The Effect of Water Mixing Temperature on Concrete Compressive Strength Containing Different Ratios of Silica Fume

The Effect of Water Mixing Temperature on Concrete Compressive Strength Containing Different Ratios of Silica Fume

Maryam H. Naser [1], Fatimah H. Naser[2] Ali Hameed Naser Almamoori[3]

[1]Civil Engineering Department, Al-Mustaqbal University College, Babylon, Iraq. email: maryamhameed@mustaqbal-college.edu.iq, maryamhameed02@gmail.com
[2]College of Water Resources Engineering, Al-Qasim Green University, Babylon, Iraq. email: fatimah_mamoori@wrec.uoqasim.edu.iq, fatimah_mamoori@yahoo.com,
[3]College of Engineering, Civil Engineering Department, Karbala University, Karbala, Iraq. email: alih@uokerbala.edu.iq, alihameedn@yahoo.com, alihameedn1@gmail.com

Abstract. This paper presents the experimental study about the effect of water mixing temperature on concrete compressive strength containing different ratios of silica fume by compressive testing of 108 cubes of (150×150×150) mm dimensions. The parameters were studied; temperature of water mixing, ratio of silica fume and age of test. The specimens were divided into four groups having different temperature of mixing water (20, 40, 60, and 80)° C, each group consisting of three set with different ratio of silica fume (0%, 10%, and 20%), each set having nine cubes tested in a different age (7, 14, and 28 days). In fresh state, the results showed that different water temperatures give different values of slump when the percentage of silica fume is constant, where the slump value decrease by about (2-4) mm for each 20° C increase in temperature. Also, the slump of the concrete decrease about (5-10) mm at each replace 10% from weight of cement by silica fume. In hardened state, the greatest increase in compressive strength obtained at 40° C by about (20-30) % in compared with 20° C and then began to drop slightly at 60° C, but at a temperature of 80° C observed a great decrease in compressive strength. It is also found that as advanced the age of test, compression strength increases but rate of increase fall at high of temperatures due to early curing causing by high temperature of hydration. it was observed in this study when the water temperature increased above 60° C, the presence of SF resulted to decreasing in the concrete strength.

Keywords: Temperature water, compressive strength, concrete, silica fume, slump..

1. Introduction

The concrete is a component of water, aggregate, "gravel and sand", and cement, in addition to chemical improvers, as it is known that the percentage of water and aggregate in concrete represents about 80 % of its weight. One of the most important mechanical properties of concrete is compressive strength. Recently, the use of some alternative additives to concrete has increased. But because of the hot weather that the region faces during the summer period and its potential impact on the properties and strength of concrete, there are those who suggest stopping the casting process in hot climates, which extends to about four months approximately every year. It is known that the high temperature of the concrete mixture increases the rate of hydration of cement, but this increase requires a study to

know the limits of its effect on the mechanical properties of concrete [1]. So the effect of the water temperature used in the concrete mixture must be studied to know the possibility of dealing with the conditions in our country (Iraq).

Numerous specialists introduced experimental investigations of effect of water curing temperature through many experimental programs. But, few researcher studies have examined the effect of mixing water temperature. These studies began in (1958) by the researcher Klieger [2] who studied the effect of different types of Portland cement used in the concrete mixture on compressive and flexural strength at different temperatures ranging from (25 - 120) F during mixing, placing and curing. The results indicate that the influence of temperature at early ages on strength of concrete is optimal in increasing strength with age. It was also found that the effect of cement type on the concrete behavior changes according to the type of cement. Etienne [3] conducted research in Eastern Nigeria to study the effects of mixing water temperature on compressive strength, workability and setting time of concrete. The river sand and granite stones were used as aggregates. The temperatures of the water used were ranged from (– 5°C - 100°C). The mix ratio used was 1:2:4 by weight of concrete with water/cement ratio equal to 0.58. It was found that the workability and the setting time of the concrete increased as the temperature of the mixing water increased. In terms of strength, the compressive strengths were increasing as the age increased. This increase reached a peak at 50°C after which the strength declined gradually to as low as at a water temperature of 100°C. Park and Noguchi [4] investigated the effects of temperature in response to curing condition, hydration heat, and outside weather conditions on the strength development of high performance concrete. The concrete walls were designed using three different types of concrete and three different sizes. The main factors studied that influence the strength developments, the hydration products, and the pore structure. Testing results indicated that the elevated temperatures did not affect the early age strength gain of concrete made using ordinary Portland cement. Strength development was significantly increased at early ages in concrete made using belite-rich Portland cement or with the addition of fly ash. Eskandarsefat [5] examined the effects of mix water temperature on some mechanical properties of concrete made with High Early (HE) strength cement. The experimental work included the tests for both fresh and hardened concrete with various water temperature ranged from 5° to 90°C. Based on the results, the optimum mixing water temperature range is 50±5°C when using HE strength cement. Also, the optimum bleeding and slump of mixtures were observed within the same temperature range. The higher temperature of mixing water out of this range resulted in higher segregation, bleeding, and further relative failures.

