Solutions to improve the quality of mass concrete construction in climate conditions of Southern Vietnam

Thi My Dung Do, Thanh Quang Khai Lam

***Abstract:** Concrete is the most commonly used material in construction works, a mixture of sand, stone, cement, water and other substances (if any). To become the concrete, the cement will create reaction with water, producing the heat, which turns the cement into the stone and concrete. This phenomenon is called hydration heat. When constructing foundation framework of high-rise buildings, related units such as investor, design consultant, supervision consultant, construction unit rarely pay attention to the phenomenon of the hydration heat because of the Vietnamese standard of TCXDVN 305: 2004 "Mass concrete - Code of practice of construction and acceptance" conventionalizes that it is necessary to pay attention to the phenomenon of hydration heat when the smallest size of concrete from 2m or more. The Southern Vietnam is a region with a tropical monsoon climate, with 2 distinct rainy and sunny seasons. The rainy season is influenced by the southwest monsoon, so the intensity of rainfall is quite large. In the dry season, thermal radiation is also higher than other regions. Such hot and humid climates have a great impact on the quality of the concrete and reinforced concrete, especially in the process of hardening and forming the original structure of the concrete. The sunny weather, hot and dry air makes the concrete dehydrate quickly during the early hardening time, creating a hollow structure which reduces the intensity and the ability of waterproofing or causes cracking the concrete surface. The high solar radiation and strong winds also increase this ability. Therefore, the article presents "Solutions to improve the quality of mass concrete construction in the climate of Southern Vietnam"*

***Keywords:** Concrete construction, reinforced concrete construction, mass concrete, concrete cracking, dehydrated concrete, etc.*

1. INTRODUCTION

The Southern Vietnam climate is a monsoon tropical climate (Savan climate) with a clear contrast between rainy and dry seasons. The rainy season is influenced by the southwest monsoon, so the intensity of rainfall is quite large. The climate of this region is quite close to the Central Highlands. The average temperature is relatively high. The thermal radiation is also higher than other regions, mainly in the dry season. The climate of Southern Vietnam is in the region IIC, including the provinces from Ho Chi Minh City, Ba Ria-Vung Tau to Ca Mau. In this region, every year, only the rainy and dry seasons are clearly contrasting. The rainy season is from April, May to November. The dry season is from December to March and April. The climate is less volatile during the year. The average annual temperature is quite high, reaching 27.4^{0}C. The highest average temperature is 34^{0}C in April. The daily temperature difference (daily temperature range) can reach nearly 10^{0}C in the dry season, only less than Son La and Lai Chau. Total average annual radiation is above 5500W//day, the highest in April reaches about 6620W//day. The rainfall is highest in July to September, reaching over 290mm, in the dry season from January to March, the rainfall is negligible, smaller than 13mm. With the concrete work in this region, it should be noted that in the dry season, the air temperature is quite high, the solar radiation is high. The daily range of air temperature is greater than that of other regions in the dry season, especially from December to February. The rain is concentrated from May to October, highest from July to September. When constructing the concrete, especially the mass concrete in the dry season, the construction unit should have a solution to reduce the internal temperature of the concrete, should not construct at noontime because the air temperature and solar radiation are the highest and needs to cover up and isolate the environment at night because of the great day and night temperature difference.

So how is the size of the structure called the mass concrete? Currently, in the world and in our country, there are different conceptions of mass concrete structures, the conception of the mass concrete according to TCXDVN 305 - 2004 [6]: Concrete or reinforced concrete structures are considered to be the mass concrete when the size is enough to cause tensile strength, arising from the hydration heat effect of the cement, exceeding the tensile strength of concrete, cracking the concrete, therefore, it must take measures to prevent the cracks. In the hot and humid conditions in Vietnam, the structure with the smallest edge of 1m and the height of more than 2m can be considered the mass concrete. The conception of the mass concrete according to American standards: ACI 207.1R, ACI 207.2R, ACI 207.4R [1] [2] [3] [4] give the definition of the mass concrete as follows: The mass concrete is any concrete with a large enough size, in order to reduce the maximum crack, it is necessary to take measures to control the heat generated by the hydration of the cement and the volume change associated with it. In terms of recognition, the conception of the mass concrete according to ACI 207 of the United States is the most widely recognized in the world. However, the difficulty of applying these standards is that there is no quantification to distinguish how the size structure

Revised Manuscript Received on April 15, 2019.

