HASAN KALYONCU UNIVERSITY

GRADUATE SCHOOL OF

NATURAL AND APPLIED SCIENCES

MASS CONCRETE AND ITS APPLICATION

M.Sc. THESIS

IN

CIVIL ENGINEERING

BY

MEHMET YALÇIN BUHARALI

OCTOBER, 2019

OCTOBER 2019 M.Sc. in Civil Engineering MEHMET YALÇIN BUHARALI

Mass Concrete And Its Application

M.Sc. Thesis

In

Civil Engineering

Hasan Kalyoncu University

Thesis Advisor

Prof. Dr. Yusuf Arayıcı

Co. Advisor

Prof. Dr. Ömer Arıöz

By

Mehmet Yalçın Buharalı

October 2019

	GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES INSTITUTE M.Sc. ACCEPTANCE AND APPROVAL FROM

Civil Engineering Department, Civil Engineering Master programme student **Mehmet Yalçın Buharalı** prepared and submitted the thesis titled **"Mass Concrete and Its Application"** defended successfully at the VIVA on the date of 10/10/2019 and accepted by the jury as a M.Sc. thesis.

Position	Title, Name and Surname Department/University	Signature:
Thesis Advisor	Prof. Dr. Yusuf ARAYICI Civil Engineering Department Hasan Kalyoncu University	
Jury Chair	Prof. Dr. Hanifi ÇANAKCI Civil Engineering Department Gaziantep University	
Jury Member	Prof. Dr. Mehmet KARPUZCU Civil Engineering Department Hasan Kalyoncu University	

This thesis is accepted by the jury members selected by institute management board and approved by institute management board.

Prof. Dr. Mehmet KARPUZCU
Director

ABSTRACT

MASS CONCRETE AND ITS APPLICATION

Buharalı, Mehmet Yalçın
M. Sc. In Civil Engineering
Supervisor: Prof. Dr. Yusuf Arayıcı
Co. Supervisor Prof. Dr. Ömer Arıöz

October, 2019
59 Pages

Today, both especially the foundations of high-rise buildings are cast thick in large mass and the densely reinforced concrete that is over C35/45, cement rich, and high quality is used on the foundations. As is known, due to the hydration heat of cement in the mass concretes, the cracks caused by the extreme temperature differences within the concrete and between the concrete and environment may cause serious problems. Therefore, since it will be in contact with the underground waters containing harmful substances, chemicals, etc.; especially in the thick foundation concrete castings, the dosage and hydration heat of the cement used, the thickness of the concrete, protection measures, staged casting, the efforts for pre-cooling and post-cooling of the concrete are important.

In this study, the internal temperatures of concrete and the environment temperatures were measured using the thermocouples placed at certain points before the concrete casting in different construction sites. In these measurements, excessive emphasis was put on the waiting times and the measures to be taken to prevent the difference between the internal temperature (hydration) of the concrete and the external temperature from exceeding 20 °C. For this purpose, the cement types with different cement dosages and mineral additives were used in different foundation thicknesses. Since the temperature increase in the concrete and minimizing the difference between the environment and the concrete surface were especially of great importance in preventing the concrete cracking; it was observed that the temperature difference was reduced and, by doing so, the concrete was cast without any crack through some measures such as reducing the casting thickness, casting the concrete in one time and covering the surface of the concrete with the materials such as nylon and styrofoam etc., and casting the concrete in several stages and waiting for the concrete to cool down.

Keywords: Mass Concrete And Its Application.

ÖZET

KÜTLE BETONU VE UYGULAMALARI

Mehmet Yalçın Buharalı
Yüksek Lisans Tezi, İnşaat Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Yusuf Arayıcı
Yardımcı Tez Yöneticisi: Prof. Dr. Ömer Arıöz

Ekim, 2019
59 Sayfa

Günümüzde, özellikle yüksek katlı binaların temelleri hem büyük kütle halinde kalın dökülmekte, hem temellerde C35/45 üzerinde, çimento bakımından zengin, yüksek kalite ve yoğun donatılı betonarme betonu kullanılmaktadır. Bilindiği gibi, kütle betonlarında çimentonun hidratasyon ısısı sebebiyle, beton içersinde ve beton-çevre arasında meydana gelen aşırı sıcaklık farklarının yaratacağı yarıklar ciddi sıkıntılar doğurabilir. Bu sebeple, toprak altında kalan ve zararlı maddeler kimyasallar vb. içeren sularla temas halinde olacağı için, özellikle kalın temel betonu dökümlerinde, kullanılan çimentonun dozajı hidratasyon ısısı, betonun kalınlığı, koruma tedbirleri, aşamalı döküm, betonun ön soğutma (pre-cooling), son soğutma (post-cooling) çabaları önem taşımaktadır.

Yapılan çalışmada, farklı şantiyelerde beton dökümü öncesinde belli noktalara yerleştirilen kablolu termometreler (thermocouple) yardımıyla, beton iç sıcaklıkları ve çevre sıcaklıkları ölçülmüştür. Bu ölçümlere beton iç sıcaklığa (hidratasyon) dış sıcaklık farkının 20 °C'nin üzerine çıkmaması için alınacak tedbirler ve bekkleme süreleri üzerinde önemle durulmuştur. Bu amaçla farklı temel kalınlıklarında, farklı çimento dozajları, mineral katkı içeren çimento cinsleri kullanılmıştır. Betondaki sıcaklık artışı, özellikle çevre ile beton yüzeyi arasındaki farkın en aza indirilmesi, betonun çatlamaması için büyük önem taşıdığından, bazı tedbirler ile; döküm kalınlığının azaltılmasının, betonun üstünün naylon ve strafor vb. malzemelerle örtülmesi ile tek seferde veya betonun soğumasını bekleyerek birkaç aşamada döküm yaparak sıcaklık farkının azalmasının sağlandığı, dolayısı ile, yarıksız beton dökümü yarıksız beton dökümü yapılabildiği görülmüştür.

Anahtar Kelimeler: Kütle Betonu ve Uygulamaları.

My precious family…

MEHMET YALÇIN BUHARALI

ACKNOWLEDGMENTS

I would like to thank Prof. Dr. Yusuf Arayıcı, who helped me on all occasions and provided full support with his knowledge, experience, and valuable time in determining the subject of the thesis and in every stage of the preparation of the study; Asst. Prof. Adem Yurtsever, who provided full support in proofreading; Dear Çetin Yalçın, the site chief of Koluman Towers; my beloved wife Asuman Buharalı, whom I neglected over the course of my study; my son Civil Engineer (M.Sc.) M. Semih Buharalı, who provided full support to me; and finally, my friends who contributed.

TABLE OF CONTETNS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

During concrete casting process, the excessive heat difference between the internal heat of the cast concrete and the surface heat have a significant effect on the cracking of fresh concrete. When the difference between the internal temperature of the fresh concrete and the outside temperature exceeds 25 °C, the cracks are formed in the concrete. These values are given as 20 °C for the non-reinforced concrete in various books in the literature.

These potential cracks in the concrete may cause the reinforcement to corrode. Since the strength and resistance level of the concrete will decrease due to being exposed to the external factors, some precautions should be taken to prevent these cracks from forming.

At the time of concrete casting, the heat can be considered as; **(Temperature= Temperature of concrete + External Heating – External Cooling)** (Özkul, 1984).

When we examine the method used; the factors such as temperature of concrete, excess use of cement, temperature of water, type of aggregate, and the transfer from cold or hot environment affect the concrete heat and the fresh concrete. Especially in summer, some measures can be taken to reduce the initial temperature of concrete. The amount of aggregate in the concrete used is an important factor in preventing the excessive temperature increase. Aggregates can be stored in the shade area or the cold water can be sprayed on them to decrease their heat. The capacity of the cement storage area can be increased. The exterior of the silos can be painted white and the cements stored beforehand in the warehouses can be used. In the cement dosage, the maximum aggregate grain diameter can be used, provided that the required level of strength is met (Özkul, 1984).

Some materials (silica fume, trass, fly ash, slag, etc.), other cements containing mineral additives, and the retarders can be added as the mineral additives. Water tanks can be built underground and for the ones above the ground it is more beneficial to apply insulation.

Transportation, placement, compaction, and the environmental conditions are as effective as the first heat of concrete in the increase of fresh concrete heat. Once the concrete is produced, it should be transported to the construction site as soon as possible. It should be transported and cast to the site using the wet curing blanket mixers. The time of the concrete casting should be picked wisely and the precautions should be taken in the extreme windy weather conditions. (Windbreakers can be placed around the concrete casting area.) It can be more appropriate to carry out the concrete casting at a time when there is no wind. In hot weathers, the concrete can be cast not in the daytime, but at night. The type of cement is thought to be the most important element of heating. The mixing of the cement with water results in an exothermic (heat-releasing) reaction, which is called hydration heat.