The previous studies lacked to study the effect of mixing water temperature on the fresh properties and mechanical properties of concrete containing different ratios of Silica Fume (SF), the most important of which is compressive strength to know the extent of the effect that may occur during different ages. The main objectives of this study are (a) examining the effect of increasing temperature of mixing water on the compressive strength in different ages and, (b) study the effect the different ratio of silica fume on compressive strength with different temperature of mixing water.

2. Experimental program

To study the effect of water mixing temperature with different ratios of silica fume which replacement of cement on some properties of concrete, 108 concrete cube of (150×150×150) mm are tested in this study. It was divided into four main groups having different temperature of mixing water (20, 40, 60, and 80)° C. Each group can be classified into three sets according to silica fume ratio.

2.1. Material Properties

The concrete was produced by selecting the best materials with quality control. The materials used in the manufacture of the concrete mixture must conform to the standard specifications according to the Iraqi specifications (IQS). Portland cement (Type I), known as KAR Cement, was used in this study.

The chemical analysis and physical properties of this cement comply with the requirements of the Iraqi Standard Specifications IQS No. 5: 1984 [6].

The natural sand used to produce concrete was brought from Al-Ukhaider region in Iraq within zone 2, the fineness coefficient (2.94) and the grading conform to IQS Standard 45: 1984 [7]. The maximum size of crushed natural gravel used in this study was 14 mm and was brought from the Al-Nebai region. It was separated by sieve analysis and recombined it to satisfying the grading according to IQS Standard 45: 1984 [7]. The micro Silica Fume (SF) named Microsilica Grade 85 D was used in this study according to ASTM C 1240-05 [8]. According to the silica fume test conducted by National Center for Construction Laboratories and Researches; the specific surface was 21 m2/g, the percent retained on 45μm (No.325) sieve was 7% and the accelerated Pozzolanic strength activity index with Portland cement at 7 days was 125.6%.

2.2. Concrete Mixing, Casting and Curing

Depending on the American method of selecting mixing ratios ACI 211.1-91 [9] and after many trial mixes, the concrete mix proportional was 1:1.5:2.5 by weight for cement, sand and aggregates respectively with water to cement ratio (w/c) equal to 0.45 and cement 400 kg/m3. Four degrees of mixing water temperature of (20, 40, 60, and 80)o C was used for mixing concrete mixture by using a laboratory heater. The slump test was conducted depending on ASTM C 143/143M-15a [10] to test of concrete workability. All cubes were poured with concrete and cured according to ASTM C 192/C 192M-05 [11] by using tap water at its normal temperatures. By using a 2000 kN hydraulic compression machine, the cubic samples (150 x 150 x 150) mm were tested in the Structural Laboratory in Al-Mustaqbal University College in the Civil Engineering Department. Three cubes average results were approved for each test according to BS 1881-part 116:200 [12].

In this study, three replacement ratios for the SF (0, 10, and 20) % by weight of cement were used; see figure 1. Appointed a replacement ratio of 20% as high ratio, 10% as medium ratio and 0% for concrete without silica fume. It was decided to keep the SF content at not more than 20% by weight of cement so that the resulting concrete mixes would not be too sticky to produce. It did not use chemical admixture in order to study the pure effect of mixing water temperature on slump and compression strength values. Figure 2 show some of equipment and experimental work.