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considered to be the mass concrete. According to Russian standards CΠ 63.13330.2012 [5] the definition of mass concrete is as follows:

The mass concrete structure has the ratio of open surface area S (surface can be evaporated to dry the structure), in m^2, compared to the volume of structure V, in m^3, equal to or less than 2.

According to Russian standards, some of the structures below are considered the mass concrete structure.

a) The basement wall is 0.6m thick, 21m long, 3m high, has 2 evaporation sides which are the formwork and the upper side, the other 3 sides are enclosed by the stakes. S/V = 1.95m-1 (86.1m^2/44.1m^2).

b) The foundation is 0.5m thick, the length and width is 10m, has an upper open side, the other sides are closed without escaping water. S/V = 2.0m-1 (100m^2/50m^2)

c) The cross section of cylinder is 1.8*2.5m, 12m high, has 5 open sides (except the base on the stone foundation). S/V = 1.99m-1 (107.7m^2/54m^2).

Thus, from the Russian point of view, the smallest edge size is just a parameter to determine whether the structure is the mass concrete or not. In some cases, the smallest edge size of 0.5m has been considered to be the mass concrete.

According to J. Gaida, M Vangeem [9], because ACI 207 does not give specific dimensions, in practice, many companies have introduced the concrete dimensions to be considered the mass concrete in construction technical conditions documents. Consequently, the concrete structures with the smallest edge size greater than 3 ft (0.9m) are called the mass concrete. Some companies use a minimum size of 0.46m. According to [9], the size of 0.9m and the limit of temperature difference inside and outside the block 20 are the statistics summarized from the actual experience of 50 years of using the mass concrete in Europe.

Therefore, from the concepts of the mass concrete as above, we realize that the mass concrete is not only the concrete layer bigger than 2m, but also the concrete with big enough sizes. As analyzed above with the temperature condition of Southern Vietnam, the cracks due to temperature difference will certainly happen, according to Vietnam standard TCXDVN 305: 2004 [6], there are 2 following conditions for the concrete cracks due to the hydration heat effect of the cement in the concrete:

Temperature difference $\Delta T > 20^0$ C - Prerequisite

Module of temperature difference MT $\geq 50^0$C /m - Sufficient condition

The meaning of these two conditions is as follows:

Without the prerequisite: The concrete cracks.

With the prerequisite: the concrete may/may not crack.

With both prerequisite and sufficient condition: The concrete certainly cracks.

So in order not to crack, we need to eliminate the necessary conditions, that is to do có $\Delta T < 20^0$ C

The prerequisite $\Delta T < 20^0$ C is understood as the temperature difference between the parts of the concrete and the temperature difference between the concrete surface and the outside air. To prevent this phenomenon in order to improve the quality of concrete construction in climatic conditions of the Southern Vietnam, it is necessary to select appropriate technical measures before, during and after the construction of surface finishes. These are solutions to limit surface dehydration in the early hours of hardening, the maximum reduction solutions can be different the temperature ΔT middle, inside and outside the concrete block, especially in the cooling phase. In order to minimize the temperature difference ΔT, depending on the nature of the project, it is necessary to select and apply the solutions simultaneously to lower the temperature of Tmax in the block, and lower the impact of the air temperature environment colder outside on the concrete surface, ie isolating direct contact of the concrete surface with the outside air environment by the most effective insulation measures. In this article, the authors introduce some construction solutions to reduce the temperature difference ΔT down.

