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Prioritizing Mass Concrete Heat Reduction Techniques through Pairwise Comparisons and the AHP Hierarchical Method

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ABSTRACT: This study aimed to determine the optimal method for controlling thermal stress in mass concrete. Accordingly, nine methods of reducing thermal stress and nine criteria for measuring the quality of concrete were obtained. Then, the pairwise comparisons based on the AHP analysis method were attempted to prioritize the different techniques according to the criteria. The results of this study showed that nine methods for reducing thermal stresses in mass concrete, according to various criteria, have priority respectively: (1) using concrete retardant additives with relative weight of 0.193, (2) use of pozzolanic materials and Quasi-cementitious materials with relative weight 0.176, (3) water cooling with relative weight 0.149, (4) use of cement with relative weight 0.130, (5)cooling aggregates (sand) with relative weight 0.077, (6)holding cold mixer and concrete mix with relative weight 0.074, (7) Synthetic (Cold Water Inlet Concrete) with relative weight 0.074, (8) cement cooling with relative weight 0.070 and (9) Natural Method with the relative weights 0.057.

KEYWORDS: Mass concrete; Heat reduction; AHP method; prioritizing; post-cooling

I. INTRODUCTION

Any volume of large concrete that requires special measures to reduce cracking caused by the heat of cement hydration is referred to as mass concrete. Although the term 'mass concrete' suggests large structures, it is essential to note that, under certain conditions, such as high cement content, severe temperature drops, or fixed boundary conditions, medium-sized structures can also be considered mass concrete. Thermal cracks can occur in such cases and are included in the definition of mass concrete, as noted by(Mehta & Monteiro, 2017).Therefore, a more straightforward way to define it is any large-volume concrete that needs measures to prevent thermal cracking. Problems related to mass concrete include the need for specialized formwork and a high volume of concrete to avoid cold joints and excessive hydration heat, which can raise the temperature to dangerous levels. Hydration heat is the most critical issue in mass concreting, as it causes high temperatures and temperature differences within the concrete, leading to thermal cracks. These cracks tend to develop as the concrete contracts and may take several weeks to become visible.

To date, numerous attempts have been made to control the heat problem in mass concrete and identify critical points. For example, (Nguyen & Luu, 2019) used insulating the shell surfaces of a mass concrete structure to minimize the core-shell temperature difference. In another study by(Rahimi, 2021)(Rahimi, 2012), The critical points of thermal stress in a roller concrete dam were investigated, and it was found that in the shell of the dam, where the temperature is lower, the concrete is under tension, while the core of the dam is under compression.

Detwiler et al. (1996)consider that one of the most effective ways to reduce the temperature of concrete is to use cementitious additives in the production of mixed cement. His research shows that the heat released is reduced by additives such as slag, fly ash, silica fume, and other natural pozzolans. Depending on the type of cementitious additives and the percentage of replacement, the rate of heat released at an early age is reduced. In the case of pozzolans, although their use due to gentle hydration reduces heat generation in concrete, in most cases, they decrease the concrete's strength in both the short and long term. Therefore, one of the challenges for researchers has been choosing the most suitable cement additive(Juenger, et al., 2012).

Lagundzija and Tiam (2017) compared possible methods for reducing the temperature of mass concrete using simulation software. The results of their research showed that the pre-cooling method with cooling pipes reduces the concrete temperature by 42% and the maximum temperature gradient by 76%. However, if cooling pipes are avoided, the best result is to replace 30% of the fly ash with cement, and roughly the same maximum temperature is achieved. The results also showed that the obtained temperature reduction is almost independent of the structure's thickness. (Patil, 2015) has identified the most important factors affecting the production of hydration heat in mass concrete and evaluated various methods to reduce it in structures. In their research,(Nguyen et al.,2019)investigated the reduction of temperature in mass concrete using the concrete surface insulation method. The recommendations of this study are to use sand layer insulation to prevent and limit cracks in concrete blocks at an early age. (Gebergziabiheret al. 2015)have concluded that the addition of slag reduces the rate of heat production. As long as sufficient calcium hydroxide from the cement reactions is present in the environment, the slag can react independently. However, at high replacement percentages of the load, the pozzolanic reactions will be quiescent due to the lack of calcium hydroxide. Bofang (2014)demonstrated that there are various methods for controlling the temperature of concrete, ranging from relatively simple to complex and from inexpensive to very expensive. Depending on the specific situation, the use of one or more methods may be more effective than others.

Nili & Salehi (2010)have performed experiments on the replacement of different percentages of cementitious additives and the development of hydration heat. It was observed that reducing the ratio of water to cement has reduced heat generation; the primary reason for this is the decrease in the amount of water required to hydrate the cement materials. Additionally, in concrete with a water-to-cement ratio of 0.46, fly ash is at its lowest level in terms of calorific value and has an acceptable level of strength.