As a result of this reaction, while the temperature level in the inner parts of the concrete reaches 80 °C, the temperature difference from the environment exceeds 50 °C. In order to prevent these high temperature differences, the cement with low hydration heat (such as the values lower than 60 cal/g in 7 days, 70 cal/g in 28 days) should be preferred (Özkul, 1984). Thus, the heat to be added to the initial temperature of concrete will be less. In addition, the heat differences will decrease. Furthermore, the thickness of the concrete cast will have a significant effect on the increase in heat. As the thickness of the concrete increases, the amount of heat also increases in direct proportion to it.

In cooling; in order to prevent the high heat differences in the concretes with large mass, the instant cooling should be avoided. It should be cured with cold or warm water. In addition, the surface area of formworks, insulation properties, external conditions (temperature, wind, humidity, etc.), and the thickness of the concrete will also have a significant effect on decreasing the heat of concrete.

Since the concrete is cast every day in the concrete castings for dam construction, the conditions in these areas should be examined in detail. For example, due to the lack of equipment which decreases the initial heat of concrete, the pre-cooling measures such as increasing the aggregate maximum grain size to 150 mm and adding the cold water or ice pieces can be taken (Özkul, 1984). In the extreme times, some precautions can be taken such as passing cold water through the concrete by means of installing the iron serpentine pipe material to prevent the internal heat of concrete from increasing too much.

As a matter of fact, the situation should be examined in terms of heat difference. Here, there is also a fallacy considered as true by everyone. This fallacy is that, due to the cold weather, the winter months are thought to be a more suitable time for the foundation mass concrete. In general, the internal temperature of the mass concrete is in any case higher than the outside temperature. While the internal temperature of concrete increases to 70-80 °C when the hydration heat is added to its initial heat, the external heat reaches 30-35 °C at most. Thus, it is ensured that the new concrete temperature is lower. It is dangerous that the concrete temperature (Neville, 2011). Is higher than the outside temperature in summer. For example, whereas both the outside temperature and the concrete temperature are 35 °C in the hot season; in the winter months, the outside temperature is 15 °C and the internal temperature of concrete is 20 °C. As a result, the internal temperature of the concrete exceeds the outside temperature with 5 °C, causing a higher temperature difference between the concrete and the outside.

Also, another important issue is that the increase of the concrete compressive strength is lagged further in time. Because as we want to reduce the temperature differences; without realizing, we happen to slow down the reactions and, by doing so, delay the concrete strength (Özkul, 1984). However, in case of using large amounts of minerals, it will be obliged to make planning not based on the standard 28-day concrete, but rather on the 56 or 90-day concrete. Therefore, this is a problematic situation for the building elements such as the shear wall, slab, and beam in terms of tear-down time; however, since it is a foundation concrete, it will not retard the wo

CHAPTER 2

LITERATURE REVIEW AND GENERAL INFORMATION

The interaction of heat with cement in the hardened concrete was investigated. Some observations were made about the damages caused by the delayed ettringite due to the excessive hydration heat. (the reaction product formed as a result of hydration of C3, one of the main components of concrete, causes an expansion in the microstructure of cement and, by doing so, leads the concrete to crack)

The types of shrinkage formed in concrete and the results emerges due to the effect of the internal and external heat differences in mass concrete were examined.

The importance of curing in fresh concrete and the methods for cooling and decreasing the internal heat of concrete were investigated (Yalçın, 2006).

2.1. Concrete

2.1.1. Definition:

Concrete is an artificial material produced using natural aggregates mostly in the construction sites or in the field conditions. In the field conditions, the control of the concrete mix is a very difficult task. Therefore, weighing and automatic mixing methods are preferred in the concrete plants. The purpose of this method is to produce as more void-free and high-strength concrete as possible. In order to obtain a concrete conforming to the standards, it is necessary to adjust the proportions of the cement, aggregate, and water in the concrete mix well, to mix them until they become uniform, and to place them in the formworks according to the rules. (Figure 2.1). However, on the first days following the concrete casting, it may be necessary to apply cure for a certain period of time.

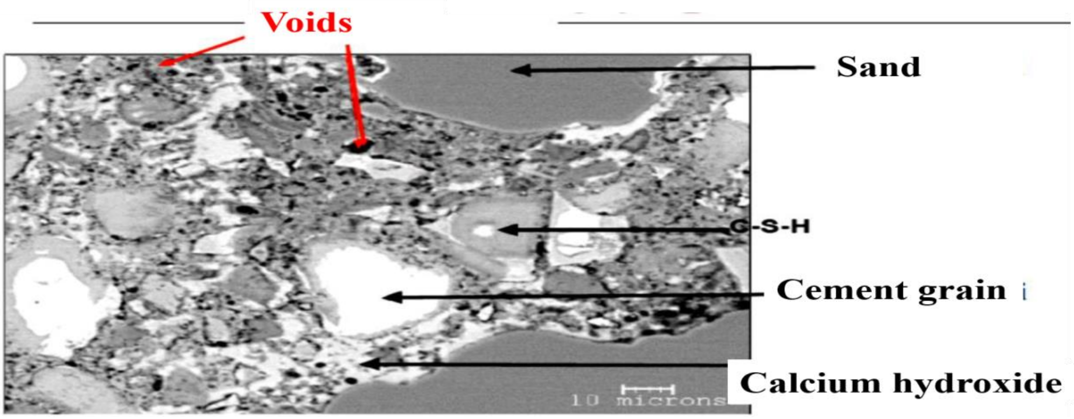

Figure 2.1. Internal Structure of Concrette (Yalçın, 2006).

The most important feature required in the concretes is a high strength along with the resistance to the physical and chemical external actions. Strength is a property that determines all other properties of the concrete. The tensile and bending forces of the concretes used in the buildings should be as high as possible. It has been seen that the more the compressive strength of concrete is high, the more the other mechanical forces are high.

The most important physical properties of concrete, a building material, are as follows;

- Strength,
- Porosity,
- Permeability,
- Density,
- Elasticity,
- Thermal characteristics (Yalçın, 2006).

2.2. Concrete And Its Properties

2.2.1. Strength

The most important factors affecting the strength of concrete are the aggregate type and grain size distribution, cement type and its dosage, water/cement ratio and the compactness which specifies how much compact the concrete is. Casting conditions and curing of concrete are also important in terms of the concrete strength.

- The goal is to produce a concrete having a density as high as possible. High concrete density may be possible only if the amount of coarse aggregate is as high as possible within the standard distribution measures. The amount and distribution of fine aggregate should also be sufficient to fill the coarse aggregate voids. In other words, both the coarse aggregate and fine aggregate should be arranged in such a way that the grain distribution gives a minimum percentage of void (Yalçın, 2006).

- The workability of concrete can be explained as the ability of the fresh concrete to maintain its structure without losing its homogeneity during the transportation, placement, and compaction processes. The workability of concrete depends not only on the amount of water in the concrete, but also on the properties of the materials creating the concrete, mixing ratios, the concrete placement and compaction operations, the condition of the formwork and reinforcement, and the ambient conditions (Yalçın, 2006).

- In addition to the mechanical strength, the concretes are expected to be resistant to various physical and chemical actions coming from the external environment. Concrete is a mixture formed as a result of the hydration reaction of aggregates and cement as a chemical structure. These compounds are not resistant to the certain chemicals, particularly the acids. Due to these properties, the concrete gets damaged by many physical and chemical actions. This situation reveals that, besides having a high mechanical strength, it must also be sufficiently resistant to the environmental actions (Yalçın, 2006).

- The most important property of concrete, which determines its resistance to environmental actions, is the compactness. Compactness is the ratio of the volume of solids in the concrete to the actual visible volume of the concrete (Yalçın, 2006).

- The strength of the concrete depends to a great extent on the type of the cement used. The conditions in which the concrete will be placed should be considered and the most suitable cement type should be used for this conditions. Since the pozzolanas bind the free lime in the concrete, the concretes made with the pozzolanic cement are known to be more void-free. Such cements are also preferred for the mass concretes where the hydration heat should be low.

In the concrete production, a mixture of two types of aggregate, that is, fine aggregate (sand) and coarse aggregate (gravel), is used. The first feature required in the aggregates is the absence of harmful components such as the clay agglomerates, organic substances, chloride and sulfate salts in the aggregate. In addition; not only the type, shape, and grain size curve of the aggregates used in concrete, but also the maximum grain diameter affects the strength of the concrete. Increasing the maximum aggregate grain diameter in a concrete prepared at the same cement dosage and consistency has an effect on decreasing the water-cement ratio. Thus, the concrete strength is expected to increase. However, the increase in the maximum aggregate diameter causes to increase the voids in the concrete. This situation negatively affects the concrete strength. Hence, the strength of concrete mixes prepared at the same cement dosage and consistency significantly decreases as the maximum aggregate grain diameter increases.

The high fineness modulus of the sand used in the concrete mix also affects the concrete strength. The same strength value can be obtained by means of using less cement and increasing the fineness modulus.

