Technical Analysis of Concrete Crack Prevention and Control in Construction Engineering

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Abstract: This paper deals with the problem of concrete cracks which influence building construction safety and resilience. This Methodology is based on understanding the three main causes of cracks: material, construction process and environmental factors; with details of corresponding technical preventive controls strategies. From the perspective of "problem-oriented - technology adaptation", it summarizes a three-dimensional prevention and control system for a comprehensive review of problems in optimizing material proportions, standardizing construction processes, adapting environmental measures. It clarifies the purposes of each in mitigating cracks and improving the performance of concrete. The aim of the research results is to provide practical prevention and control solutions for engineering practice, which can help reduce concrete cracks and ensure the long-term stability of construction sites.

1. Introduction

Concrete cracks are a typical quality problem in construction engineering, which not only affects the appearance of buildings but also reduces structural load-bearing capacity and service life. The appearance of cracks is directly associated with the proportions of materials, workmanship and environmental conditions. When not effectively managed and bypassed, cracks will directly lead to the follow-up problems of water leaking and steel corruption. In order to solve this pain point, it is necessary to systematically comb the causes of cracks, carry out in-depth research on prevention and control technologies targetedly, and determine the key technical points of each period. From a technical analysis perspective, the following will discuss specific concrete crack prevention and control solutions aimed at preventing structural cracks from weakening the load-bearing capacity of structures, ensuring building safety, preventing rainwater and harmful substances from infiltrating into their interiors and causing corrosion to steel reinforcement, prolonging the service life of long-lasting structures, It also can lay preconditions for subsequent maintenance costs reduction as well as improve economic benefits while inferring that engineering design quality must comply with standards hence contribute to stable operation for construction engineering in future.

2. Causes of Concrete Cracks in Construction Engineering

2.1 Unreasonable Material Proportions

There is consists of the contradictions of the cementitious materials about amount and hydration heat. A large amount of heat is released in the cement hydration process, which makes the internal temperature of concrete rise rapidly, while the surface temperature lags behind and lowers due to fast heat dissipation when the cement content in the mix proportion is too high. If the temperature stress generated by the internal–external temperature difference exceeds the tensile strength of concrete, irregular temperature cracks will occur on the surface of the structure. In particular for massive structures, this temperature differential between the interior and exterior, leads to cracking in concrete that can penetrate deeply into the material [1]. Another reason is a bad management of the water-cement ratio. When water-cement ratio is too large, the lost moisture during hardening gives rise to an important dry shrinkage deformations of concrete. Moreover, surplus water will

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create voids within the concrete matrix itself and lower its structural density as well as tensile properties. It has a tendency to develop dry shrinkage cracks in the direction of steel reinforcement or randomly distributed in dry weather conditions. Variations in total gradation and mixture content also lead to cracking. If the overall shaping is discontinuous or the supply of great mixture is extra, the workability of concrete combining decreases and contains larger hazard to segregation through building. Furthermore, following setting, the bonding zone between aggregates will reduce the natural tensile capability of the entire composition as well. During setting shrinkage, fine cracks easily produced, and with time, these small cracks will be lead to spread that affects durability of structures.

2.2 Non-standard Construction Processes

During the pouring process, Improper Vibration Operations When the interval distance by moving of an immersion vibrator is large and time of vibration is not sufficient enough, then air bubbles and voids will stay within the concrete mass, creating local weak sections in it. I.e.; these zones are where first to fail under loads or when heated/cooling. Conversely, excessive vibration can cause the aggregate to sink and the cement paste to float up — that is a "segregation layer" The shrinkage of the surface cement paste layer is maximum method, which cleverly change with the net-shaped crack in hardening position. Negligent in the curing process will also result in cracking. If the concrete surface is not covered to maintain moisture within 12 hours after pouring, and if water spraying during curing is not frequent enough, the surface water of the concrete will be lost quickly. The surface will contract much more rapidly than the interior is, resulting in what we call "surface tensile stress." At this moment, when the tensile stress exceeds the tensile strength of the surface concrete, parallel surface shrinkage cracks along the pouring direction will appear. Despite being shallow, these cracks can harm the concrete surface's integrity and provide access paths for the ingress of aggressive agents [2]. Cracks may also be caused by incorrect timing of formwork removal. The removal of load-bearing formwork is not possible before the concrete reaches 75% of the strength as specified in design, since this would lead to bending cracks in mid-span or at supports (particularly if the loading has already been applied). These cracks, which primarily run perpendicular to the direction of the applied load can lead to structural deformation in extreme cases.

