Crack Control Technologies of Mass Concrete

Chunhao Du¹, Qiang You²*, Xin Gu¹ and Yiliang Peng¹

¹Powerchina Henan Electric Power Survey & Design Institute Corporation Limited, 212 Zhongyuan West Road, Zhongyuan District, Zhengzhou, Henan Province, China
²Department of Civil Engineering, Xi’an Jiaotong University, 28 Xianning West Road, Xi’an, Shaanxi, China
E-mail: yq574485585@stu.xjtu.edu.cn

Abstract. With the rapid development of national economy, a variety of large-scale complex projects continue to emerge, resulting in the pouring of mass concrete has become an important part of the construction process. Due to various stress factors, cracks are easy to occur in mass concrete construction, which will not only affect the aesthetic performance of construction projects, but also their quality. Therefore, it is necessary to strengthen and control the construction of mass concrete for construction projects. This paper introduces crack prevention technology of mass concrete, including construction technology analysis, cause analysis and control measures. Through the literature review, the research status of related fields can be understood, thus providing theoretical basis for the future relevant projects.

1. Introduction
As the national economy grows with high speed and quality, China has strengthened its investment and construction of infrastructure since the 21st century. Various bridges, high-rise buildings and large-scale complex projects are constantly emerging, which makes the application of large volume in practical engineering more and more widely used [1]. As we all know, the long construction period of mass concrete, and its sensitive environmental impact and the great hydration heat makes the temperature cracks of mass concrete are easy to occur in the construction process. Therefore, preventing and curing dimensional cracks in mass concrete has become an unavoidable topic in large-scale building structures [2]. In the construction of mass concrete, a good control of temperature rise is the key to restrain temperature cracks. Therefore, it is of great theoretical and practical significance to strengthen the control of temperature cracks in mass concrete [3]. In this paper, some relevant technologies are summarized to provide insights for engineers in this field, including construction technology analysis, cause analysis and control measures.

2. Construction Technology Analysis of Mass Concrete
According to the analysis of mass concrete construction technology in recent years, three aspects can be summarized. The first is the choice of materials. The material quality and performance have an important impact on the quality of mass concrete. So, we should not only control the basic materials performance, but also optimize specific adjustments to the mix ratio in the construction of mass concrete [4]. The second is to improve the analysis technology. In the construction of mass concrete, technical perfection can ensure the consistency of the whole construction. The standards and norms of engineering monitoring can also be achieved by above process, which enhances the importance of emphasizing the control of whole mass concrete construction. Thirdly, in the construction of mass
concrete, we need to apply some modern advanced technology, including the temperature measurement technology and mix proportion control technology. These technologies can effectively evade the influence factors of mass concrete quality, further improving its quality [5].

3. Causes Analysis of Crack Formation in Mass Concrete

3.1. Temperature Crack
Temperature crack of concrete comes from cement hydration heat release and the direct sunlight, resulting in internal and external temperature imbalance. Then, temperature stress is generated by shrinkage or expansion. If the temperature stress exceeds the design tensile strength, crack will be generated [6]. The hydration heat makes the internal temperature of concrete rise, resulting in great temperature difference, and the concrete internal stress keeps rising, which leads to occurrence of the surface tension stress and the resulting crack if the tension stress exceeds the design one. According to the Chinese design code "Code for Construction of Mass Concrete" (GB50496-2012), mass concrete refers to the concrete whose minimum geometric size is more than 1m. Thus, most kinds of buildings conceptually belong to mass concrete buildings in modern society, such as high-rise buildings, water conservancy projects, large-scale equipment and so on [7]. Because the minimum size of mass concrete is more than 1m, the hydration heat reaction of cement tends to be more intense, leading to the higher internal temperature than the external temperature. Therefore, the temperature stress is also quite large, causing large and deep concrete temperature cracks and affecting the safety and normal use of the structure.

3.2. Shrinkage Crack
There are two reasons for shrinkage cracks in mass concrete. The first is condensation, namely, the overall volume reduction in the process of concrete solidification, which is due to the water evaporation as well as its gradual combination with the particles in the process of concrete solidification [8]. In most cases, the drying and solidification of cement is mainly from the surface to the interior, leading to water content gradient in the concrete. If the water content gradient shrinks unevenly, the tensile force of the surface concrete will also increase. Once the bearing pressure of the interior concrete exceeds the tensile strength, shrinkage cracks occur as a result of accumulated shrinkage. Secondly, the shrinkage of water collection cannot be neglected. When concrete is solidified, the surface water will evaporate a lot of heat, which leads to the volume shrinkage of concrete. In this process, water on the surface has rapid lost rate, resulting in the pressure on the surface of concrete increase and thus leads to shrinkage deformation [9]. If the tensile force of surface concrete exceeds the design tensile strength, cracks will also occur.