In (Gruyaert et al., 2010) study, it was found that replacing 50% of the slag reduced the total heat of hydration and the maximum temperature of the concrete sample. The maximum temperature in the sample containing 50% slag was reached earlier than in the sample without slag. By examining the microstructure of the slag-containing samples, the researchers found that the cement initially reacted, increasing the alkalinity of the concrete pores. Increasing the alkalinity of concrete and the production of calcium hydroxide accelerates the pozzolanic reactions, and this alkaline environment dissolves the impermeable layer around the slag grains. In 100% slag samples, due to the lack of calcium hydroxide production, hydration and subsequent temperature increase are not observed.

In their study, (Balim & Graham,2009) investigated the effect of fly ash, silica fume, and blast furnace slag on the heating process of concrete. In this study, it was observed that replacing slag with up to 60% of the cement's weight reduced the rate of hydration and heating of the concrete, thereby lowering the maximum temperature of the concrete. Curing temperature, as another factor, plays a role in the heating of concretes containing mineral additives. In concretes containing slag, increasing the curing temperature, which accelerates the hydration of cement and slag, increases the maximum hydration temperature of concrete samples. Additionally, the maximum temperature occurrence time decreases with increasing curing temperature, and concrete samples experience the maximum temperature in a shorter period.

Castillo et al. (2018)modeled finite elements to simulate the hydration and heating process during the concreting of an arch concrete dam. According to the results of this study, the thermal condition of the dam is not only affected by climatic conditions, but also by concrete components and heat reduction methods. In this research, an exponential function has been proposed and calibrated to calculate the heat of cement hydration at the ages of three, seven, and 28 days.

Matos et al.(2019)investigated the effectiveness of fly ash in reducing the heat production of hydrated concrete. In this research, a thermal efficiency index was presented by defining the ratio of temperature increase to compressive strength. This index decreased by 45% in concrete containing fly ash in the resistance class of 20 MPa, and by 15% with the increase in the resistance class to 35-55 MPa.

Accurate prediction of concrete properties is necessary for the thermal stress analysis of mass concrete structures, as analysis results are primarily dependent on these properties. However, it is uneconomic or impractical to evaluate directly concrete properties, such as the thermal expansion coefficient, elastic modulus, shrinkage, and creep (Sang-Lyul Seung-Seop, 2020).

Lu et al. (2021) proposed a new method for controlling the temperature of hydraulic mass concrete to reduce temperature stress. In their study, based on the characteristics of the dam temperature distribution, an external heating and cooling source is used to circulate water through the pre-embedded pipe net in the concrete surface layer, thereby controlling the concrete temperature.

According to (Nataraja et al., 2022), mass concrete contains large-sized aggregates, specifically 40 mm, 80 mm, and 150 mm. In their work, supplementary cementing materials (SCMs) were used to control the heat of hydration, and different SCMs were recommended by the codes of practice, namely fly ash and ground granulated blast-furnace slag.

Inthe study by (Hu et al., 2021), on-site temperature measurements were conducted for 29 days and 16 days, respectively, for the mat foundation and the slab of the first floor of the same building. The measurement data revealed temperature evolution at different depths of mass concrete placed in August and November. For the mass concrete placed in August, due to extensive diurnal temperature range (DTR), low humidity and high initial temperature of fresh concrete, there were not only a sharp temperature increase in the middle of mass concrete within 48 h after placement, but also a substantial overrun of temperature difference between core and surface, especially at position of larger thickness.

Given the above and the scattering of options in research to reduce the heat of mass concrete, this article aims to provide a solution for selecting a priority method to control thermal stresses. For this purpose, after identifying the methods in the researchers' articles, nine different options for reducing temperature are extracted. A hierarchical analysis of AHP is then used to present a ranking model that prioritizes these options.

II. DECISION MAKING BY HIERARCHICAL ANALYSIS

The Choice of mass concrete temperature control method in construction projects such as dam construction is a complex and important issue that requires a decision-making process and its integration with construction management approaches. In the past, extensive research has been conducted on the problem of bulk heating, both in the laboratory and through numerical studies. However, in most of these studies, little attention has been paid to selecting the optimal method based on various technical, economic, and executive criteria. Given the importance of mass concreting and the reduction of thermal stresses in controlling cracking in structures made with this type of concrete, selecting the optimal method is crucial. In multi-criteria decision making, practical methods for heat control and reduction of thermal stresses are first identified. Then, using the expertise of experts, an approach is provided on how to make decisions and select the optimal method based on quality criteria. To make decisions and prioritize the obtained information, the AHP hierarchical analysis method, first proposed by Dr. Saaty in 1980, is used, along with Expert Choice software (Saaty, 1980; Saaty, 1997).This method is one of the most crucial approaches in multidisciplinary decision-making. Ultimately, each factor is identified, and after determining their importance, they are prioritized through pairwise comparisons.