2.3 Environmental Factors

Temperature changes can cause cracks. In summer, when co-temperature is high, after the concrete is poured and exposed directly to sunshine, its surface will heat up quickly. When there is a large rainfall and sudden cooling at night, the surface concrete will outside shrink rapidly with "temperature shock", while the internal concrete still is expanding as heat dissipation compared to radical. The difference in stress from internal expansion and external shrinkage will give rise to uneven temperature cracks across the surface, primarily radial or net-shaped. When the box data in winter construction under low temperature conditions is poured with concrete, if there is no insulation measures, the ambient temperature less than 0 ° C, will cause free water in the concrete to freeze and expand, volume increasing about 9%. It will destroy the internal structure of the concrete. Pores and micro-cracks are formed inside after thawing, which can progressively split into macro-cracks under subsequent loads. Another cause of cracking is uneven settlement of the foundation. If on the construction of the foundation not completely compacted, the foundation building will unevenly consisturent after concrete pouring or uneven distribution of various soil layers in each other. The bottom of the structure will be subjected to "differential settlement forces", and inclined settlement cracks will occur at weak stiffness positions. These fissures mainly range in the foundation upwards and even through the entire structural layer in extreme situations, influencing framework stability [3]. Dry shrinkage cracks can occur due to changes in humidity. When the concrete is kept for a long time in a dry environment, moisture in the concrete itself will continuously diffuse outward so that an overall dry shrinkage deformation of concrete can be produced. Since the structure is restrained and cannot shrink freely, "restraint tensile stress" will be generated. The parallel dry shrinkage cracks propagate along the direction of the restraint when this tensile stress reaches the tensile strength of the concrete. These cracks tend to be straight and spaced evenly apart.

3. Application Strategies of Concrete Crack Prevention and Control Technologies in Construction Engineering

3.1 Optimizing Concrete Material Proportions

Step One - Optimize the cementitious material system. Once the benchmark mix proportion is worked out based on the engineering type (mass concrete or ordinary beam-slab concrete) then reduce cement content (e.g. mass concrete can be controlled below 300 kg/m³). Reduce the total cementitious materials content by adding Class I fly ash (20%-30% of the total cementitious materials) or S95 ground granulated blast-furnace slag (30%-40% of the total cementitious materials), respectively. These admixtures can replace a portion of the cement, thus reducing hydration heat and lowering maximum internal temperature by 8-12°C, as well as fill in voids between cement particles which increases concrete density [4]. In parallel, manipulate the water-binder factor. Its value must be less than 0.55 for standard concrete and less than 0.5 for mass concrete. Using polycarboxylate superplasticizers (0.8%-1.2%) to improve the workability of mixture, reduce unit water consumption, and reduce the source of dry shrinkage deformation risk; Then, modify the aggregate gradation and dosage. Choose Continuous Graded Aggregates continuously (such as 5-25 mm Crush Stone) and Get the Gradation curve which meet Specification Limits. There should be no less than 60% of the intermediate coarse aggregate (10-25 mm) and the amount of fine aggregates (medium sand) it is each portion throughout 30%-40%, excessive amount of fine aggregates can cause shrinkage rate increased. The aggregates (crushed stone and sand) should be tested for silt content prior to entering the site (silt content for crushed stone must not exceed 1%; silt content of sand must not exceed 3%). Aggregates with high silt content will weaken the bonding force between aggregates and cement paste, and water washing treatment must be performed to reduce the silt content to the standard range [5]. Thirdly, add functional admixtures. When cracks are expected in the structure, addition of 0.9 kg/m³ polypropylene fibers of length 6-12 mm to the mix proportion. The fibers can aggregate into a three-dimensional network structure in the concrete body to diffuse shrinkage stress, enhance the tensile strength of concrete (15%-20%), and hinder micro-crack formation and growth. In the case of underground structures that require resistance to cracking, 8%–10% calcium aluminate expansive agents can also be added so that their expansion effect compensates for concrete dry shrinkage; this method further reduces crack risks.

