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<th>その他（別言語等）のタイトル</th>
<th>鉱山地域環境での建物表面の腐食メカニズムの研究</th>
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<td>著者</td>
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Research on Corrosion Mechanism of Surface Buildings under the Mining Area Environment

Jianfei LIU *, Weihong CHEN **

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The corrosion mechanics of reinforced concrete have received extensive attention. Taken the surface of structures in the Pingdingshan Coal Group as an example, mining area environment have been investigated in the paper. Based on the analysis on atmospheric environment, water environment and solum environment, the main pollution factors have been obtained. The conclusion that the carbonization and destruction of concrete by freezing and thawing are the main external factors for influencing the concrete durability has been obtained. Furthermore, structures service life is internal factor in designing the building, especially some structures service for resource. Some improving structures durability measures were presented in the paper correspondingly.

Keywords : Mining Area Environment, Reinforced Concrete, Corrosion Mechanics

1 INTRODUCTION

Since the emergence and first practical user of concrete as a building material for industrial purpose in the late nineteenth century, concrete has become one of the most versatile and widely produced materials in the world. Although normally considered by engineers the most durable and soundest of materials, concrete must, under certain conditions, be listed as vulnerable due to various example causes which result in cracking, corrosion of the steel or the chemical deterioration of the paste and the aggregates. In recent years various examples of unsatisfactory durability of concrete structures have been reported. Especially the number of concrete structures exhibiting signs of premature deterioration is rapidly growing.

The durability of concrete can be defined as its resistance to deterioration resulting from external and internal causes. The external causes include the effects of environment and service conditions to which concrete is subjected, such as weathering, chemical action and wear. Many reasons have contributed particularly chlorides, sulphates and aggregate to corrosion, as stated in Durability Design of Concrete. The internal causes are the effects of salts, alkali Structures and Construction Guideline (hereinafter referred to as “Guideline”), it can be classified into five categories depending on different corrosion mechanism of the environment of structure on concrete materials.

However, main corrosion factors are bound to exist in particular environment. At present, more attention is paid on studying of durability of hydraulic architecture and buildings construction in cold region than corrosion of structure in mining area environment. Taking Pingdingshan coal mine environment as an example, this paper makes analysis on corrosion factors of concrete components of ground structure to determine the corrosion mechanism of components in mining area, which services as a basis for reinforcing of structure, also provides reference for new structure design of mining area.
Pingdingshan mining area is located at transitional zone from subtropical zone to warm-temperate zone, which is characterized with transitional climate, monsoon climate is obvious and the four seasons are distinct. Pingdingshan mining area is not only an important base of our country, but also an old mine which is constructed early, currently, with 21 production mine, and through 50 years of coal mining, part of production buildings in mining area have been corroded severely and needs reinforcing as soon as possible.

2 ANALYSIS ON EXTERNAL FACTOR OF CORROSION

2.1 Carbonization of concrete
Under atmospheric environments, the interaction between CO₂ and alkaline substance in concrete is a complex physical and chemistry process. Because concrete is a porous body, there are capillary, hole, bubble with different sizes, or even flaw inside it. When CO₂ in the air infiltrates into the void of concrete, it reacts with carbonatable substance in the hole and produce carbonate or other substance, which can decrease the original strong basicity of cement and accelerate of carbonization of concrete, but also an important reason for decreasing of durability of buildings.

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2.2 Influence of polluted gas on buildings
The mining area is in an industrial production environment, and a large number of polluting substance can be emitted, in order to study the influence of such pollutant on concrete components, we made monitoring on the air environment in mining area. The result is as following table2:
failure. The maximum value of sulfur dioxide slightly exceeds the lower limit, however at most time and place the value does not exceed the limit, so it is supposed that sulfur dioxide has little impact. The monitoring result indicates that mining area environment do not reach extreme pollution standard, the components of buildings in mining area are not shot at right angles by waste gas, that is atmospheric environment in mining area has little impact on concrete components.