- Theoretically, the water-cement ratio for the cement hydration reaction is around 23-24%. This excess water, which is by necessity mixed into the concrete, then evaporates and leaves the concrete body. Thus, the voids are formed in the concrete and the concrete strength decreases. The high water/cement ratio prevents the fresh concrete from squeezing sufficiently in the formwork, causing a decrease in the compactness. This situation has a negative effect on the concrete and causes an increase in the permeability of the concrete. Adding less water to the concrete than needed has some drawbacks. In this case, it gets difficult to uniformly place the cement in the formwork. However, this problem is tried to be overcome by adding the plasticizing admixtures into the concrete mixture. In order to increase the physical and chemical strength of the concrete, the water/cement ratio should be kept as low as possible (Yalçın, 2006).

2.2.2 Permeability

As is the case with the strength, there is a close relationship between the compactness and permeability of concrete. The higher the concrete compactness, the lower the permeability. It is important whether the voids in the concrete are interconnected. If the voids in a concrete with low compactness, that is to say, having a high porosity, are not interconnected; this concrete can be impermeable. The main intended purpose of the pozzolanas is to chemically bind the free lime released after the cement hydration. While the formation of more binding products leads to an increase in the strength, the decrease of free lime in the concrete voids improves the void structure and, by doing so, decreases the permeability (Yalçın, 2006).

2.2.3. Shrinkage

Shrinkage is the volume decrease seen in the concrete that occurs in the first days after the casting. The shrinkage is mainly due to the water loss. Therefore, a considerable shrinkage occurs in the early period of the fresh concrete (Yalçın, 2006).

In the fresh concrete, the plastic shrinkage occurs within a few hours from the acceleration of the mixture. As a result of the plastic shrinkage, random cracks like a spider web are formed on the surface of concrete. These cracks cannot reach the inter parts of the concrete. Therefore, the plastic shrinkage has no detrimental effect on the concrete strength.

The shrinkage mainly depends on the water/cement ratio and the aggregate/cement ratio. In addition to this, the type and dosage of the cement, the proportion of fine materials, and especially the environmental conditions such as temperature and wind are the factors that have an effect on the shrinkage (Yalçın, 2006).

2.2.4. Concrete as a Construction Material

- Concrete is a very easily moldable construction material. Before hardening, fresh concrete is as soft and fluid as a clay paste. After hardening, a hard and firm layer like a stone is formed. With this feature, it is a very useful construction material.

- Many properties of concrete and steel are compatible with each other and this has given prominence to the steel-concrete (reinforced concrete) structures. The concrete adheres very well to the steel put into it. The hardened concrete and steel act as a single material and become a very useful material as a construction material.

- The reason why the concrete has a wide range of application as a construction material is that it is extremely economical compared to other construction materials.

- Another advantage of concrete over other construction materials is that, during the service period of the concrete structure, the concrete does not need any special care such as painting and the like.

- Although the concrete has these superior features, its biggest mechanical disadvantage is that it has a very low tensile strength. In order to overcome this drawback, the steel bars (concrete reinforcing bars) are used in concrete for the structures to be subjected to the tensile and bending. By mean of applying pre-stress to the steel, the deformations that occur under stress are tried to be eliminated.

- The water permeability of concrete is also not good. Waters having harmful components can easily permeate the concrete structure. The waters permeating the concrete cause two major problems. First, the water frozen in the concrete voids causes the concrete to crack. Second, the sulphate and chloride ions, which are dissolved in water and permeate the concrete structure, corrode the concrete and concrete reinforcing bars.

2.3 Cement

2.3.1. Definition

The word “Cement” is derived from the Latin word “COEMETUM”, which entered into French as “CEMENT” and German as “ZEMENT” “Çimento” in Turkish is derived from the word “Cemento” in Italian. Materials that harden by reacting with water and bind the surrounding materials to each other are called "Hydraulic Binders".

The cements are hydraulic binder materials and, after being mixed with water and becoming a paste, they get hardened slowly both in the air and in the water and turn into an artificial stone (Şimşek, 2003).

2.3.2. General Properties

- Fineness: Obtaining a high strength at the end of the hydration depends on the cement grains being active. Activeness occurs by means of grinding the cement [Şimşek, O., 2003]. The grain sizes in cements generally vary between 6.5-90 microns. The majority is around 30 microns. In order to develop the hydration and increase the binding, it is desirable that the proportion of the grains larger than 74 microns in cements should not exceed 14% (Yazıcı, 2012).

- Setting time: The time between the moment when the cement is mixed with water and the moment when the cement paste hardens and loses its plastic property is called “setting time” (Yazıcı, 2012). The hardening speed as a result of the reaction of cement with water should be within certain limits. As a result of the reaction of cement with water, the hardening rate should be within the certain limits. In the specifications, this limit is 1 hour for the initial setting and 10 hours for the completion of setting (Şimşek, 2003).

- Hydration Heat: Heat energy is generated when the materials react with water. This reaction is called “hydration heat.” With this heat, the heat of concrete increases, in these moments the temperature rises to the high values. This phenomenon has negative effects on the properties of concrete material. The higher the dosage, the higher the heat of the concrete. Heat causes the concrete to shrink and crack (Güner, 2018).

- In order to decrease the hydration heat, the followings should be done;

- Stock the materials in shade.

- Cool the mixing water with ice.

- Cast the concrete to the site in the evening or at night in cool weathers (Güner, 2018).

- Specific gravity: The specific gravity of the cement material is at the level of 2.95-3.05 g/cm^3.

Figure 2.2. Plastic Shrinkage Cracks

2.3.3. Hydration

The clinker materials that make up the cement material are potentially and chemically active. These materials can easily react with water. A hydrolysis reaction occurs in the solution reaction. This reaction which occurs with water and cement material is called "hydration reaction" (Güner, 2018). Due to these reactions, the cement paste solidifies and the hardening (gaining strength) occurs (Erdoğan, 2010).

Until the setting time; the mortar, paste or the concrete is in a "fresh" state, that is, "plastic", which can easily be formed and molded. During this period, the following operations take place: the mixing and transporting the concrete material, placing it into the formwork, and compacting and flattening the concrete. Heat energy is generated during the hydration reactions. In the paste, cement, mortar, and the concrete; the internal heat rises.

Phases of hydration reaction (Figure 2.3.):

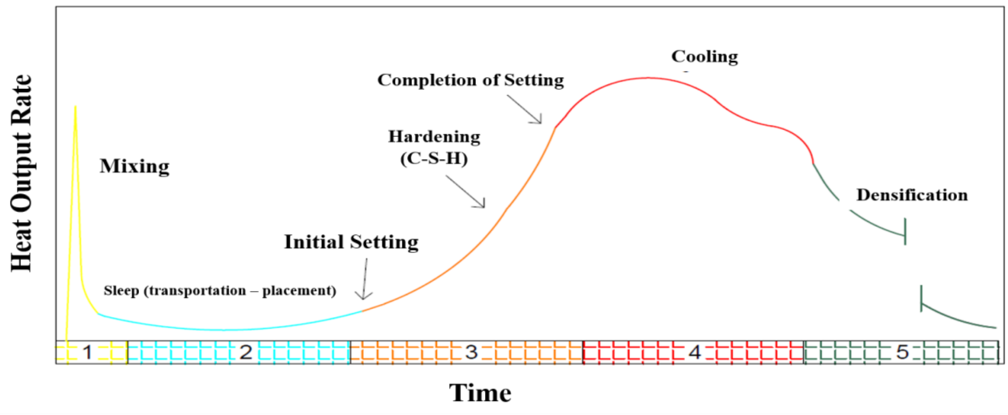

Figure 2.3. Hydration Phases (Akçansa, 2012).

Mixing phase: In this process, the aluminates and gypsum dissolve rapidly in water and react within a few minutes. Compounds formed as a result of the rapid reaction cause a high heat release. If this situation cannot be controlled, a false or sudden setting occurs in the concrete. This is an undesired situation. As a result of the rapid dissolution of gypsum added to the clinker, a gel-like layer is formed around the cement particles which react with the dissolved aluminates and water (Akçansa, 2012).

- Hardening (setting) phase: When the mixing water becomes supersaturated with the dissolved calcium ions, the hydration starts and therefore the temperature rises. This phenomenon is called the initial setting. The completion of setting is a period of time at the end of which at least you can walk on the concrete (Akçansa, 2012).

- Densification phase: During this period, the reaction starts to slow down and the heat release significantly decreases. Hydration products continue to increase and develop (Akçansa, 2012).

2.3.3.1. Cement Hydration Heat

The cement + water reaction is an exothermic reaction. When 1 kg of cement reacts with water, 500 kJ of energy (heat) is generated. The excess amount of heat energy comes out after the concrete is cast. Since the heat transmission coefficient of the concrete is very low, the energy (heat) generated cannot be discarded immediately and the heat release continues for a while. The temperature increases of the concretes kept under adiabatic conditions within the first 70 hours after the casting is shown in

(Figure 2.4.) As shown in the figure, the temperature rise in all cements reaches the maximum value within the first 60 hours, even if the hydration heats are different.

