching water	—
3	August 30th	12:00am to 17:30pm, 12:00am began watering, every 30min drench once, every drench continued 3min, 12 times	2.338
4	August 31st	11:00am to 16:30pm, 11:00am began watering, every 30min drench once, every drench continued 3min, 12 times	2.338
5	September 22nd	Non-drenching water	—
6	September 23rd	11:00am to 17:00pm, 11:00am began watering, every 45min drench once, every drench continued 3min, 8 times	1.559
7	September 24th	Non-drenching water	—
8	September 25th	11:00am to 17:00pm, 11:00am began watering, every hour drench once, every drench continued 3min, 7 times; (During the actual operation, no water was poured at 14:00pm)	1.169
9	September 26th	Non-drenching water	—

Water which is poured from the bottom of the tank when it is poured, is directly measured by a mercury thermometer, with an average temperature of 29.9°C.

The experimental results show that the influencing factors for the cooling effect of watering contain the first time of watering, watering rate, the way of watering, and water storage capacity. For the summer of Guangzhou, the best watering time on asphalt road is 9:00 to 9:30 in July and 9:30 to 10:30 on Aug. and Sep. days. Albedo of asphalt road surface would reduce by 0.055 after watering. The surface temperature of asphalt road would be reduced by 8.21°C after watering, air temperature at 1m height above road would be reduced by 1.30°C after watering. And there is no obvious difference about humidity and SET\* after watering.

The surface temperature of C point on different experimental days is chosen as the example, as shown in Figure 1. It can be seen that drenching water directly reduces the surface temperature of the road and changes regularly with the drenching period. The first time drenching water on each day, the temperature of the road has a sudden drop in the instant. Water began to drench at 12:00am in August 30. At 11:00am in August 31, the highest temperature is 55°C. In September 23, the drenching water interval was 45 minutes. The road temperature rises in the partial drenching water period and the average amplitude is about 1°C. But from the whole period, it shows a downward trend. In September 25, the drenching water interval is 1 hour.

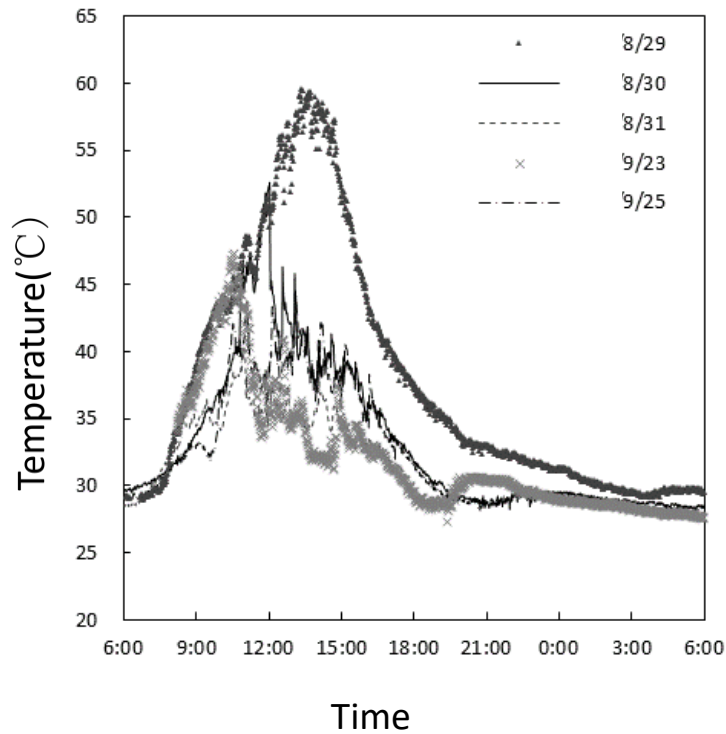


Figure 1 Surface temperature of the same C measuring point on different experimental days

The method of saving water has been argued. Average evaporation rate during watering time on open asphalt road in Guangzhou can reach to the value of  $0.169\text{mm/h} \leq E \leq 0.179\text{mm/h}$ . And it will be the most economical way when watering rate reach evaporation rate. Purling and spraying are better way for cooling. Data also shows that heat taken from road by watering occupies 7.58% of all energy that the road absorbs.