3.2 Standardizing Construction Process Operations

Control vibration quality strictly during the pouring process Assign vibration parameters according to the slump of concrete (180±20 mm). Select Φ50 immersion vibrator (vibration time 20–30 s, the distance between moving space in within 300–400 mm) when floating slurry appears on the concrete surface and no longer sinks, indicating that no bubbles escape. Vibrate for 50 mm in the lower layer of concrete so that the upper and lower layers have a corresponding bond. Do not touch the steel reinforcement or the formwork with a vibrator, otherwise it will cause the position to move and leak concrete; so that in affecting local density concrete. Where the concrete reinforcement is dense, use Φ30 small vibrator, at the same time cooperate with manual tamping and so on, in order to ensure that these areas appear vibration and avoid due to vibration blind spot (vibration bottle) cause hole [6]. Apply the requirements of "cover in time, keep moist all the time" in curing. In summer, cover the concrete with geotextile (or plastic film) within 4 hours after pouring; In winter, cover it in no more than 8 hours. There should be no air bubbles — the mother film or cloth must be firmly glued to a concrete basis. Keep ambient humidity under control when curing In summer, spray water 3 ~ 4 times a day to keep the geotextile moist, and in winter, use double curing of covering with film and insulation quilt to prevent rapid evaporation of water. The curing time of ordinary concrete is applied no less than 14 days, and the curing time of mass concrete should be extended to more than 28 days due to its slow heat release period. Monitor the surface temperature of the concrete curing and make sure that the internal-external temperature difference does not exceed 25 °C [7]. Carry out the formwork removal in accordance with the principle of "strength compliance and orderly removal". Determine the strength of the concrete specimens cured under identical conditions prior to removal. In the case of load-bearing formwork, these can only be removed as the specimen strength reaches 75% of the design value [need citation], while for cantilever structures they have to reach 100% of the design value before being removed. Retitting the hal pattern (non – load bearing first, structural frame later and lateral form last bottom,) remove internal scaffolding in order of forming. After pouring, the formwork is slowly removed gradually with special tools to prevent violent tearing of the concrete surface or vibration cracks. Once the formwork is removed carefully examine the surface of concrete. In the case of fine cracks, fill them with cement-based permeable crystalline waterproof coatings in time to prevent further expansion of cracks.