The cement hydration heat is released in a very long time, so it is not possible to directly determine the cement hydration heat experimentally. According to the thermodynamics laws, the heats of the chemical reactions do not depend on the path. Following a different way, the heat generated during the hydration reaction can be known. The difference between the heat of solution in acid of a certain amount of cement and the heat of solution in acid of the hydrated cement having the same amount will be equal to the hydration heat. These heats are measured in the laboratory through a calorimeter test. Thus, the hydration heats of various hydration degrees are determined experimentally.

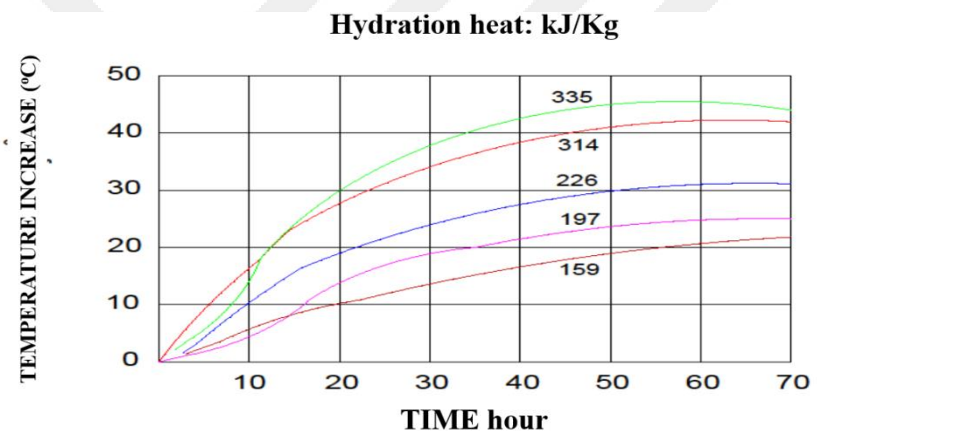

Figure 2.4. Temperature Increase in Concretes Made with the Cements Having Different Hydration Heats (Üte, 2012).

(Water/Cement = 0.60. The values given in the graph are 3-day hydration heats)

The total hydration heat of a cement remains constant; however, the hydration heat output rate depends on the temperature. The higher the temperature, the higher the hydration heat output rate. As the temperature increases, the amount of heat released over a certain period of time increases. The figure 2.5 shows the hydration heats of various-type cements kept at different temperatures for 72 hours.

Temperature °C	Type-1 Cement kJ/kg	Type-3 Cement kJ/kg	Type-4 Cement kJ/kg
4	154	221	108
24	285	348	192
32	309	357	195
41	335	390	214

Figure 2.5. Hydration Heats of Various-Type Cements Kept at Different Temperatures for 72 Hours (Akçansa, 2012).

The hydration heat output rate varies depending on the type and fineness of the cement. In general, however, it is said that half of the hydration heat is released within 1-3 days, three quarters of it within the first 7 days, and 90% of it within 6 months. These values depend on the proportion of the clinker compounds in the cement. The compounds that have the highest hydration heat are tricalcium aluminate and tricalcium silicate. The effects of the clinker compounds on the hydration heat output rate are shown in (Figure 2.6) and (Figure 2.7).

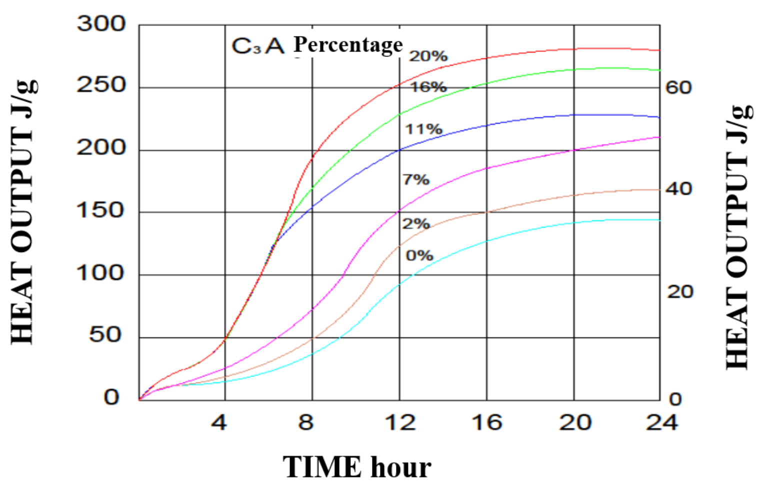

Figure 2.6. The Effect of the Percentage of C_3A in Cement on the Hydration Heat Output Rate (Percentage of C_3S is kept constant) (Üte, 2012).

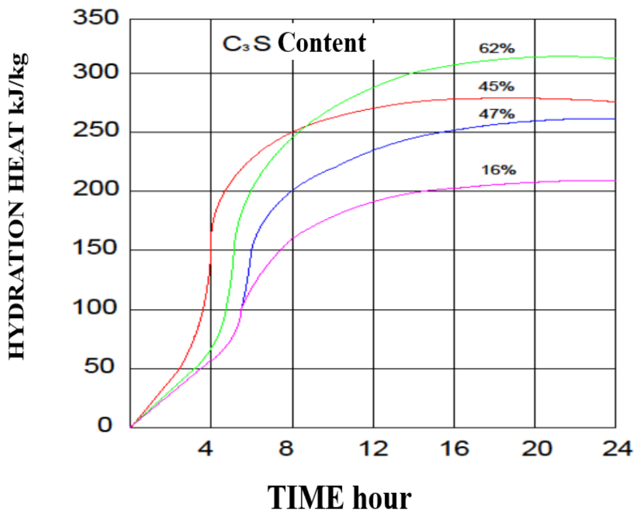

Figure 2.7. The Effect of the Percentage of C3S in Cement on the Hydration Heat Output Rate (Percentage of C3A is kept constant) (Üte, 2012).

Not only the hydration heat output rates of the clinker compounds are different, but also their total hydration heats are different. The hydration heats of clinker mineralogical compounds in pure state are as follows.

Compound		Hydration Heat
C_3S	:	502 kJ/kg (120 kcal/kg)
C_2S	:	260 kJ/kg (62 kcal/kg)
C_3A	:	867 kJ/kg (207 kcal/kg)
C_4AF	:	419 kJ/kg (100 kcal/kg)

The hydration heats of cements can be calculated using these values. Since the proportions of the clinker compounds in different types of portland cements are different; naturally, the hydration heats of these cements are also different from each other. Approximate hydration heat values of five portland cement types within the ASTM standard are shown in the Figure 2.10.As seen in the figure, the cement with the highest hydration heat is the Type 3 portland cement. The 3-day hydration heat of this cement is equal to the 90-day hydration heat of Type 4 cement. The hydration heat of Type 4 cement maintains its lowest level during the entire hydration period.

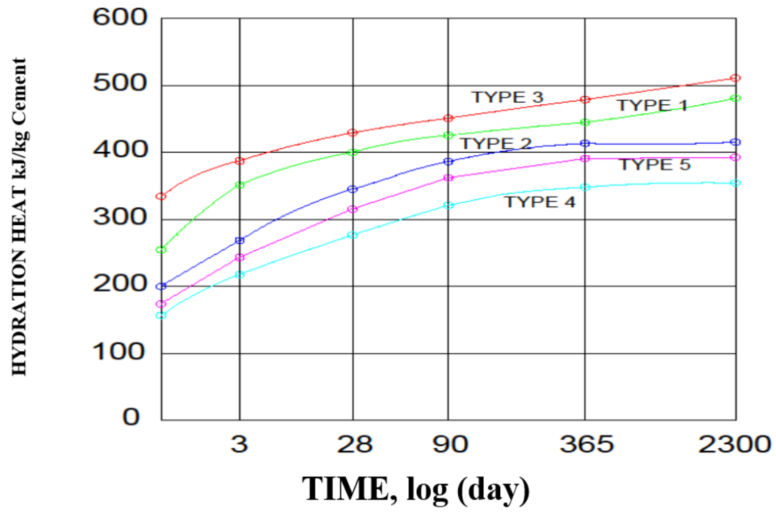

Figure 2.8. Hydration Heats of Various-Type Portland Cements (Water/Cement= 0.40, Cure Temperature = 21°C) (Üte, 2012).

2.4. Water

Although water is the most readily available material among the concrete components, it is an important element for the concrete. The quality and measure of the water used in the concrete is very important for the concrete strength. Excessive water decreased the quality. It disrupts the cement paste and makes it difficult for the grains to bind together. The homogeneity of the concrete deteriorates.

It is important to use the water used in concrete in different places.

