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Cracks Analysis and Control Measures of Mass Concrete

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Abstract. Based on the cracking causes of a raft foundation in a project, this paper expounds the common types of mass concrete cracks and their causes. The effects of raw materials, admixtures, etc. on temperature cracks of mass concrete are mainly discussed, and the mutual effects need to be considered when using composite admixtures.The prevention measures of mass concrete temperature cracks are expounded from the perspectives of raw material selection, construction organization design, etc.

Keywords: mass concrete; crack; raw materials; admixture

1. Introduction

With the rapid development of engineering construction, mass concrete is widely used in housing construction, water conservancy, transportation and nuclear engineering and other fields[1]. At present, the definition of mass concrete in various countries has not been completely unified. In Chinese GB50496-2418 "Construction Standard for Mass Concrete", the minimum size of concrete structure entity is not less than 1m or concrete that may cause harmful cracks to appear due to temperature changes and volume shrinkage brought about by the hydration reaction of the cementitious material in the concrete is called mass concrete. Mass concrete cracks have always been criticized in the construction industry, which has plagued engineers and technicians for a long time, and is also a research hotspot by scholars at home and abroad. According to statistics, among the cracks in engineering structures, the cracks in mass concrete structures are as high as 80%. Mass concrete cracks will affect the functionality, durability, integrity, and even safety of constructions. There are many factors that affect the cracking of mass concrete, such as: raw materials (thick and fine aggregate), mix ratio, admixtures, selection of construction methods and methods, post-maintenance, etc. How to control and prevent mass concrete cracks has important practical significance for ensuring engineering safety.

2. The types and causes of mass concrete cracks

The common types of mass concrete cracks are settlement cracks, shrinkage cracks and temperature cracks:

2.1 Settlement cracks

Due to the foundation with uncompact backfill, soft foundation, long-term flooding, or geological disasters. Uneven settlement of the foundation occurs. When the tensile and shear stress of the concrete is greater than its strength, the concrete is damaged and cracks are generated.

2.2 Shrinkage cracks

During the hardening process of concrete, about 20% of the water is necessary for the hydration reaction, and the remaining 80% of the water mainly leaves the concrete by evaporation. The evaporation of water will cause the natural shrinkage of the concrete volume. The amount of shrinkage is larger than that of conventional concrete, and the resulting shrinkage stress is also

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relatively large. When the shrinkage stress exceeds the ultimate tensile strength of the concrete at that time, shrinkage cracks will occur in the concrete.

2.3 Temperature cracks

At the initial stage of mass concrete pouring. A large amount of hydration heat will be generated, which will cause the internal temperature of the concrete to rise sharply, the surface concrete will be in contact with the outside air, and the heat will be dissipated quickly. The heat of hydration cannot be conducted in time, resulting in a large temperature difference between the interior and the surface of the concrete, resulting in thermal stress. At this time, the concrete has a short age and low strength. When the tensile stress exceeds the tensile strength limit of the concrete, cracks will occur on the concrete surface. Temperature cracks are divided into microscopic cracks and macroscopic cracks. The cracks that affect the structural function and safety are macroscopic cracks. Macroscopic cracks can be divided into surface cracks, deep cracks and penetration cracks. In engineering construction, the generation of through cracks should be avoided [2].

2.4 Cracks caused by alkali-aggregate reaction

After concrete is mixed, alkaline ions will be produced, and these ions will chemically react with some active aggregates and absorb water in the surrounding environment and expand in volume, causing the concrete to loosen and crack.

2.5 Cracks generated under external conditions

External acid-base environment, corrosion of concrete, penetration into concrete and corrosion of steel bars, chemical reactions occur, causing concrete to expand and crack; under external load, it exceeds the limit of concrete structure. Tensile loads will cause deformation and cracks.

Among the above-mentioned cracks, the causes and influencing factors of temperature cracks are extremely complex and dynamic, and the control of temperature cracks is the key to preventing cracks in mass concrete.

3. Analysis of the cracking cause of a raft foundation

The project covers an area of about 7,700 square meters, of which the tower building area is about 70,000 square meters, with 2 underground floors and 33 to 34 floors above ground. The tower foundation is a raft foundation with a thickness of 1.3m to 2.0m. After the foundation was poured, it was found that a large number of irregular cracks appeared on the surface of the foundation, and some cracks had water seepage.

According to the actual situation on site. The non-metallic ultrasonic detector is used to detect the width and depth of cracks. After testing, most of the cracks have a width between 0.1mm and 0.5mm. The crack depth is between 20mm and 250mm. Individual cracks are through-cracks, and there is water seepage at the position of the through-cracks. According to the crack shape, the raft foundation cracks are mainly surface cracks.