III. HEATING OF MASS CONCRETE AND METHODS OF REDUCİNG IT

Due to the relatively low thermal conductivity of concrete, the heat dissipation rate is slow. When the dimensions of the concrete are such that heat exchange between the concrete and the environment is not easily possible, it will increase the temperature of the concrete member and cause temperature differences between the concrete and the environment. Heat generation first leads to the expansion of the concrete member. After the concrete reaches its maximum temperature, it cools slowly to its final temperature. Subsequent lowering of the concrete temperature and reaching the final equilibrium temperature causes the concrete to shrink. Reports from engineers working on mass concrete structures indicate that the core temperature of these structures sometimes rises to approximately 94 degrees Celsius. A noteworthy point in bulky structures is the temperature difference between the shell and the core. This is because the shell of the structure rapidly cools due to direct contact with the environment. At the same time, the core temperature may remain below the maximum temperature for an extended period due to the low thermal conductivity properties of concrete. The temperature difference between the shell and the core (thermal gradient) causes tensile stress, which sometimes exceeds the tensile strength of the concrete, leading to cracking. The heat released in mass concrete structures can cause internal tensile stress, resulting in cracking and damage. Such failures can reduce the bearing capacity of the structure and compromise the durability of concrete through the penetration of destructive ions, such as sulfate and chloride.

There are several methods to control the heat generation of concrete, including layer-by-layer concreting, deceleration through the use of additives, pre-cooling, and post-cooling. Of course, in this research, it is assumed that the concrete is applied layer by layer, and the layer thickness is obtained by thermal analysis and is constant. Therefore, the layer thickness parameter is not taken into account in the decision-making process. The following are the methods of controlling the heating of concrete.

A) Select the type of cement and additives

The most important cause of heat in concrete is the hydration of cement. The type of cement is very effective in reducing heat generation. In addition to the type of cement, the lower the grade of cement, the less heat is generated. Therefore, in the mixing plan, a percentage of the cement used can be replaced with pozzolanic materials, such as fly ash, slag, and zeolite (Emamzadeh, 2020) to achieve the required strength, while also reducing cement consumption. Some materials can cause an endothermic side reaction during the hydration of cement. Pozzolans and cementitious materials can reduce the heat of hydration. These side reactions can absorb heat at a constant rate and act as a heat shield. In some cases, they are even able to store heat and release it later. Quasi-cementitious materials exhibit latent hydraulic properties and react similarly to Portland cement only in alkaline environments with the presence of water. Pozzolans are silica materials with aluminum silica that, when reacted with calcium hydroxide, form cementitious compounds. At least 30% replacement of cement with suitable pozzolan can reduce concrete consumption and improve the performance of concrete in terms of reliability against chemical attack and cracking. Another option is to use water-reducing materials or retarding additives, as a constant ratio of water to cement results in less water being used, which in turn reduces the amount of cement in concrete and consequently generates less heat. Is created. The use of air conditioners or bubble builders has the same water-reducing effect. For every one percent of air entering the concrete, the amount of water consumption is reduced by 2 to 4 percent, and this reduction in water consumption also reduces the amount of cement used. Therefore, in some projects, the use of air-conditioning materials in mass concrete is mandatory. The use of these additives usually delays the final setting time. One of the most important roles of these materials is to control the setting of concrete, thereby maintaining its efficiency. These additives are also used to compensate for bad weather conditions.

B) pre-cooling

Pre-cooling refers to a method in which the temperature of fresh concrete is reduced by lowering the temperature of the concrete components, including water and aggregates. This method was first used in the construction of the Norfolk Dam in the United States in the early 1940s. In this method, an attempt is made to lower the temperature of the concrete so that, firstly, the temperature of the concrete increases at a slower rate and, secondly, the maximum temperature of the concrete during the hydration period is within the technical specifications. The lower the temperature of concrete at the time of conversion from plastic to hardened, the lower the tendency of concrete to crack. The pre-cooling method is done in different ways.

One of the most common and convenient methods in the pre-cooling method is cooling the mixing water. Because water has the highest specific heat capacity among concrete components, in other words, water has the highest heat absorption in concrete, and on the other hand, cooling water is much easier than other concrete components. Water consumption in concrete, due to its high heat capacity, plays an important role in controlling the hydration temperature. In addition to using cold water or ice, cooling the aggregates is also one of the most cost-effective pre-cooling methods. Since aggregates constitute the most significant volume of concrete, they have the greatest effect on the temperature of fresh concrete. As a result, cooling the aggregates has the most significant effect on reducing the temperature of concrete. Another way is to prevent the mixer from overheating due to sunlight or heat. The heat of the mixer causes the concrete temperature to rise, in addition to the heat generated through hydration, which serves as a secondary source of heat. To prevent this problem, a white mixer that does not absorb heat can be used, or a wet sack can be wrapped around the mixer's surface to absorb heat and prevent it from reaching the concrete. This slows down the hydration process and keeps the concrete temperature low before it is applied.

