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Original research article

# Research on crack control of mass concrete structure

**Honglong Su*, Dongtang Duan, Zhibin Lu**

*School of Environment and Municipal Engineering, Tianjin Jiaotong University, Tianjin, China*

*** Corresponding author:** Honglong Su, Honglong1202@gmail.com

***Abstract:*** With the development of economy in our country, the scale of construction has become more and more complicated. This causes the problem of mass concrete cracks in industrial and civil buildings increasingly prominent and become a fairly common problem. The problem of mass cracks in mass concrete is very complex and involves all aspects related to the engineering structure. The control of temperature cracks in mass concrete foundation is related to geotechnical, structural, building materials, construction, environment and other multi-disciplinary. The hydrothermal heat released by the mass concrete in the hardening process which produces a large temperature change, and the resulting of temperature stress is the main factor leading to the occurrence of cracks in the concrete, thus affecting the integrity of the structure, water resistance and durability, and become structural hidden dangers. Therefore, the mass concrete in the construction must consider the crack control. The reason and control measures of the temperature cracks of mass concrete are analyzed and summarized. According to the specific situation, these measures are applied to the concrete large-scale basic engineering construction, and the material selection, mixing ratio, admixture, construction arrangement and pouring process, conservation and other aspects to take a strict control measure. At the same time the basic position of the internal and external temperature difference was monitored. The temperature control measures and monitoring results taken for the basic engineering provide a reference for the construction of similar projects and provide the basis for further theoretical research.

***Keywords:*** mass concrete; crack control; hydration heat; temperature stress

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## 1. Introduction

### 1.1. Background and practical significance of the subject

Many concrete structures in the construction of the project and the use of engineering in varying degrees, different forms of cracks, which is a fairly common phenomenon. It is a long plagued technical problems of construction workers. The microscopic study of the strength of concrete and the experience provided by a large number of engineering practices have shown that the cracks in the structure are unavoidable. The cracks are a kind of acceptable material, such as the requirement of anti will pay a huge economic cost; scientific requirements should be to control the extent of its tolerance within the allowable range. These aspects of the prediction, prevention, and treatment of cracks, collectively referred to as 'building cracks control', this aspect of scientific research work is important for practical significance, technical and economic significance, a large volume of concrete structure cracks are mainly due to deformation.

Definition of mass concrete:

For the definition of mass concrete, the American Concrete Society has had the requirement that ‘any large volume of concrete in situ, which is large by volume, must be required to take measures to solve the problem of hydration heat and consequent volume deformation, limit the cracking to reduce the crack’[1]. Japan Institute of Architectural standards is defined as: ‘the minimum size of the structural section of more than 800 mm, while hydration heat caused by the maximum temperature of concrete and the difference between the outside temperature is expected to exceed 25 ℃ of concrete, for the mass of concrete’[2]. China’s engineering sector that when the concrete structure section size is greater than 1m, it is called large volume of concrete[3]. The literature pointed out: in the industrial and civil building structure, the general cast-in-place continuous wall structure, underground structures, and equipment base is easily caused by the temperature shrinkage stress caused by the structure, commonly known as ‘mass concrete structure.

From the definition of mass concrete from above mention, mass concrete is larger in geometric dimensions, taking into account the volume change and fracture problems caused by cement hydration heat.

Application of mass concrete in engineering:

In the water conservancy project, mass concrete is mainly used for the pouring of concrete dams, such as the pouring of concrete in the Three Gorges Dam, and its concrete pouring scale has attracted much attention. In bridge engineering, large volume concrete pouring is mainly used for piers. Industrial and civil building structure, large equipment foundation, high-rise building box foundation floor, raft foundation floor, continuous wall and underground tunnel are large volume concrete structure. With the strengthening of economic strength, China’s high-rise buildings in large numbers, the scale of the project is expanding, the structure is also increasingly complex, large-scale industrial and civil buildings in some of the basis of its size of several thousand $m^3$ or more common, and some high-rise civil construction of the raft-based concrete volume of some is more than 10,000 $m^3$, the thickness is 2–4 m, the length is more than 100 m. For example, Shanghai Jinmao building large volume concrete raft foundation, the thickness is 4 m, and the total concrete volume is 13,500 $m^3$.