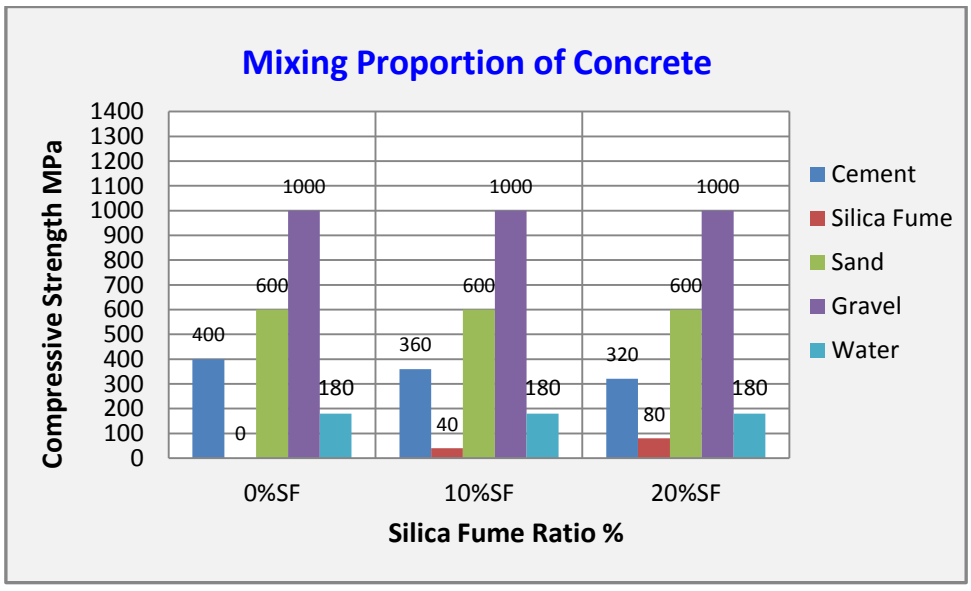

Figure 1. Mixing proportions at 1 m^3

a-laboratory heater b-mixing in mixer c-slump test

d-compaction process e- casting process f- compressive test

Figure 2. Some of the equipment and the experimental work

3. Experimental Results and Discussion

3.1. Relation Between Slump and Temperature of Mixing Water

When the SF is constant and the water temperature is different, the concrete mixture will give a different slump. Figure. 3 shows the effect of water temperature on the slump of concrete containing various percentages of SF.

From figure 3, it was found that slump decreased about (2-4) mm for each 20° C increase in temperature. It was found that the change in the mixing water temperature reduces the slump of concrete with constant the components of the concrete mixture. This is due to the increase in the rate of reaction the water with cement, which led to a decrease in amount of the free water in the concrete mixture (in other words, the high water temperature leads to an increase in the hydration cement process). These changes are accompanied by an increase in compressive strength, but at certain limits.

From the test results, it was also found that the slump of the concrete decrease about (5-10) mm for each replace 10% SF from weight of cement as shown in figure 3.