C) After cooling

Cooling occurs after concreting, with maximum efficiency achieved during the first three to four days following concreting. Because the temperature of mass concrete usually reaches its peak during this period and undergoes the most thermal stresses during this period. One of the most common post-cooling methods is the use of cold-water piping within concrete. In this method, before concreting, special pipes (thin-walled steel pipes with a diameter of 25 mm and a thickness of 1.5 mm) are installed as a network, which is connected to a cooling source. This method was first used in the Hoover Dam in the United States in

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1930.

IV. COMPARING THE PROPOSED OPTIONS

The results of the previous sections showed that, in general, the primary methods of reducing thermal stress in mass concrete can be classified into three main categories of methods of slowing down the heating process, pre-cooling, and post-cooling. In addition, previous research has shown that when selecting the optimal method, executive factors (characteristics of fresh concrete), including efficiency, separation, dewatering, setting time, and percentage of air in fresh concrete, as well as technical factors (characteristics of concrete), should be considered. Hardened) including compressive strength, reliability, heat generation, and cooling rate were considered as the most important factors in choosing the appropriate option.

After determining the practical methods and parameters in selecting the optimal method to reduce and control thermal stresses in mass concreting, an attempt has been made to develop an executive model from the perspective of construction management using the Analytic Hierarchy Process (AHP) method. For this purpose, after combining different methods and effective parameters to select the optimal method, a table has been compiled, as shown in Table 1, and comparisons have been made. Experts made comparisons for the nine criteria selected in the nine options. Necessary analyses are performed on these comments, and the final weight results are presented in the form of tables. It is necessary to note that, to facilitate the calculation process and avoid interfering with the text, each method is designated by English symbols and letters (A to I), and the criteria are identified by indicators M1 to M9.

Paired comparisons are used to compare the relative importance of each option to another at the same level of importance. Comparisons are typically made between couples based on their importance or preference. Table 3 shows the pairwise comparison of temperature control options based on efficiency criteria. Eight other criteria were measured in the same way by designing a questionnaire.

Table 1: The proposed options for reducing thermal stress and the effective indicators

Alternatives	Symbol	Indicators	Symbol
Use of retarder cement	A	Performance	M1
Use of pozzolanic materials and cement-like materials	B	Separation	M2
Use retardant additives	C	Bleeding	M3
Cool the water	D	Setting time	M4
Cooling the cement	E	Percentage of fresh concrete air	M5
Cooling aggregates (sand)	F	CompressiveStrength	M6
Keep the mixer and concrete mix cool	G	Durability	M7
Synthetic (cold water piping inside concrete)	H	Heating	M8
Normal	I	Cooling rate	M9

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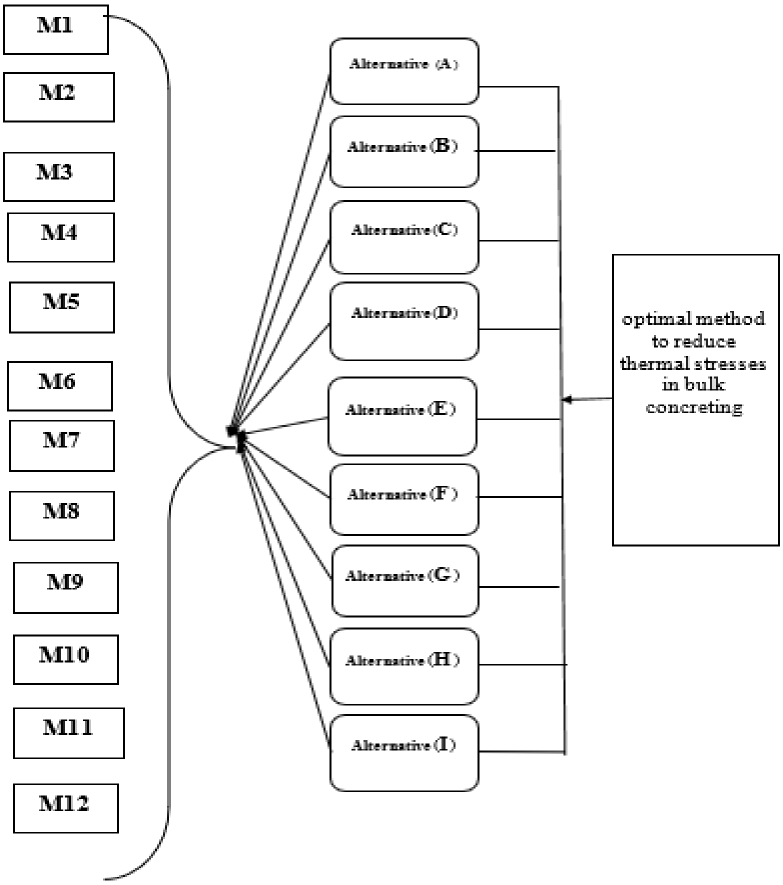