### 1.2. Research status

Domestic situation:

China has done more research on the cracking of concrete, and in the construction project, there are some achievements in cracking of concrete under the action of load. With the large-scale capital construction, the new problems brought by the application of commercial concrete, the study of concrete cracking under non-load is mainly focused on the causes and control measures of cracking.

Professor Huang[4] from the concrete material itself analysis of the reasons for the early concrete cracking and the construction unit in order to improve the transition period to pursue the early strength of cement and cement manufacturers in order to meet the needs of the market is also the pursuit of early strength, and even ‘super early strong.’ While the early performance of early strength concrete is relatively insufficient. A lot of cement 3 days strength has exceeded a lot of national standards, too high early strength prone to early cracks. At the same time, early strength is easy to cause deterioration of concrete performance.

International situation:

From the international norms and some of the major projects of the actual design shows that the deformation of the building structure caused by the cracks caused by the objective existence of two types of schools:

The first class, the design specification is very flexible, there are no clear provisions of the calculation of cracks, the design method left to the designer free to deal with. The installation of the expansion joints and settlement joints, there is no strict rules, basically set by experience, there are many projects without leaving the expansion joints, leaving no settlement joints, basically take the ‘crack on the block, block on the row’ of the actual treatment means. Some of the relevant cracks are calculated only as a reference and not as a requirement.

The second class, the design specifications are clearly defined, there are formulas for the calculation of the load cracks and have a strict allowable width limit. There is no calculation of the cracks caused by deformation, as long as the specification at a certain distance to leave an expansion joints, the load difference is large, leaving the sagging that the problem no longer exists, that is, leaving the seam is not broken design principles.

The impact of temperature on the deformation of concrete structures, countries have the corresponding provisions. For the pouring temperature of a large volume of concrete, the United States does not exceed 32 ℃; while, for Japan Civil Engineering Society construction specifications do not exceed 30 ℃ and the Japanese Institute of Architects regulations do not exceed 35 ℃. The former Soviet Union stipulates that the temperature of the concrete from the mixing station is not more than 30 to 35 ℃ when the pouring surface coefficient is greater than 3; the original West standard stipulates that the temperature of the fresh concrete unloading shall not exceed 30 ℃. In China, ‘hydraulic concrete structure construction and acceptance of norms’ (SDJ207-82) provides: large volume of concrete pouring temperature should not exceed 28 ℃; and in the ‘high-rise building concrete structure technical regulations’ (JGJ3-2002) only provides: ‘The basis of large volume of concrete continuous pouring, should be measured by the temperature difference’, but no specific control value.

### 1.3. The content of this study and research methods

The contents of the study:

(1) Study on the causes of mass concrete cracks in combination with engineering practice

In the process of mass concrete construction, since the hydration of cement in concrete is exothermic, the mass concrete itself has a certain heat preservation performance, so its internal temperature rise is much larger than the temperature rise of its surface. During the cooling process after the peak temperature of the concrete, the internal cooling rate is much slower than that of the surface. During these processes, the thermal expansion and contraction of the concrete parts (called temperature deformation) and the effect of their mutual restraint and external restraint and the stress generated inside the concrete (called the temperature stress) are quite complex. Once the temperature stress exceeds the tensile limit of the concrete, the concrete will crack. This is the first crack produced by the temperature rise after concrete pouring.

The second crack due to the temperature rise is a shrinkage crack. This kind of crack occurs in the cooling stage of the concrete, that is, when the concrete cools down, due to the gradual cooling and shrinkage, coupled with the concrete during the hardening process, due to the mixing of concrete within the water and evaporation, glial gel and so on, to promote the shrinkage of concrete hardening. These two kinds of shrinkage, when contracted due to the substrate or the structure itself, will have a large shrinkage stress (tensile stress), if the resulting shrinkage stress than the concrete tensile strength at that time, will produce shrinkage cracks in concrete, this shrinkage cracks sometimes through the whole cross-section, a structural crack, bringing serious harm.

(2) To study the technical measures of mass concrete crack control

Design: the use of permanent deformation of the seam or set up after pouring; reasonable plane and facade design, to avoid cross-section of the mutation, thereby reducing the restraint stress: rational distribution of distribution of steel, as far as possible the use of small diameter, close spacing, distribution of tendons; to avoid the use of high-strength concrete, as far as possible the use of low-strength concrete, with 60 days or 90 days strength; use sliding layer to reduce the basic constraints.