After investigation, it was found that the raft foundation was poured in June 2019. During this month, there were 22 calendar days of rainy weather at the site of the project, and the rest were mostly cloudy. The ambient temperature is relatively low, and the temperature difference between day and night is large, which increases the temperature difference between the inside and the surface of the raft foundation, which accelerates the development of this type of crack. The early type of temperature cracks in mass concrete is surface cracks. Influenced by factors such as improper maintenance in the later period. Thermal cracks will develop further. From surface cracks to through cracks.

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Fig 2.1 Distribution of cracks

Figure 2.2 Fracture depth detection

4. Research on crack control of mass concrete

4.1 Influence of raw materials on cracks in mass concrete

The quality of cement, coarse and fine aggregates, etc. all play a decisive role in the control of concrete cracks. Low-heat cement and non-alkali reactive crushed stone with a small thermal expansion coefficient should be used first.

4.1.1. Influence of cement on additives and early hydration reaction

The performance of cement directly determines the quality of cement gel and plays a decisive role in the crack resistance of concrete structures[3]. Different cement fineness also has a certain influence on the adaptability[4]. The uniformity coefficient of particle distribution should be set between 0.9 and 1.0. The fineness of cement is too small, which also has a certain influence on the performance of concrete. Under the same water-cement ratio, the larger the specific surface area, the larger the contact area between cement and water. The free water between the cement particles becomes less, the fluidity of the cement slurry becomes worse, the early hydration speed of the cement becomes faster, and the more flocculent hydration products are, which further reduces the fluidity of the cement slurry and accelerates the early hydration reaction speed. The temperature difference between the interior and the surface of the concrete increases, which is not conducive to the control of mass concrete cracks[5].

4.1.2. The influence of coarse aggregate on the shrinkage of concrete

Generally, coarse and fine aggregates account for about 70-80% in concrete[6]. Properly increasing the proportion of aggregate is beneficial to reduce the shrinkage of concrete. Especially for large-volume concrete, the gradation of coarse and fine aggregates should be more reasonable and scientific. Aggregates with uniform texture and good strength should be used, and crushed stones or aggregates with original cracks and high activity should not be used. For example: for C30 concrete, the concrete prepared by mixing 60% machine-made sand and 40% natural sand has better workability and mechanical properties;Machine-made sand concrete is more superior in terms of resistance to chloride ion penetration and dry shrinkage, and its durability is also greatly improved[7].

4.2 Influence of admixtures on cracks in mass concrete

The effect of admixtures on concrete is crucial, including setting time, compactness, air content, durability, strength, etc.

4.2.1. uperplasticizer:

The shrinkage and deformation of the gelling system are greatly affected by superplasticizers[8]. Naphthalene and sulfamate superplasticizers can improve the performance of concrete. A suitable superplasticizer can reduce the surface tension of the solution. However, it increases the shrinkage and deformation of concrete. The experimental study of water-reducing agent found that 0.2%-0.3% of wood calcium water-reducing agent can effectively reduce the hydration heat of cement[9]. It not only saves about 10% of the cement consumption, but also improves the 28-day compressive strength of concrete by 10%-15%. Adding a specific range of wood calcium can prolong the initial setting and final setting time of cement.

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4.2.2. Shrinkage reducing agent and expansion agent

Adding an appropriate amount of shrinkage reducer and expansion agent to concrete is beneficial to reduce the hardening shrinkage of concrete. Adding ettringite expansion agent and shrinkage reducer to concrete with large amount of mineral admixture cannot completely eliminate the shrinkage of concrete[10]. But for engineering, adding an appropriate amount of shrinkage reducer is of great significance for later use. Micro-expanded concrete can effectively self-expand to compensate for the shrinkage of the concrete itself, but the degree of shrinkage is greater when cured in a dry environment[11]. The expansion rate of the cementitious material was studied by adding UEA expansion agent at different temperatures. The results show that the specimens can obtain higher strength and expansion rate when cured at 30℃ and 40℃. High strength can be obtained, but the expansion ratio is slightly lower than that at 30℃ and 40℃[12].

The mixed use of admixtures will also bring some problems. For example, if the retarder and the superplasticizer are mixed in a low temperature environment, segregation will occur, and plastic cracking will occur in severe cases[13].When retarder and sulfoaluminate type expansion agent are used in combination, the effect of expansion agent will be reduced[14]. The dosage must be appropriately increased in order to achieve the effect of single-blended bulking agent. Admixtures can improve concrete properties. However, it needs to be scientifically and reasonably configured in practical engineering applications. It is advisable to test and verify the optimal dosage according to the specific situation.

