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The Mechanism of Shrinkage and Reduction Measures of Concrete

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Commentary

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ABSTRACT

The shrinkage of concrete is an important index for its durability. This paper mainly introduces the common shrinkage types of concrete and their mechanisms as well as the methods commonly used in engineering and experimentation to reduce concrete shrinkage.

Keywords: Concrete; shrinkage; reduce shrinkage.

1. INTRODUCTION

At present, the durability of concrete is one of the key points of scientific research on concrete, and the shrinkage performance of concrete is an important aspect of the durability of concrete and a prerequisite for achieving good long-term performance of concrete. Excessive shrinkage often leads to cracking and performance deterioration of concrete, so the shrinkage problem of concrete has been a concern by all sides [1]. Many studies have shown [2] that concrete shrinkage is one of the main causes of cracks in concrete, and cracks caused by concrete shrinkage and deformation account for 80% of total cracks in concrete. When the concrete component has cracks, the corrosive substances can easily enter the concrete interior, accelerate the deterioration of the concrete, and thus reduce the durability of the component. Therefore, reducing the shrinkage of concrete and improving the long-term durability of concrete has always been urgent problems.

1.1 Shrinkage Mechanism of Concrete

Since the first discovery of the shrinkage of concrete in the 19th century, many well-known

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scholars and researchers have done a lot of work in this field. So far, people have made a lot of achievements in the shrinkage mechanism of concrete materials, shrinkage inhibition methods, and shrinkage prediction model methods. The shrinkage of concrete can be roughly divided into self-shrinkage, drying shrinkage, chemical shrinkage, plastic shrinkage, and temperature shrinkage [3].

(1) Self-contraction

For self-contraction, the current widely accepted definition of self-contraction was proposed in 1940: "The volume deformation of the concrete itself should be defined as the volume deformation caused by the physical and chemical changes in its interior; self-shrinkage refers to the water in the internal pores of concrete due to the reduction of the hydration reaction, from the saturated state to the unsaturated state, resulting in the reduction of the concave surface of the water in the hole, the capillary pressure increases, and the phenomenon of macro deformation of concrete." Self-shrinkage is not equal to chemical shrinkage, which refers to the absolute value of the volume change before and after the hydration reaction of concrete. When the concrete is in the plastic stage, the self-shrinkage is similar to the chemical shrinkage. After the initial setting, the concrete skeleton is gradually formed, and the concrete self-shrinkage is smaller than the chemical shrinkage. The research shows, that compared with ordinary concrete with the same amount of cementing material, self-compacting concrete has a lower water-binder ratio and less water content. When concrete shrinkage occurs, self-compacting concrete provides relatively less water for hydration reaction, and the rapid water consumption in concrete makes the pressure of pores greater and the self-shrinkage more serious.

(2) Drying shrinkage

Drying shrinkage means that after the end of concrete curing, the water in the pores is lost, the pressure of the water surface of the pores continues to increase, the tension of the pores becomes larger, and the pores shrink. To keep the pressure at the concave surface of the pores in a balanced state, the tension on the wall of the pores will continue to increase, resulting in the phenomenon of concrete volume reduction. The drying shrinkage of concrete is irreversible. When the shrinkage occurs, the water inside the pores evaporates and loses water, and the pore structure inside the concrete changes. However, the hardness and strength of concrete are constantly developing, so the drying shrinkage cannot be recovered. For ordinary concrete, the drying shrinkage value is much greater than the self-shrinking value, which can reach (200~1000) ×10-6, and the self-shrinking value is only about (20~100) ×10-6. For high-strength concrete with a low water-binder ratio, the drying shrinkage is only about 600×10-6, and the self-shrinking will increase [4].

(3) Chemical shrinkage

Chemical shrinkage means that the volume of the hydration product formed at the initial stage of hydration is smaller than the volume change of the initial reactants (water and cement) during the hardening process. Chemical shrinkage is used as a measure of absolute internal volume reduction, and self-shrinkage represents the external volume change of concrete. After the initial structure of the slurry is formed (roughly called early coagulation), further hydration causes voids to appear inside the matrix. At this stage, the self-shrinkage rate is less than the chemical shrinkage rate, because the chemical shrinkage rate measures the apparent reduction volume. The cumulative volume of the hole is taken into account in the determination of the chemical shrinkage value. In the plastic phase, self-shrinkage and chemical shrinkage can be used interchangeably. However, the study of Holt [5] shows that when the water-binder ratio is as low as 0.3, the early self-shrinkage of concrete specimens is not equal to the chemical shrinkage. In addition, the addition of high-efficiency super plasticizers with a low water-binder ratio can improve the chemical shrinkage and self-shrinking water rates to varying degrees. It should be noted that when w/b is 0.45, no self-shrinkage is observed in the presence of water, whereas chemical shrinkage is evident.