Material: scientific use of a material ratio, with a lower water-cement ratio, water and cement consumption; selection of hot or low heat cement varieties; mixed with admixture; mixed with fly ash to reduce the amount of cement; strict control of gravel and the amount of clay in the aggregate.

Construction: the use of thermal insulation method for the maintenance of mass concrete; control hydration heat temperature rise, the concrete center and the surface of the maximum temperature difference is not higher than 25 ℃; control cooling rate; with straw bags and plastic film insulation and moisture; Use cooling water pipes to reduce hydration heat, or use micro-expansive concrete; use of layered pouring or jumping warehouse pouring method.

Methods of research:

In this paper, the construction practice of Daqing Petrochemical high-pressure polyethylene plant explosion-proof dam platform, take the corresponding crack control measures to monitor the mass concrete temperature, analyze the temperature curve, study and analyze the mechanism of mass cracks in mass concrete, analyze the main factors of the temperature stress, cracking cause and crack control measures of mass concrete are studied from the aspects of design, raw material, mix ratio, admixture, construction technology and so on, and the effect of crack control measures is verified.

## 2. Cause analysis and prediction of cracks in mass concrete

### 2.1. Types of cracks

In previous study[5], it is pointed out that concrete cracks can be divided into ‘microcracks’ and ‘macroscopic cracks’ according to the different crack width of concrete.

Microscopic cracks:

Since the 1960s, through the modern experimental equipment of concrete (such as various solid microscopes, X-ray equipment, etc.), can be confirmed in the concrete structure has not yet bear the existence of the invisible micro-cracks. Its width is below 0.05 mm. Microcracks are mainly composed of adhesive cracks, cement stone cracks, and aggregate cracks.

Macroscopic cracks:

Cracks in the concrete with a width of not less than 0.05 mm are visible cracks, also known as macroscopic cracks. The macroscopic fracture is the result of the continuous expansion of microscopic fractures.

Macroscopic cracks can be divided into surface cracks, deep cracks and through cracks in three.

### 2.2. Analysis of cracks in mass concrete

The temperature cracks in the mass concrete construction phase are the result of the development of internal contradictions. Concrete stress and strain due to internal and external temperature difference, on the other hand, the external constraints of the structure and the constraints of the concrete particles is to prevent this strain, once the temperature stress can withstand the ultimate tensile strength of concrete, will produce different degrees of the cracks.

Effect of hydration heat:

The cement produces a lot of heat during the hydration reaction. This is the main source of heat for mass concrete internal temperature rise. The test proved that the amount of heat per gram of ordinary Portland cement up to 500 J. Due to the large thickness of the mass concrete, the hydration heat is not easily distributed in the structure, so it will cause the concrete structure inside the rapid warming. In the water conservancy project is generally 15–25 ℃[7]. While the construction project is generally 20–30 ℃, or even higher. Experiments show that cement hydration heat in 1 to 3 days to release the most heat, about 50% of the total heat, concrete pouring after 3 to 5 days, the highest temperature inside the concrete.

The architectural structure of concrete strength grade is increasing, but there are many structures inappropriate selection of the high strength level. Used to think: ‘The higher the strength level, the greater the safety, the high is not low, improve the strength of concrete no harm.’

Impact of internal and external constraints:

All kinds of concrete structure in the deformation changes must be subject to certain constraints, thus hindering its free deformation, hinder the deformation of the factors known as the constraints. Constraints are divided into inner and outer constraints.

1) Outer constraints

The deformation of an object is hindered by other objects, and the deformation of a structure is hindered by another structure. The interdependence between the structure and the structure, between objects and objects is called ‘outer constraint’. Because of the different conditions of the various building structures, there are different degrees of constraints between the structures. According to the size of the constraint degree, the outer constraints are divided into three kinds which are unconstrained (free body), elastic constraints and full constraints (embedded solids).

2) An object or a component itself between the various particles of the role of mutual restraint, known as the ‘internal constraints.’ There may be different temperatures and shrinkage deformations along the cross-section of a member, causing internal confinement stresses between successive points of the continuum. The cracks in the structure, non-penetrating surface cracks accounted for 60% to 70%. The reason for its cracking is mainly due to the deformation caused by the self-restraint stress. When the mass of concrete is greater than or equal to 500 mm, it may be due to the uneven cooling of hydration heat and uneven shrinkage caused by significant self-restraint stress, resulting in surface cracking.