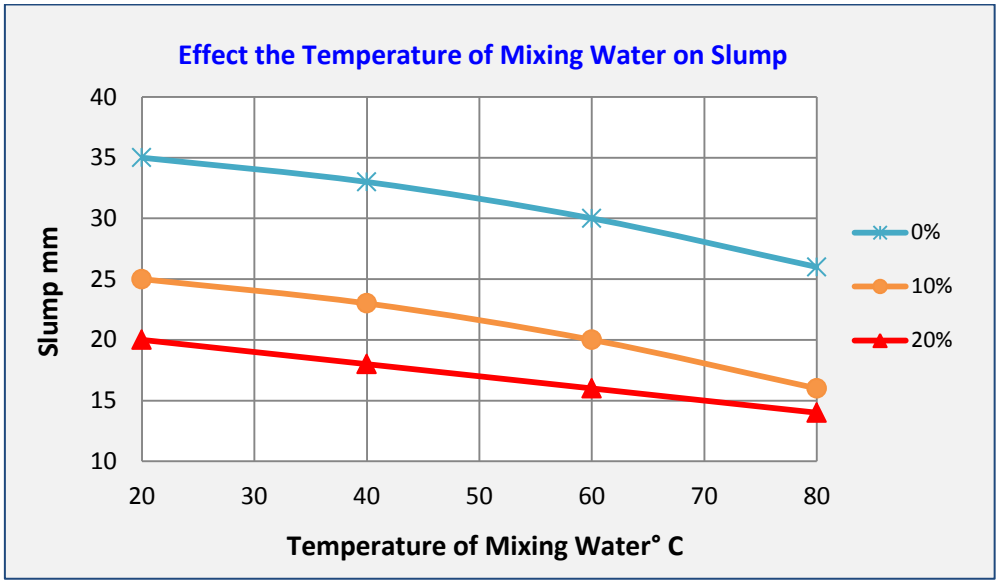

Figure 3. Effect the water temperature on slump

3.2. Effect the Mixing Water Temperature on Strength Development

Figures (4-6) shown the effect of temperature water mixing and amount of SF used as replacement of cement on compression strength development at 7, 14, and 28 days. High of temperature increases the strength development with age and accelerates curing. This property continues until 60° C where it is observed that at 80° C clear decrease in strength of concrete. The reason for this behavior is increased temperature water leads to other problems such as shrinkage and low slump which leads to falling compressive strength in spite of the concrete was cured at normal water temperatures below about 23° C.

