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# Cooling the city with "natural wind": Construction strategy of Urban Ventilation Corridors in China

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**Abstract:** "Building urban ventilation corridors" has been written into the overall planning of many cities such as Beijing, but the concept of urban ventilation corridors is not well known yet. Therefore, some misunderstandings were produced such as "Does the construction of urban ventilation corridors require large demolition?" or "Weather it is only be engaged in idle theorizing?" To answer these questions, the existing research results were reviewed and some cases of building urban ventilation corridors in China were analyzed. In this study, some common questions like "What is urban ventilation corridors?" "Why the government need to build it?" "What strategies should be followed?" and "How is the effect?" were answered.

## 1. Introduction

"City General Plan in Beijing (2016-2035)" proposes that five primary ventilation corridors with a width of 500 meters or more will be formed, and multiple secondary ventilation corridors with a width of 80 meters or more will be formed by 2035. And network system of ventilation corridor will be formed in the long term. The area assigned to the ventilation corridor shall strictly control the construction scale, and gradually open up the key nodes that hinder the corridor connection.

Not only Beijing, but Chengdu, Jinan, Nanjing, Shaoxing and other places are planning to build urban ventilation corridors [1]-[5]. As a new and unfamiliar concept, urban ventilation corridors are not well known. People can't help but wonder what exactly is a ventilation corridor? Why is it necessary to "build a ventilation corridor system" when building a livable city and an ecologically civilized city? Will there be major demolition and construction during the construction of the ventilation corridor? Is the ventilation corridor just an empty talk? This article will introduce several such issues in detail.

## 2. What is an Urban Ventilation Corridor?

Although the ancients were limited by the level of science and technology, they paid attention to the natural view of "the harmony between man and nature" and fully considered the climatic conditions to build a city. Nowadays, the development of science and technology has created modern civilization, and



at the same time it has broken the constraints of the natural environment. Urban construction has become more and more intensive and sprawling, disorderly and invisible, causing significant changes in the local climate and causing problems for today's cities. Urban construction and human activities generate a large number of heat sources. At the same time, dense buildings weaken the air circulation capacity in the city. The heat is continuously generated but can't be discharged in time, and the air pollution is not effectively exchanged. This makes the urban micro-climate form a vicious circle. A series of climate issues such as "urban heat island" and "weak urban wind" will ultimately affect the comfort and livability of the city [6]-[10]. For example, since 2000, the area of Beijing's urban area has increased by about 1.6 times, while the area of heat islands has increased by about 2 times. At the same time, the heat islands in the central urban area and the western part of Tongzhou (the sub-center) and the northern part of Daxing (the new airport) have a tendency to concatenate, which is in line with the direction of city expansion. By the end of 2017, the area of heat island in the six districts of the city is 1115 km<sup>2</sup>, accounting for 80% of the total area of the six districts [6] (Figure 1). Long-term residence here will inevitably affect the livability of the city and be also detrimental to the sustainable development of the city.

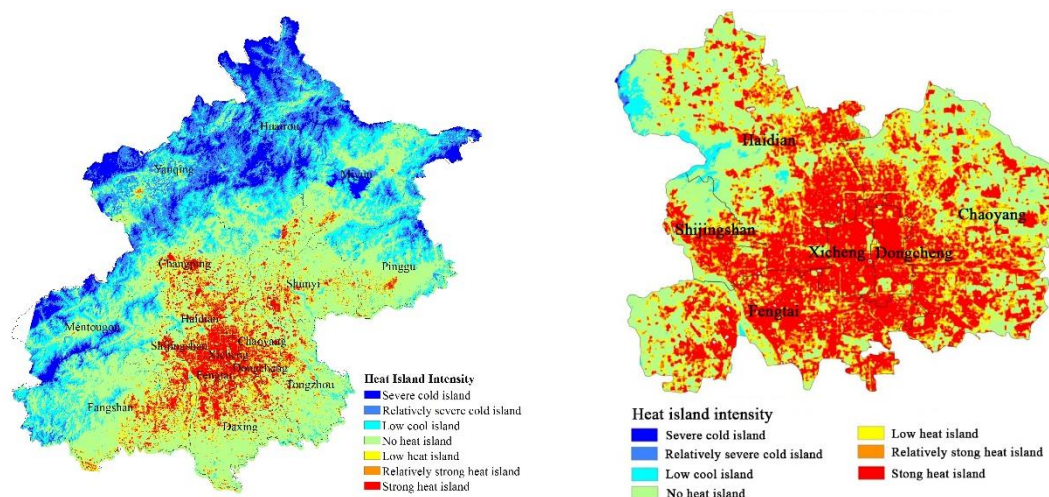


Fig. 1 The results of remote sensing monitoring of the heat island intensity in Beijing (left) and Chengliu District (right) on July 10, 2017