The impact of external temperature changes:

During the construction phase of Mass Concrete Structures, changes in outside air temperatures have a significant impact on the prevention of massive concrete cracking. As the higher the ambient temperature, the higher the pouring temperature of the concrete; and if the outside temperature decreases, but also increase the rate of concrete cooling, especially the temperature drop, will greatly increase the outer concrete and internal concrete temperature gradient, which will lead to transition of the temperature stress, easy to make large volume of concrete cracks.

The internal temperature of the concrete is composed of the adiabatic temperature rise of the hydration heat, the temperature of the pouring temperature and the heat dissipation temperature of the structure, and the temperature stress is caused by the temperature deformation which caused by the temperature difference. At the same time, under high-temperature conditions, a large volume of concrete due to the thickness of large, difficult to heat.

Impact of shrinkage and deformation of concrete:

1) Concrete shrinkage:

Most of the concrete structure cracks due to deformation caused by the role, and deformation, including temperature, humidity, and uneven settlement. In several deformations, the cracks caused by changes in humidity and the main part.

The important component of concrete is cement and water, through the cement and water hydration, the formation of cementitious materials, the loose aggregate into artificial stone-concrete.

The concrete contains a lot of voids, coarse pores, and pores. The presence of moisture and moisture in these voids affects a series of properties of concrete, especially the nature of 'humidity deformation', which plays an important role in fracture control. The moisture in the concrete is chemically combined with water, physical-chemical combination of water and physical mechanics combined with water.

2) The type of contraction

The shrinkage caused by chemical action during the hardening of concrete is the result of a chemical combination of water and cement, also known as hardening shrinkage, which has nothing to do with the change of outside humidity.

Plastic shrinkage:

After 4 to 15 h of concrete pouring, cement hydration reaction is intense, the molecular chain gradually formed, there is bleeding and water evaporation phenomenon, causing water loss contraction, the initial coagulation process occurred in the contraction, also known as condensation. This time between the aggregate and the binder also produce uneven shrinkage deformation, which have occurred in the concrete before the final condensate, that is, plastic stage, so called plastic shrinkage.

Carbonization shrinkage:

Atmospheric carbon dioxide and cement hydrate chemical reaction caused by shrinkage deformation known as carbonation shrinkage.

Shrinkage (water shrinkage):

Cement sludge in the dry and wet environment to produce shrinkage and wet up phenomenon, the biggest contraction occurs in the first drying, the shrinkage and expansion of deformation are partially reversible.

3) The impact of contraction factors

The greater the amount of cement, the greater the amount of water, the greater the amount of cement slurry, slump, the greater the contraction, so avoid pouring concrete in the rain, in case of rain, should take measures to prevent rain (especially the cutting site) and adjust water-cement ratio.

4) Concrete volume deformation

Concrete in the cement hydration process produces a certain volume deformation and a free volume deformation. The shrinkage mechanism of concrete is complicated, and its main reason may be the capillary-gravity caused by the change of internal void water evaporation. Contraction is largely reversible. If the concrete shrinks, then in the water-saturated state, you can also return to expansion and a few years to reach the original volume. Dry and wet alternating will cause alternating changes in the volume of concrete, which is very unfavorable to concrete.

# 3. Control measures for mass concrete cracks

## 3.1. Control measures for mass concrete cracks

Practical experience shows that the cracks in the existing mass concrete structures are mostly caused by temperature cracks. To prevent the occurrence of temperature cracks is a large volume of concrete research important issue, China since the 1960s began to study, has accumulated a lot of successful experience. Engineering measures commonly used to prevent concrete cracks are: the use of low-heat cement varieties; the concrete structure of a reasonable sub-sub-block; to meet the strength and other performance requirements under the premise of minimizing the amount of cement; to select the appropriate aggregate; embedded water pipes, water cooling, reducing the concrete out of the machine temperature and pouring temperature; use of surface protection, â ... ¢ control of the concrete out of the temperature and pouring temperature; Thermal insulation measures to reduce the temperature difference between inside and outside; to take measures to prevent a large volume of concrete cracks.

Design measures:

(1) Set up after pouring

In the cast-in-place reinforced concrete structure, only temporary construction joints retained during construction are called ‘post-pouring belts’. The ‘post-pouring belt’ according to the specific conditions, to retain a certain time, in the filling closed, after pouring into a continuous whole non-expansion joints. Since this slit exists only during construction, it is a special construction seam. However, as it is aimed at eliminating the permanent deformation of the structure in the structure, and the structure of the temperature shrinkage stress and differential settlement, so it is a design of the expansion joints and settlement joints, a temporary deformation of the seam. It is both construction measures, but also design means.