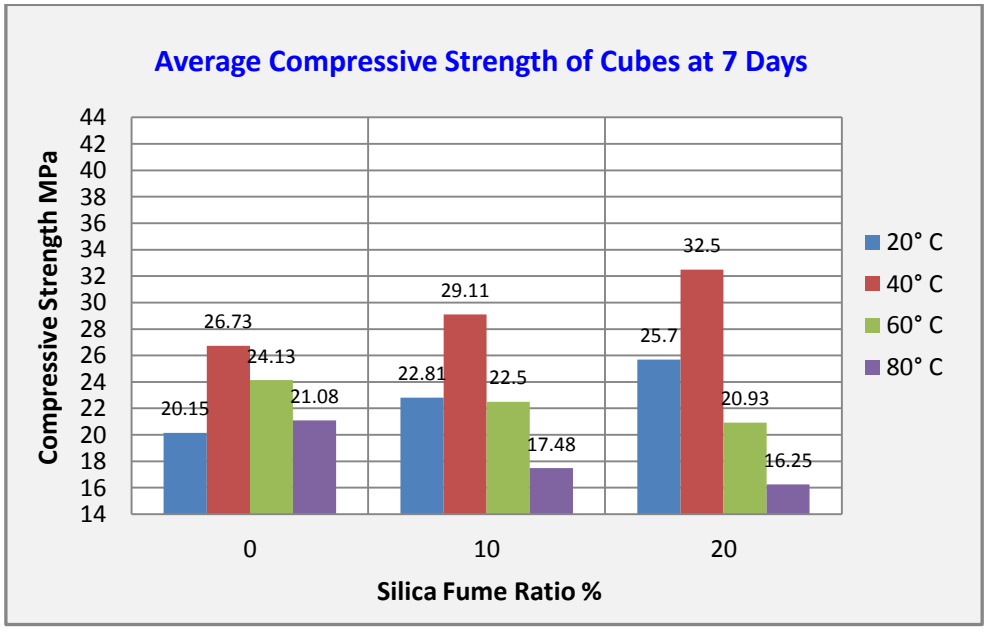

Figure 4. Effect the water temperature on compressive strength at 7 day

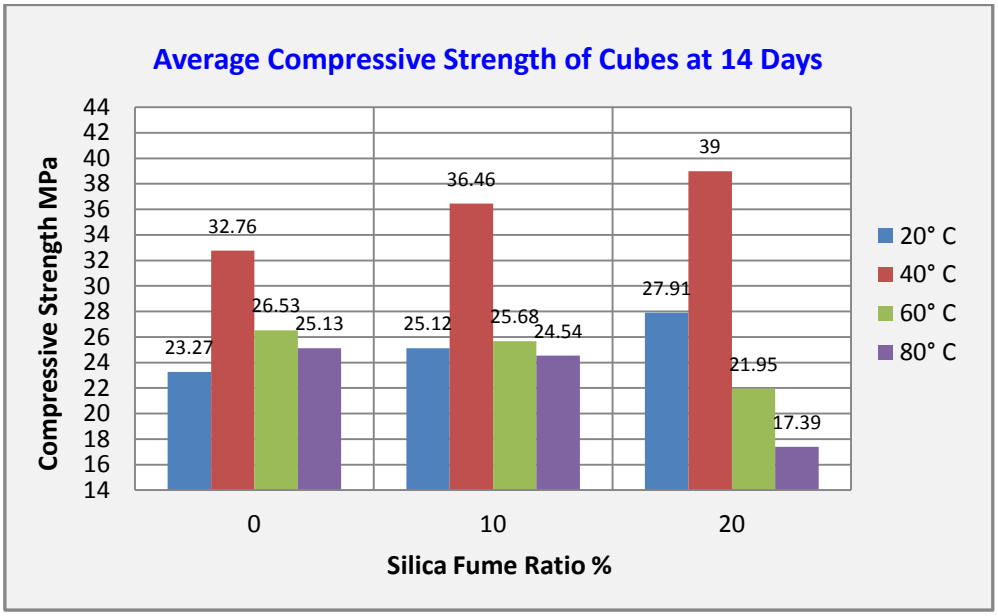

Figure 5. Effect the water temperature on compressive strength at 14 day

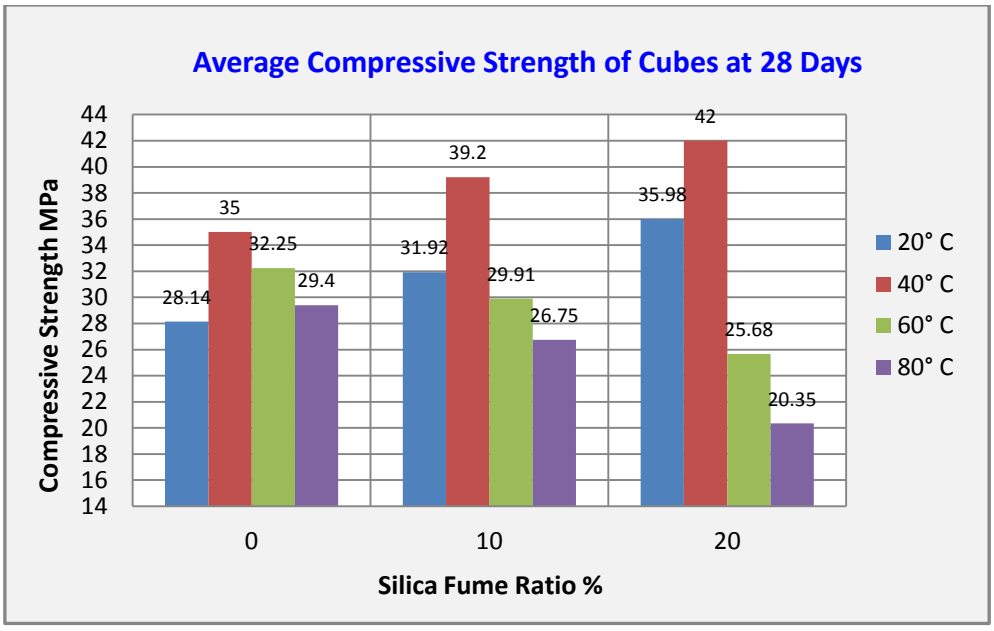

Figure 6. Effect the water temperature on compressive strength at 28 day

The greatest increase in compressive strength obtained at 40° C by about (20-30) % in compared with compressive strength at 20° C and then began to drop slightly at 60° C, but at a temperature of 80° C noticed a great decrease in compression strength.

3.3. Effect of Age and Mixing Water Temperature on Strength Development

The development of compression strength can be explained by taking into account changes in the values of both mixing water temperature and the test age. However, the effect mixing water temperature on compressive strength is influenced by the amount of cement used and the proportions of SF replacement with it. The best results were obtained in all ages when the water temperature used to mixing concrete was 40° C as shown in figure7.