Fig. 1 Hierarchical decision tree to select the optimal method for reducing thermal stresses of mass concrete

Table 2: Frequency of demographic parameters of experts

Parameter	Component	Frequency	Frequency Percentage	Cumulative Frequency
Age	20 to 30 years	5	25	25
	30 to 40 years	6	30	55
	40 to 50 years	7	35	90
	More than 50 years	2	10	100
Construction project work experience	Less than 5 years	3	15	15
	5 to 15 years	5	25	40
	15 to 25 years	10	50	90
	More than 25 years	2	10	100
Work experience in the field of mass concreting	Project Engineer	7	35	35
	Project Consultant	2	10	45
	Employer	5	25	70
	Contractors	6	30	100
Education	Associate Degree	3	15	15
	Bachelor	5	25	40

	MA	9	45	85
	Doctorate	3	15	100

Table 3 Pairwise comparison of the importance of concrete temperature control options based on efficiency criteria (M1)

Alternative	Extreme	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Extreme	Alternative
Use of pozzolanic and quasi-cementitious materials (B)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Use of concrete retardant additives (C)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Water cooling (D)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Cement cooling (E)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Cooling aggregates (sand) (F)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of retarder cement (A)
Use of concrete retardant additives (C)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Water cooling (D)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Cement cooling (E)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Cooling aggregates (sand) (F)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of pozzolanic and quasi-cementitious materials (B)
Water cooling (D)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete retardant additives (C)
Cement cooling (E)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete retardant additives (C)
Cooling aggregates (sand)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete

Alternative	Extreme	Very Strong	Strong	Moderate	Equal	Moderate	Strong	Very Strong	Extreme	Alternative
(F)										retardant additives (C)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete retardant additives (C)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete retardant additives (C)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Use of concrete retardant additives (C)
Cement cooling (E)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water cooling (D)
Cooling aggregates (sand) (F)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water cooling (D)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water cooling (D)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water cooling (D)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Water cooling (D)
Cooling aggregates (sand) (F)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cement cooling (E)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cement cooling (E)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cement cooling (E)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cement cooling (E)
Cool mixer and concrete mix (G)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooling aggregates (sand) (F)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooling aggregates (sand) (F)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cooling aggregates (sand) (F)
Synthetic (cold water piping inside concrete) (H)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cool mixer and concrete mix (G)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Cool mixer and concrete mix (G)
Natural (I)	☐	☐	☐	☐	☐	☐	☐	☐	☐	Synthetic (cold water piping inside concrete) (H)

V. RESULTS AND DISCUSSION

To propose an effective method for reducing thermal stresses in mass concrete, a pairwise comparison of all criteria across the nine existing methods is conducted. Experts performed comparisons using the Analytic Hierarchy Process (AHP) for the nine proposed options, as outlined in Table 1. First, the arithmetic mean of the experts' responses was calculated based on pairwise comparisons. Then, the sum of the normalized values of the line elements was determined, and the incompatibility of the matrices was assessed— all compatibility numbers being less than 10, indicating sufficient validity of the options and criteria. After deriving the weight of each criterion for each method, comparative graphs illustrating the selection of the optimal method per criterion were presented. Following expert opinions and pairwise comparisons of options, necessary calculations were performed on the responses, resulting in the final weights of each method based on nine different criteria, as shown in Figs. 2-10.

In the previous section, the final weights of each method for reducing the thermal stress of mass concrete were determined based on different criteria. In the final step, using the Expert Choice

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software, the prioritization of options was determined, and the results are presented in Fig. 11.

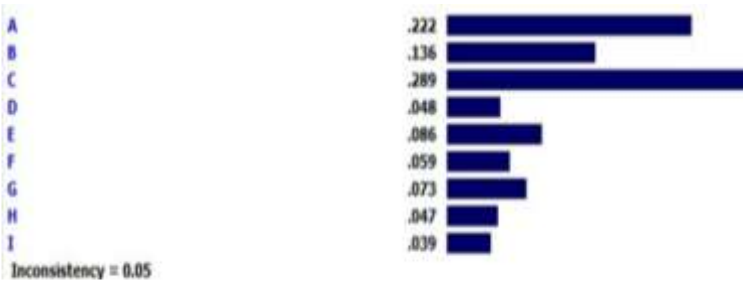

Fig. 2 The final weight of the first index (Workability M1)

Fig. 3 The final weight of the second index (Separation M2)

Fig. 4 The final weight of the third index (Bleeding M3)

Fig. 5 The final weight of the fourth index (Setting time of M4)

