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Effect of High Heating and Cooling on Concrete Strength

Asst. Lecture. Douread Raheem
Ph. D Student in Tun Hussein Onn University
Engineering faculty
Batu Pahat, Johor, Malaysia

Lecture. Dr. Thaer Matlab Mezher
Kufa University
Engineering faculty
Najaf, Iraq

Lecture. Dr. Ahmed Sagban
Basrah University
College of Engineering
Basrah, Iraq

Asst. Lecture. Alyaa Abdulrazzaq
Ph. D Student in Tun Hussein Onn University
Engineering faculty
Batu Pahat, Johor, Malaysia

***Abstract*— This paper presents the results of an experimental study for effective of high temperature and cooling by water with different temperature and different concrete mixture. The 36 concrete cubes with (100× 100 ×100) mm were cast at the same time to be ensure all cubes have same test condition. All concrete cubes were cured within 28 days. Twelve concrete cubes were used as a guide and another 24 cubes were subjected to fire with different temperature (400,600,900) C° and cooling before testing. Also finite element analysis by ANSYS V.14 was done to validate the results with experimental work. The compressive strength for cube that were tested under 400 C° was higher than another burned cubes. On the other hand, the cubes that burned till 900 C° showed a smallest compressive strength. The burn by fire decreased the compressive concrete strength 3-6 times when the temperature increased. Moreover, the results that recorded by Ansys model gave a good validation with experimental results.**

Keywords—Heating And Cooling; Concrete Cubes; Compressive Strength.

I. INTRODUCTION

Many researches were conducted to study the behaviour of concrete under high temperature. Moreover, the last studying on concrete that subjected to fire are still not enough to give a good enhancement for increasing of temperature on concrete strength. The building subjected to fire that may happened normally or suddenly still more dangerous comparing with another riskiness. However, the concrete surface that subjected to fire is exposed due to increasing of temperature up to 800 °C within less than 60 minutes [1-4]. On the other hand, the concrete that used for building subjected to explosion like furnaces wall and dampers, industrial chimneys and flues, floors below boilers and kilns and nuclear- reactors also need to development and studying of effective of high temperature on concrete to using in future design [5-8]. In addition, the temperature, nature, and distribution of fire loading, ventilation and compartment size are the most parameters that increasing or decreasing of effect of fire on structural members. The reinforced concrete slabs is a one of structure that subjected to fire and the high temperature is more effect on it than another members. Also, the properties of reinforced concrete members are changed when this members subjected to fire. The time or period of fire is also more important and effective on concrete failure properties ASTM E-119 [9]. The main objective of this paper is to investigate the effect of high temperatures on the compressive strength of the concrete. Three deferent temperatures that subjected on concrete (300, 600, and 900) in this paper to study the effective of heat on concrete with deferent temperatures. Moreover, the last studying on concrete that subjected to fire are still not enough to give a good enhancement for increasing of temperature on concrete strength.

II. EXPERIMENTAL PROGRAM

This paper studies the behaviour of compressive strength for concrete cubes that subjected to three different temperature. Twelve concrete cubes were used as a guide and another 24 cubes were subjected to fire with different temperature (400,600,900) C° and cooling before testing. After that, the 24 cubes were inserted inside oven and heated within three groups depend to test it with different temperature. The concrete cubes were subjected to (400,600,900) C° as a different temperatures. After that, the concrete cubes were cooling with water. Also, two different type of concrete mixtures (1: 1.5: 3 and 1: 2: 4) and also two water to cement a 30% and 50% were used in this research. Figure 1 and 2 show the concrete casting and test steps respectively.

