Analysis of Climatic Characteristics and Multiple Corrosion Factors of Salty Spray Environment in Shenzhen

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Abstract: In the coastal salt fog area, there are many sources of atmospheric corrosion in the ocean. For the concrete structure, the effects of carbonization, sulfate, chloride and other complex effects should be considered. The experiment was carried out by setting up a station in the coastal salt fog area of Shenzhen, and the carbon dioxide and chloride ion content in the atmosphere were observed on the spot. The study found that the coastal environment of Shenzhen has the characteristics of high temperature and high humidity, and the rainfall is large. The average temperature in the past five years has reached 23.5 degrees Celsius and the average humidity has reached 75.4%. The atmospheric carbon dioxide content in the coastal salt spray area is higher in spring and winter, and lower in summer and autumn. The atmospheric chloride ion concentration in the coastal salt spray area is characterized by high winter and low summer temperatures throughout the year, and the annual chloride ion concentration fluctuates greatly.

1. Introduction

From the global perspective, there are a large number of coastal areas. In the coastal environment, there are many corrosive factors in the atmosphere, which will adversely affect the durability of the reinforced concrete structure, which may lead to structural safety problems. Premature failure of concrete structures is caused by a certain chemical reaction between the harmful medium in the environment and the calcium hydroxide and cement hydration products in the concrete, resulting in changes in the internal components of the concrete [1]. Concrete may gradually lose gelation.

There are many corrosive factors in the coastal environment. Concrete is a non-uniform, porous solid, liquid and gas three-phase composite material. Corrosion ions in the environment will enter the structure through the pores of the concrete [2, 3]. Shenzhen is located in the south of China and belongs to the typical marine atmosphere. There are a large number of reinforced concrete buildings located in the coastal salt fog area. It is necessary to consider the effects of carbonation and chloride ions. When analyzing these factors, it is necessary to understand the main areas of the coastal salt spray area, the content of corrosive ions. In this paper, a field observation station is set up in the coastal salt fog area to measure the content of chloride ion and carbon dioxide in the salt spray zone. It has certain practical significance for analyzing the durability of the concrete structure in the coastal salt spray area.

2. Experiment

An environmental observation station was set up in Shenzhen to measure the content of chloride ions and carbon dioxide in the atmosphere. The distance between the measuring points and the coastline is 200 meters.
3. Results and Analysis

3.1. Shenzhen Coastal Environmental Climate Characteristics
Shenzhen is located south of the Tropic of Cancer, east longitude 113°46' to 114°37', north latitude 22°27' to 22°52'. It is located in the south of Guangdong Province, east to Daya Bay and Dapeng Bay, west to the Pearl River Estuary and the Boyang Sea. It is a subtropical maritime climate zone with mild climate, abundant rainfall and long sunshine hours. This paper collected the main meteorological data from 2014 to 2018 from the website of Shenzhen Meteorological Bureau.

Table 1. 2014-2018 Shenzhen meteorological data

| Year | Average temperature/°C | Maximum temperature/°C | Minimum temperature/°C | Total rainfall/mm | Rainy days/d | Average relative humidity/% |
|------|-------------------------|-------------------------|-------------------------|-------------------|--------------|----------------------------|
| 2014 | 23.2                    | 35.0                    | 4.4                     | 1725.5            | 129          | 73                         |
| 2015 | 23.9                    | 36.2                    | 8.6                     | 1500.8            | 123          | 72                         |
| 2016 | 23.2                    | 36.7                    | 1.7                     | 2490.6            | 153          | 79                         |
| 2017 | 23.6                    | 36.9                    | 7.4                     | 1967.1            | 127          | 77                         |
| 2018 | 23.4                    | 35.6                    | 4.2                     | 1957.2            | 121          | 76                         |

3.1.1. Temperature and Humidity
From 2014 to 2018, the average temperature is 23.5°C, the maximum temperature is 36.9°C, the minimum temperature is 1.7°C, and the annual average humidity is 75.4%. It can be seen from Fig. 1 and Fig. 2 that Shenzhen has the characteristics of high temperature and high humidity, and the temperature and humidity changes throughout the year are relatively stable, almost at a relatively high level.

