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Complex Environmental Characteristics of Coastal Salt Spray Area and Effect of Carbon Dioxide Content on Corrosion of Steel Bars

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Abstract: In the coastal atmospheric environment, corrosive media exists due to natural and man-made pollution, which has a great impact on the durability of concrete structures. Taking the environment of Shenzhen coastal salt spray area as an example, the environmental parameters were observed on site, and the content of carbon dioxide in the atmosphere was measured. The influence of steel corrosion on steel was analyzed. The study found that the annual temperature change range of the coastal salt spray area is 15 ℃ to 37.9 ℃, and the change is first rising and then decreasing. The temperature rises in the first half of the year, and the temperature gradually decreases in the second half of the year. The highest humidity in the measurement area is 74.7%. The minimum is 56%, and the overall level is maintained at a high level, which is between 55% and 75%. The carbon dioxide content of the five measuring points is consistent throughout the year, and the carbon dioxide content is high in spring and winter.

1. Introduction

In the construction of marine and coastal structures, concrete and steel are currently used as building materials. In most environments, the normal service life of concrete structures is long. However, due to the harmful medium in the environment, it will penetrate into the interior of the concrete structure, and some chemical reaction will occur in contact with the saturated solution of calcium hydroxide and cement hydration products. May cause premature failure of concrete structures [1,2]. In the coastal environment, due to natural and man-made reasons, there are many corrosion factors, which have a great influence on the durability of materials. Among them, sulfur dioxide, acid rain and chloride ions have great influence. Since concrete is a porous material, there are often defects such as capillaries, pores, and bubbles in its interior, which have a certain gas permeability. The CO2 in the air first penetrates into the pores and capillaries filled with air inside the concrete, and then the liquid phase dissolved in the capillary interacts with substances such as calcium hydroxide and hydrated calcium silicate produced during the hydration of the cement to form carbonic acid [3,4]. Calcium hydroxide is one of the main hydration products of cement. For ordinary Portland cement, the calcium hydroxide formed by hydration can reach 10% to 15%. On the one hand, calcium hydroxide maintains the high alkalinity of concrete, and on the other hand, it is one of the most unstable components in concrete, and it is easy to neutralize with acidic media in the environment, thereby carbonizing concrete. During the carbonization process, the calcium hydroxide in the concrete is consumed, which may cause damage to the passivation film of the steel bar, thereby causing corrosion of the steel bar.

Shenzhen is located in southern China and is a typical marine atmosphere. To analyze the impact of environmental factors on structural durability, it is necessary to first define the coastal environmental

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parameters. In this paper, the station is set up in the coastal salt fog area, and the humidity, temperature and carbon dioxide content are observed. It has certain practical significance for studying the durability of the concrete structure in the coastal salt spray area.

2. Experiment

In Shenzhen, the salt spray area environment was selected, an observation station was set up on site, and measuring points were set at 0, 100, 200, 400, 1000 meters from the coastline. The carbon dioxide concentration, temperature and humidity of the salt spray area were measured by a carbon dioxide meter. The measurement time of each measurement point is 5 minutes, and the measurement results are stable and recorded.

3. Results and Analysis

3.1. The variation Law of Temperature in Coastal Salt Spray Area

Table 1. Temperature changes in Shenzhen from 2016 to 2018

Year	Average temperature/ ℃	Maximum temperature/ ℃	Minimum temperature/ ℃
2016	23.2	36.7	1.7
2017	23.2	36.9	7.4
2018	23.4	35.6	4.2

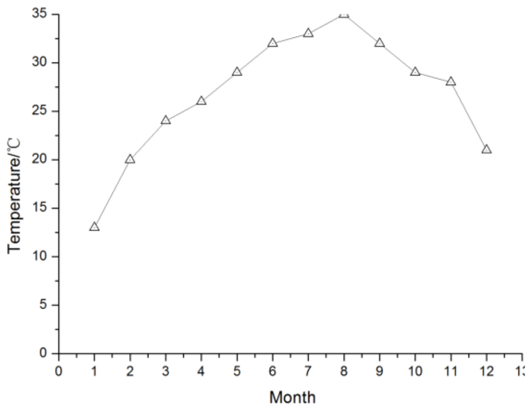

Figure 1. Average temperature of the measuring point as the month

The annual average temperature reaches 23 degrees Celsius, and the highest temperature from 2016 to 2018 is 36.9 degrees Celsius and the lowest is 1.7 degrees Celsius. In view of the high temperature characteristics of Shenzhen, it has a significant impact on the durability of concrete. The corrosion of steel bars in concrete is a dynamic electrochemical process. The corrosion rate is mainly controlled by environmental factors, besides the influence of its own materials. It mainly includes factors such as ambient temperature and relative humidity. The following is the change of temperature in the coastal salt spray zone from the temperature records of each measuring point through one year.