Figure (1) Concrete casting and molding

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Figure (2) Test procedure

III. EXPERIMENTAL RESULTS

The compressive strength for control cubes that were recorded during test can be showed in Table 1.the effect of mixing the concrete cubes that the resistance ratio of mixing ratio (1:1.5:3) gives the highest mixture of resistance (1:2:4) so as to increase the cement content, as well as the effect of impact the water to cement ratio is low whenever they gave the highest resistance. Ordinary Portland cement (Iraqi cement) was used throughout the works. Moreover, the percentage of mixing were done depend on Iraqi code. Figure 1 show the stage of concrete material mixing at laboratory. Moreover the compressive strength for normal cubes (N.C) that were tested can be showed in Table 1. Tables 2, 3, 4 describe the compressive strength of all burn cubes with different mixing ratio and water to cement ratio. Finally, the compressive strength for all cubes that were tested can be showed in figures 3 and 4.

Table 1. Compressive strength of control cubes with different mixing ratio and water to cement ratio

Item	Mixing ratio(1:1.5:3)		Mixing ratio(1:2:4)	
	Water cement ratio 30%	Water cement ratio 50%	Water cement ratio 30%	Water cement ratio 50%
Compressive strength MPa	30.17	25.1	19.76	19.16
	33.2	26.1	25.4	16.09
	27.16	26	23.39	16.12
Average(Mpa)	30.2	25.76	22.85	17.12

Table 2. Compression test results for Burn cubes at a temperature of 400℃ for two hours and then cooled by water

Item	Mixing ratio(1:1.5:3)		Mixing ratio(1:2:4)	
	Water cement ratio 30%	Water cement ratio 50%	Water cement ratio 30%	Water cement ratio 50%
Compressive strength MPa	14.3	14.31	12.56	12
	15.41	12.76	13.01	11.2
Average (Mpa)	14.86	13.5	12.78	11.6

Table 3. Compression test results for Burn cubes at a temperature of 600℃ for two hours and then cooled by water

Item	Mixing ratio(1:1.5:3)		Mixing ratio(1:2:4)	
	Water cement ratio 30%	Water cement ratio 50%	Water cement ratio 30%	Water cement ratio 50%
Compressive strength MPa	6.2	4.3	3.1	2.1
	7.1	4.8	2.85	1.76
Average (Mpa)	6.65	4.55	2.975	1.93

Table 4. Compression test results for Burn cubes at a temperature of 900℃ for two hours and then cooled by water

Item	Mixing ratio(1:1.5:3)		Mixing ratio(1:2:4)	
	Water cement ratio 30%	Water cement ratio 50%	Water cement ratio 30%	Water cement ratio 50%
Compressive strength MPa	2	1.67	1.13	0.98
	1.6	1.6	1.42	1.1
Average(Mpa)	1.8	1.64	1.28	1.04

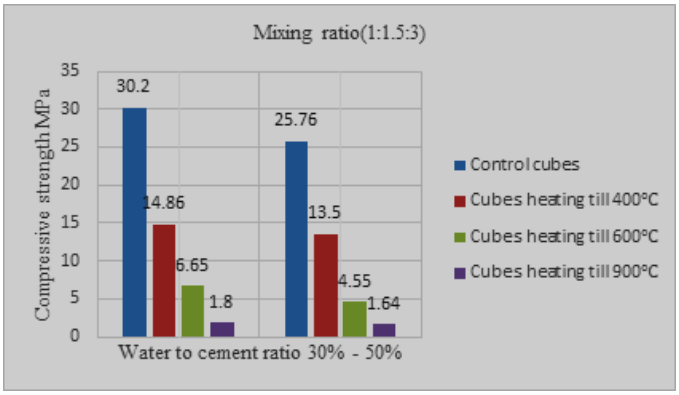

Figure (3) Compressive strength of (1:1.5:3) mixing ratio for control cubes compared with Burn cubes

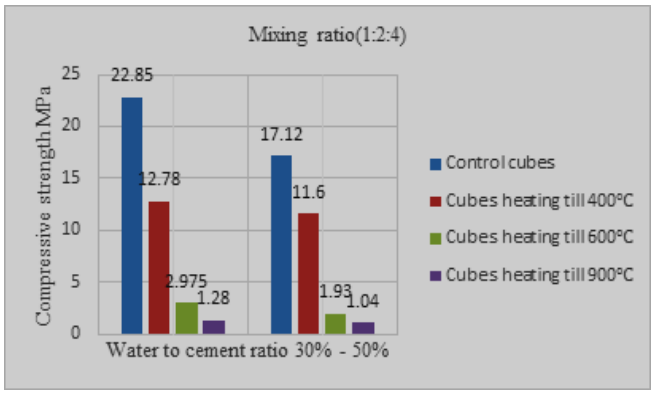

Figure (4) Compressive strength of (1:2:4) mixing ratio for control cubes compared with Burn cubes