Figure 1. Temperature change in Shenzhen coastal environment
3.1.2. Precipitation

The precipitation in Shenzhen is quite abundant. The average precipitation from 2014 to 2018 is 1928.2 mm. The annual rainfall varies greatly, with the most years 2490.6 mm, mainly due to the strong weather and climate in Shenzhen due to the strong El Niño in 2016. It is characterized by “winter cold, hot summer, heavy rainfall, and typhoon and rain”. The accumulated rainfall is nearly 30% higher than the average climate of the same period, 66.0% more than in 2015, 50% more than the past five years, and 68.4% more than last year. A total of 12 heavy rains, 3 heavy rains, and strong convection were recorded. The year with the least rainfall is only 1500.8 mm (2015). In general, 85% of the annual rainfall occurs from April to September, 48% of which is distributed from July to September, with an average rainfall of more than 900 mm; the average rainfall from April to June is more than 700 mm, mainly from cold air and the tropical warm and humid air flow is formed together. The monthly rainfall changes during the year are unimodal, up to August, at least December.
3.2. *Carbon Dioxide Content in Coastal Salt Spray Area*

The cement hydration product is alkaline, and the presence of alkaline components ensures the stability of other hydration components. Carbon dioxide and other acid gas pollutants from the atmosphere react with hydroxides formed in concrete, and these hydroxides are reacted. Conversion to non-alkaline carbonates, causing the pH in the concrete to drop [4, 5], this may damage the passivation state of the reinforcement. Calcium carbonate is deposited in the pores of the concrete, blocking part of the pores. As the reaction continues, the pH in the pores drops to 8.3, and the silicate, aluminate and ferrite become unstable and begin to decompose. It is no longer passivated, and as oxygen and moisture enter the pores, the steel begins to corrode, and carbon dioxide has a greater impact on the durability of the concrete structure.

![Figure 4. Carbon dioxide content in the survey area changes with the month](image)

In the observation area of Shenzhen Binhai, it can be seen from Figure 4 that the carbon dioxide content is higher in spring and winter, and the carbon dioxide content in summer and autumn is lower. The carbon dioxide content in each month does not change much, and it varies from 440 to 470 ppm.

3.3. *Chloride Ion Content in The Atmosphere of Coastal Salt Spray Area*

In the atmosphere near the ocean, seawater droplets containing sodium chloride are mixed into the atmosphere when the water droplets are scattered. The sea breeze and the mist contain a large amount of particles of chloride or NaCl, and the chloride ions accelerate the corrosion of the steel [6]. In general, the high alkalinity of cement hydration produces a dense passivation film on the surface of the steel in the concrete. Previous studies have suggested that the passivation film is composed of iron oxide, but recent studies have shown that the passivation film contains Si-O bonds, which have strong protection for steel bars. Chloride ions are extremely strong depassivating agents. When chloride ions are added to the concrete to reach the surface of the steel bar and adsorbed to the local passivation film, the place can be the pH value is rapidly lowered and the pH of the steel surface is lowered to below 4, thereby destroying the passivation film on the surface of the steel.
Figure 5 shows that the chloride ion concentration is characterized by high winter and low summer temperatures throughout the year. In general, high clustering in 10, 11 and 12 months, low clustering in 4, 5, 6, 7, 8, and September, the annual chloride ion concentration fluctuated greatly.

4. Conclusion
1. In the coastal salt fog area, there are many sources of atmospheric corrosion in the ocean. For the concrete structure, the effects of carbonization, sulfate and chloride ions should be considered.
2. Shenzhen coastal environment has the characteristics of high temperature and high humidity. The average temperature in the past five years has reached 23.5 degrees Celsius and the average humidity has reached 75.4%.
3. The atmospheric carbon dioxide content in the coastal salt spray area is higher in spring and winter, lower in summer and autumn, and little change in carbon dioxide content in each month.
4. The concentration of atmospheric chloride ions in the coastal salt spray area is high in winter and low in summer. The chloride ion content in October, November and December is high, and the chloride ion concentration fluctuates greatly throughout the year.

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