Construction solutions include lowering the temperature of concrete mixture such as cooling concrete aggregates, selecting construction time, the solution for pouring concrete, the solution for reducing heat absorption during construction, thermal conductivity in the concrete blocks out, solution for insulation of the concrete surfaces with surrounding environment, etc., depending on the size of the block and the capacity of the construction unit in order to select suitably and effectively.

2. RESULTS AND DISCUSSION

2.1. Solution for lowering the temperature of concrete mixture

Solution for lowering the temperature of concrete mixture including lowering the aggregate temperature, lowering the water temperature of mixing concrete, selecting the construction time, the solution of dividing concrete blocks and the solution for pouring the concrete.

To reduce the temperature of Tmax for the mass concrete, it is necessary to apply the measures to lower the temperature of concrete components including sand aggregate, macadam, gravel, mixed water and air (ambient temperature).

+ Lowering the aggregate temperature: A general and synchronous solution selected to lower the temperature of the input materials, including: warehouses of aggregate sheds: the sand, macadam and gravel warehouses used for the concrete must be shaded so that these materials are not heated by the solar radiation. Frequently spraying the water on macadam and gravel to lower this aggregate temperature when the water evaporates. These two things are simple, insignificant investments, but not all sites are interested. Cooling the sand with cold water: the cooled water flow through the sand container to lower the sand temperature before mixing. This cold water returned to the chiller to be cooled again. Spraying the cold water on the aggregate: the cooling water is sprayed on the sand or macadam, gravel before entering the mixer. Dipping the macadam and gravel into cold water: the macadam and gravel are placed in a puncture-proof container, dipped into the cooled water to lower the aggregate temperature before mixing. The above measures are often selected for large foundation blocks of high-rise buildings, bridge pier foundation, large bridge piers, gravity dams, etc.

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+ Lower the water temperature of mixing concrete

Using the ice water for mixing the concrete: the ice water in the form of small gravel prepared to replace a part or all of the concrete mixing water. The solution for lowering the water temperature of mixing concrete is also an important solution to reduce the temperature of concrete mixture. The ice water has cooled the aggregates and reduces the hydration heat of the cement during the retarding process. The amount of ice water for mixing the concrete needs to be calculated to ensure cooling and reasonable plasticity for the concrete construction.

+ Pouring the concrete at night

One of solutions for lowering temperature of Tmax is to select a suitable concrete pouring time for the concrete mortar mixture to not be further heated by the solar radiation. Therefore, it should not be constructed in the hottest time of the day, especially in the summer, avoid pouring the concrete from 12h-15h. It is best to work in the evening or at night and finish in the next morning so that the concrete does not dehydrate strongly in the first hours after finishing the surface (finish of pouring concrete). This solution is quite simple, currently, most construction units often select it because the effectiveness of this solution is relatively high.

+ Division of concrete pouring blocks

Dividing the block into many pouring phases: because of the mass concrete, the internal temperature escapes slowly, creating high temperature difference between inside and outside the concrete block, so for the mass concrete, when constructing, it is necessary to divide the block into several phases according to the height. The height of each pouring phase creates the concrete block so that it is not a mass concrete, so the height of each pour phase should be smaller than 1.5m. After each pouring phase, there should be a rest period of not less than 4 days, depending on the size of the concrete block, so that the new concrete block has enough time to reduce the cement hydration heat, limiting the accumulation of much heat in the concrete block before the next phase. This is a solution to reduce the temperature of Tmax, resulting in a reduction in ΔT temperature difference inside and outside the concrete block. The concrete generates strongly heat in 2-3 days of age (2-3 days after finishing the surface of the block). After 4 - 5 days, depending on the size of the heating stage in the concrete, it is almost finished, gradually stabilizing and then entering the cooling phase. It is the next pouring phase.

2.2. Solution for reducing heat absorption during construction

+ Shading: This solution is simple, can be applied in projects of the Southern Vietnam when constructing on hot sunny days with air temperature above 35^0C. The shading can be done by covering the concrete directly with the pouring layer, when returning to the next pouring layer, it is lifted and then covered again when the pouring layer is completed.