However, it can be seen from Figure 1 (on the right) that the Guomao CBD in the strong heat island area has Olympic forest park in the north, Tiantan Park in the south, Beihai Park in the west, and the East Fourth Ring Green Belt in the east. There is also fresh breeze in these parks in summer, with the temperature significantly lower than that of the CBD, which is 10 kilometers away. If natural wind blows the "cold air" into the "cement forest", wouldn't it not only save energy and protect the environment, but also improve the urban climate environment?

The idea of building urban ventilation corridors came into being. At the beginning of urban construction planning, through reasonable climate analysis, combined with urban topography and land layout, a certain passageway can be reserved in the city to guide natural wind through the urban construction area, so as to improve urban air mobility, and promote air exchange in the suburbs, thereby it can alleviate urban heat islands, reduce building energy consumption, and improve urban livability. These corridors allow natural wind to flow better in the city, that is, "urban ventilation corridors" [11]-[12].

In terms of urban ventilation environment research, Stuttgart in Germany can be regarded as a model of urban-scale ventilation corridor research and application. It divides the urban ventilation system into action space, compensation space and air guidance channel, and forms relevant planning guidelines and technical standards, which is applied in city's developing. Japan has planned a five-level ventilation system by analyzing the sea and land breeze, valley breeze, and park breeze in the capital Tokyo Bay to alleviate the climate problems of high-density cities [13]-[14]. China has experienced 40 years of rapid

urbanization development. The scale of urban construction, urban population, geographic environment and other characteristics are quite different from those of foreign countries, so do the planning strategies for ventilation corridors. How to construct urban ventilation corridors scientifically, reasonably and effectively in China is an issue of concern to all walks of life. This article will introduce in detail.

### **3. How to Construct "Urban Ventilation Corridor"**

#### *3.1 Technical Theory*

China's construction of urban ventilation corridors currently has a relatively mature technical system. Firstly, it assesses the urban thermal environment, learns about the distribution of heat island clusters, identifies areas that need improvement, and discovers ecological cold sources that can produce fresh air. Secondly, it assesses the city's background wind field, analyzes the city's dominant wind and local circulation, and determines the direction of the main ventilation corridor and the local ventilation corridor. Then, by evaluating the city's surface ventilation potential, it identifies that the belt-shaped areas in the city with greater ventilation potential and finds the available ventilation context. Finally, it combines the current status of urban land use and planning and layout, constructs reasonable ventilation corridors to connect ecological cold sources, runs through the heat island area and small wind areas, improves the air circulation capacity within the city, divides the urban heat island, and prevents the heat island from intensifying and contiguous development.

In addition, the construction of ventilation corridors should respect the existing pattern of the city, and should not be demolished and built. It is required to protect and repair the existing areas of the city with better ventilation environment, reserve and increase ecological land. The area divided into the ventilation corridor should be kept as open as possible, and the construction scale, building height, density and arrangement method should be controlled. For some key nodes that are not conducive to the construction of corridors, they will be gradually updated in combination with the deconstruction of urban functions and comprehensive management.

The above theories need to be combined with the actual characteristics of the city to carry out related work. Taking Beijing as an example, the following paper introduces in detail the construction methods of urban ventilation corridors.

#### *3.2 Detailed Case Explanation: Construction of Ventilation Corridors in Central Beijing*

##### *3.2.1 Thermal Environment Assessment*

Figure 1 shows the distribution of heat islands throughout Beijing. It can be seen from Figure 1 (on the left) that Beijing's heat islands are mainly concentrated in the central urban area and satellite cities in various districts. There are no heat islands in the surrounding mountainous areas and rural areas. Further focusing on the central urban area of Beijing (on the right of Figure 1), it is found that the six districts of the city are concentrated and contiguous, accounting for 80% of the total area of the six districts of the city.