The study also made some field experiments on the asphalt pavement samples in summer, as shown in Figs.2-3.

According to the relevant road pavement standards, the pavement test boxes were made to measure the temperature and water content of the surface and internal layers under the action of water-spraying within one day. The results show that the lowest temperature which can be reached by the water spray is the most relevant to the long-wave radiation and the total solar radiation intensity, and the appearance time is mostly 10~20 minutes after watering. The average surface temperature after watering is reduced by  $5.13\text{ }^{\circ}\text{C} \sim 8.53\text{ }^{\circ}\text{C}$ , and the average temperature difference with air is reduced to  $0.43\text{ }^{\circ}\text{C} \sim 7.42\text{ }^{\circ}\text{C}$ . The surface temperature is lower than the air temperature after the period of 16pm to 17pm.

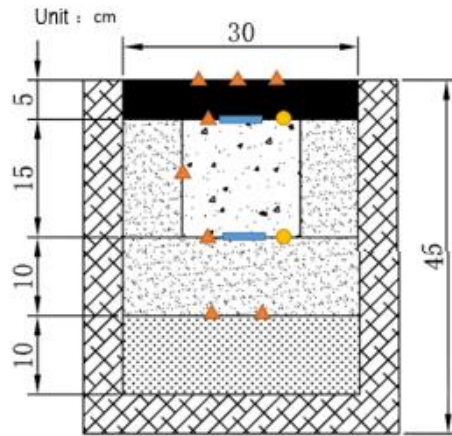
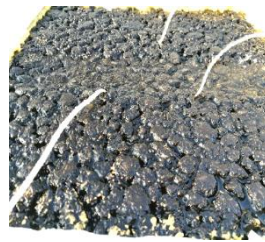


Fig. 2 Test sample of asphalt road



a) Non-spraying



b) 10 seconds spraying



c) 30 seconds spraying

Fig. 3 The appearance of asphalt pavement after different spraying time

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, Jiejing Cai, **Qiong Li**, Jiyun Zhao. The regional scale atmospheric dispersion of radionuclide <sup>131</sup>I: A simulation method based on WRF-Chem model. *Radiation Physics and Chemistry*, 2019, 156(3):81-93.
3. Hao Li, **Qiong Li**, Qinglin Meng, Yoshino Hiroshi. Investigation into the usage and health effects of air-conditioning equipment used by the elderly in Guangzhou. *South Architecture*, 2019, 2: 37-42.
4. Bixia Xu, **Qiong Li**, Hiroshi Yoshino, U. Yanagi, Kenichi Hasegawa, Peijie Tang. Investigation on summer indoor environmental conditions of urban and rural elderly housing in Guangzhou. *The 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC2019)*, July 12-15, 2019, Harbin, China.
5. Peijie Tang, **Qiong Li**, Hiroshi Yoshino, U. Yanagi, Kenichi Hasegawa, Bixia Xu. Investigation on the sleep quality and fatigue of the elderly in Guangzhou. *The 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC2019)*, July 12-15, 2019, Harbin, China.
6. Yuchao Wu, **Qiong Li**. Simulation study on the influence of fengshuitang on the thermal environment of hakka villages. *Building Environment & Energy*, 2019, 5:65-68.
7. Lingling Li, Qinglin Meng, Lei Zhang, **Qiong Li**. Numerical simulation of wind field and temperature field in a non-neutral atmospheric boundary layer using a wind tunnel test. *South Architecture*, 2019, 1:107-113.
8. Lingling Li, Qinglin Meng, Lei Zhang, **Qiong Li**. Development of multi-parameter dynamic hot-humid climate wind tunnel. *Experimental Technology and Management*, 2019, 36(10):95-99.

9. Xiaohui Lu, **Qiong Li**. Analysis on the potential of rainwater utilization of urban hardened pavement based on low impact development concept. The 2nd Landscape Architecture and Microclimate International Conference, January 17-19, 2020, Chongqing.
10. Yu Qin, **Qiong Li**, Yingli Xuan. Measurement and analysis of the thermal environment of the bus shelter in summer: a case study of Guangzhou. The 2nd Landscape Architecture and Microclimate International Conference, January 17-19, 2020, Chongqing.
11. Fuxiang Li, Qinglin Meng, **Qiong Li**. Improvement of heat and moisture coupled calculation model of capillary pressure as potential. Proceedings of 2019 Conference on Building Thermal Engineering and Energy conservation in China, October 19, 2019, Shenyang.

