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Causes of cement concrete pavement diseases in high-cold and high-altitude areas and progress in repairing techniques

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ABSTRACT

The climatic characteristics of high-cold and high-altitude areas are low temperature, large temperature differences, and strong ultraviolet radiation. This paper analyzes the causes of cement concrete pavement diseases in high-cold and high-altitude areas and summarizes the common disease types of cement concrete pavements in high-cold and high-altitude areas. Moreover, new repair techniques to improve the maintenance quality of cement concrete pavements in high-cold and high-altitude areas are introduced.

Key words: High-cold and high-altitude areas; cement concrete; disease; repair

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1. INTRODUCTION

The annual average temperature in the high-cold and high-altitude areas is low, the daily temperature difference is significant, the ultraviolet radiation is intense, and the climate in some areas is dry and rainless. These factors greatly aggravate the deterioration of materials and structural properties. For example, frequent positive and negative temperature alternations easily result concrete structures suffering from freeze-thaw damage. The daily temperature and humidity alternately change, which causes structural fatigue stress to accumulate, leading to cracking. Dry weather conditions will increase the drying and shrinkage of structural materials, so high-cold and high-altitude areas are prone to cement concrete pavement diseases. It is necessary to explore the rapid repair technology of cement concrete in view of the climate and environmental characteristics of high-cold and high-altitude areas.

2. Causes of cement concrete pavement diseases in high-cold and high-altitude areas

In engineering, the alpine and high-altitude area generally refers to the extremely cold climate zone above 2000m, mainly distributed in Tibet, Qinghai, Gansu, and other regions in China. Take Qinghai Province as an example: the average annual sunshine time are 2350-2976 hours. Solar radiation is intense. The yearly average total solar radiation is 730,000 J/cm^2 [1]. The annual average proportion of solar UV radiation in the Qinghai-Tibet Plateau is about 4%-5%, and the total amount of solar UV radiation is about 36,500 J/cm^2, the average daily ultraviolet radiation is about 100 J/cm^2 [2], the total and daily UV radiation in high altitude area were significantly higher than that in plain area. The annual average temperature is 0.4 -- 7.4^{o}C, the lowest average temperature in January is -5.0 -- 10.3 ^{o}C, and the highest average temperature in July is 10.8 -- 19.0 ^{o}C [1].

When only UV radiation applied, the compressive strength of cement concrete neither increase nor decrease [3]. But according to the Jia Fei et al. and Xu Fan et al, when uv radiation combined with freeze-thaw weathering, it will cause lower cement concrete frost resistance, and strength of concrete in early and later age frost resistance is reduced. The higher the water cement ratio and the worse the frost resistance is [4].

3. Common disease types of cement concrete pavement in cold and high altitude areas

The climatic characteristics of cold and high-altitude areas are low temperature, significant temperature difference, and strong ultraviolet radiation. Typical

diseases in alpine and high altitude areas include broken slabs, subsidence, and surface diseases, which are characterized by the early and frequent occurrence of diseases, causing great trouble to road maintenance personnel [6].

3.1 Broken board

Slab fracture of cement concrete pavement refers to full-thickness strip crack of cement concrete pavement, and plate fracture affects driving safety. Cement concrete pavement fracture can be divided into fatigue fracture and non-fatigue fracture. The non-fatigue fracture of cement concrete pavement is mainly caused by the defects in the construction stage, including factors such as raw materials, mix ratio, health maintenance, and so on. Fatigue fracture of cement concrete pavement includes reflection of cracks of foundation and base, coupling of ultraviolet rays and freezing-thawing [7], as shown in Figure 1.

Figure 1. Broken slab of cement concrete pavement

3.2 Subsidence

Subsidence is the subsidence of the road surface in the range of local sections, mainly caused by the insufficient quality of subgrade filling or compaction degree. According to the investigation and analysis by Zhang Jinzhao et al., Yongguo Wucai et al., on the cement concrete pavement disease of Jiangling road to Qingshuihe section of G214 Qingkang Highway, the cement concrete pavement is in the high-altitude frozen soil region formed in the alpine and high-altitude area. The annual rise of ground temperature in the permafrost region changes the water-heat balance of permafrost, destroys the plateau permafrost environment, causes the upper limit of permafrost to move down, and causes uneven settlement of roadbed and road surface [8,9], as shown in Figure 2.

