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On causes, prevention and repairing measures of concrete cracks

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Abstract

At present, domestic and overseas researches on concrete cracks mainly focus on the formation of cracks from external factors, such as cracks caused by temperature, external loads and uneven settlement of foundation. Based on other scholars' study on the reason and settlement of cracks, this paper starts from the defect of concrete structure, and proposes three factors affecting concrete cracks: internal and external stratification during the process of concrete placement, the presence of the transition zone of concrete and multiphase porous system of the cement. In addition, the author has summarized the prevention and repairing measures of cracks.

Key words: concrete; cracks; causes; structural defects; prevention and treatment measures

I. Introduction

As one of the most common building materials, concrete is now widely used in industrial and civil construction, water conservancy, city construction, agriculture and forestry, transport and Harbour Engineering. The biggest disadvantage of concrete, however, is that it is easy to crack , which leads to the decline of the durability of concrete and causes structural damage, thus bringing huge losses to the national economy. If cracks appear, it would produce a large number of water seepage, and corrode concrete, which would badly influence the safety of concrete structure; after the wall, column, beam, plate of factory, residential and office buildings have cracks, it will affect the appearance and life expectancy. Some serious cracks will threaten people's lives and property safety. The crack extension is also a major cause of damage to concrete structures and buildings. To research on the formation of cracks, prevention and treatment of cracks is imminent and of important engineering significance.

Domestic and international research and engineering on concrete cracks proved that the appearance of concrete cracks was inevitable. The direction of present research is mainly how to keep concrete cracks within a safe range to ensure the beauty and safety of the structure. As concrete is a mixture of a variety of brittle materials, and it is prone to cracking when subject to external and internal factors such as shrinkage pressure and temperature.

Mainly based on former research achievement, t his paper makes a new study of the cracks.

II. The cause of cracks

When the tensile stress generated by the temperature, the shrinkage of concrete and other factors is greater than the ultimate tensile strength of concrete, the restrained concrete will generate cracks.

Currently, investigations and researches on concrete cracks have been done widely and deeply by experts and scholars. [1--3] analyze its reasons and come up with solutions from the perspective of design, material, mix ratio, field operation and other aspects in their papers. Ju-Liyan[4] deems that the cracks are mainly caused by the deformation and external load. [5] Exploration from four aspects of the causes of crack, including materials,

construction, use of the environment, structure and external force.[6--8] piont that there are four main reasons for the crack, a. the shrinkage deformation of concrete constrains the crack; b.The stress cracks of concrete structure; c. cracks generated by chemical reaction; d. Plasticity crack. Wang-Tiemeng [9] also summarized 18 factors to control the shrinkage crack through a large number of engineering examples.

At present, yet, the influence of the defect of concrete structure is often overlooked. The exploration of concrete cracks should be back to concrete structure itself. Design, material, mix ratio, the uneven subsidence of foundation and field operation are not the real reasons of cracks. It is more appropriate to view them as prevention and control measures of concrete crack because most of the "reasons" are controllable.

1.1 The effect of concrete segregation

Before the setting and hardening of concrete, due to the deposition of coarse and fine aggregate forming the outer layered, it is not easy to maintain its stability, and most of it will have certain delamination, which will cause the macro-structural concrete in the direction of pouring uneven, with the upper strength less than that of the bottom, making the surface the most loose and weak part. Besides, delamination will occur beneath the concrete coarse aggregate, where the water-filled area has the largest water content, making it easy to form pores, which often becomes the birthplace of cracks and pores.

1.2 The effect of interfacial transition zone

The existence of transition zone is also an important reason of concrete cracks. Due to the unevenness of transition zone, the original micro-cracks will be easily developing into harmful cracks under the influence of external pressure, which will further affect structural safety. This is mainly because in the process of preparing fresh concrete, micro and macro bleeding effect inside the concrete will produce uneven moisture in different locations around the area, which further affects the uniformity of the transition zone.[10] The intensity of transition zone, that is the size of cohesion force is mainly determined by the adhesion force of van der Waals, so the strength of the transition area is related to the size and volume of the pore. Due to the transition zone of high water-cement ratio around the aggregate particles, the adhesion force of van der Waals is relatively weak, and it will produce shrinkage cracks when the shrinkage deformation is greater than the adhesion force of van der Vaals. In addition, because of external load, transition zone as shear force weak zone is also prone to cracking. Besides, due to high water-cement ratio, these areas will have a larger plastic shrinkage, thus producing plastic shrinkage cracks.