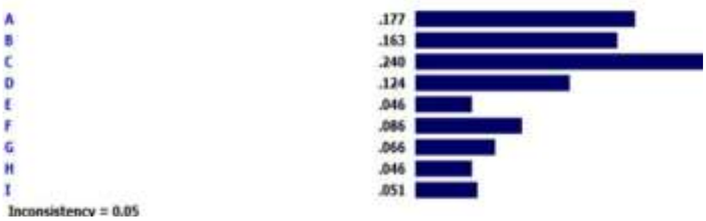

Fig. 6 The final weight of the fifth index (air percentage of fresh concrete M5)

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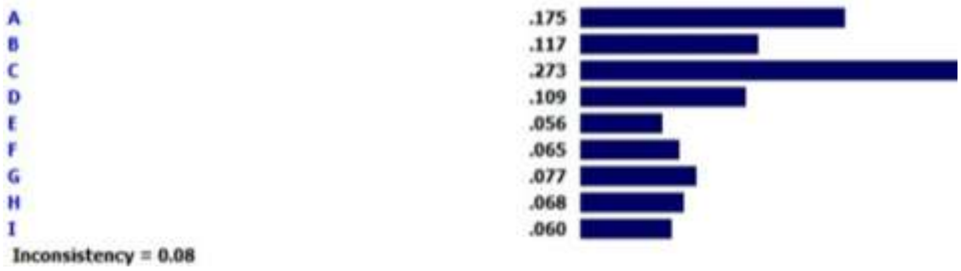

Fig. 7 The final weight of the sixth index (compressive strength M6)

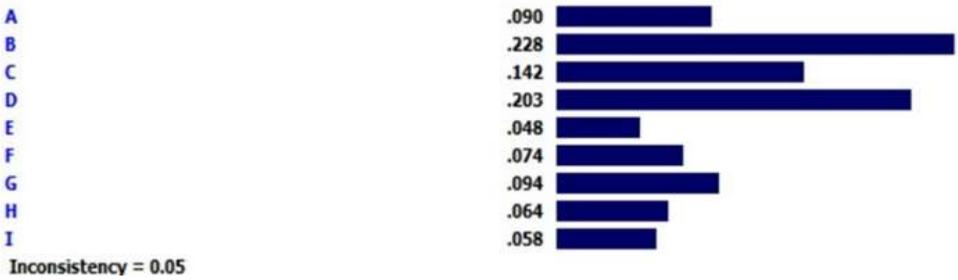

Fig. 8 The final weight of the seventh index (Durability M7)

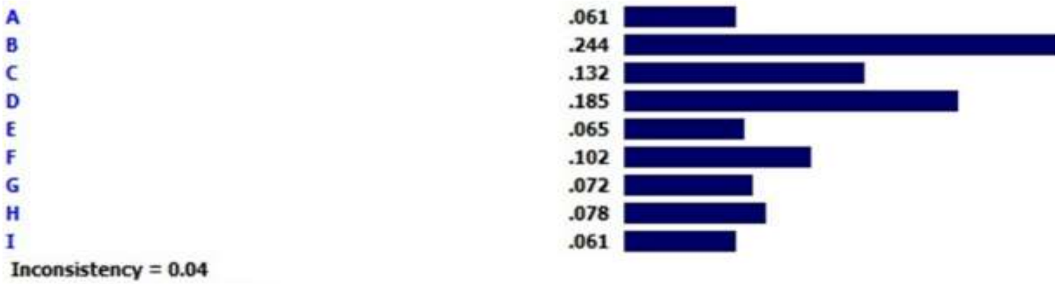

Fig. 9 The final weight of the eighth index (heat generation rate M8)

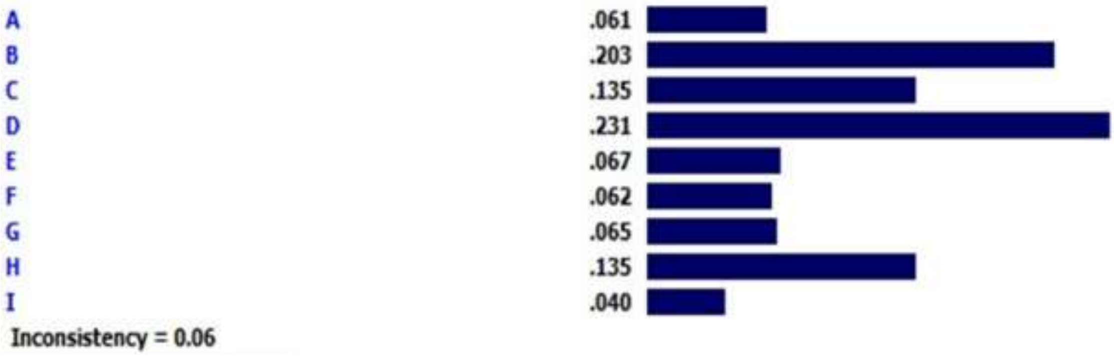

Fig. 10 Final weight of the ninth index (cooling rate M9)