The temperature changes of the five measuring points in the coastal salt fog area are basically the same. The annual temperature change range is from 15 ℃ to 37.9 ℃, and the change is first rising and then decreasing. The temperature in the first half of the year is rising continuously, and the temperature is gradually decreasing in the second half. 1,2,3,4,5,6,11,12 months, the temperature is lower, the temperature is higher in July, August and September, which is in line with the subtropical maritime climate in the coastal areas of Shenzhen, which is characterized by the cold spring and winter and the hot summer and autumn. From January to December, the temperature in the construction area of the west port area is 37.9 ℃, the lowest is 13.9 ℃, the lowest temperature in January, and the highest temperature in August.

3.2. Change Law of Humidity in Coastal Salt Spray Area

Table 2. Changes in rainfall and humidity in Shenzhen from 2016 to 2018

year	Total rainfall /mm	Rainy days/d	Average relative humidity
2016	2490.6	153	79
2017	1967.1	127	77
2018	1957.2	121	76

Shenzhen is the rainy season from May to September every year. The average rainfall from 2016 to 2018 is 2490.6 mm, and the annual average relative humidity is 77.3%. The environmental humidity has a great influence on the micro-environment inside the concrete, which determines the size of the pore water saturation inside the concrete, and has the resistivity of the structural concrete, the diffusion rate of oxygen inside the structure, and the supply of corrosion reaction electrochemical corrosion. Larger impact, which has an effect on the corrosion rate of the steel. Shenzhen is a high-humidity environment with an annual average relative humidity of about 77%. It is above the critical humidity for most of the year, so it provides sufficient conditions for the electrochemical corrosion of steel bars, which is highly prone to humid atmospheric corrosion.

According to annual observations and records, the highest humidity in the measurement area is 74.7%, the lowest is 56%, and the overall level is maintained at a high level, about 55% to 75%. The changes in humidity at the five measuring points were basically the same. The humidity gradually increased in the first half of the year and the humidity dropped in the second half. The higher humidity months are concentrated in summer and autumn. In the second and third quarters, rainfall is abundant, the temperature is humid and hot, and the relative humidity is between 70% and 75%. The overall temperature is high, and the month is generally characterized by high temperature and rain. In the first quarter and the fourth quarter, the rainfall is relatively small, the temperature is dry and cold, and the relative humidity is between 60% and 65%, which is low overall.