However, there are also some weak cold islands in the sixth district of the city, such as Olympic forest park and Kunming Lake. These areas of water, woodland, farmland and urban green space are called ecological cold sources, which can reduce the surrounding temperature, increase humidity, and improve the local climate environment of the city. They are the most important resources used by the urban ventilation corridors. The intensity of the ecological cold source depends on two aspects. The one is the comprehensive reflection of the vegetation leaf area index, vegetation coverage and the green quantity of the vegetation structure, which can be obtained through satellite reflectivity. The other one is the land use type. According to this, the distribution of ecological cold sources in Beijing area is obtained, as shown in Figure 2 <sup>[6]</sup>.

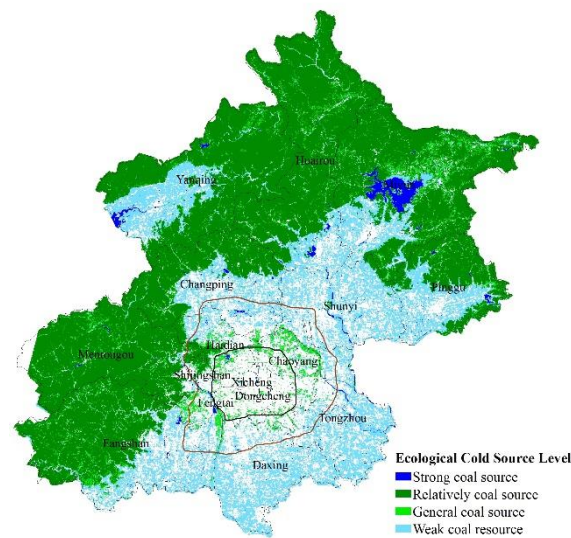


Fig. 2 Distribution of Ecological Cold Sources in Beijing Region, 2017<sup>[6]</sup>

It can be seen from Figure 2 that the waterbody is a strong cold source, and the woodland is a relatively strong cold source. There are large areas of cold sources in the north and west of Beijing urban area, which are the key objects to be used when constructing corridors. There are also a certain number of strong or general cold sources in the central city, mainly composed of small water bodies, forest parks, and green spaces. Therefore, when planning corridors in the central urban area, it is necessary to connect the cold sources effectively and reasonably. Which cold sources to choose and how to connect is the next step to be studied.

### 3.2.2 Assessment of Prevailing Wind Direction

The construction of the ventilation corridor needs to analyze the wind direction that can be effectively used to provide a basis for determining the direction of the ventilation corridor. It consists of two parts, that is, analysis of the city's dominant wind direction and local circulation affecting small areas. The theoretical basis is that when the angle between the direction of the ventilation corridor and the dominant wind direction is not more than  $30^\circ$ , the ventilation and air movement in the city can be maximized. Therefore, the direction of the main corridor should be close to the dominant wind direction of the city. Affected by topography, underlying surface, etc., there are local circulations (valley breeze, land and water breeze, etc.), and local wind field characteristics can be used to construct local ventilation corridors according to local conditions <sup>[15]</sup>. More vividly, the ventilation corridor can be compared to the veins of leaves. The main direction of the leaves is the main ventilation corridor, which conforms to the prevailing wind direction of the city, plays a role in attracting wind, and introduces the fresh air of the mountains, rivers, forests, lakes into the city. In the interior of the city, the local ventilation corridors are like leaf veins, which makes wind directly flow into different areas inside the city, and plays a role in guiding the wind and dissipating heat and preventing the urban heat island from being connected.

Scholars first analyzed the prevailing wind direction in Beijing, with the results shown in Figure 3 <sup>[6]</sup>. As can be seen from the figure, the frequency of annual southwest wind (SSW) is highest in Beijing urban area, followed by north wind (N) and northeast wind (NE). The frequency of northwest wind (NNW) is highest in winter in January, and the frequency of south wind (S) is highest in summer in July. As for Beijing, there are many ecological cold sources in the north, such as mountainous areas, woodlands, and green spaces. The northerly wind is the main source of clean air. Therefore, the main direction of ventilation corridor can be determined to be from north to south.