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IV. FINITE ELEMENT SIMULATION

ANSYS V.14 software program were used to validate the compressive strength and failure pattern for cubes with experimental work. In this analysis, one water cement ratio were used and it was 30% and that is means the modulus of elasticity for all cubes was taken from experimental work (compressive strength of control cubes) to compute the maximum load, maximum compressive strength and effective of temperature on failure pattern. On the other hand, the cube were subjected to three different temperature and compression load as a boundary condition and resolution by loading to know the effective of cooling on compressive strength compared with experimental work. The mode of failure that noted by Ansys for all cubes are shown in Figure 5. Moreover, the compressive strength for cubes is also recorded as shown in Table 5.

Table 5. Compressive strength results for all cubes

Item	Mixing ratio(1:1.5:3)	Mixing ratio(1:2:4)
	Compressive strength MPa	Compressive strength MPa
Control cubes	34.6	26.33
Cube heating till 400℃	11.51	10.22
Cube heating till 600℃	1.5	1.2
Cube heating till 900℃	0.52	0.31

The effect of mixing the concrete cubes that the resistance ratio of mixing ratio (1:1.5:3) gives the highest mixture of resistance (1:2:4) so as to increase the cement content, as well as the effect of impact the water to cement ratio is low whenever they gave the highest resistance. Table 6 shows the differences between finite element analysis (F.E.A) and experimental (EXP) compressive strength.

Table 6. Compression between compressive strength results for all cubes

Item	Mixing ratio(1:1.5:3)			Mixing ratio(1:2:4)		
	EXP Compressive strength MPa	F.E.A Compressive strength MPa	DIFF %	EXP Compressive strength MPa	F.E.A Compressive strength MPa	DIFF %
Control cubes	30.2	34.6	-14.5	22.85	26.33	-15.23
Cube heating till 400℃	14.86	11.51	22.5	12.78	10.22	20
Cube heating till 600℃	6.65	1.5	77.4	2.97	1.2	59.6
Cube heating till 900℃	1.8	0.52	71.1	1.28	0.31	75.78

V. CONCLUSIONS

This paper presents the research findings of effective of heating and cooling by water on concrete with different temperature and with different of mixing ratio for concrete. Thirty six cubes (12 cubes as a guide) were cast and tested to calculate the compressive strength of normal and burn cubes. From the results that obtained and recorded, the following comment were done:

1. The compressive strength for all burn cubes is smaller than normal cubes and the compressive strength decreases from 50%-94% for burn cubes and (1:1.5:3) mixing ratio and from 32.3%-94.4% for cubes burn and (1:2:4) mixing ratio compared with normal cubes.
2. All cubes that subjected to fire gave a weak resistance compared with normal cubes and this is due to the material lose its cohesion and bond, that lead to separate the gravel and cement also lose its chemical properties.
3. The finite element analysis gave a good validating results respect to experimental work.
4. The water cement ratio was effective on concrete compressive strength for normal cubes but the percentage of decreasing still same for burn cubes compared with normal cubes.
5. The cubes that burn till 900℃ gave a smallest compressive strength compared with another burned cubes.
6. The concrete that designed with 50% as a water to cement ratio was 32%-86% and gave decreasing by compressive strength less than 30% water to cement ratio.
7. The cooling by water decreased the compressive strength 3-6 time compared with cubes that not subjected to fire.

From all results that got and concluded above, the cooling by water is very dangers and led concrete to fail and the concrete will be lost all characteristic and resistant. The cooling by wetting or air may be a good way to solve this problem and better than cooling by water.