3.3 Adapting Construction Measures to Environmental Conditions

For summer high-temperature construction, reduce from two aspects: temperature and rhythm control. In the case of raw materials, lessen the temperature by constructing a sunshade over an aggregate stockpile to prevent direct sunlight. Add ice water during mixing with aggregates, the ice water temperature is lower than 5°C; both crushed ice can be added in concrete mixing, but without exceeding 20% of the total amount of mixing Water, control the concrete placing temperature below 30°C, and keep pouring rhythm by avoiding to pour at noon high-temperature period (11:00-15:00) and choose morning and evening time. Pouring layer-wise in layers not longer than 5 m and covered immediately [8]. Embed temperature sensors inside the concrete for constant internal temperature measurement. Make up some insulation quilts, when the interior and exterior temperature difference is greater than 25°, so as to reduce Temperature Difference Stress through "Insulating delay heat output". It involves a three-step method "raw material preheating, pouring thermal insulation and curing later" when applied in low-temperature construction during the winter season. Keep the mixing water heated to 80°C, heat aggregates with steam not lower than 5 °C (to meet the concrete discharge temperature does not fall below 10 °C and placing temperature does not fall below 5 °C), speed up construction rhythm during pouring so that the concrete in situ stay for a shorter time and avoid rapid drop in temperature. Immediately after pouring the concrete, cover with insulation quilts and electric blankets to prevent cooling and if necessary install heating pipes on outside of the formwork in contact with concrete to maintain a temperature above 0°C, regularly detect the strength of the concrete during refraction without needing to remove the insulation until it reaches at least 75% of its design value with ambient temperatures stabilising above 5 °C [9]. In order to solve the risk of foundation settlement, carry out layered compaction treatment of the foundation before construction. The thickness of each layer of backfill soil in the embankment should not exceed 300 mm, and the compaction degree (detected by the ring knife method) should reach 93% or more. You can use replacement methods (directly replaced with graded sand and gravel) or lime soil lime soil compaction column piles to reinforce the foundation. Some routines that can be considered:In one set up the following: monitoring points will be placed in the 4 corner positions of the structure and middle position when pouring concrete, follow up are made with a frequency of 3 days. In the case of adjacent observation points, if the settlement difference is greater than 5 mm, it needs to be adjusted: change the order of pouring from small settlement areas to large settlement areas, and slow down the pouring speed as far as possible from completionshe density (or elastic modulus) ratio on a hull bottom which secures such a foundation so that it has enough time to adapt to this load; structural cracks caused by uneven settlements should therefore be avoided.

4. Conclusion

The above analysis reflects that the control and prevention of cracks in concrete should be based on the causes of cracks to create a full-process technical system. The proportions of these materials are optimized during the design stage so that the internal stress remains to a minimal figure obtained from the source by changing cementitious materials, aggregate gradation and use of admixtures. Control standardization of key links such as pouring vibration, curing and formwork removal to avoid cracks caused by improper operation in construction process. Therefore environmental measures must be adjusted for and controlled in a targeted way with respect of temperature – as it occurs in summer or winter – but also the influences resulting from the type of founding. The synergistic effect of these three types can effectively reduce the formation of cracks, ensure the construction quality and safety of concrete structures, and provide reliable technical references for crack prevention and control in similar projects.

References

[1] Wang Huafeng. Analysis of the causes of concrete cracks in construction engineering and research on prevention and control technologies [J]. China Building Decoration, 2025(7): 104-106.

[2] Zhou Dawei. Exploration of concrete crack prevention and control technologies in construction engineering [J]. Modern Engineering Science and Technology, 2024, 3(6): 9-12.

[3] Su Yankai. On the prevention and control technologies of concrete cracks in construction engineering [J]. Building·Building Materials·Decoration, 2024(9): 157-159.

[4] Wu Ankang. Research on concrete crack prevention and control technologies in house construction engineering [J]. Building Materials Development Orientation, 2024, 22(16): 100-102.

[5] Liu Yaolong. Research on crack prevention and control technologies for mass concrete construction in high-rise building engineering [J]. Construction Machinery and Maintenance, 2024(3): 26-28.

[6] Yuan Shengqi, Cui Qiumei. Causes of concrete cracks in construction engineering and the application of prevention and control technologies [J]. Brick World, 2023(14): 4-6.

[7] Liu Feng. Causes of concrete cracks in construction engineering and prevention and control technologies [J]. Brick World, 2023(16): 52-54.

[8] Lv Qingyuan. Research on factors related to the formation of concrete cracks in construction and prevention and control technologies [J]. China Building Decoration, 2025(6): 189-191.

[9] Zhao Yuan, Huang Shuaigang. Construction treatment technology standards for concrete cracks in civil engineering buildings [J]. Popular Standardization, 2025(12): 28-30.