- It is one of the three important elements in the production of the fresh concrete (Cement, Aggregate, Water).
- Curing water ensures that the fresh concrete cast is kept moist.
- After procuring the aggregate supply, as a result of the stone being crushed, washing and cleaning the dust of the aggregates

- The materials such as acid, salt, etc. in the mixing water of concrete can create some adverse effects on the concrete. Before using such suspicious waters, the water must be analyzed in a laboratory.

- The excess water decreases the concrete strength by means of creating voids in the concrete and the harmful substances (Chlorine, Salt, Sulfate, etc.) entering the cracks formed due to the excess water damage the concrete and reinforcement and this may shorten the life of the reinforced concrete.

2.5. Concrete Admixtures

Admixtures are the substances added to the composition when making the concrete material in order to differentiate the effects of hardened or fresh concrete material. These substances fulfill their functions with the physicochemical effects such as absorbing the water, changing the surface tension, forming colloids, and creating a catalyst effect in the cement+water reaction during the hydration.

Despite their many benefits, the unconscious use of concrete admixtures can be extremely dangerous. If the patented products sold in the markets are used in accordance with the points specified in the prospectuses, there is no problem. However, it is essential that the admixtures be put to a laboratory test beforehand. Because the additives being used for various purposes, as is the case with the medicines used by people, can improve some properties of the concrete and deteriorate some other properties.

- Concrete admixtures can be categorized under 8 main groups by their intended use.

- Concrete mixing water-reducing/plasticizing admixtures

- Super plasticizing admixtures

- Air-entraining admixtures

- Set accelerating admixtures

- Set-retarder admixtures

- Permeability-reducing admixtures

- Set accelerating / water-reducing / plasticizing admixtures
- Sett-retarder / water-reducing / plasticizing admixtures

CHAPTER 3

DEFINITION AND HYDRATION HEAT OF MASS CONCRETE

3.1. Definition

Mass concretes are the large-size concretes that require taking some precautions due to the fact that during the reaction of the cement material with water, energy (hydration heat) is generated and this leads to the thermal cracks due to differences in volume.

The foundation concretes of the high-rise buildings are cast both in large blocks and in a thick form. In the foundation concretes, the iron-reinforced concrete over C35/50 with a high cement ratio is used. The heat increase in the concrete and the temperature difference between the environment and the concrete surface should be minimized. After the heat difference is decreased to a certain level (around 20 °C), the top layer mass concrete should be cast and the concrete without crack, that is, the concrete with no strength loss should be tried to be obtained.

3.2 Discussion on the Subjects of Mass Concrete Casting and Hydration Heat (According to the Experiments)

The difference between the internal heat of the concrete and the surface heat of the concrete (external heat) during the mass concrete casting as a very important factor causing the concrete to crack. At any given time, the cracks occur when the heat difference between the inner parts of the concrete and the environment exceeds 25 °C (Üte, 2012). In some publications, this value (Üte, 2012). Is given as 20 °C for the non-reinforced concretes.

According to this formulation, the measures to be taken to decrease the temperature of fresh concrete are as follows; the aggregates in large amount in the concrete can be stored in shade, the concrete can be cooled by means of spraying water on it. The cement can be stored in a cool and sun-free environment; the silos can be painted white. The cements containing set-retarder admixtures can be used. Water tanks can be insulated. Immediately after the production, the concrete can be transported to the delivery site very quickly using the wet curing blanket mixers. In the concrete casting, what causes the heating is the cement material. As a result of mixing the cement and water, an exothermic (heat-releasing) reaction occurs and the hydration heat is released. Due to the hydration heat, reaction, while the temperature level in the inner parts of the concrete reaches 80 °C, the temperature difference from the environment exceeds 50 °C. In order to prevent these high temperature differences, the cement with low hydration heat should be preferred (Taşdemir, 2014).

3.3. Purpose

The heat exchange between the heat inside the concrete material, which is cast in mass and thick form, and the outside heat is important in terms of not cracking the concrete material. In order to observe the heat inside the concrete, it is necessary to measure the temperature using the thermocouple. We can examine the heat exchanges between the inside and outside of the concrete in 2 different ways.

1. During the concrete casting, while the heat of the concrete increases, the heat in the center of concrete increases, examining the heat exchange in the center and the surface of the concrete.

2. After a certain time from the concrete casting, while the heat within the concrete decreases, examining the heat exchange on the surface area and above the concrete.

3.4. Concrete Heat Control with the Thermocouples

In order to determine the internal heats of the concrete, a thermocouple was placed in different points and fixed to the edge of formwork for the measurement. The thermometer should be placed in the center of the concrete and at a certain height to measure the surface value. The measurements are made at certain intervals, a heat measurement graph is prepared, and thus the heat can be monitored.

3.5. Mass Foundation Concrete Casting in Several Times

Some precautions should be taken in order not to destroy the mass shape of the concrete material. An adherence-enhancing syrup can be used. It was found that after

2 weeks (waiting time between the layers) from the 1st layer casting, the hydration heat drops to around 20 °C and the 2nd layer could be cast (Figure 3.1).

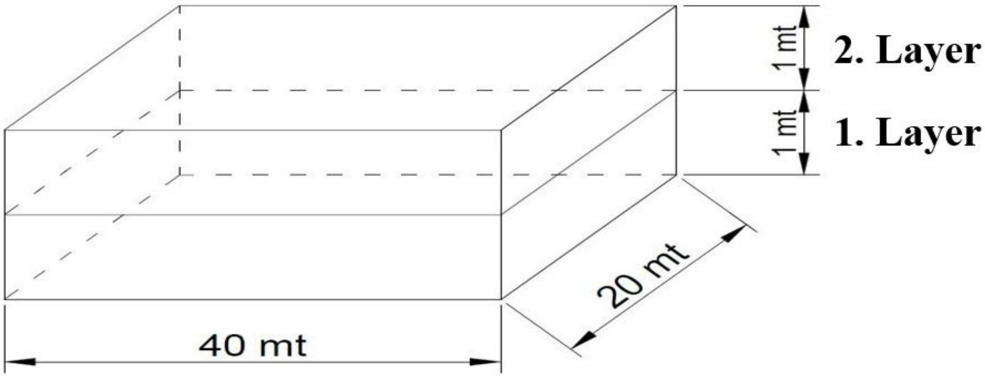

Figure 3.1. Concrete Casting Layers

CHAPTER 4

HEAT CONTROL IN MASS FOUNDATION CONCRETE

In the mass concrete, the hydration of the cement releases a large amount of heat, which is due to an exothermic reaction that starts when the cement and water are mixed. In this kind of concretes, the outer surface cools faster than the inner core. An expansion occurs as the internal temperature increases, on the contrary, the rapidly cooling outer surface attempts to shrink. If the sufficient precautions are not taken; as a result of the shrinkage and expansion, the thermal cracks occur. As a result of this situation, the concrete strength significantly decreases.

In the specifications, the prescribed temperature difference between the internal and external concrete is generally 20 °C. For the sufficiently reinforced concrete foundations, this value can be up to 25 °C.

In various experiments, it was found that in the concretes made with the coarse aggregates whose coefficient of thermal expansion was not too high, the temperature and stresses generated with the concrete significantly decreased.

In the literature, it was asserted that the internal and external temperature difference of the hydration heat could be around 20 °C - 25 °C in the mass concretes made with the aggregates with high coefficient of thermal expansion such as limestone.

In various studies, it has been suggested that if the internal temperature exceeds 68 °C - 75 °C at the end of the placement of the mass concrete, the delayed ettringite may occur and many years later the concrete may be cracked due to the internal expansion. On the other hand, keeping the internal heat of the concrete low keeps the cooling time of the concrete short. Hence, this has a positive effect on the construction time.

It was found that when the formworks preventing the heat loss were taken early, the heat difference between the inner parts of the mass concrete and the surface of the concrete exceeded 20 °C, consequently, the cracks might occur.

In the foundation concretes, the heat of concrete casting is very important. The lower the initial concrete placement heat, the slower the hydration development, the stronger the adhesion between the cement paste and the coarse aggregate. By the way, the amount of heat will be less.

In order to make a mass concrete with less heat, the following can be done;

- Adding the cements with the admixtures having the lower hydration heat
- Using the portland cement with low hydration heat
- Cooling the materials used in the concrete, adding ice to the mixing water, and stocking the aggregates in shade
- Using the set-retarder chemical admixtures.

4.1. Methods for Curing Concrete

The concrete mix should be kept in saturated humidity in the first days after the casting. Inadequate curing of concrete, especially in the first days after the casting, not only decreases the strength, but also reduces the adherence of concrete to the reinforcing bars, and causes to increase the shrinkage and micro cracks.

In practice, the concrete curing is usually carried out by means of continuous spraying of water. However, under unfavorable weather conditions, that is, very hot and dry weather, it gets difficult to maintain the proper curing conditions. Under such conditions, the application of the impermeable membrane can be preferred to keep the water within the concrete for a long time.