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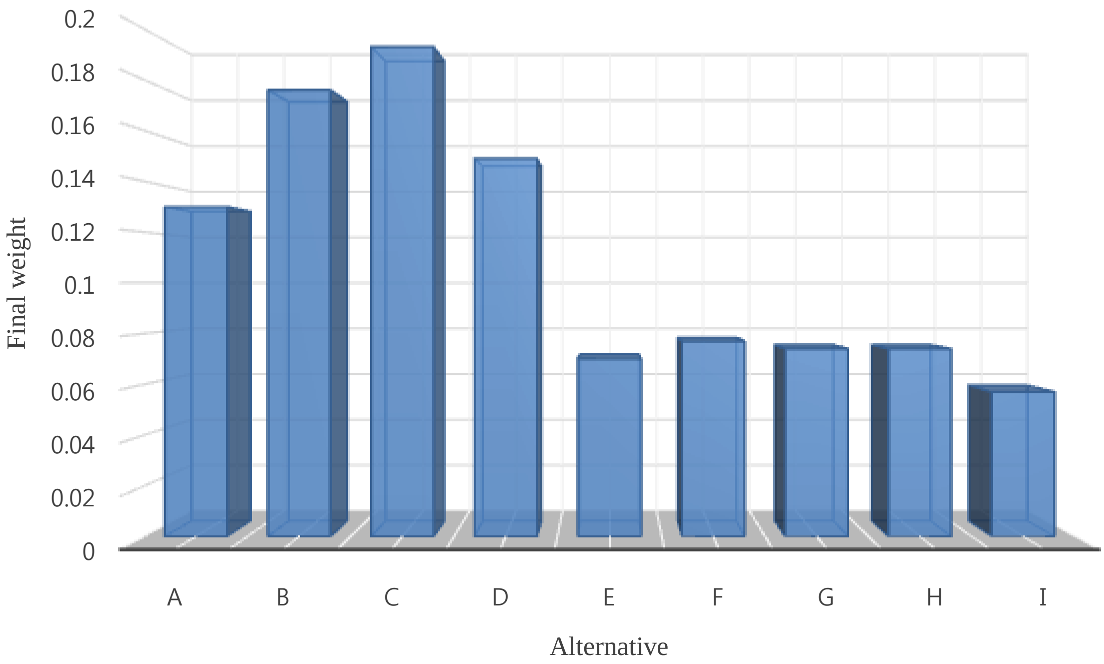

Fig. 11 The final weight of nine options for reducing the thermal stress of mass concrete based on all different criteria

According to the final weight determination, the prioritization of the proposed options for reducing the thermal stresses of mass concrete is as follows.
1. Use of concrete retardant additives (C)
2. Use of pozzolanic and cement-like materials (B)
3. Water cooling (D)
4. Use of retarder cement (A)
5. Cooling aggregates (sand) (F)
6. Keep mixer and concrete mix cool (G)
7. Synthetic (cold water piping inside concrete) (H)
8. Cooling of cement (E)
9. Natural method (I)

It is observed that the use of retarding additives has the highest priority, and the natural method has the lowest priority in controlling the temperature of mass concrete.

VI. CONCLUSİON

According to the results of this study,
1- If the goal is to achieve simultaneous performance and reduce the temperature of concrete, the use of retarding additives and retarding cement may be more appropriate than other options.
2- In the separation criterion and the dehydration criterion, the options of using retarding additives, using retarding cement, and using pozzolanic and quasi-cementitious materials are the first, second, and third priorities. With these three methods in mass concrete, both the separation and dehydration criteria can be kept appropriate, and thermal stresses can be reduced.
3- In the criterion of dehydration, as well as the separation method, the method of using concrete retardant additives and the method of using retarder cement and the method of using pozzolanic and cement-like materials, the first to third priorities are preferable, which with these three methods in mass concrete can both keep the dehydration rate appropriate and reduce thermal stresses.
4- In terms of setting time, among the nine methods of reducing thermal stresses, the use of concrete retardant additives and the use of retardant cement have gained higher priority than other cases.
5- In terms of the percentage of fresh air in concrete, four methods of using concrete retardant additives, using retardant cement, using pozzolanic and quasi-cementitious materials, and cooling water with a slight difference in final weight, have the first to fourth priorities.
6- In the criterion of compressive strength, the use of retarding additives with a difference compared to other methods was preferred in first place, and then the use of retarding cement won second place. In terms of reliability, the use of pozzolanic and quasi-cementitious materials, as well as the method of water cooling, were ranked first and second, respectively. The use of retarding additives was

ranked third. Concrete retardant additives are in the following ranks.