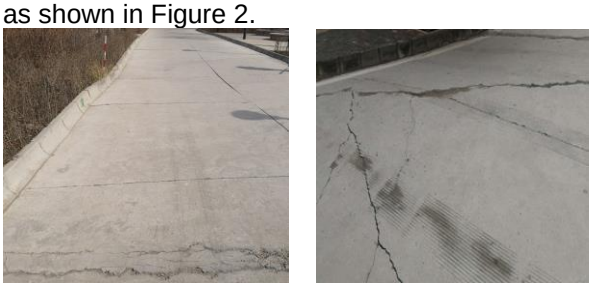

Figure 2. Cement concrete pavement subsidence

3.3 Surface diseases

Surface diseases of cement concrete pavement include aggregate shedding, peeling, and pit. Surface diseases are mainly caused by materials, coordination ratio and quality control of construction process, etc., which are accelerated under the repeated coupling of ultraviolet and freezing-thawing and the repeated action of vehicles. Surface diseases do not affect the structural strength of road surface but affect the flatness of road surface and reduce the driving quality [10], As shown in Figure 3.

Figure 3. Surface diseases of cement concrete pavement

4. Progress in restoration technology

The average winter in high-cold and high-altitude areas is more than half a year, and the daytime temperature in winter is often lower than –15℃. At present, the common repair materials cannot be solidified and hardened in a low temperature environment, which makes it difficult to repair the broken plates, subsidence and surface diseases of the cement concrete pavement in winter, resulting in serious hidden dangers to driving safety. Therefore, it is very important to carry out rapid pavement repair in low temperature environment. This paper mainly introduces the new technology of cement concrete pavement repair in low temperature environment in alpine and high altitude areas.

4.1 Magnesium phosphate cement rapid repair technology

According to Jia Xingwen et al., based on the preparation method of high-performance magnesium phosphate cement concrete, high early strength magnesium phosphate cement concrete with 2h compressive strength not less than 30MPa and bending strength not less than 3.5mpa under -20 ~ -10℃ was developed. It was successfully applied to the quick repair construction of G109(Beijing-Lhasa) Hohhot section and G110(Beijing-Yinchuan) Zhuozishan section of concrete pavement in winter, realizing the goal of resuming traffic within two hours after the completion of winter repair construction [11,12]. The technology can be constructed in a temperature above -20℃, has the advantages of fast setting and hardening, no shrinkage, fast strength development at low temperature, good durability, and can effectively solve the problem of maintenance caused by long negative temperature time in high altitude areas. This technology can be applied to the repair of broken slabs, subsidence, and surface diseases, and it is expected to become

the main technology for the repair of cement concrete pavement with negative temperature in cold and high altitude areas, as shown in Figure 4.

Figure 4. Magnesium phosphate cement rapid repair technology

4.2 Polyurethane road filler

The settlement of foundation in alpine and high-altitude areas is formed during repeated freezing-thawing, and some foundations are directly constructed on the frozen soil due to the settlement caused by temperature rise. If the traditional method of excavating the road surface and redisposing the roadbed is adopted to repair, especially in alpine and high-altitude areas, the repair cycle is long, and the cost is high. According to Sabre Foundation Repair's website, it compares the injection of polyurethane foam with cement grouting. The injection of polyurethane foam can complete the settlement of the disease in 15 minutes. Polyurethane foam is waterproof and light and does not increase the weight of the base [15]. Polyurethane road filling agent perfectly solves the problem that the water coagulation in the low-temperature environment in the alpine and high-altitude area needs several days to improve the strength and can't be opened to traffic, and also solves the problem of repeated freeze-thaw of materials. In addition, polyurethane road filling has good heat insulation performance and has a good effect on solving the settlement of frozen soil subgrade.

5. The conclusion

This paper analyzes the causes of cement concrete pavement disease in high cold and high-altitude areas. Under the action of ultraviolet and freezing-thawing coupling, the frost resistance of cement concrete pavement decreases in the early stage, and the frost resistance of high strength concrete decreases in the late stage. The greater the water-cement ratio is, the worse the frost resistance is. The typical diseases of cement concrete pavement in these areas include broken slabs, subsidence, and surface diseases. At present, the common repair materials cannot be properly set and hardened in the low temperature environment, which makes it difficult to repair the cement concrete pavement when it is damaged in winter. This paper introduces the new technology of cement concrete pavement repair in the low temperature environment. New technologies for cement concrete pavement repair in high cold and high altitude areas include magnesium phosphate cement quick repair technology and polyurethane pavement filler, both of which have the advantages of low temperature construction, fast hardening, no shrinkage, good durability and low cost. It is necessary to further study the causation mechanism of cement concrete pavement in cold and high-altitude areas, explore the repair technology suitable for optimization and solve the problems of unmaintenance and difficult maintenance.

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