3.3. Reinforcement Corrosion
In mass concrete construction projects, there are many imperfect qualities of concrete construction, such as lack of compactness of concrete, holes, pitting surface, cracks on the surface, or insufficient thickness of reinforced concrete protective layer. Thus, external carbon dioxide will spread to the surface of reinforcement through protective layer, causing corrosion of reinforcement [10]. In this process of steel corrosion, concrete cracks expand along the direction of steel cracks, and ultimately destroy the overall structure. Therefore, in order to effectively prevent steel corrosion, it is necessary to strengthen the effective control of concrete pouring density, cracks, and the thickness of steel protective layer. When pouring concrete, concrete construction quality should also be strengthened and the concrete density and its protective layer thickness should be controlled. By this way, the invasion of external carbon dioxide can be strictly decreased to improve the ability of steel corrosion prevention.
3.4. Reinforcement Corrosion
Frost heave cracks mainly occur in winter. When the temperature drops below zero, the moisture content in concrete is too large and is easy to freeze. Thus, the volume expansion of concrete can expand and finally result in cracks. Note that if construction is carried out in low temperature season, it is necessary to strengthen insulation measures for prestressing holes. Otherwise, frost heave cracks will easily appear along the pipeline direction after grouting of prestressing holes. Herein, the generating conditions of frost heave cracks and temperature cracks are quite different and the former mainly affect cold areas in the north, so engineers in such area should pay more attention [11]. In addition, mass concrete easily causes higher surface temperature than other parts after long-term exposure in cold areas, so that local tensile stress increases and cracks occurs. Also, under extreme weathers such as thunderstorm, surface temperature of mass concrete drop fast while internal temperature does not change obviously, which also leads to a gradient of temperature between inside and outside. Therefore, in the actual construction process, varieties with lower hydration heat is more applicable and the amount of cement should also be strictly controlled. In the process of mass concrete curing, measures of heat preservation and temperature control should be taken. If these measures are not performed well in winter, the problem of sudden cooling and heating on the surface of concrete can also occur due to the change of temperature in the external environment, which lead to cracks [12].

4. Control Measures for Cracks in Mass Concrete

4.1. Preparing for Construction Technology
In the process of concrete construction, the specific measures are necessary to accurately evaluated according to the actual situation by organizing technical and quality departments to demonstrate the construction scheme with the aim at clarifying the technical standards and quality requirements. If commercial concrete is employed, the technical submission of commercial concrete should be strengthened to ensure that the use of commercial concrete meets the relevant requirements. Temporary water and electricity are laid out in place at the construction site, and adequate vertical and horizontal transportation tools are provided to ensure the smooth progress of concrete construction. In addition, it is necessary to equip enough materials for concrete maintenance and draw and arrange the plan layout of temperature measuring points in advance. It is also necessary to prepare in advance to ensure the temperature control effect of subsequent concrete construction.

4.2. Strengthening the Management of Material Ratio
On the basis of meeting the requirements of design and specification, mass concrete construction should reduce the hydration heat and shrinkage performance of concrete to a minimum. The relevant measures include the reasonable selection of raw materials, choosing cement with low hydration heat to reduce the effect of hydration heat, adding reasonable water reducing agent, reducing water cement ratio, and controlling sand content. In the design of concrete mix proportion, attention should be paid to water cement ratio and sand content [13]. According to the experimental analysis of the mix proportion of various raw materials, it is found that the larger the water cement ratio and the more water content, the more easily the concrete has air holes after drying, resulting in the brittle performance of the whole mass concrete and causing cracks, so the water cement ratio should be reduced. In addition, sand content is an important factor affecting the consistency of cement concrete. If the water cement ratio is small enough and the sand content is too high, it can lead to less cement slurry, thicker sand layer, and reduce the wear resistance and overall hardness of concrete. In addition, if the expansive agent and other additives are used, it is necessary to know the performance of the additives in the process of mixing materials. Then, select the type of additives and carry out experiments before construction to optimize the configuration according to the effect of the experiments.
4.3. Strengthening Temperature Control of Mass Concrete