4.1.1. Curing with the Impermeable Membrane

Immediately after the concrete casting, the concrete surface is covered with a thin layer of impermeable material (curing compound) in order to prevent the evaporation of the water within the concrete. For this purpose, a liquid resin is sprayed onto the concrete surface with the paint spray guns. Shortly after this application, the solvent of the resin evaporates and an impermeable film remains on the surface. This film cracks after 4-5 weeks due to the effect of sun rays and flakes off from the concrete surface. This curing method is equivalent to the wet curing applied for the first 15 days after the casting. Sometimes, the white or gray dye pigments may also be added into the curing compound. This has two purposes. The first is to reflect the sun rays. The other is to distinguish between the parts of the concrete where the curing applied and not applied.

Applying the curing compound prevents the evaporation of water within concrete. This prevents the concrete from cooling itself through the evaporation. The first days are the days when the hydration heat output is high. The majority of this heat release takes place by means of the evaporation of the water. Undesired increases in the heat of the concrete occur in case the curing compound is not applied.

In order to prevent the evaporation from the concrete surface, it is beneficial to apply the curing compound to the concrete surface in two layers. In practice, 1 liter of paint is sufficient for the 4 m^2 concrete surface. The curing compound should be applied to the vertical surfaces immediately after removing the formwork. If the surface of the concrete is dried and gets a whitish color; before the curing compound is applied, the concrete must be saturated with water and then coated with the curing compound. It is not correct to apply the curing compound to a dry concrete surface. In this case, the paint fills into the concrete voids and prevents its hydration.

4.1.2. Curing with Water Spraying

Curing can be applied to the surface of the concrete cast by means of spraying water in a period that prevents it from getting dry. Excessive amount of water should be prevented from adversely affecting the lower parts of the structure.

4.1.3. Using Wet Burlaps

By means of wrapping the concrete with wet burlaps, sudden drying caused by the sun or wind on the surface can be prevented. For this purpose, a burlap or similar water-absorbing and water-retaining cover is covered on the concrete surface and it is wetted with water. This cover is continuously kept wet and, by doing so, the water evaporation from the concrete surface is prevented. These processes are continued until the concrete reaches a certain strength. It is a controversial how many days the concrete will be wetted in the various environments. In practice, the best solution is as follows: The curing should be continued until the concrete being cured reaches the compressive strength equivalent to the concrete age of 7 days at 18 oC and 100% relative humidity. This period is accepted as about 14 days for the concretes in which the portland cement is used and about 21 days for the concretes in which the pozzolanic cement is used.

4.2. Cooling the Concrete

Precautions should be taken in case the concrete casting is carried out in the hot environments. With the help of these precautions, it is ensured that the water within the concrete does not evaporate in a short time and does not go away from the area. In the windy weathers, the amount of water within the concrete can evaporate in a short period of time. The concrete heat increases. These precautions should be taken to prevent the concrete temperature from rising above 30 °C.

- Sand and gravel should not be stored in the sun. Before the concrete casting, the materials should be cooled by means of spraying water on the sand and gravel. The excess water in the aggregates is not desired.
- Cold water should be used as the mixing water.
- Concrete mixing water tank should be in a shady area. Outer surface of the tank should be painted with light color.
- In case the outside temperature excessively increases, ice should be added to the concrete mixing water.
- In the concrete casting, hot cement should not be used. The cement should be specially cooled.

4.2.1. Concrete Cooling During the Production-Transportation

It is possible to obtain the concrete with long durability, high strength, and long placement time by means of cooling the material before the casting. Because the initial temperature of the mix made with the cooled material will be low, it will prevent the concrete from reaching the high temperatures during the ongoing hydration process. However, in very hot climates, the cooling of the materials to be added to the mix is not an effective method; because it is very costly.

- Cooling the mixing water,
- Adding ice instead of some of the mixing water,
- Keeping the aggregates in a closed storage area,
- Transporting the aggregates to the mixing tank with closed conveyors,
- Cooling the aggregate stock by means of spraying steam,
- Dehumidifying the aggregate,
- Adding liquid nitrogen into the mixer during the mixing,

Figure 4.1. Post-Casting Cooling System Refrigeration (Cooling Pipes).

The cooling pipe is placed inside the concrete. After the cooling time is completed, we must fill it like the grout mortar having some conditions of the concrete.

CHAPTER 5

HEAT CONTROL ON THE FOUNDATION CONCRETE OF KOLUMAN TOWERS

Koluman Towers, which was being constructed in Şehitkamil, Gaziantep and designed as the office and Mercedes sales and service building, was projected as 35-floor building with a height of about 140 m. As a result of the static calculations for Koluman Towers building; the C50 concrete grade which is high quality and rich in cement, Ø 32 iron as the reinforcement, and the raft foundation having a thickness of 2 m in the rising part and 1 m in other parts were calculated. The cracks caused by the heat differences can lead to serious problems for the structure. During the mass concrete casting, the followings are important; the amount of cement of the concrete grade chosen, the thickness of the concrete, protection measures (hot-cold, environmental actions), casting the concrete in stages (for enabling the concrete to discard the hydration heat), and cooling the concrete once the concrete is set.

Minimizing the temperature increase in the concrete and especially the difference between the open area and the concrete surface is of great importance in order to prevent the concrete from cracking. The measures to be taken for a crack-free proper concrete casting are as follows: decreasing the casting thickness, application of thermal insulation (styrofoam, eps, xps, geotextile felt) to prevent the concrete from cooling quickly, covering with some materials such as nylon-tarpaulin not to expose to wind, and decreasing the heat difference by means of making cold joints.

In the studies we conducted, the designer and the construction site authorities decided that, as it can be seen from the cross section, the foundation mass concrete should be cast in two stages in order to keep the construction rate at the maximum level and minimize the cracks that can potentially occur due to the temperature caused by the hydration heat. In addition, in order to control the heats that can be reached and to ensure the next concrete casting and observe the temperature differences in the 1st stage concrete, the thermocouples were placed at different points and heights of the concrete and the heat measurements were made. These points were placed in the lower, middle, and upper parts of the concrete and the measurements were made for the heat differences. These measurements play a decisive role in determining the casting dates of the 1^{st} and 2^{nd} stage concretes. Following the 1^{st} stage concrete casting; after the concrete started to set, that is, the hydration heat started to be released, the measurement values taken were about 86 °C for the lower part, about 82 °C for the middle part, and about 76 °C for the upper part. These daily measurements play a role in determining the cooling rate of the concrete and the casting time of the 2^{nd} stage concrete. In the specifications of our project, once the difference between the heat inside the concrete and the outside temperature is 19-20 °C, it is allowed to continue to the other stages (Figure 5.1).

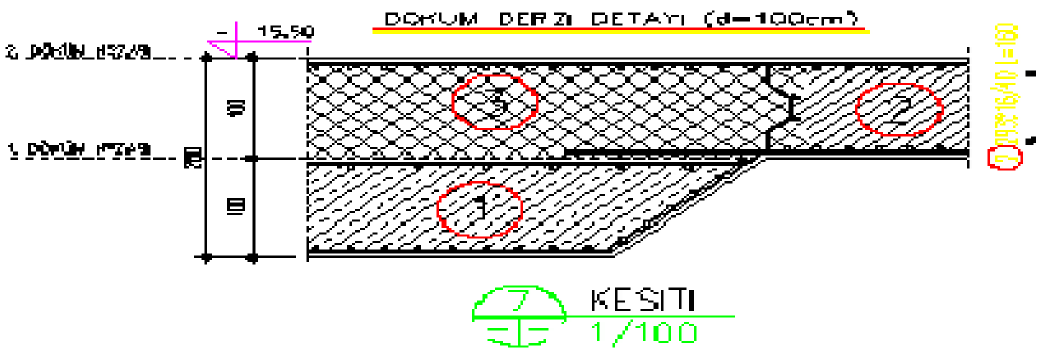

Figure 5.1. Details of the Casting Joint

Since the outer surface of the mass concrete is in contact with the atmosphere, it tries to cool faster than the middle and lower parts of the mass. While the heat increase in the inner and lower parts causes the mass to expand in these parts; in the surface area that is in contact with the atmosphere, the mass tries to shrink as the energy (heat) decreases. If the necessary measures are not taken, the formation of cracks resulting from the expansion and shrinkage becomes inevitable. The depths of the cracks affect the physical properties of the concrete material and the condition of the reinforcement. This type of cracks in concrete make the concrete exposed to the corrosion. Since due to the exposure to the external effects the strength of the concrete will decrease, the necessary measures should be taken to prevent the formation of such cracks.

In addition, another important point is that the compressive strength of concrete will shift to a later time. Because, while reducing the heat differences, we slow down the chemical reactions due to the materials used and, by doing so, we also delay the concrete strength. Thus, when we consider the construction in general; in the stages such as the column, shear wall, and slab, the removal of the formwork will be delayed and this will cause problems in terms of construction rate. Therefore, the application only in the foundation where the mass concrete production is made will not change the construction time. The goal was to monitor the internal heat of concrete.