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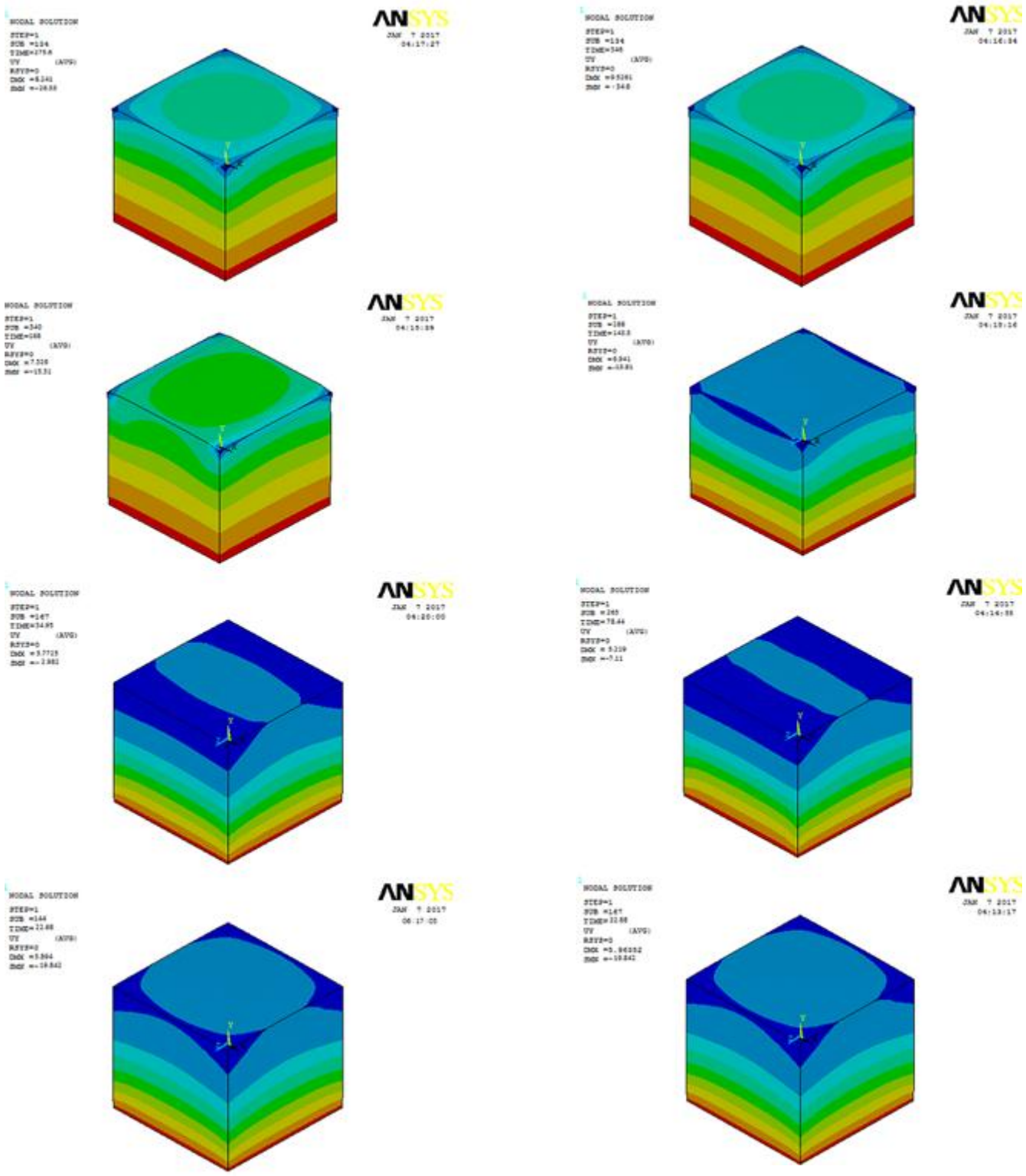

Figure (5) Failure pattern of cubes

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