7- In terms of calorific value, the use of pozzolanic and quasi-cement materials as the best method, and then cooling the water, are the most appropriate methods according to experts. In terms of cooling rate, water cooling and the use of pozzolanic and quasi-cement materials with the first and second priority can be the most appropriate methods.

REFERENCES

[1]. Ballim, Y., Graham, P.C.(2009).“The effects of supplementary cementing materials in modifying the heat of hydration of concrete”.Materials and Structures, **42**(6), 803-811.

[2]. Bofang, Z. (2014). “Thermal Stresses and Temperature Control of Mass Concrete”. Butterworth-Heinemann.

[3]. Castilho, E., Schclar N., Tiago C., Farinha, M. (2018).“FEA model for the simulation of the hydration process and temperature evolution during the concreting of an arch dam”, Engineering Structures, 174, 165-177.

[4]. Detwiler, R.J., Bhatty, J.I., Bhattacharja, S. (1996). “Supplementary cementing materials for use in blended cements.” Portland Cement Association, Skokie (Illinois).

[5]. Emamzadeh, S.Sh. (2020). “An Experimental Study on Workability and Durability Properties of Zeolite-based Self Compact Concrete”, Concrete Research, 13(3), 77-91.

[6]. Gebregziabiher, B.S., Thomas, R., Peethamparan, S. (2015). “Very early-age reaction kinetics and microstructural development in alkali-activated slag.” Cement and concrete composites, 55, 91-102.

[7]. Gruyaert, E., Robeyst, N., De Belie, N. (2010). “Study of the hydration of Portland cement blended with blast-furnace slag by calorimetry and thermogravimetry”, Journal of Thermal Analysis and Calorimetry, 102(3), 941-951.

[8]. Hu, Y., Chen J., Zou F., He M., Mao J., Liu X., Zhou C., Yuan Z. (2021). “A comparative study of temperature of mass concrete placed in August and November based on-site measurement”, Case Studies in Construction Materials, 15, doi.org/10.1016/j.cscm.2021.e00694.

[9]. Juenger, Maria & Provis, John & Elsen, Jan & Matthes, Winnie & Hooton, Doug & Duchesne, J. & Courard, Luc & He, Huan & Michel, Frédéric & Snellings, Ruben & Belie, Nele. (2012). “Supplementary Cementitious Materials for Concrete: Characterization Needs”, MRS Proceedings. 1488. 10.1557/opl. 2012.1536.

[10]. Lagundzija, S., Thiam M. (2017). “Temperature reduction during concrete hydration in massive structures”, Student Thesis, Royal Institute of Technology, Stockholm.

[11]. Lu, X., Chen B., Tian B., Li Y., Lv C., Xiong B. (2021). “A new method for hydraulic mass concrete temperature control: Design and experiment”, Construction and Building Materials302,doi.org/10.1016/j.conbuildm at.2021.124167.

[12]. Matos, P., Junckes, R., Graeff, E., Jr, L.R. (2019). “Effectiveness of fly ash in reducing the hydration heat release of mass concrete”. Journal of Building Engineering, 28, 101063.

[13]. Mehta, P.K., Monteiro, P.J. (2017).“Concrete Microstructure, Properties and Materials”, 4th ed., McGraw-Hill Education.

[14]. Nataraja, M.C., Shivakumara, M.J., Dalawai, Vibha N.(2022). “Effect of design parameters on the proportioning of mass concrete using fly ash and ground granulated blast furnace slag”, Materials Today: Proceedings, 62(8),5329-5335, doi.org/10.1016/j.matpr.2022.03.410.

[15]. Nguyen, T.-C., Luu, B. (2019). “Reducing temperature difference in mass concrete by surface insulation”, Magazine of Civil Engineering. 88, 70-79.

[16]. Nili, M., Salehi A.M. (2010). “Effect of Heat Curing in Core and Surface of Massive Concrete Structures on Long Term Strength of High Strength Concrete”, Amirkabir Journal of Civil Engineering (In Persian), 42(2).

[17]. Patil, A. (2015). “Heat of hydration in the placement of mass concrete”. International Journal of Engineering and Advanced Technology (IJEAT), 4(3), 1-4.

[18]. Rahimi, A. (2012). “Evaluation on heat of hydration in roller compacted concrete dams during construction phases, Australian Journal of Basic and Applied Sciences, 6(6) 151-156.

[19]. Saaty, T.L. (1997). "A Scaling Method for Priorities in Hierarchical Structures", J. Match. Psychology, 15: 234-281.
[20]. Sang-Lyul, C., Seung-Seop J.(2020). "Prediction of thermal stresses in mass concrete structures with experimental and analytical results", Construction and Building Materials, 258, doi.org/10.1016/j.conbuildmat.2020.120367.
[21]. Wind, Y., Saaty, T. L. (1980). "Marketing applications of the analytic hierarchy process". Management science, 26(7), 641-658.