(4) Plastic shrinkage

Plastic shrinkage refers to the shrinkage of concrete within 3 to 12 hours after mixing. Due to the sinking of aggregate, the newly mixed concrete will exhibit) stratification and surface bleeding, and the water on the surface of the concrete will continue to disperse in the surrounding environment. When the water loss rate is greater than the bleeding rate, the volume will be reduced. This phenomenon generally occurs before the final solidification of concrete, when the internal skeleton of concrete has not yet formed and concrete is in a plastic state, so it is called plastic shrinkage [6]. Plastic shrinkage is the main cause of early-age cracking.

(5) Temperature shrinkage

Temperature shrinkage refers to the volume reduction of concrete in the initial hardening period due to an excessive temperature gradient or temperature drop in the inner and outer layers [7]. This temperature difference is mainly due to higher temperature than the ambient temperature caused by thermal evolution during the hydration process of cement. The hydration heat increases the self-drying property of the system and affects the self-shrinking of the system. In some cases, the release of heat is accompanied by thermal expansion, which occurs at the same time as the onset of self-contraction when thermal expansion is greater than self-contraction. However, in general, the self-contraction rapidly exceeds the expansion, and the concrete shrinks after the initial expansion stage. If the temperature of the concrete drops rapidly, the temperature shrinkage can accumulate to cause self-shrinkage.

(6) Carbonization shrinkage

Carbonization shrinkage refers to the phenomenon that the volume of calcium carbonate generated by the reaction of concrete hydration product Ca(OH)2 with CO2 in the air is less than the volume of hydration product Ca(OH)2, resulting in a reduction in the volume of concrete. Carbonization shrinkage occurs on the surface of concrete for a long time, and its value is small, so the effect of carbonization shrinkage on the volume of concrete can usually be ignored.

2. MEASURES TO REDUCE SHRINKAGE

Because the shrinkage of concrete will have adverse effects on testing and engineering, scholars and engineers in various countries will adopt some measures to reduce the shrinkage of concrete. At present, the commonly used measures to reduce concrete mainly include the following:

(1) Curing technology

Many experimental studies show that the shrinkage value of concrete curing in a wet environment is lower than that in dry a environment. In actual engineering, water storage curing can make the concrete fully wet curing and curing agents, sealing layers, and coatings can also be used to keep free water in the concrete for a long time, thereby delaying and reducing concrete shrinkage.

(2) Blended fiber

Adding an appropriate amount of fiber to the concrete mix can also effectively reduce the early shrinkage of concrete and improve the mechanics and durability of concrete engineering. At present, the fibers used in concrete mainly include steel fibers, carbon fibers, glass fibers, polypropylene fibers, etc. After adding a certain amount of fibers to concrete, the evenly distributed fibers form a complex three-dimensional disoriented system inside the concrete, and generate adhesive friction between the matrix, which can not only effectively inhibit the aggregate sinking in concrete but also improve the homogeneity of the concrete. It can reduce its inherent defects, block the passage of water overflow, reduce or delay the loss of water [8], and thus reduce the shrinkage performance of concrete. In addition, another reason why fiber can improve the shrinkage performance of concrete is that it can improve the microstructure of concrete. After the addition of steel fiber, not only is the cumulative water loss of the specimen smaller than that without the addition of steel fiber, but also the pore structure has obvious changes. Compared with the specimen without the addition of steel fiber, there are more holes with a larger diameter in the pore structure, and the larger pores reduce the pressure of the pores. Thereby reducing water escape.

(3) Shrinkage reducer

The shrinkage control principle of concrete is completely different from other shrinkage reduction measures. The application of shrinkage reducer in concrete can be like other admixtures, which can be uniformly dispersed in concrete free-water and the surface tension of the concrete hole solution can be reduced by more than half. According to the theory of capillary tension, shrinkage is caused by the capillary tension caused by the loss of water in the cement pores and gel pores, and the capillary tension is proportional to the surface tension of the solution, so the shrinkage reducer can also reduce half of the self-shrinking stress.

(4) Expansion agent

Expansion agent to inhibit concrete shrinkage is mainly the use of the expansion agent itself, hydration, or the reaction between the cement hydration products and the micro-expansion, to compensate for the shrinkage of concrete. At present, the expansion agent used for concrete is different due to the formulation of components caused by the expansion law. Accordingly, its effective components can be divided into five categories, such as calcium sulfoaluminate, calcium oxide, calcium sulfoaluminate, magnesium oxide, and metal, but the most commonly used is calcium sulfoaluminate or ettringite expansion agent. Calcium sulfoaluminate expansion agent mainly compensates for the shrinkage of concrete by the volume expansion of calcium sulfoaluminate components generated by ettringite during the hardening and strength development of concrete.

3. CONCLUSIONS

The shrinkage of concrete will hurt the long-term performance of concrete. The main types of shrinkage of concrete in different periods should be fully understood in the actual test and engineering to take appropriate measures to reduce shrinkage.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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