Iranian Journal of Science and Technology, Transactions of Civil Engineering (2022) 46:91–99
https://doi.org/10.1007/s40996-021-00758-w

RESEARCH PAPER

Curing High-Performance Green Concrete Under Hot Weather

Zainab Hashim Abbas Alsalami[1]

Received: 29 August 2019 / Accepted: 30 September 2020 / Published online: 21 October 2021

Abstract

Curing has a substantial function on the progress of strength and durability of concrete. Previously, researchers focused on the curing of normal concrete. The number of investigations on the curing of concrete under hot weather is quite limited. Regrettably, investigators have not concentrated on curing of high-performance concrete under hot weather. This paper investigates the behavior of eco-friendly green high-performance concrete casted in hot weather and cured by conventional methods without using high quantity water. Three types of curing were investigated: immersion in water inside the laboratory, curing compounds outside the laboratory and wet sheet outside the laboratory. A comparison between curing methods inside and outside the laboratory under hot weather for mixtures with (0%, 40%) fly ash replacement and with (0%, 30%) palm kernel shells replacement was conducted. High-performance concrete properties were obtained by various tests such as compressive strength, flexural strength and modulus of elasticity at 7, 28, 56, 90 and 180 curing days. Also, air dry density, absorption and length change were investigated at 28 curing days. The results showed a slight decrease in strengths of curing compound concrete compared to immersion in water curing due to fly ash and palm kernel shells replacements. When comparing concrete mixture with 30% palm kernel replacement and 40% fly ash replacement cured by immersion in water (IWP30F40) with that cured using curing compounds (OCP30F40), the decrease ratio in compressive strength and modulus of elasticity were 1,5% and 3.7%, respectively, at 28 days of curing age. The maximum shrinkage value at 28 days of curing was 0.0859 mm/m for mixture cured via wet sheets without fly ash or palm kernel shells replacements (OSP0F0).

Keywords Curing methods · Dry weather · Fly ash · Green concrete · Hot weather · Palm kernel

1 Introduction

In general, the early strength of concrete is positively affected by elevated production and curing temperature, but later-age strength is adversely affected. Concrete durability and deterioration of concrete quality have been a well-confirmed truth. Judgments diverge, however, as to the specific causes and the deductions to be deduced with respect to concreting in a hot climate.

Tsui Leung-Cho (Tsui 1971) discovered that due to hot weather circumstances, under 38 C° air curing temperatures and depending on the temperature of mixing (19–33) °C the compressive strength at 7 days of age was 73–82% of strength at 28 days of age. This was extremely higher than at normal (30 C°) air curing temperatures, as the strength at 7 days was around 2/3 of that at 28 days.

Ridgley (Ridgley 1959) detected that a 15% reduction in strength at 28 days of curing age occurred in concrete mixed at an average temperature of 30 °C and relative humidity of 70–87%, and cured under water at 23 °C. There was also some decrease in the strength at 28 days informed by C.L A' Court (A'Court 1960), namely, at 32 C° the strength was 92% of that at 20 °C.

Creep is significantly affected by temperature: higher creep occurs with higher temperature, even if the higher temperature influences only for a short period of time (Jaegermann 1971). Nasir et al. (Nasir et al. 2017) found that shrinkage strain was effectively decreased by curing compound method. Suitable curing of concrete becomes more substantial with the increase in supplementary cementing materials because of needing water at later ages of hydration for pozzolanic reaction (Bentur and Goldman 1989).

It is proper to mention that, broadly, abrasion of concrete resulted by aggressive factors, and spoiling of reinforced

---

✉ Zainab Hashim Abbas Alsalami
zainab89@wrec.uoqasim.edu.iq; z198995@yahoo.com

[1] College of Water Resources Engineering, Al-Qasim Green University, Al-Qasim, Iraq

concrete resulted by the deterioration of reinforcement, is more critical matter in hot climate countries than in mild climate countries. Ben-Yair (Ben-Yair M.–"The effect of chlorides on concrete in hot and arid regions" 1971) inspected the properties of concrete subjected to chlorides effect in hot weather, with and without sulfates, the results demonstrated that there was a decisive influence of climatic factors on the feature and quantity of erosion.