In the mass concrete applications, the CEM 4 Pozzolanic cements were preferred for their low hydration heat and permeability reducing effect in the all mediums where the chemical effects exist

CHAPTER 6

DISCUSSION ON THE FINDINGS

Before the casting, on the raft foundation, some preliminary studies and measurements were made with different cement types. In these experiments, it was observed that the initial casting heat of the concrete, the highest initial temperature the concrete reached, and whether the concrete could provide the desired concrete strength.

After the foundation concrete casting, the surface was finished, then the surface was covered with blanket to prevent the vapor release from the top, and finally it was cured with its own vapor and moisture.

The internal and external temperature of the concrete were observed through a few measurements a day using the thermocouples at the depths of 15, 50, and 100 cm from the concrete surface. The hydration heat was continuously controlled through a graph.

Since the internal heat of the concrete was measured with the thermocouples; the thermometers were placed at different parts of the concrete surface and fixed to the suitable places for the measurements. The thermocouples were placed in the lower parts (10-15 cm above the ground) and middle parts of the concrete material and on the different points of the concrete surface. 7 hours after the concrete casting, the concrete heat and the environment heat started to be measured. In the first days, the measured values were examined 3-4 times a day. On the following days, the measurement frequency was reduced (1-2 times a day) and the measurements continued. (Figure 6.1). 3 measurement values belonging to the site are given below (Figure 6.2).

Figure 6.1. Measurement with the Thermocouple

Figure 6.2. Measurement Points

6.1. Mass Concrete Casting in One Time

The concrete surface was covered with nylon to keep the heat exchanges between the concrete and the environment under control. On the 13th day, when the temperature difference between the concrete and the environment fell below 25 °C, the cover was removed from the concrete surface (Figure 6.3).

Figure 6.3. Concrete Casting Site

6.2. Mass Foundation Concrete Casting in Several Times

In case of a concrete casting in layers, if necessary, additional reinforcement can be put into the layers by the construction site supervisor, furthermore, if needed, some chemical materials can be used in order to overcome the problems.

The waiting time between the concrete layers was measured as about 12-13 days.

6.3. Analysis of the Hydration Heat in the Mass Concrete Used in Casting Raft Foundation

6.3.1. Estimation of Maximum Internal Temperature

For determining the excessive heat (hydration heat) occurring in the first 10 days after casting the mass concrete used in the foundations of high-rise buildings; the internal temperature of the concrete was estimated by using the method in which the temperature of the admixtures and the clinker (natural materials), which constitutes the content of cement, were calculated without any laboratory work (Boque's Equation).

In the first step, the complex components (C_3S, C_2S, C3A, and C_4AF) of the major oxide components of cement (CaO, SiO_2, Al_2O_3, and Fe_2O_3) were calculated. Based on these complex components, the theoretical hydration heat of the binder was found and thus, the time-dependent temperature of the mass concrete was estimated by means of a formula depending on the followings;

i) Hydration temperature of active binder (Q),

ii) The amount of binder which is calculated as a cement weighted value (W),

iii) The degree of hydration which is calculated using an empirical formula (m),

iv) Accepted specific heat of concrete (c),

v) Unit weight of the concrete casted (p).

6.3.1.1 Hydration Heat of the Binder out of the Complex Compounds of Cement (Q)

As is known, the major oxide components of cement are CaO, SiO_2, Al_2O_3, and Fe_2O_3. The short forms for these components are as follows: CaO = C, SiO_2 = S, Al_2O_3 = A and Fe_2O_3 = F.

The four complex compounds were calculated using the Bogue Formulas given below and the complex compounds (C_3S, C_2S, C_3A, and C_3A) calculated based on the oxide compounds are given in the Table 1.

C_3S = $4.071CaO – (7.6 + 6.718Al_2O_3 + 1.430Fe_2O_3 + 2.852SO_3)$

C_2S = $2.867SiO_2 – 0.7544C_3S$

C_3A = $2.650Al_2O_3 – 1.692Fe_2O\ SiO_{23}$

C_4AF = $3.043Fe_2O_3$

Name of the Complex Component	Oxide Component	Short Form of the Complex Component
Tricalcium Silicate	$3CaOSiO_2$	C_3S
Dicalcium Silicate	$2CaOC_3ASiO_2$	C_2S
Tricalcium Aluminate	$3CaOAl_2O_3$	C_3A
Tetracalium Aluminoferrite	$4CaOAl_2O_3Fe_2O_3$	C_4AF

Figure 6.4. Complex Components of Portland Cement (Üte, 2012).

The hydration heat required for the expected temperature increase in the foundation concrete can be computed by the following formulas:

The complex components (C_3S, C_2S, C_3A, and C_4AF) of the major oxide components (CaO, SiO_2, Al_2O_3, and Fe_2O_3) found in the chemical analysis of the cement were computed using the Bogue Formulas given above. Thus, the complex components of the cement clinker phase were as follows: C_3S = % 61.81;

C_2S = % 12.42

C_3A = % 12.08

C_4AF = % 739.

The heat required for the hydration heat of 1 g of cement = 136 C_3S + 62 C_2S + 200 C_3A + 30 C_4AF cal. 1cal/g = 4.19 kJ/kg, so the theoretical value of the hydration heat can be computed as follows:

$$Q = [136\, C_3S + 62\, C_2S + 200\, C_3A + 30\, C_4AF] \times 4{,}19 \text{ kJ/kg}$$

$$= 136(0{,}6181) + 62(0{,}1242) + 200(0{,}1208) + 30(0{,}0739) = 495$$

6.3.1.2 Amount of Binder (W)

The amount of CEMII/B-M (L-W) 42,5 R cement used in the concrete composition is 260 kg/m^3 and the silica fly ash content is 155 kg/m^3 as per TS EN 450-12. As per TS EN 297-1, this is a pozzolan cement and normally its calcareous fly ash ratio varies between 21% and 35%. There is also a small amount of limestone (L) in this cement. According to those presenting the indicator in kJ/kg, 65.13% of this cement is clinker and 30% is fly ash. In this case;

W_{cement} = 169,3 kg/m^3 (the clinker ration in the cement is % 65,13; so, computed as 260 x 0,6513 = 169,3 kg/m^3)

Since it is 30% of the fly ash in the cement + 155 kg/m^3 (fly ash used), the total mineral admixture was computed as follows:

$W_{mineral\ admixture} = 260 \times 0{,}30 + 155 = 78 + 155 = 233$ kg/m^3

So, the total binder was computed as follows:

$W = W_{cement} + 0{,}30\ W_{mineral\ admixture} = 169{,}3 + 0{,}30\ (233) = 239{,}2$ kg/m3

6.3.1.3 Degree of Hydration (m)

The degree of hydration (m) was computed using the following equation.

$M = 0{,}43 + 0{,}0018\ W_{cement} = 0{,}43 + 0{,}0018\ W_{cement} = 0{,}43 + 0{,}0018(169{,}3) = 0{,}7347$

6.3.1.4 Specific Heat of Concrete (c)

In the computations, the specific heat of the concrete was accepted as to be 1 kJ/kg °C.

6.3.1.5 Unit Volume Weight of Concrete (p)

The unit weight (p) of the concrete used in deep foundations of Folkart Towers project is = 2382 kg/m^3.

The time-dependent temperature increase in the mass concrete is computed using the following formula.$T_{(t)} = W.Q.[1 – e^{(-m.t)}] /c.p$

The meanings of the abbreviations used in this formula are as follows:

$T_{(t)}$: maximum temperature at t time (°C)

T: time expressed in days

W: Amount of Binder (kg/m^3)

Q: Total Hydration Heat of Cement (495 kJ/kg)

M: Degree of Hydration

C: Specific Heat of Concrete (1 kJ/kg °C)

P: Unit weight of concrete (kg/m^3).

The first 10-day increase in the time-dependent temperature increase in the mass concrete was computed according to the formula above.