2.3 Freezing and thawing failure of concrete
The environment of concrete structure which is featured with alternation of positive and negative temperature, more water content inside the concrete, under such circumstance, freezing and thawing cycle would happen on the concrete, which will lead to fatigue failure \(^{(5,6)}\). Accordingly, freezing and thawing failure of concrete is one of the typical indicator which can influence the durability of concrete. In order to study freeze thawing failure of buildings in mining area, firstly, we collect meteorological data in recent years, it is showed that: in recent 40 years, the highest temperature is 42.3 °C, the lowest is -17.9 °C within one year, annual average temperature is 15 °C, year-to-year precipitation difference is great and it is distributed evenly in a year, the maximum annual precipitation 1288.5mm, the minimum is 408.2mm, and 62.5% of annual precipitation is mainly in June-September, the days of annual average precipitation is 118 days, annual average evaporative capacity is 1488.6mm, average relative humidity is 67%, the ice period is usually in November of the current year to March of next year, with the longest period 170 days.

As revealed in documentation \( (7) \) the place with average temperature in the coldest month of -3 ~ 2.5 °C belong to gentle frozen, general freezing and thawing environment; when average temperature is higher than 60%, it belongs to medium and high humidity environment, and even more rainfall in this region, it belongs to frequent rainfall region. Therefore, the buildings in mining area are mainly in dry and wet alternation and freezing and thawing environment, the corrosion of natural environment on buildings can not be ignored.

Another test is made on part of buildings in mining area, such phenomenon as microcrack, shrinkage on surface, flaking, cracking, aggregate exposure reveal of reinforcement are found on the concrete. It is concluded that the buildings in mining area have been in general freezing and thawing environment.

2.4 Influence of water quality of atmospheric precipitation on buildings
The acid rain has serious impact on the buildings, and the acid rain area in our country is expanding 100,000 km\(^2\) each year, thus we make monitoring on atmospheric precipitation environment in mining area. The result reveals that the pH value of rainwater is 8.31, and the pH value of melt water is 8.11, alkalescent. Other indicator in atmospheric precipitation such as the content of \( \text{SO}_2^{2-} \), \( \text{Cl}^- \) and \( \text{NO}_3^- \) does not exceed the standard at which it would erode concrete materials. We can assume that the influence of atmospheric precipitation on concrete is slight. It is concluded that in specific environment, the influence of water quality of atmospheric precipitation on concrete is very slight.

2.5 Influence of chloride
The single freezing and thawing failure of concrete is actually physical process of hydration product from compact to loose media \( (8) \). However it can be deemed as very serve freezing and thawing failure if the failure of concrete is caused by combined action of salt compounds and freezing and thawing. Its failure degree and speed is several times larger than general freezing and thawing. In northern part of our country, some salt-ice is sprayed on the road to melt the ice in order to prevent slipping in the winter, which leads to severe denudation of roadway, or even erosion of reinforcement.

Although the mining area does not belong to marine environment, and there is no need to spray salt, but it is necessary to detect of concentration of chloridion of concrete components in mining area. The method is make sampling through drill core, detect the invasion depth of chloridion, and determine the content of \( \text{Cl}^- \) through microcosmic test of X diffraction.

Through analysis, the main ingredients of sample are silicate hydrate, silicon dioxide and calcium carbonate, and no \( \text{Cl}^- \) is detected, combining with that no white salt crystals is found in the crack of detected components, the possibility of erosion of chloridion can be excluded basically. Except that mining area environment is seldom influenced by chloride, it has a bearing on the flyash added in original materials of concrete without sea sand in mining area.

2.6 Influence of solum environment on buildings
The bad stability of the earth's surface due to coal mining causes such geologic hazard as surface collapse. Presently, collapsed land is more than 400,000 km\(^2\) all over the country, 0.2km\(^2\) would collapse for 10,000 ton coal mining averagely. In Pingmei mining area, the collapsed area is 185.4km\(^2\) at present, the total area influenced by coal mining is 15520hm\(^2\) the sinkage depth of the earth's surface is usually 2 ~ 6m, the maximum sinkage depth can reach 10m.

The influence of mine goaf on buildings is: after underground mine is extracted, a space is formed inside the lithesome and the original balancing of stresses of its surrounding is destroyed. The stress shall be distributed again until new balance is established. This complex physical mechanics changing process is also a process of moving and destroying of terrane and the
earth's surface\(^{(9)}\). When the area of mine goaf expands to a certain scope, the moving of terrane extends to the earth's surface, enabling the earth's surface to move and deform.