Mineral admixtures concrete may be more sentient to curing than normal concrete (Sajedi et al. 2012). During curing, the hydration of cement continues and hardened properties of cement is promoted. Long-term durability of concrete counts on the efficiency of the curing as concretes can suffer some problems, such as weak surface, obvious cracks and microcracks. The microstructure and durability of concrete are significantly enhanced by perfect curing (Guneyisi et al. 2009; Ramezanianpour and Malhotra 1995; Khatib and Mangat 2002; Bonavetti et al. 2000).

Liu et al. (Liu et al. 2018) notified that the quality of concrete, especially the surface quality, is significantly affected by the curing statuses for concrete with 50% mineral admixtures replacement. Due to technical, economic and environmental advantages, pozzolanic cementing materials are considered as one of the solutions proposed for concrete in hot weather. However, this solution may not be considered adequate under dry and hot environment as it may cause plastic shrinkage cracks, thus extra attention in curing is required (Khatib and Mangat 2002).

The performance of concrete during mixing and casting is directly affected by hot conditions of weather (elevated ambient temperature incorporated or not with low relative humidity, wind speed, and solar radiation) as per ACI 305 (ACI 2015).

There were fewer studies on curing statuses of high volume mineral admixtures concrete. The impact of curing methods on high volume fly ash high-performance concrete under hot weather has not been thoroughly investigated and because of the desert climate of Iraq, where summer temperature could reach 50 C°. Therefore, the paper studied adding new admixture, palm kernel shells and high volume fly ash, to concrete to produce high-performance concrete under hot weather cured by conventional curing methods and without using high quantity water.

Concrete is one of the most vastly used construction materials; it can consume manufacturing wastes in high quantities. The use of waste and by-product materials as cement and aggregate substitutes in concrete is considered as an outstanding manner to decrease the unwanted ecological effect of concrete. Fly ash is one of such waste material; it is generated as a by-product from thermal power plants in high volume. Environmental and storage problems could result from leaving a substantial amount of unused fly ash. One of the most effective methods to remove fly ash in large quantities is by sintering lightweight aggregate with fly ash (Nadesan and Dinakar 2017).

When dealing with dry hot climate, more attention and more active curing ways and techniques should be investigated (Bushlaibi and Alshamsi 2002). Most researchers have focused on curing of normal strength concrete (Alamri 1988; Arafah et al. 1995; Neville 1983; Popovics 1986). Notification about curing influences on the characteristics of high-performance concrete (HSC) is comparatively less certified. The literature doesn't contain any studies regarding the impact of different classical curing ways on the strength progression of (HSC) with high volume fly ash and with partial substitution of aggregate by date palm kernel shells (PKS); therefore, this is investigated in this paper.

In high-temperature zones like Iraq and South Africa, the palm trees are germinated. The manufacture of molasses of date palm is accompanied by (PKS). Curing methods inspected here are ordinarily identical to those used in field.

Due to scarcity of water and high cost of desalinated water in some regions, curing compound method is more effective way to cure concrete. Under hot weather, the curing of concrete is more important because the loss of water from concrete is higher than that under other weather. Due to cost of immersion in water curing method, this research studies other curing methods such as curing compound methods and wet sheet, and then compares them with curing via immersion in water. As an economic achievement to produce low-cost concrete and as part of environmental gains, this study investigates utilizing (fly ash, PKS) as an alternative to cement and gravel, respectively, and their advantages in hot weather.

2 Experimental Program

Ordinary Portland Cement (OPC) which approves to ASTM C150, Type 1 (ASTM 2005) was used. Its physical and chemical characteristics comply with IQS No.5 (IQS (Iraqi Specification) xxxx). The sand and crushed gravel of 12 mm maximum size were in accordance with IQS No.45 (IQS (Iraqi Specification) 1984). Palm trees are plants that need a hot climate to grow; thus they are cultivated heavily in Iraq. Date palm kernel shells were used in this study (as a partial substitution by gravel). The properties of gravel and palm kernel shell used in this study are given in Table 1. Figure 1 illustrates the date palm kernel shell. Category F fly ash was provided by a local provider and adjusted to satisfy ASTM C618 (ASTM 2002). PC200 super-plasticizer was used to reduce water and increase the strength and durability of concrete.