+ Cooling the surrounding air

In the case of wide construction ground, slow concrete pouring speed, each 30-40cm pouring layer lasting for about 20-30 minutes, the air cooling by spraying air on the surface of the block has positive effect. Among the above solutions, it is necessary to apply a shading method to cover the blocks during the construction process. This method is cheap, easy to implement and has a double effect to avoid the direct impact of heat on the blocks, and to limit the water dehydration causing soft cracking of the surface of the block.

2.3. Solution for thermal conductivity in the concrete blocks out

With the mass concrete, high accumulation of heat in the block is due to slow heat escape, creating a large temperature difference of ΔT between inside and outside the concrete block. The bigger the volume, the higher the accumulation temperature in the block, the greater the ΔT difference. Therefore, for the mass concrete structures such as podium of bridge pier foundation, solid part of bridge pier body, foundation piles of super high-rise buildings, towers, etc., it is necessary to apply Tmax temperature reduction solution by the thermal conductivity in the block out. This solution has been implemented in many works as follows:

Placing the pipe in the block: the heat extraction pipe placed in the block usually uses steel pipes with a diameter of 25- 30mm, a thickness of 1.5mm. The size of the pipe is determined according to the size of the concrete block that needs to install the heat extraction pipe.

Pumping the cold water into the pipe: the cold water is pumped through the pipe to bring the temperature out. It is possible to use water of river, lake, tap water or cooled water to pump into the pipe, depending on the concrete block size, construction position and conditions, so as to achieve the effect of reducing heat in the block. The operation of the pipe should be maintained continuously for 2-3 weeks, depending on the cooling requirements to achieve the difference ΔT set. Therefore, it is necessary to organize to monitor the temperature of the concrete blocks continuously during the operation time of the pipes. After cooling, the cement grout is pumped to fill the pipe.

2.4. Insulation of the block surfaces with surrounding environment

To avoid direct contact of the concrete block surface with the air environment, so that the surface is not or less affected by the air temperature impact when the external ambient temperature drops, the solution for insulation of the block surfaces with surrounding environment can be applied, ie insulating the block surface. This is the solution to reduce the temperature difference ΔT in the direction of reducing the internal temperature and increasing or not reducing the external temperature.

In order to isolate the concrete surface, the following measures can be carried out: Wrap the surface insulation material to keep the heat in the concrete block after pouring to accumulate in the block, leading to thermal balance between core zone with the area around the block. Normally, after 1-2 days, the temperature in the concrete will reach Tmax depending on the size of the block. Therefore, the insulation wrapping should be done no later than 2 days after finishing of pouring the concrete. Thereby,

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the size of the block is determined so that the continuous pouring time does not last more than 2 days to cover the surface insulation material. If it ends later, the concrete is poured on the first day with high temperature, the surface is not covered, the temperature difference ΔT will be greater when the air temperature drops at night, which may cause the cracking of concrete before wrapping.

Dismantling the insulation materials: Depending on the size of the block, the time of dismantling the insulation materials is not less than 5 days. With the larger blocks, the time for covering will be longer so that the internal concrete has cooled and accumulated a certain intensity. Therefore, it is necessary to organize to monitor the temperature in the concrete block during the covering time and it will not less than 7 days. If after 7 days, the temperature difference ΔT between inside and ambient air temperature at the coldest time is greater than 20, then the wrapping time should be extended. The cover is dismantled only if the difference is less than 20.

Dismantling sequence: Dismantling sequence is carried out in 2 steps. Step 1: dismantle the insulation panels from the surface of the block. If it is a separated material, then invert, mix this cover layer after dismantling the upper nylon layer. Step 2 is carried out the next day: separately dismantling from the concrete block surface (including the vertical formwork surface) and clearing the site.