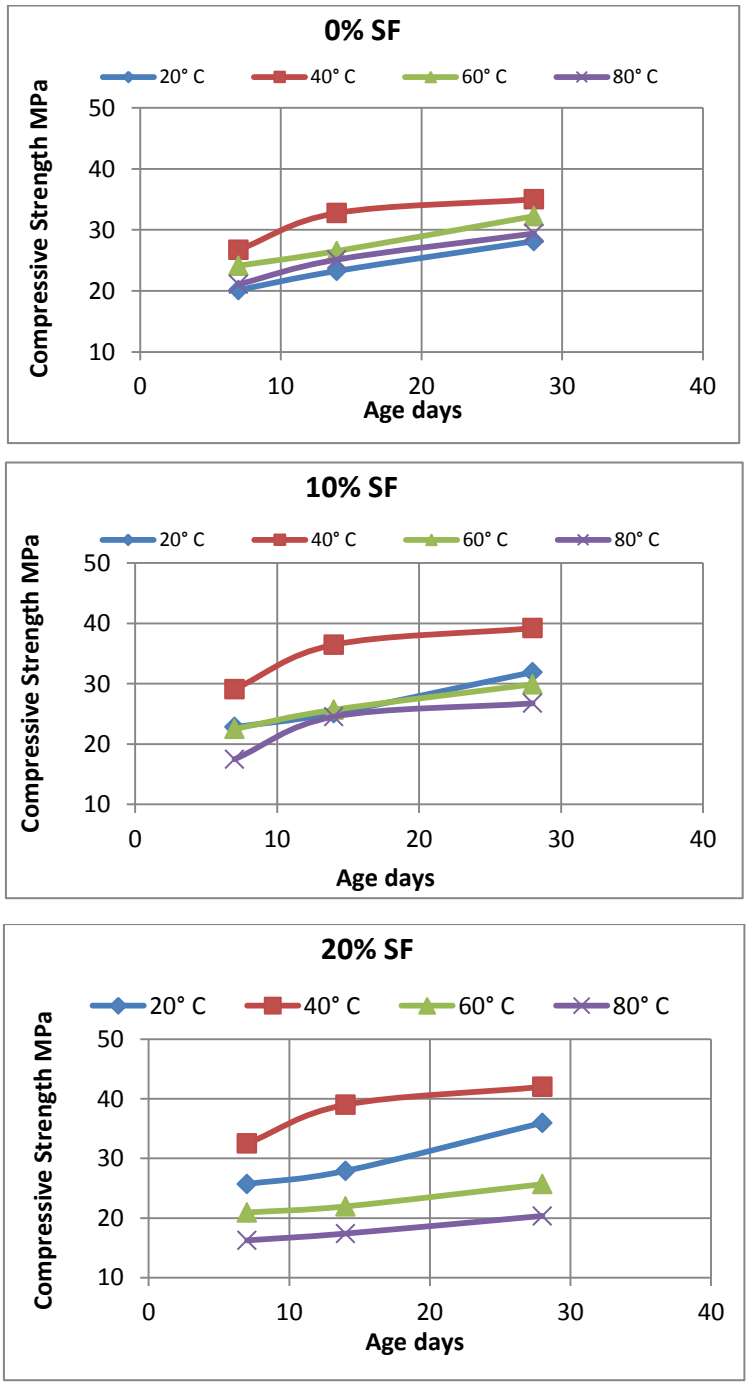

Figure 7. Effect the age on compressive strength at 20, 40, 60, and 80 c°

Thus, a temperature of 40° C was chosen as the maximum temperature for mixing water for this concrete. In general, as advanced the age of test, compression strength increases but rate of increase fall at high of temperatures due to early curing causing by high temperature of hydration.