Setseal 22 is water-based curing compound formulated from selected emulsified paraffin to compose a low viscosity wax emulsion. The color is a white liquid that generates

Table 1 Properties of gravel and palm kernel shell

Number	Properties	Gravel	Palm kernel shell	IQS No.45 limits (IQS (Iraqi Specification) 1984)
1	Specific gravity	2.63	1.9	–
2	Sulfate content (SO_3) (% by weight)	0.07	0.42%	≤0.1%
3	Chloride content (% by weight)	-	0.041%	–
4	Absorption (% by weight)	0.4	5.98%	–
5	Thermal conductivity (W/m. K)	0.65	0.05	–


(a) Date palm tree (b) PKS

Fig. 1 Date palm kernel shell

a white film when put on concrete surfaces and reflects (60–80) % of the sunlight. Setseal 22 was applied after 24 h of age, except for the top face of the casting mold where the liquid compound was applied after 1 h of age.

One mixture combination ratio was used: 1:1.37:1.55. Fly ash alteration ratios (F) were (0, 40% by weight of cement). The palm shell alteration ratios (P) were (0, 30% by weight of gravel). These percentages were chosen because previous studies (Alsalami et al. 2018; Al-sallami et al. 2019) have found that above these percentages (40% fly ash replacement, 30% palm replacement) the strength of concrete could be reduced significantly. Also, (w/c = 0.3) has been preserved for all mixes. Concrete was mixed in drum laboratory mixer with a capacity of $0.05m^3$. Before starting, it was necessary to keep the mixer clean, moist and free from previous mixes. First, sand and gravel were mixed; then cement was added to the mixer. Finally, the water was added. The entire mixture was mixed until reaching homogeneous batch in 1.5 min. The mixes were poured into the tight steel molds until the mold was completely filled without any compaction. The specimens were left in the molds for 24 h and then cured until time of testing.

The mixture components are shown in Table 2. All the concrete mixtures were casted inside lab during the summer months of June and July between 9:00 am to 12:00 noon (the ambient relative humidity was 30–40%, while the maximum ambient temperature was about 32 C°) and then cured either inside lab (samples cured by immersion in water method) or outside lab (samples cured by curing compounds or by wet sheet method). Outside lab, the ambient relative humidity at that time was 25–35% while the maximum ambient temperature was about 50 C°. Relative humidity, temperature, and wind speed varied when concrete was cured outside laboratory, whereas these factors were constant when concrete was cured inside laboratory. Three types of curing were processed outside the laboratory (O): immersion in water (W), curing compound (C) applied immediately after casting, and wet sheet (S). Also, there was one type of curing inside laboratory (I): immersion in water (W). Types of curing are shown in Fig. 2.

IWPF: inside laboratory, immersion in water curing, palm shell, fly ash.

OCPF: outside laboratory, curing compound, palm shell, fly ash.

OSPF: outside laboratory, wet sheets, palm shell, fly ash.

A reference mixture was set without any type of replacement. The mixture was cured inside the laboratory using water, and it was symbolized with (IWP0F0). Three specimens were used for each mixture, each age and each test. The information of each test and specimens for each mixture are explained in Table 3.

Table 2 Mixture proportioning for one cube of concrete

Number	Symbol	Replacement ratio %		w/p	Cement (kg)	Fly Ash (kg)	Sand (kg)	Gravel (kg)	PKS (kg)	Super plasticizer (kg)	Total mixing Water (kg)
		PKS,%	FA, %								
1	IWP0F0, OCP0F0 & OSP0F0	–	–	0.3	0.58	–	0.8	0.9	–	0.0145	0.174
2	OCP0F40 & OSP0F40	–	40	0.3	0.348	0.232	0.8	0.9	–	0.0145	0.174
3	OCP30F40&OSP30F40	30	40	0.3	0.348	0.232	0.8	0.63	0.27	0.0145	0.174

3 Results and Discussion

The results of tests are given in Figs. 3, 4, 5, 6, 7, 8, 9 and 10. Also, compressive and flexural strengths, elasticity modulus, density, absorption, length change and flow value – average and min–max are shown in Table 4.