(2) Reasonable configuration of steel

At room temperature and allow stress state, the performance of steel is relatively stable, and its thermal expansion coefficient of concrete is not much difference.

(3) Set the sliding layer

To reduce the concrete due to the existence of constraints on the boundary to produce temperature stress, in contact with the external constraints on all the sliding layer, the length of the calculation can be reduced by about half.

(4) Avoid stress concentration

In the structure of the hole around the variable cross-section of the corner, transfer, etc., due to temperature changes and concrete shrinkage, will produce stress concentration and lead to concrete cracks. To this end, can be added around the hollow with inclined bars, steel mesh; in the variable section to avoid cross-section mutation, for local processing to gradually cross-section transition while adding a certain amount of anti-cracking steel, which is to prevent cracks have a great effect.

(5) Set the buffer layer

Set the buffer layer, that is, in the high and low floor junctions, floor beams, etc., with 30–50mm thick polystyrene foam for vertical isolation to cushion the lateral compression when the lateral pressure.

(6) Set stress relaxation trench.

Material control measures:

(1) Cement variety selection and dosage control

The main reason for the cracks caused by the mass concrete structure is that the thermal conductivity of the concrete is poor and the cement hydration heat accumulates in a large amount, which causes the early temperature rise and the later temperature drop of the concrete. Therefore, the control of cement hydration heat caused by the temperature rise, that is, to reduce the temperature difference between concrete inside and outside, to reduce the temperature stress, to prevent the occurrence of temperature cracks will play a very important role.

(2) Add the additive

The volume of concrete is large, and its main features are: the structure is thick, concrete is large, cement hydration heat causes temperature rise and shrinkage deformation, so concrete crack control is a very important technology. To ensure the integrity of the concrete, the durability and durability are not affected, in the mass concrete mixed with admixtures and admixture, make full use of their respective advantages, complement each other and take a scientific construction technology and reasonable concrete curing measures to control the cracks, to prevent leakage, so as to ensure the quality of mass concrete construction. Ordinary admixtures commonly used in concrete are admixtures and admixtures.

(3) The choice of aggregate

The strength required for mass concrete is not very high, so the composition of concrete sand than the high-strength concrete is higher, accounting for about 85% of the total mass of concrete, the right choice of sandstone to ensure the quality of concrete, saving cement, heat, reduce the cost of the project is very important. The choice of aggregate should be based on the principle of local materials, first consider the lower cost, good quality, to meet the requirements of natural sand and gravel material.

Construction measures:

1) Control the concrete exit temperature and pouring temperature

To reduce the total temperature rise of mass concrete and reduce the internal and external temperature difference of the structure, it is also very important to control the concrete discharge temperature and pouring temperature.

Control the concrete out of the machine temperature

According to the total heat of the concrete raw material before stirring and the principle of the total heat of the concrete after stirring, the formula can be calculated by the following formula:

$$T0 = [(CS + CWQS)\ WSTS + (Cg + CwQg)\ WgTg + CcWcTc + Cw\ (WwQsWc\text{-}QgWs)\ Tw]/(CsWs + CgWg + CwWw + CcWc)$$

where CS, Cg, Cc, Cw are the specific heat of sand, stone, cement, and water, J/kg·°C; Ws, Wg, Wc, Ww—for each $m^3$ sand, stone, cement, and water consumption, kg;

TS, Tg, Tc, Tw are the mixing temperatures of sand, stone, cement, and water, respectively; QS, Qg are sand, stone water content, %.

Calculated when the general take CS = Cg = Cc = 800 (J/Kg·°C); Cw = 4000 (J/Kg·°C).

It can be seen from the above calculation formula that the specific heat of gravel is relatively small in concrete raw materials, but it accounts for about 85% of the total mass of concrete. The specific heat of water is larger than 6% of the total concrete mass. Therefore, the impact of the concrete temperature is the largest stone temperature, sand temperature followed by the smallest temperature of the cement. To reduce the concrete discharge temperature, the most effective way is to reduce the sand, stone temperature. For example, the high temperature, in order to prevent the direct exposure of the sun, sand and gravel can be erected in a simple shade device, sand and gravel temperature can be reduced by 3–5 ℃. Rinse the coarse aggregate with cold water before mixing, cold pre-cooling in the storage silo, and add the stack of dust to make the temperature of the concrete reach 7 ℃.