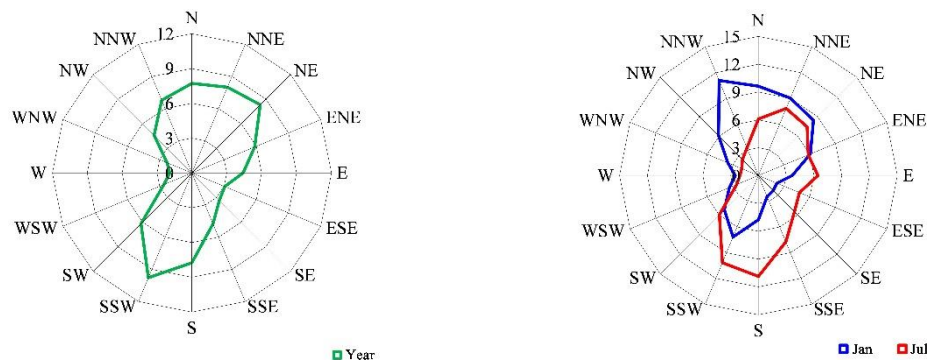


Fig. 3 Wind Observation Map of Beijing Observatory in the Past 30 Years<sup>[6]</sup>  
(Left: Annual wind rose illustration Right: wind rose illustrations of January and July)

Due to the large area in Beijing and the different underlying surface layouts, the dominant wind direction of each region varies. In order to make better use of the local wind field, scholars analyzed the 10-minute average wind speed and wind direction data of the national meteorological observatories (Chaoyang, Haidian, Fengtai, Shijingshan) from 2010 to 2014 (picture omitted) in 4 representative areas in different directions within the Beijing Fifth Ring Road, which showed that there are certain differences in the dominant wind direction of different stations. Haidian in the north is dominated by northeast winds, Fengtai in the south is dominated by southwest winds and west winds, and Shijingshan in the west is dominated by south, west and northeast winds <sup>[6]</sup>. Therefore, the direction of local corridors in different areas of the city can be constructed by the dominant wind direction in each area.

### 3.2.3 Potential Assessment of Ground Surface Ventilation

As mentioned above, even within the six districts of Beijing, there are small ecological cold sources such as Xiangshan Park, Kunming Lake, Olympic forest park, and Chaoyang Park. By assessing the city's surface ventilation potential, the most suitable connection with these ecological cold sources can be found on the determined corridor direction. The former is the height at which the wind speed of the near-surface layer decreases downwards to zero hour. The roughness of the ground surface can be used to find the most suitable connection of these ecological cold sources in the determined corridor direction by evaluating the urban surface ventilation potential. The higher the roughness value, the greater the obstacle to local air circulation. The latter refers to the degree of obscuration by surrounding buildings or the environment. The smaller the value, the more obscured the sky. The above two indicators are calculated through satellite remote sensing data and building information <sup>[16]-[20]</sup>. The results show (the figure omitted) that the high-value areas of surface roughness are mainly located in the North Fifth Ring Road to the South Fourth Ring Road, and the East Fourth Ring Road to the West Fourth Ring Road, with an average value higher than 1 meter, among which the roughness of some areas such as CBD is higher than 2 meters. The low-value areas of sky openness are mainly concentrated within the Fourth Ring Road. Some areas such as CBD, Financial Street, and Zhongguancun have values as low as 0.35, which quantitatively proves the poor ventilation environment between tall buildings <sup>[6]</sup>. Scholars further combined the two and gave a method to evaluate the surface ventilation potential <sup>[21]</sup>, and obtained the distribution of surface ventilation potential in the urban area of Beijing and its surrounding areas (Figure 4) <sup>[6]</sup>. The results showed that most ecological cold sources have good ventilation potential. At the same time, river courses and wide streets also have high ventilation potential, which can all be used as ventilation corridors with series cold sources.