In the process of concrete mixing, the initial temperature of concrete mixing material should be lowered. When mixing concrete, ice chips can be added into mixing water to reduce the temperature of mixing water. In high temperature weather, shade should be set in sand-stone yard to avoid sunshine on coarse aggregate and reduce the temperature of sand-stone. Meantime, stones are scoured with cold water to achieve cooling effect. In the process of concrete transportation, wet hemp bags are wrapped around transport tank trucks and pumping pipes, and cold water is sprayed. Before pouring, the base or formwork of concrete structure is flushed and cooled to control the temperature of concrete before pouring into the formwork. The cooling pipe is embedded in the concrete structure and circulating cooling water is used to take part of the heat away by circulating water (figure 1). If the temperature of concrete is very high, the stress is too large, it is easily lead to temperature cracks.

Figure 1. Cooling pipe laying.

4.4. Improving the Quality of Concrete Casting and Strengthening the Maintenance Management

Firstly, construction quality management should be strengthened in the process of reinforced concrete construction. The installed reinforced skeleton should be ensured to have fixed and reliable the position with effective thickness of reinforced concrete protective layer. Secondly, concrete pouring should be vibrated in place to ensure the compactness of concrete construction. After the completion of concrete pouring, water and voids can be cleared by secondary vibration, and initial setting cracking can be reduced. In addition, the concrete has been poured in time to take heat preservation, moisture and other maintenance control measures. During construction in summer with high temperature season, concrete should be sprinkled and maintained as early as possible and covered with straw bags and moisturized (figure 2). In addition, wetting measures are should be taken on concrete surface to prevent concrete moisture evaporation from losing too quickly. In winter construction, the external temperature of concrete is low and the external temperature environment changes greatly, so the formwork used for construction can adopt heat conduction. For the low coefficient thermal insulation formwork, the top surface of concrete must be covered with thermal insulation materials in time to avoid frost damage and ensure that the surface temperature of concrete is not lower than that of normal solidification and hardening (figure 3) [14].
5. Conclusions
In this paper, the problems of mass concrete cracks are summarized, including construction technology analysis of mass concrete, causes analysis of crack formation in mass concrete and control measures for cracks in mass concrete. Through the summary, readers can have a better understanding of the causes of cracks and control technology in the construction process of mass concrete, and provide reference for future engineering practice.

Acknowledgments
This research work was financially supported by the National Natural Science Foundation of China (Grant No.51978570).

References
[1] Gong J and Li H W 2012 Crack control of mass concrete construction Constr. Technol. 41 (06) 28-32
[2] Lu L and Li X G 2012 Research and progress of control for mass concrete temperature crack J Water Resour. Archit. Eng. 10 (01) 146-50
[3] Gou J 2008 Study on the effect of mass concrete hydration head on structure (A thesis from Guangxi University, available through cnki.net)
[4] Lu E X 2007 Analysis and controlling of hydration head temperature in massive concrete pile cap (A thesis from Hunan University, available through cnki.net)
[5] Li B B 2007 Finite element analysis of thermal stress of massive concrete (A thesis from Xi’an University of Architectural Science and Technology, available through cnki.net)
[6] Xu W Z 2007 Engineering research for controlling temperature crack of mass concrete foundation structures (A thesis from Tongji University, available through cnki.net)
[7] Chen M 2006 The mechanical analysis and control on shrinkage cracking for concrete structure (A thesis from Wuhan University of Technology, available through cnki.net)
[8] Chen H. 2006 Han F H. Factors and controlling measures caused by the temperature cracking of mass concrete Concr. 02 74-5
[9] Chen B 2005 Prevention of early deficiency and mix-proportion optimization research on concrete building (A thesis from Zhejiang University, available through cnki.net)
[10] Zhu Y T 2005 Experimental investigation and theoretical modelling on early-age shrinkage cracking in concrete (A thesis from Zhejiang University, available through cnki.net)
[11] Tong Y L 2004 Crack control study of mass concrete structure (A thesis from Chongqing University, available through cnki.net)
[12] Li Y 2004 Temperature and cracking control of mass concrete (A thesis from Wuhan University of Technology, available through cnki.net)
[13] Duan Z, Ma Z L and Wang L L 2003 Causes and prevention of cracks in cast-in-situ mass concrete *Concr.* **05** 48-58
[14] Dai Z C 2001 Crack prevention of mass concrete *Concr.* **09** 9-11