1) Control the pouring temperature of concrete:

After the concrete is discharged from the mixer, the temperature of the concrete after transportation, unloading, pouring, vibrating and other processes by means of a mixer or other tools is called the concrete pouring temperature.

2) Control of Mass Concrete Mix Proportion:

When the strength level of mass concrete is above C20, the strength of concrete can be used as the basis for concrete strength evaluation, engineering acceptance and concrete mix design with the consent of the design unit. This will help reduce the mass concrete construction due to cement hydration heat caused by the temperature rise, to reduce the temperature stress purposes, but also save construction and insulation maintenance costs.

The choice of mass concrete mix ratio should be carried out in accordance with the principle of rational use of materials, reduction of cement consumption and reduction of adiabatic temperature rise of concrete under the premise of ensuring the strength and durability requirements of basic engineering design and satisfying the characteristics of construction technology.

3) Concrete pouring and curing Pouring program

The pouring method of concrete can be used to continuously pour or push the continuous casting.

For the larger amount of work, pouring area is also large, a continuous casting layer thickness is not (generally not more than 3 m), and the pouring capacity of concrete projects should adopt the continuous casting method.

4) Winter construction of mass concrete

In the winter construction of reinforced concrete structures in industrial and civil buildings, it is mainly to prevent the early concrete from being frozen. In the winter construction of mass concrete, the situation is different. In addition, to preventing the early concrete from being frozen, there is still control Temperature difference, to prevent cracks in the problem, and between anti-freeze and anti-cracking often there are contradictions. In the design and construction, we must properly solve this contradiction, both anti-freeze and anti-cracking requirements. This is the main feature of large volume concrete construction in winter.

(1) The principle of mass concrete construction in winter:

5 days for the average daily temperature below 5 ℃, that is, into the concrete winter construction stage.

The construction of mass concrete in winter should take into account both the anti-freeze and anti-cracking requirements, and therefore should follow the following three basic principles: sand, stone and other raw materials cannot contain frozen blocks, the concrete mix should also have a certain temperature to ensure that the transport and pouring process will not freeze.

Concrete can reach the critical strength before being frozen, so as not to damage the internal structure of concrete, the final strength of the loss.

The temperature difference between the inside and outside of the concrete and the maximum temperature cannot exceed the specified value, in order to avoid cracks, damage the overall structure.

(2) Technical measures for the construction of mass concrete in winter

In order to meet the above principles of winter construction, a series of technical measures must be taken. the choice of concrete temperature and pouring temperature.

Foundation and cold preheating:

Before pouring concrete, apply the steam to remove all ice, snow, and frost on the foundation, the embedded iron and the cold wall (old concrete, prefabricated concrete form, etc.) in contact with the new concrete, and raise the surface temperature.

Raw material heating:

Water heating can be used boiler, electric or steam, the sand material can be used to heat the closed snake tube, stone heating the most convenient to use steam.

Transport in the insulation:

The heat loss during transport is related to the means of transport. For example, the use of large transport tank, heat loss is generally not large.

Reduce the heat loss during pouring:

Concrete is layered pouring, each layer thickness of 200–500 mm, due to the thickness of thin, large heat dissipation area, pouring the process of heat loss is great.

Insulation conservation:

After the completion of concrete pouring should take strict insulation conservation measures, so that the strength of concrete has been fully developed.

Monitoring measures:

In the process of concrete pouring, the temperature of concrete pouring should be monitored during the temperature control of mass concrete. In the process of curing, the concrete pouring block should be heated and lowered, cooling rate and ambient temperature monitoring. These monitoring results can timely feedback the actual situation of the temperature change in the mass concrete pouring block, and the effect of the construction technology measures adopted, so as to provide the scientific basis for the engineers to take the temperature control countermeasures in time.

### 3.2. Crack treatment of concrete structures

Despite the variety of anti-cracking measures for mass concrete structures, engineering practice has shown that cracks are likely to occur during concrete pouring soon or during construction due to various complex factors. The general repair methods of cracks are surface repair method, internal repair method, and structural reinforcement method.

## Conflict of interest

The authors declare no conflict of interest.

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