$T_{(4)}$ = 239,2 x 495[1-2,718$^{(-0,7347,4)}$] / 1 x 2382 = 47,2 °C

$T_{(1)}$	25,82 °C
$T_{(2)}$	38,28 °C
$T_{(3)}$	44,22 °C
$T_{(4)}$	47,20 °C
$T_{(5)}$	48,44 °C
$T_{(6)}$	49,10 °C
$T_{(7)}$	49,41 °C
$T_{(8)}$	49,56 °C
$T_{(9)}$	49,64 °C
$T_{(10)}$	49,68 °C

Figure 6.5. Hydration Heats on the Concrete Casting Day and the Subsequent Days (expressed in °C)

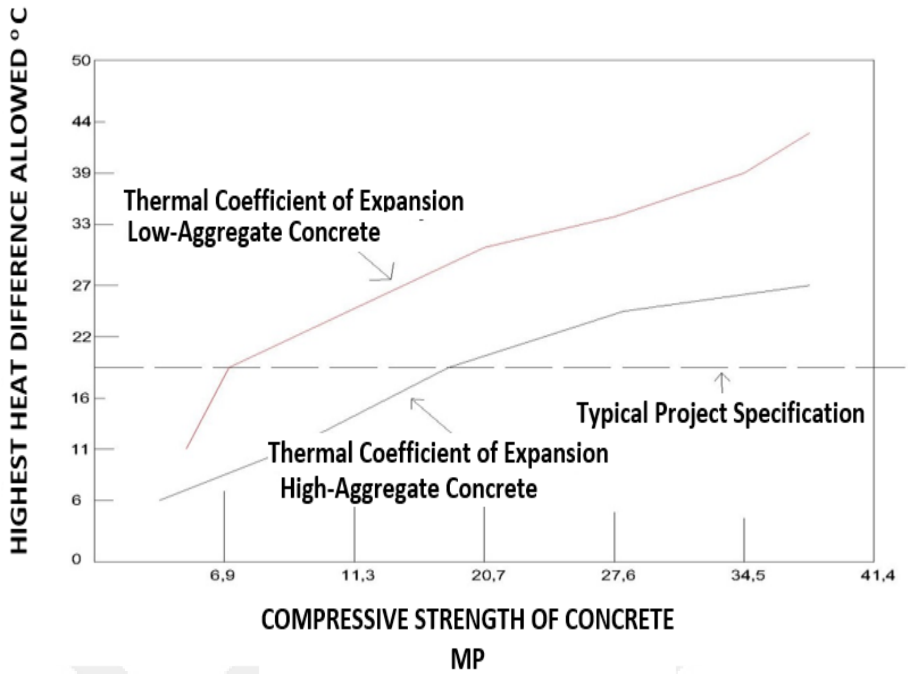

Figure 6.6. Compressive Strength in the Highest Heat Difference between the Inner Center and the Surface in Mass Concrete (Üte, 2012).

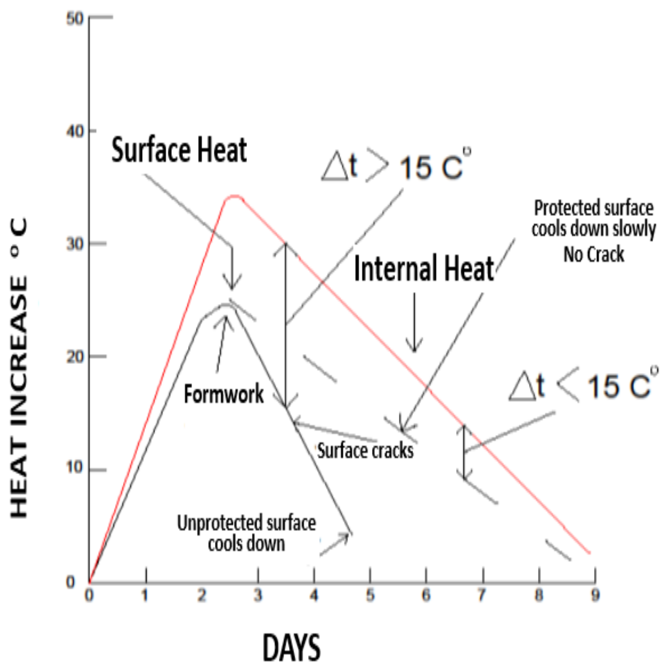

Figure 6.7. Casting Stages and Heat Measurement Stages in Mass Concrete.(Üte, 2012).

If a critical temperature difference such as 20 °C is exceeded, the cooling of the mass is not slow, and there is no protection; the concrete cracks. If the temperature difference is minimized, cracking does not occur (Taşdemir, 2014).

Properties	**%**	**Limit in TS Standarts**
CaO	53,07	
SiO_2	24,66	
Al_2O_3	8,80	
Fe_2O_3	2,73	
MgO	2,18	
Na_2O	0,17	
K_2O	0,95	
Ignition Loss	4,06	≤%5,00: TS EN 196-2
Chloride	0,0085	≤%0,10: TS EN 196-2
SO_3	2,74	≤%4,00: TS EN 196-2
Free CaO	3,21	Na_2= + 0,658 x K_2O
Total Alkali	0,80	
Total Admixture	34,81	21 ≥ B ≤ 35: TS EN 196-4

Figure 6.8. Structural Properties of Cement Thought to be Used in Design (Üte, 2012).

Parameter	Value (%)	Parameter	Value (%)
CaO	65,68	Na2O	0,22
SiO_2	20,99	K2O	1,02
Al_2O_3	6,11	Cl	0,005
Fe_2O_3	2,43	Ignition Loss	0,30
MgO	2,73	Free Lime	2,26
SO_3	0,51	Insoluble Matter	0,07

Figure 6.9. Chemical Properties of Clinker Phase of Cement Thought to be Used in Design (Üte, 2012).

Properties	Limit in TS EN 450-1	Value
Ignition Loss	53,07	% 100
Chloride	24,66	% 0,0014
SO_2	8,80	%0,47
Free CaO	2,73	%1,01
Reactive CaO	2,18	%4,11
Total CaO	0,17	%4,45
Thinness (over 45 minites)	0,95	%44,3

Figure 6.10. Admixture Fly Ash Composition for the Concrete Thought to be Designed (Üte, 2012).

Concrete Grade	C40/50
Water (kg/m^3)	168
Cement (kg/m^3)	260
Fly Ash (kg/m^3)	155
Fine Aggregate 0/2 mm (kg/m^3)	448
Fine Aggregate 0/4 mm (kg/m^3)	285
Coarse Aggregate 4/16 mm(kg/m^3)	521
Coarse Aggregate 16/22 mm(kg/m^3)	539
Chemical Admixture (kg/m^3)	4,2
Water Cement Ratio (kg/m^3)	0,48

Figure 6.11. Mixing Ratio of C 40/50 Raft Foundation Concrete Thought to be Designed (Üte, 2012).

CHAPTER 7

CONCLUSIONS

In the mass concrete works, in the first week, an insulation material was laid on the concrete surface and the concrete was put under protection in order to keep the difference between the surface temperature and the internal temperature of the concrete at the level of around 20 °C. By this way, it was tried to make a crack-free concrete.

In case the liquid-nitrogen cooling methods, which are not yet applied in our country, are adopted and the ready mixed concrete plants invest in these fields; the concrete casting heat will be about 10 °C lower and this will save time for the constructor. Recently, due to the increase in building heights, the cement ratio and dosage in the concrete have been increasing and thus high grade concretes have been being produced. Since the building heights increase, the foundation thicknesses of the buildings increase and the concretes, almost like the mass concrete, are being made. Furthermore, the thicker foundation concretes have had to be cast like the mass concrete in order to avoid cracking and splitting due to the hydration heat.

With a good planning process, it can be applied without damaging the foundation concrete and exceeding the project duration. And economically, the concrete casting can be carried out in one time or in several times and layers. As a result of the studies based on the findings reached through the on-site studies;

Mineral additives should be applied to decrease the concrete temperature

In cases where it is necessary to cast the concrete in one time, the concrete surface should be covered with nylon and the temperature difference should be prevented from increasing.

In case the concrete is cast in layers, it should be allowed to cool for 1-1.5 weeks.

The concrete heat should be monitored using the thermocouples and the problems should be overcome.

REFERENCES

ACI 207.4r-93, 1993, “Cooling And Insulating Systems For Mass Concrete”, ACI Committee Report, *Reported By ACI Comitee* **207**, 3-18

Akçansa, “Çimentonun Hidratasyonu”, Teknik Notlar-3, Http://Www.Akcansa.Com.Tr/Docs/20120216160047_Teknik-Notlar-3.Pdf

Dokuz Eylül Üniversitesi, İnşaat Mühendisliği Bölümü, Http://Kisi.Deu.Edu.Tr/Halit.Yazici/

Erdoğan, T.Y., 2010 Mart, “Beton”, *ODTÜ Geliştirme Vakfi Yayıncılık, Ankara*, 11

Güner, M.S., 2018, “Malzeme Bilimi-Yapı Malzemesi Ve Beton Teknolojisi”, *Aktif Yayınevi*, (10-11)

Neville A.M., 1981, “Properties Of Concrete Heat Of Hydration Of Cement, U.K, 3

Özkul, H., 1984, “Soğuk Ve Sıcak Havada Beton Dökümü”, Dsi Beton Semineri, 1-3

Şimşek O., 2003 Ağustos, “Yapı Malzemesi Ii”, *Beta Basım Yayım Dağıtım*, İstanbul, 9-10

Taşdemir.M. Ali, 2014, “Makale Palladium Tower Projesi”, İstanbul, 20-38

Üte. A. Atacan, 2012, ”Hazır Beton 73 Makale Folkard Tower Projesi”, İzmir, 19

Yalçın, H., Gürü, M., 2006, “Çimento Ve Beton*”, Palme Yayıncılık*, Ankara 4-8

Yazici, H., “Beton Teknolojisi, Agregalar-1”, Yapı Malzemesi Ii Dersi Sunuları, 10