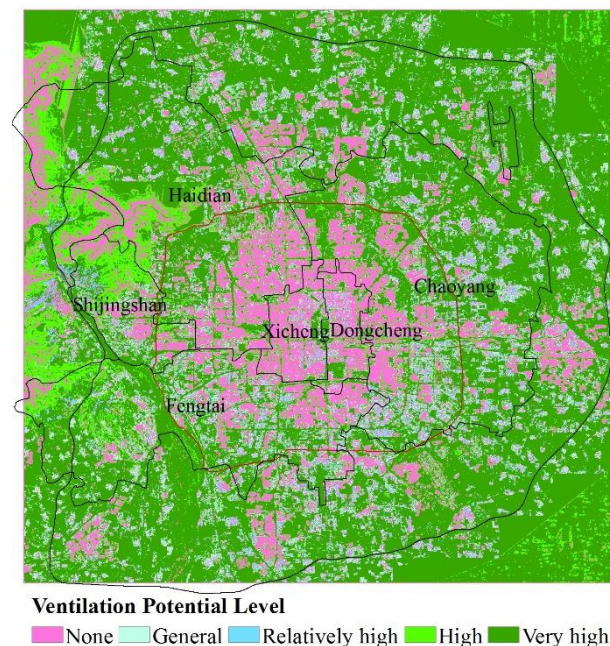


Fig. 4 Distribution of ventilation potential in urban and surrounding areas of Beijing<sup>[6]</sup>

### 3.2.4 Analysis of Construction Strategy of Beijing Ventilation Corridor

After the above analysis, we can understand the construction strategy of the ventilation corridor in the central city of Beijing (Figure 5).

There are five first-level corridors, all of which follow the prevailing wind direction of Beijing from north to south. It takes the corridor of “improving the ventilation environment of the area along the Jiuxianqiao-CBD” (the second main corridor from the right in Figure 5) as an example to illustrate the construction strategy. The corridor starts from Qinghe Country Park, ends at the Beijing-Shanghai Expressway and the green belts on both sides, passing by Chaolai Forest Park, Sun Palace Park, Chaoyang Park, the green space of the Northeast Fifth Ring Road, and the southeast Fenzhong Temple. These cold sources can continuously provide fresh air for the corridor. The East Fourth Ring Road connects these cold sources and guides the continuous flow of the air, that is, wide and continuous roads have high ventilation potential, which is an important resource for building ventilation corridors without affecting the existing layout of the city.

In addition, the water itself is an excellent ecological cold source, and at the same time, due to thermal differences, there is always an effective wind that can be guided by the corridor around it. If there is a long river in the city and its flow direction is similar to that of the corridor, it can be used as an excellent ventilation corridor. The corridor for “improving the ventilation environment in the northwest” was built on this basis (the second main corridor from the left in Figure 5). It starts from the botanical garden, extends southeast along the Kunyu River, and finally Yuyuantan, passing through Kunming Lake, Zizhuyuan Park and other ecological cold sources, There are “cool breeze” and beautiful scenery along the way.

Finally, the secondary corridor in the southwest corner of the city is analyzed. Affected by geographical conditions, large water bodies can bring about obvious local circulation, with the southwest wind prevailing in the southwest of the city and the Yongding River passing through the city. Based on such conditions, the water body itself can be used to construct a corridor, or wide road networks such as Yongding River Bridge, Yuquanying Bridge, and Beijing-Shanghai High-speed Railway can be used to make the corridor eventually run through the cold source along the way to achieve the purpose of air exchange.

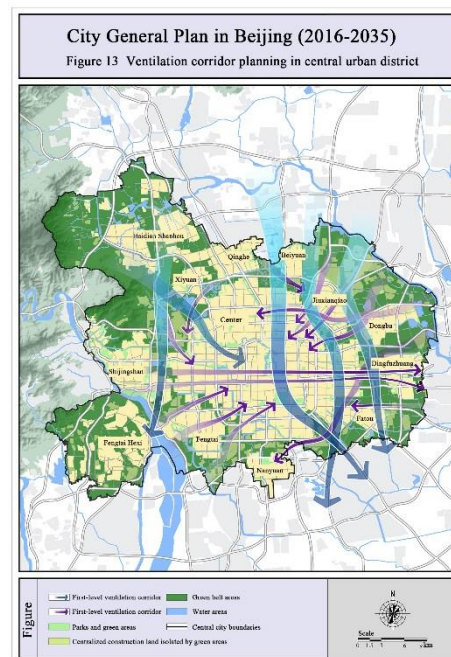


Fig. 5 Beijing Urban Ventilation Corridor Planning

### 3.3 Brief Case Description: Construction characteristics of ventilation corridors in other cities

In addition to Beijing, other domestic cities have also carried out similar construction of ventilation corridors. Its essence and technical theory are consistent with those of Beijing, but there are some differences in actual planning. It is necessary to adapt measures to local conditions according to the city's topography, topography and layout.