1.3 The effect of multiphase porous system of the cement

The multiphase porous system of the cement can also cause concrete cracks. With the hydration process going on, the original water-filled space is reduced while the space without hydration products is gradually divided into pores of irregular shape. Although pores mainly effect concrete's permeability and frost resistance, it has the same effect on cracks, for example, the existence of open pores has provided a channel for air and water to enter into the concrete, causing concrete and rebar corrosion, and further developed into rebar cracks and carbonation shrinkage cracks.[11]

III. Crack precautions

3.1 The control of water-cement ratio

Chen Luyi and others researcher that proper water-cement ratio can reduce the width of transition zone beneath the aggregate interface to 60-70μm while the width beyond interface does not change much. On the other hand, reducing water-cement ratio can avoid delamination. The main mechanism is to reduce water and weaken internal micro water bleeding when vibrating. Water-cement ratio below the aggregate is relatively reduced, thus improving the unevenness of the transition zone and reinforcing

crack resistance of concrete in order to achieve the prevention of cracks formation under external force.

In addition, the water-cement ratio is also closely related to multiphase porous system of the cement. When the water-cement ratio is same, the higher the degree of hydration, the more cement hydration products. But the amount of cement particles without hydration and the number of capillary voids is relatively reduced, as a result, the cement structure is dense, of good durability and can be under high pressure and tense. As to cement structure of different water-cement ratio with same degree of hydration, the proportion of pores of large water-cement ration of cement paste relatively increases, so the durability and strength of cement under this state will reduce. In order to improve the durability and strength of cement, the void content of the cement should be minimized as much as possible. To this end, reducing water-cement ratio and improving the intensity of mud or concrete when molding can control premature concrete cracks from its source.

3.2 Adding silica fume

The particle size of silica fume is two orders of magnitude smaller than that of cement, in the process of setting and hardening of silica fume cement, it can rapidly react with cement hydration to produce CSH and ettringite. Those do not participate in the reaction can fill the gap between the original cement particles and aggregates, and reduce the water-cement ratio in transition zone, thus decreasing the width of interfacial transition zone, and finally make the transition zone even, strengthen force weakened area, which can avoid premature concrete cracks in some degree.

3.3 Choosing high quality aggregate

The interfacial transition area of concrete will be affected by aggregate of different nature. Using aggregate of fine nature is of importance to the interfacial transition area of concrete. If the aggregate absorbs water, the water-cement ratio around the aggregate will be reduced and thereby reduce the negative factors of interface, such as using aggregate with absorption property, then the water-cement ratio around the aggregate, especially in the lower side of the slurry will be reduced. Thereby the interface will be improved, as well as the overall strength of the concrete, which can avoid further development of micro-fractures.

IV. Crack repair measures

Cracks in concrete structures should be treated on the basis of identifying crack types to make sure whether the crack is harmful and design proper measures when in need. At present, there are three main ways widely used and relative mature: surface filling, pressure grouting and caulking method.[12][13]

4.1 Surface filling

For crack width of micro-cracks less than 0.2mm, it is the most simple and common repairing method to brush polymer or elastomeric sealant on the surface in order to prevent moisture, carbon dioxide and other harmful materials. But the drawback is that it belongs to the repair of shallow surface and cannot seal deep cracks, and irreparable cracks due to reduced carrying capacity and cracks not suitable for obvious water pressure.

Method procedure: surface bristles and rinse→ embed and complement surface defects (option: epoxy clay) →smear selection.

4.2 Pressure grouting

This method is mainly applied to deep cracks with width bigger than 0.3mm. Grouting materials can inject into cracks under pressure grouting equipment to repair structural integrity, water resistance and durability. Currently, main grouting materials are epoxy resins, polyurethanes, slurry and other chemical materials. The equipment is YJ-automatic pressure grouting machine. Although it is more complex than surface filling method, the repair is better and able to recover its integrity basically.

Method procedure: gauges→bury packer→ seal

→check seal→deploy slurry→fill in slurry→seal holes→check the quality of slurry.

4.3 Caulking method

This method is mainly applied to cracks with a width bigger than 0.5mm. Concrete should be hewn into "U" shape or "V" shape along the cracks, and then insert into filling materials. Filling materials can be divided into plastic materials(such as PVC cement, plastic ointment, butyl rubber) and rigid materials(such as polymer cement mortar). This method is also relatively widely used and can partly recover the integrity of cement structure. But it is not easy to gauge and concrete with no cracks next to those cracks without is easily damaged. Cement interface is also hard to deal with.

Method procedure: gauges→primary treatment (concrete cleanse, steel rusting)→smear cement→fill with repair materials→surface leveling.

In addition, Ju Yanli[4] has also proposed electrochemical reinforcement method and biomimetic self-recovering method in her research. Anchorage(prestressed anchorage) method[13], carbon fiber reinforced adhesive method[14], concrete replacement method all have achieved good recovery results in engineering practice. They are also currently in promotion and there is no need to mention too much here.

V. Conclusion and outlook

The occurrence of concrete cracks is mainly due to structural defects of the concrete itself. The internal factors are: internal and external stratification during the process of concrete pouring, the existence of concrete transition zone and multiphase porous system of concrete. However, the reason for those internal factors is that the material itself can not be well solved during the process of pouring, which is also the direction for future research on concrete cracks and prevention.

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