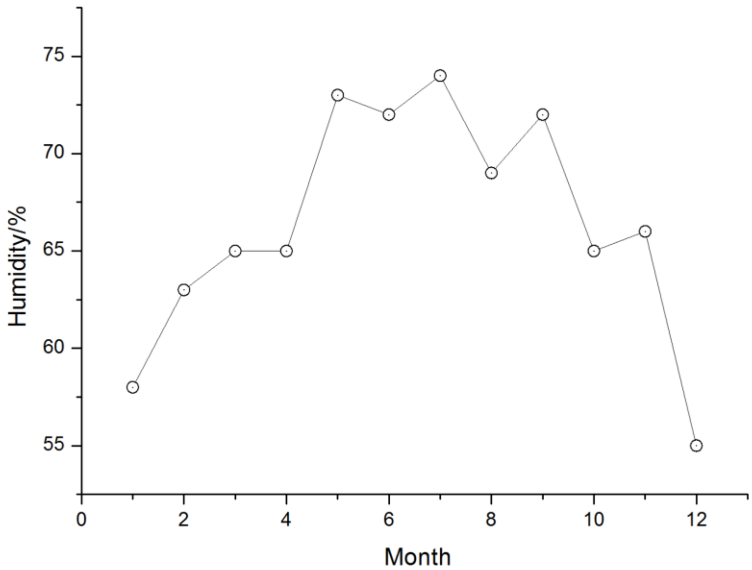

Figure 2. Average humidity as a function of the month

3.3. Factors Affecting Carbon Dioxide Content in Coastal Salt Spray Area

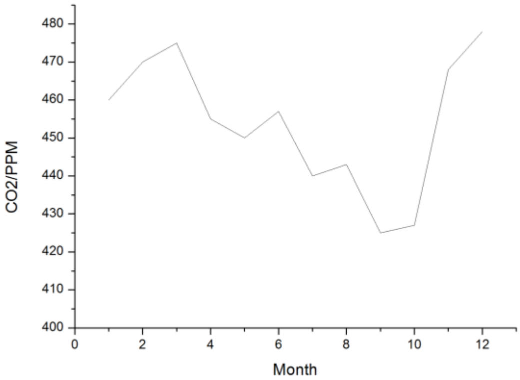

Figure 3. Carbon dioxide content of measuring point one changes with the month

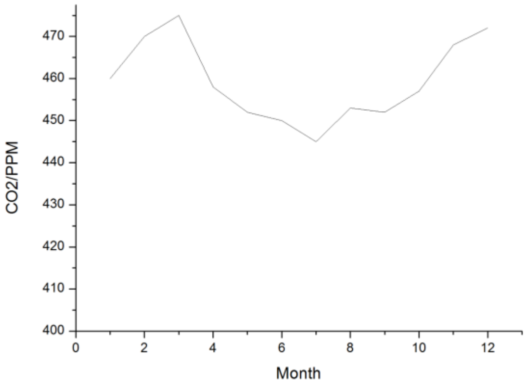

Figure 4. Carbon dioxide content of measuring point five changes with the month

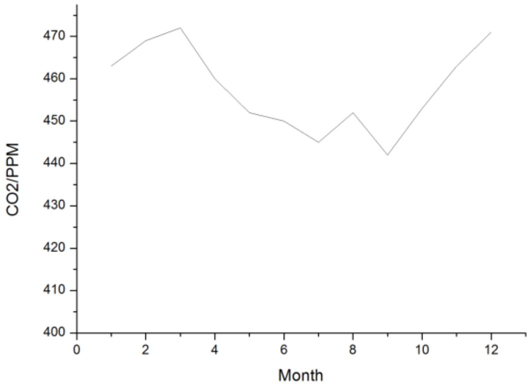

Figure 5. Average carbon dioxide content in the survey area as the month

The carbon dioxide in the coastal salt spray area will cause carbonization of concrete. The carbonization of concrete refers to the action of acid gas such as CO2 and SO2 in the air and calcium hydroxide in the liquid phase of concrete, and the neutralization process of CaCO3 and H2O [5,6]. In the coastal environment, there are many corrosion factors. It is of great significance to study the atmospheric carbon dioxide content and the influencing factors on the durability of concrete structures. The following is a measure of the variation of carbon dioxide content at each measurement point with the month and weather.

The change of carbon dioxide content in the five measuring points is consistent in the whole year, the carbon dioxide content in spring and winter is higher, and the carbon dioxide content in summer and autumn is lower; however, the change of carbon dioxide content in each measuring point is small, and each test in the same month The carbon dioxide content is similar. It can be seen that in the case of a small area, the carbon dioxide content of each place is basically at the same level. The carbon dioxide content in this area is basically between 460 (ppm) and 480 (ppm). From the average carbon dioxide year of Figure 5, it can be seen that the carbon dioxide content of spring air in Shenzhen is the highest in March, and the lowest overall content in July, August and September is between 450 and 480 (ppm); the carbon dioxide content is rising from January to March. After that, it continued to drop to September, and then continued to rise to December. During the whole year, the content of carbon dioxide is high in autumn and winter, and the land vegetation is reduced accordingly. The photosynthesis is reduced and the carbon dioxide content is high. The annual carbon dioxide content is low in spring and summer, and the land vegetation increases during the period. The effect is increased and the carbon dioxide content is low. Second, affected by the monsoon, the spring and summer winds blow from the sea to the land, bringing a lot of oxygen; the autumn and winter winds blow from the land to the sea, and the carbon dioxide content increases accordingly.

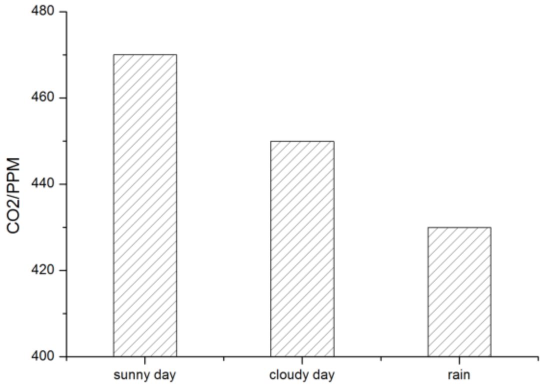

Figure 6. Effect of weather on carbon dioxide content

Figure 6 analyzes the effect of weather on carbon dioxide content, with the highest carbon dioxide content in sunny days, followed by cloudy days and rainy days. Because carbon dioxide is soluble in water, the air humidity in the rain is high and the air pressure is high, so the carbon dioxide content in the air is low. The difference between the carbon dioxide content of sunny days and cloudy days is about 20 ppm, and the difference of carbon dioxide content between sunny days and rainy days is about 40 ppm.

4. Conclusion

1. The average annual temperature from 2016 to 2018 is above 23 degrees Celsius, the maximum temperature is 36.9 degrees Celsius and the lowest is 1.7 degrees Celsius. The temperature changes of the five measuring points in the coastal salt spray area are basically the same. The temperature in the first half of the year is rising continuously, and the temperature is gradually reduced in the second half of the year.

2. The highest humidity in the measurement area is 74.7%, the lowest is 56%, and the overall temperature is maintained at a high level, about 55% to 75%. The humidity changes of the five measuring points are basically the same, and the humidity gradually rises in the first half of the year. The humidity will drop in the second half of the year.

3. The change of carbon dioxide content in the five measuring points is consistent in the whole year. The carbon dioxide content in spring and winter is high. The carbon dioxide content in summer and autumn is low. The carbon dioxide content in sunny air is the highest, followed by cloudy days and rainy days.

5. Acknowledgement

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