[Presentations at academic societies]

1. Speaker: **Qiong Li**. Title: Adjustment mechanism and design method on urban thermal environment. Conference: The 2nd Landscape Architecture and Microclimate International Conference, January 19, 2020, Chongqing, China
2. Speaker: **Xiaohui Lu**. Title: Analysis on the potential of rainwater utilization of urban hardened pavement based on low impact development concept. Conference: The 2nd Landscape Architecture and Microclimate International Conference, January 19, 2020, Chongqing, China
3. Speaker: **Qiong Li**. Title: Study on the mechanism of cooling hardened pavements by watering and the evaluation of watering schemes in hot and humid areas. Conference: 2019 Conference on Building Thermal Engineering and Energy conservation in China, October 19, 2019, Shenyang, China
4. Speaker: **Qiong Li**. Title: Study on the regulation mechanism of the outdoor thermal environment caused by the pouring water of the hardened pavement in the hot and humid area. Conference: International Conference for Global Chinese Academia on Energy and Built Environment, July 20-22, 2019, Chengdu, China
5. Speaker: **Qiong Li**. Title: Adjustment mechanism and design method on modern urban thermal environment. Conference: The Fifteen International Conference on Green and Energy-Efficient Building, April 4, 2019, Shenzhen, China
6. Speaker: **Qiong Li**. Title: Evaluation and design of mesoscale urban thermal environment based on lumped parameter method. Conference: The 11th Youth Green Building Technology Forum, November 29, 2019, Xiamen, China
7. Speaker: **Qiong Li**. Title: Investigation of summer indoor thermal environment and health in houses in Guangzhou. Conference: The 11th International Symposium on Heating, Ventilation and Air Conditioning, July 14, 2019, Harbin, China
8. Speaker: **Qiong Li**. Title: Investigation on the indoor environment of rural houses in Guangzhou. Conference: International Forum on Healthy Housing and Building Energy Conservation, December 14, 2019, Jiaxing, China

[Published books]

1. Building Physics (The Fifth Edition). China Architecture and Building Press, 2020.

5. Research Group

1. Representative Researcher

Qiong Li (South China University of Technology)

2. Collaborate Researchers

1. Yingli Xuan (Tokyo Polytechnic University)

2. Xiaohui Lu, Xiangyu Du, Yanhan Li (South China University of Technology)

## 6. Abstract (half page)

Research Theme: Study on the regulation mechanism of pavement-watering on the thermal environment of urban street block in hot and humid area

Representative Researcher (Affiliation): Qiong Li (South China University of Technology)

Summary • Figures

In order to relieve the urban heat island effect and improve the urban thermal environment, the water cooling of the city surface has been widely noticed. However, the researches on the water cooling mainly concentrated on the building envelope, especially the roof. Little research has been done on the cooling effect of watering on the asphalt pavement. This study is to analyze the factors affecting the water-cooling effects of evaporation and the mechanism of water cooling in urban hardened pavement, explore its influence mechanism on the thermal environment and put forward a watering method for road surface cooling in hot and humid area of China.

The results show that: 1) The factors affecting the impact of water cooling contain the first time of watering, watering rate, the way of watering, and water storage capacity. The best first time of watering is 9:00 to 9:30 in July and 9:30 to 10:30 on Aug. and Sep. days. 2) Albedo of pavement surface would reduce by 0.055 after watering, and it also reduces by about 8.21°C on surface temperature of asphalt road, 1.30°C on the air temperature at 1m height above road. 3) Average evaporation rate during watering time on asphalt pavement can reach to the value of  $0.169\text{mm/h} \leq E \leq 0.179\text{mm/h}$ . And the heat taken away from road by watering occupies 7.58% of all energy the road absorbs throughout the day. 4) The lowest temperature in the watering cycle usually appears 10 to 20 minutes after watering. 5) It is most economical way to save water when watering rate reach evaporation rate. -



The filed measurement on the road



The working water drenching instruments in South China University of Technology, Guangzhou, China