3.4. Effect SF Ratio and Mixing Water Temperature on Strength Development

Figure 8 shows the strength development with different SF ratio under effect of different mixing water temperature. It is clear that SF enhanced compressive strength; because of the Portland cement mixture containing SF produces a significant reduction in the size of large pores and is therefore useful in increasing compressive strength at all ages. Also, the Pozzolanic reaction of SF produces aqueous calcium silicate (C-S-H) and reduces the content of CH crystals in the region which plays a vital role in the compressive strength of concrete.

Both field and laboratory experience confirm that concrete containing silica fume tends to develop shrinkage cracks. On the basis of these, the surface of this concrete is subjected to rapid evaporation of water. This leads to reduced workability and slump and may affect the development of concrete strength subjected to high temperatures. In this study, it was observed that when the water temperature increased above 60 ° C, the presence of SF lead to decrease in the concrete strength as shown in above Figures.

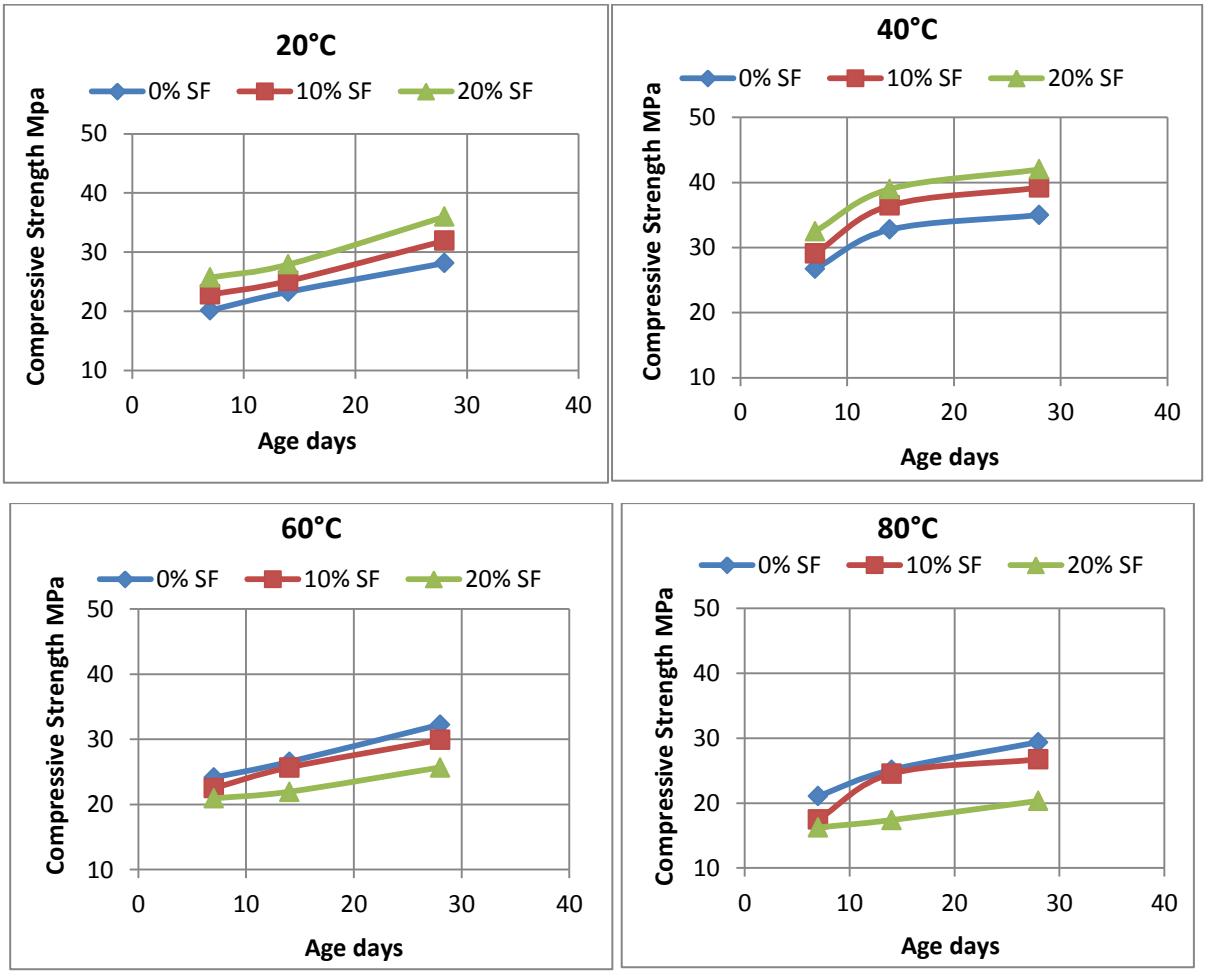

Figure 8. Effect SF ratio on strength development at 20, 40, 60, and 80 c°

4. Conclusions

This paper presents an experimental studied on the effect of water mixing temperature on concrete compressive strength containing different ratios of silica fume. The following conclusions can be written within the scope of the current study:

1- The slump value decreased about (2-4) mm for each 20o C increase in temperature. Also, the slump of the concrete decrease about (5-10) mm at each replace 10% from weight of cement by silica fume.

2- The higher compressive strength obtained at water temperature 40° C by about (20-30) % in compared with compressive strength at 20° C. Thus, a temperature of 40 ° C was chosen as the maximum temperature for mixing water for this concrete.

3- The compressive strength of concrete began to drop slightly at water temperature 60 C°, but, at a temperature of 80 C°, a great decrease in compressive strength occurre.

4- The compression strength increases with the advanced age but rate of increase fall at high of temperatures 60o C and above due to early curing causing by high temperature of hydration.

5- The increasing temperature value of mixing water lead to increase compressive strength. But, the presence of SF lead to decrease in the concrete strength when the water temperature increased above 60 ° C.