From Fig. 3, it was clear that at day 7 of curing, the compressive strength cured via curing compound and wet sheet was higher than concrete cured by water immersion for all mixtures in which is in agreement with (Zeyad 2017). The same behavior was for flexural strength and modulus of elasticity as illustrated in Figs. 4 and 5, respectively. The early enhancement in compressive strength for curing compound and wet sheet mixtures may be related to the hot climate with high moisture, which increased the rate of cement hydration through the early stage of curing (Nóbrega et al. 2018). The inverse behavior was at long term curing (28, 56, 90 and 180 days), i.e. the values of compressive strength, flexural strength and modulus of elasticity cured via water immersion, curing compound and wet sheet arranged from higher value to lower value, respectively. That can be attributed to the higher strength development established with low temperature, due to a comparatively more regular microstructure of the hydrated cement paste (particularly the pore size distribution), smaller and stronger crystalline gel structure (Mehta and Monteiro 2006).

Also, it was obvious from the results that the most effective curing method was water immersion then curing compounds and wet sheet, respectively. But, the decrease in compressive strength, flexural strength and modulus of elasticity of concrete cured via curing compound or wet sheet (considering water immersion as a reference mixture) is less with fly ash and date palm shells replacements. With date palm shells replacement the compressive and flexural strength of concrete decreased for mixture cured in normal weather as reported (Alsalami et al. 2018). However, it was inverse behavior in this investigation as modulus and strengths increase with date palm shells replacement for mixture cured in hot weather; this is because the using of palm kernel shell as replacement by gravel played a good role in reducing the effect of hot weather by its low heat conductivity coefficient as compared to natural aggregates well as less cost. The same behavior was for mixture with fly ash replacement since compressive strength, flexural strength and modulus of elasticity increased with fly ash replacement for mixture cured in hot weather due to reduced heat of hydration.

The decrease in percentages (with considering IWP0F0 as a reference mixture) in compressive strength, flexural strength and modulus of elasticity for all mixtures at 28 days of curing age is shown in Fig. 10. It is clear that

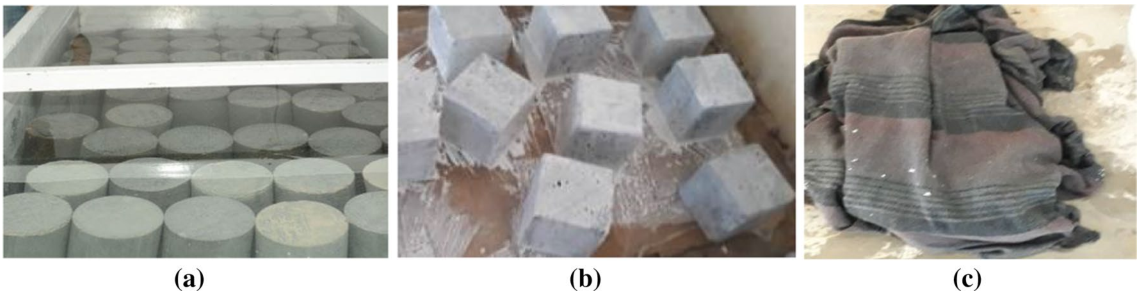

Fig. 2 Types of curing

Table 3 Information of tests for each mix

Number	Name of test	Specimens			Standard specification
		Number	Shape & Dimension	Age of test	
1	Compressive strength	15 (3 for each age)	(100×100×100 mm^3) cube	7, 28, 56, 90 & 180 days	B.S 1881- part 4 (BS 1989)
2	Flexural strength	15 (3 for each age)	(100×100×500 mm^3) prism	7, 28, 56, 90 & 180 days	ASTM C78-84 (ASTM 2003)
3	Modulus of elasticity	15 (3 for each age)	(150×300 mm^3) cylinder	7, 28, 56, 90 & 180 days	ASTM C469 (ASTM C469 2002)
4	Air dry density	3	(100×100×100 mm^3) cube	28 days	ASTM C642 (ASTM 2006)
5	Absorption	3	(100×100×100 mm^3) cube	28 days	ASTM C642 (ASTM 2006)
6	Change in length	3	(75×75×285 mm^3) prism[*]	28 days	ASTM C157/C157M (ASTM C157, C157M 2004) and ASTM C490 (ASTM C490 2004)
7	Flow table	-	Flow cone	Immediately after mixing	BS EN 12,350–5 (En 2009)