#### 3.3.1 The Construction Plan for Ventilation Corridor in Chengdu

The urban ventilation corridor planning scheme of Chengdu is shown in Figure 6 [2, 6]. It can be seen from the figure that the ventilation corridors in Chengdu are mainly north to south. At the same time, there is a first-level corridor from southeast to northwest in the southeast area, due to Chengdu's unique topographical wind and city construction.

In the Chengdu area, the dominant wind direction is northeast wind, and the secondary dominant wind direction is north wind. Northwest wind prevails in mountainous areas such as Dujiangyan in the northwest. However, southwest wind prevails in the southeast Pujiang and other places in summer. In order to enhance the summer ventilation effect of the city, a main corridor from southeast to northwest is planned in the southeast area.

Secondly, compared with Beijing, the inner city of Chengdu is more compact, with broad green areas, water bodies or roads within the third ring road. The wide corridors from north to south can't directly penetrate the city. Thus, after extending the first-level corridor (above 500 meters in width and more than 5,000 meters in length along the dominant wind direction) to the periphery of the urban area, it connects the second-level corridor (above 50 meters in width and more than 1,000 meters in length along the dominant wind direction) through the urban area.

In summary, the construction of Chengdu's urban ventilation corridor embodies the idea of "adjusting measures to local conditions".



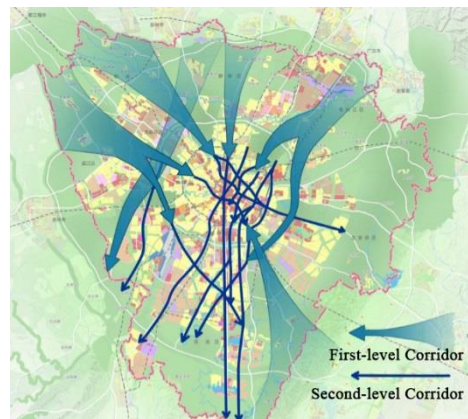


Fig. 6 Chengdu Urban Ventilation Corridor Planning [2,6]

### 3.3.2 The Construction Plan for Ventilation Corridor in Jinan

The southern part of Jinan is hilly, which is a natural large-scale ecological cold source, while there is a large body of water (Yellow River) passing through the city in the north, which is also a natural ecological cold source. There are also a large number of available small-scale cold sources in the city (Jinan also called "Spring City", with dense natural water bodies inside the city). Therefore, Jinan's ventilation corridor planning focuses on how to connect these cold sources.

The ventilation corridor of Jinan City finally planned by the scholars is shown in Figure 7 [3,6], which fully embodies the concept of connecting ecological cold sources.

The plan divides the city into dozens of small areas through 3 main corridors and 11 secondary corridors, and introduces fresh cold air from the north and south sides into the urban area to effectively alleviate the heat. At the same time, large wetland parks are used to connect the corridors that have not yet been penetrated, taking into account the practicality of urban construction planning.

In addition to Jinan, scholars also make full use of natural cold sources, such as large water bodies and hills and mountains when planning ventilation corridors in other cities. The corridor planning of Jiangbei New District in Nanjing [4, 12] and Shaoxing City [5] also reflects this kind of idea.

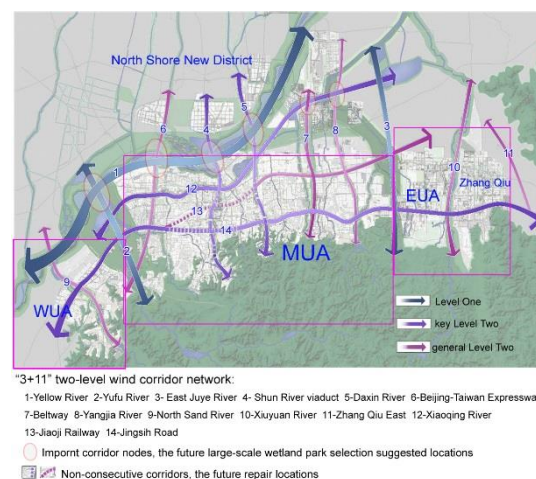


Fig. 7 Ji'nan Urban Ventilation Corridor Planning [3,6]