References

[1] Rasheed, S. R., (2017), " Effect of Curing Temperature and Conditions on Compressive Strength of Concrete Containing Supplementary Pozzolanic Materials" Journal of Engineering and Sustainable Development, Al-Mustansyriah University, V. 21, PP 1-12.

[2] Klieger, P., (1958), " Effect of Mixing and Curing Temperature on Concrete Strength" Journal of the American Concrete Institute, June 1958, VOL. 54, PP. 1068-1081.

[3] Etienne, C. O., (2015), "Effect of Water Temperatures on The Compressive Strength, Slump and Setting Time of Concrete" International Journal of Engineering Research and General Science (www.ijergs.org), September-October, 2015, VOL. 3, PP. 390-395.

[4] Park, B.K. and Noguchi, T., (2017), "Effects of Mixing and Curing Temperature on the Strength Development and Pore Structure of Fly Ash Blended Mass Concrete" Journal of Advances in Materials Science and Engineering (Hindawi), September-October, 2015, VOL. 2017, PP.11., https://doi.org/10.1155/2017/3452493.

[5] Eskandarsefat, S., (2018), "Investigation on the effects of mix water temperature on High-Early strength cement concrete properties – An experimental work and a case study", Journal of Building Engineering, https://doi.org/10.1016/j.jobe.2018.07.023

[6] Iraqi Specification Standards IQS No.5, (1984), "Portland Cement", Central Agency for Standardization and Quality Control, Planning Council, Baghdad, IRAQ, (in Arabic).

[7] Iraqi Specification Standards IQS No.45, (1984), "Aggregate from Natural Sources for Concrete and Construction", Central Agency for Standardization and Quality Control, Planning Council, Baghdad, IRAQ, (in Arabic).

[8] ASTM C 1240-05, (2005), "Standard Specification for Silica Fume Used in Cementitious Mixtures", PP. 1-7.

[9] ACI Committee 211.1-98, (1998) "Standard Practice for Selecting Proportions for Normal Heavyweight, and Mass Concrete", Manual of Concrete Practices, American Concrete Institute, pp.1-38.

[10] ASTM C 143/C143M-15a, (2015), "Standard Test Method for Slump of Hydraulic-Cement Concrete", Book of ASTM Standards, American Society for Testing and Materials, pp. 1-4.

[11] ASTM C 192/C 192M-05, (2005),"Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory", Annual Book of ASTM Standards, American Society for Testing and Materials, pp. 1-8.

[12] BS 1881-Part 116, (2000) "Method for Determination of Compressive Strength of Concrete Cubes", British Standards Institute BSI, London.