5. crack prevention measures

5.1 Material selection

5.1.1. Cement

Choose cement with slow hydration reaction and low heat of hydration, such as Portland cement. The slower the hydration reaction, the lower the heat of hydration, which is conducive to reducing the temperature difference between the interior and the surface of the concrete, thereby reducing the temperature stress caused by the temperature difference. Conducive to the control of concrete temperature cracks.

5.1.2 Coarse aggregates

Crushed stone with particle diameter of 5mm~25mm, good gradation and low mud content should be selected as coarse aggregate[15]. Well-graded coarse aggregate can improve the workability of concrete. The larger the particle size of the coarse aggregate, the less the amount of water and cement used, thereby reducing the hydration reaction rate, reducing the temperature difference between the interior and the surface of the concrete, which is conducive to the control of temperature cracks.

5.1.3Fine aggregate

The selection of fine aggregate should control its mud content and particle size. The fine aggregate with large particle size and low mud content can reduce the amount of water, improve the fluidity of the cement slurry, and is conducive to the control of concrete temperature cracks.

5.1.4. Admixtures

Adding a certain amount of admixtures (such as fly ash, water reducing agent, retarder, etc.) to the concrete can reduce the amount of cement and water in the concrete. While ensuring the good performance of the concrete, the hydration reaction of the concrete is minimized. The heat released during the process can reduce the probability of thermal cracks. Water reducing agent and air-entraining agent are particularly important for controlling temperature cracks in mass concrete, which can improve concrete mechanics, deformation, durability and other properties.

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5.1.5 Strictly control the mix ratio of concrete

Under the condition that the concrete has good working performance, the water consumption, cement consumption and water-to-binder ratio should be reduced as much as possible, and low-heat concrete or micro-expansion concrete should be used; Crack resistance.

5.2 Optimized design and construction plan

1) Adopt the idea of regional constraints: Add structural reinforcement in the stress concentration area. Thereby improving the tensile properties of the structure. Large-diameter steel bars should not be used for reinforcement, but high-strength steel bars should be used. Set the sliding layer at a reasonable position to reduce the constraints of boundary conditions.

2) Choose a reasonable construction plan:The length of mass concrete has a great influence on cracks, and the longer the length, the easier it is to produce cracks. Reasonably design the position of the post-pouring belt before pouring the concrete, and pour it in sections and blocks reasonably. Layered pouring and vaulting pouring can be used.

3) Emperature control of pouring concrete:When the concrete is poured, the cooling water pipe is buried to reduce the temperature difference between the inside and outside of the concrete. Pre-cooling aggregates, cooling mixing water. The mold temperature should be higher than 5℃ in winter, and the mold temperature should not be higher than 30℃ in summer.

4) Strengthen the tamping of concrete, improve the compactness, and avoid the occurrence of construction quality problems such as uncompacted vibration.

5.3 Strengthen post-maintenance

Reduce the impact of the external environment on concrete - insulation, moisture. Insulation is to reduce the temperature gradient of the concrete surface and prevent the large temperature difference between inside and outside. Temperature monitoring can be carried out during and after the pouring of mass concrete. When the temperature difference exceeds a certain value, cooling measures can be taken immediately. The tensile stress generated by the temperature difference is smaller than the tensile strength of the concrete itself, thereby reducing or avoiding the occurrence of cracks. Especially for the generation of through cracks, thermal insulation materials such as rubber-plastic boards can be used for thermal insulation. Moisturizing is to ensure that the chemical reaction has sufficient water, so that the concrete surface will not dehydrate and cause shrinkage cracks. The smooth progress of hydration can improve the tensile strength of concrete.

6. Treatment measures for cracks

Structural stress cracks larger than 0.3mm are designated as cu-level components, and reinforcement measures are required to deal with them. Generally, methods such as increasing the section, sticking steel, and prestressing are used. For non-structural stress cracks, surface repair and grouting can be used to improve waterproofness, impermeability and durability. The bionic self-healing method can also be used[16], that is, the self-healing of shape memory alloys is used, and hollow capsules and fibers containing repairing agents are embedded in concrete. Remediation of concrete using mineral deposits caused by bio-microbial reactions.

7. Conclusion

Temperature cracks in mass concrete have always been a difficult problem in the construction industry, and have plagued engineers and technicians for a long time. The causes of temperature cracks in mass concrete are extremely complex, which are related to the material properties of concrete itself, construction plans, construction environment and boundary constraints. The control of temperature cracks in mass concrete needs to start from the selection of raw materials, concrete mix ratio, construction plan and later maintenance, so as to track and monitor the whole process,

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and take effective "crack resistance" and "crack resistance" measures in time to reduce penetration Cracks and other cracks that affect the function of the structure are generated.

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