## 4. Effect Verification of Urban Ventilation Corridor

The "ventilation and cooling" effect of the corridor is the focus of research [1]. The researchers conducted the research on August 26-27, 2015 (typical summer sultry weather) through a mobile meteorological observation station around the Kunyu River ventilation corridor in Beijing. The observation points of

comparing the observation experiment were located in the corridor area (Station 1) and non-corridor area (Station 2). After 24 hours of uninterrupted observation, hourly temperature and wind speed data at two stations were obtained, with results shown in Figure 8. In terms of wind speed (on the left of Figure 8), the wind speed at station 1 is generally greater than that at station 2 during the observation period, especially when the wind speed is greater than 0.6m/s, the average wind speed (1.11m/s) at the observation point of the ventilation corridor is significantly greater than that of the non-corridor observation point (0.8m/s). However, when the wind speed is small or still (wind speed <0.2m/s), the difference in wind speed between the two observation points is not large. The above shows that under the background of medium and small wind speeds, the ventilation corridors can significantly increase the wind speed, but when the wind is still or close to still, the influence of the corridors on the wind speed is not obvious.

In terms of temperature, the daytime temperature at Station No. 1 (27.9°C) was significantly lower than that at Station No. 2 (29.2°C), indicating that the corridor has a significant cooling effect. At night, due to the larger specific heat capacity of the water in the corridor area, the cooling temperature is slower, while the asphalt pavement in the non-corridor area cools down quickly, resulting in a slightly higher temperature at station 1 than at station 2, with fewer differences. Even so, considering that there is still more obvious air flow near the corridor at night, the body comfort is still better than that at the surrounding areas.

In summary, the actual observation results show that the wind speed near the ventilation corridor is higher than that among the building groups, and the daytime temperature is lower than that among the building groups, which has a certain effect on improving the local climate environment of the surrounding areas.

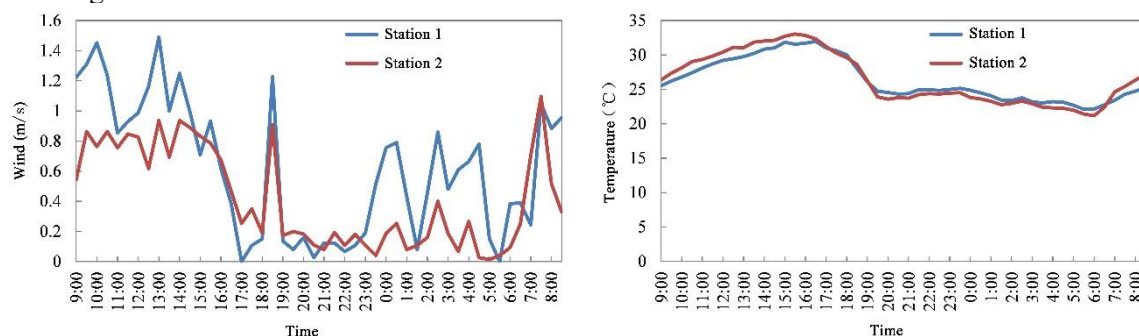


Fig. 8 Results of wind speed and temperature from corridor observation point and non-corridor observation point<sup>[1]</sup> (Left: wind speed; Right: temperature)

## 5. Conclusion

The above gives a more detailed introduction to China's urban ventilation corridors. Obviously, the purpose of constructing ventilation corridors is not to "blowing fog and haze", but to make urban areas and suburbs, cement forests and surrounding green spaces better. The "ventilation" of the city can achieve the purpose of alleviating heat islands, saving energy and reducing emissions, and improving the livability of cities.

At present, China has also formed a relatively mature urban ventilation corridor construction strategy, which can be roughly divided into four categories, that is, assessment of urban thermal environment, analysis of dominant winds in different regions, assessment of urban surface ventilation potential, and planning of ventilation corridors based on urban terrain conditions and land use layout. Each step has a relatively complete research method, which provides theoretical and technical basis for the construction of ventilation corridors in various cities in the future. The construction of ventilation corridors in many cities shows that in the face of the increasing urban heat island phenomenon, we are not helpless. As long as we make full use of the dominant wind and local circulation in different regions, we will have the opportunity to connect the ecological cold sources in the city, and then divide the heat island area to alleviate the heat island effect. Field observations also prove that the climatic conditions near the

corridor are more livable.

In summary, the construction of a ventilation corridor does not require major demolition and construction. It is more to reflect the idea of harmonious development between man and nature in urban construction planning, make full use of the existing natural resources of the city, and let the air flow in the city at a lower cost, so as to cool the increasingly "hot" city via natural wind.

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