The reason for having to dismantle 2 steps for the concrete surface not pulse heat due to sudden contact with cold air outside. For the formwork, after dismantling the insulation panels from the surface in the above order, then it is dismantled in 2 steps as above from the surface of the block, ie: firstly, dismantling the formwork from the surface, then dismantling separately and moving on the next day. To avoid thermal shock causing the cracking, the concrete of beam, compartment, wall, etc. dismantling formwork also needs to follow the above order. Cracking beams of high-rise buildings, cracking compartment of underground tunnels, buildings, bridge piers, etc., corridor walls, upstream of dam body mainly due to thermal shock when dismantling the formwork not in accordance with the technical order.

Concrete maintenance in the first phase of hardening.

Dehydration is the main cause of concrete cracking during early hardening. In hot and dry climates, the concrete has a large open side, the faster the rate of dehydration, the concrete not only has strong surface cracking, but also changes the original structure due to the formation of air bubbles replacing the water bubbles evaporated, causing the concrete to have a hollow structure, reducing the intensity later. Many studies show that the concrete can reduce by more than 30% intensity due to the dehydration. Therefore, watering for concrete maintenance in the early days of hardening to prevent the dehydration as well as cooling the concrete blocks is extremely important and mandatory for the construction of concrete. After finishing the construction of surface, do not water for the maintenance because it can wash away the surface because the concrete is not yet strong. Watering only when the concrete reaches a strength of about 0.5MPa, which is the intensity watered directly to the surface without being washed away. After forming, the concrete should immediately cover the open surface with moistened materials (with available appropriate objects or materials). At this time, there is no mechanical impact and no watering directly on the concrete surface to avoid damaging the concrete surface. When necessary, lightly watering the surface of the wet covering material. It is also possible to cover the concrete surface with water-insulating materials such as nylon, tarpaulins, or spray film-forming agent to prevent the evaporation. When using a film-forming agent on the concrete surface, the spraying is carried out according to the manufacturer's instructions. Mist sprayer is also used to spray water into mist directly on the concrete surface without covering. The moistening of concrete surfaces during the initial maintenance period is essential when constructing in conditions of rapid dehydration (such as severe sun in Southern Vietnam). Other cases may not cover the concrete surface, but must be monitored to ensure that the concrete dehydration is limited, avoiding the concrete cracks. The moistening of concrete surfaces during the initial maintenance period lasts until the concrete reaches a certain compressive strength value, ensuring that the concrete surface can be watered directly without causing damage. The time to achieve this intensity can be determined by watering the surface of the concrete, if the concrete surface is not damaged, it is good, then the next maintenance phase will be started.

The next maintenance phase: Implemented immediately after the initial maintenance period. This is a period of continuous watering and moistening of all open surfaces of the concrete until the maintenance is stopped. The maintenance period depends on the climate of each geographic region (see Table 2 TCVN 8828: 2011 [8]). The number of watering times per day depends on the local climate, so that the concrete surface is always wet. Watering and moisturizing should be maintained both day and night to ensure that the surface of the concrete is kept moist, avoiding being dry in the night. The water which is used to moisturize the concrete surface may be water of river, lake without impurities harmful to the concrete to maintain the moisturizing in the concrete.

3. CONCLUSION

In the provinces of the Southern Vietnam, the temperature change is not much during the year, they are less affected by the cold of the monsoon, the rain often occurs at the end of the year; Southern climates have 2 distinct seasons: dry and rainy seasons. In the dry season, the air temperature is quite high, the solar radiation is large, the temperature difference is considerable. The phenomenon of concrete cracking during the early hardening time is quite common phenomenon, especially with the current mass concrete using high grade fresh concrete, lots of cement, construction in hot dry climate conditions.

The cracks are formed and developed during the early hardening period, including cracking of surface, deep cracking, even through cracking, affecting the bearing capacity, waterproofing ability and long life of the works if not being resolved. This article only introduces some construction solutions to reduce the temperature difference ΔT. In order to bring high efficiency in preventing the cracking for the mass concrete, it is necessary to combine with the solution on material use.

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