Two main influence factors contribute to the deformation: the first is geological conditions, such as formation lithology, geologic structure and layers, thickness, attitude, embedding condition of coal bed, the second is production technique of mining area, such as mining method, strata control method and advance direction and speed of working face.

At present, the deformation area caused by mine goaf in Pingmei mining area is approximate to 620km\(^2\), it not only include the buildings that the influence of foundation deformation does not be considered when designing, but also include the architecture on which destabilizing factors appear although technology measures are taken. The number of victims therefrom reaches 100,000 and 258,438,000 Yuan has been compensated.

3 ANALYSIS ON INTERNAL FACTOR OF CORROSION

3.1 Investigation on service life of structure in mining area

As one of the large-scale coal mining enterprise found at the earliest in our country, Pingmei Group, in construction of mining area, due to limitation of design standard and various technology forcing as well as the performance and types of raw materials, combined with little experience in coal ground system construction and deficiency of comprehensive consideration in design and lack of long-term production plan, short-term consciousness is obvious. Table 4 shows the service life of part of mines in Pingmei mining area:

From the table 4, we can see that the structures in mining area are beyond service life and lack of regular maintenance, which leads to decreasing of durability, part of structures can not meet the requirements as prescribed in prevailing national standard specification, which can endanger security or can not be used normally, and measures are required to be taken.

<table>
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</tr>
<tr>
<td>NO.2 mine</td>
<td>1957</td>
<td>20</td>
</tr>
<tr>
<td>NO.5 mine</td>
<td>1958</td>
<td>20</td>
</tr>
<tr>
<td>NO.7 mine</td>
<td>1959</td>
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3.2 Non-destructive inspection of structures in mining area

Considering long service time of structures in mining area, it is determined to make non-destructive inspection, which mainly adopts elasticity tester to make intensity measurement. Ultrasonic-rebound method is applied in individual components for correction and the measurement on reinforcement is made by applying reinforcement admeasuring apparatus. Inspection and test is made on ground production structure of Pingmei Group, which can be conducted by three steps: preliminary investigation, detail investigation and supplementary investigation. The main content for such test contains: structure layout of workshop and brace system, bearing structure (structural element, structural texture and joint structure) as well as space enclosing structure. As for structure layout, inspection mainly focus on the rationality of layout and load path, the correctness of structural style and type selection of structure, the reliability of structural texture and joint. As for reinforced concrete components, inspection mainly focus on cracking breakage, structures and joint, deformation as well as intensity of concrete, carbonization, corrosion, reinforcement corrosion, etc. As for space enclosing structure, inspection mainly focus on roofing system (waterproof and drainage), setup of wall beam, space enclosing wall (cracking, breakage, corrosion and deformation), door and window (cracking, breakage, deformation) ground apron and underground drainage system. The results show that part of buildings in mining area could endanger security or can not be used normally, and measures are required to be taken.

4 CONCLUSION

This paper make analysis on the corrosion mechanism of concrete components one by one according to five categories as listed in Guideline. Excluding the corrosion factor such as chloride and other chemical substances, we can conclude that the main factors of concrete corrosion in Pingmei mining area are carbonation, alternation of wetting and drying and general freezing and thawing environment. The main factors shall be taken into consideration when constructing production buildings thereafter.

4.1 Consideration of design working life of structures

The designed lifetime of structure is service period of structure or components of structure stipulated in the design which can be used for specific purpose without overhaul \(^{(10)}\). As for production structure in mining area, it is necessary to consider its service life, that is because if designed lifetime is too long, it will cause waste of structure, if it is too short, although the service life can be extended through reinforcing, however from the point of repair, it will pay greater price if it is repaired when the materials deteriorate seriously\(^{(11)}\). Therefore, the design of structure in mining area must combine with service life.
of mine, and the development potential shall be taken into consideration.

4.2 Consideration of measures resisting of environment corrosion factors

With regard to the characteristic that concentration of carbon dioxide in mining area is higher, adding various ornamental surfacing can be taken into account in order to suspend carbonization speed and delay the corrosion time of reinforcement, considering that Pingmei mining area belong to general freezing and thawing environment and alternation environment of wetting and drying, it is a routine method to introduce bleed air to prepare durable concrete, at the same time, all person in mining area shall cooperate actively to carry out integrated control of environmental pollution in order to alleviate pollution corrosion and provide a favorable ecological environment.

REFERENCES