[*] Special pins extend 17.5 mm into the both ends of the specimens to facilitate length change measurement were used

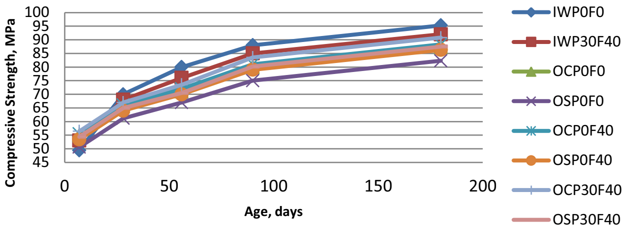

Fig. 3 Compressive strength for all mixture with age

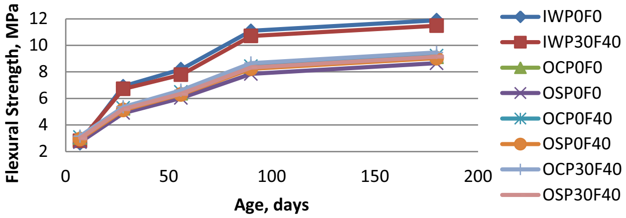

Fig. 4 Flexural strength for all mixture with age

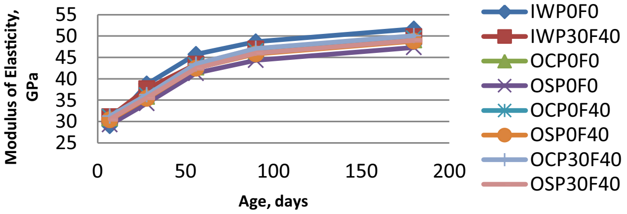

Fig. 5 Modulus of elasticity for all mixture with age

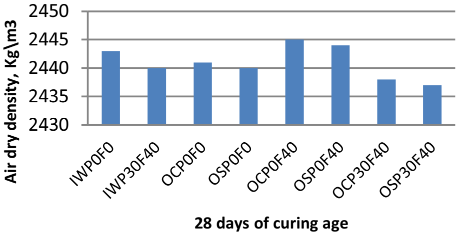

Fig. 6 Air dry density at 28 days age

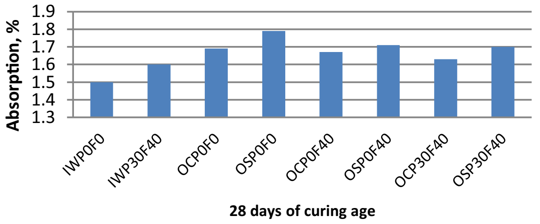

Fig. 7 Absorption at 28 days age

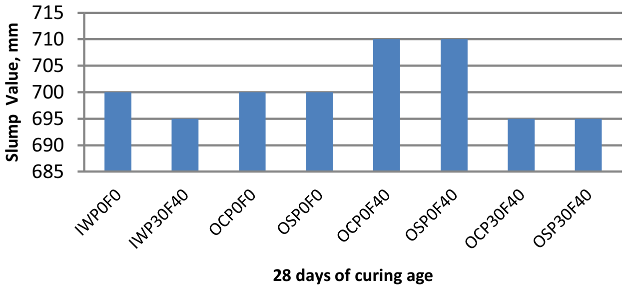

Fig. 8 Slump value at 28 days of curing age

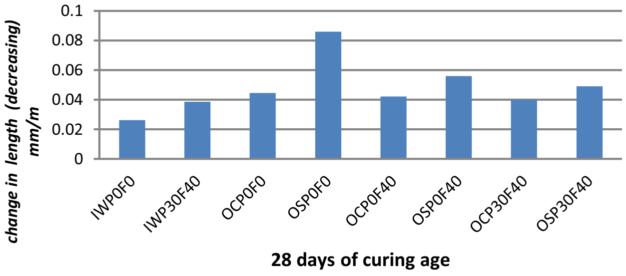

Fig. 9 Change in length at 28 days of curing age

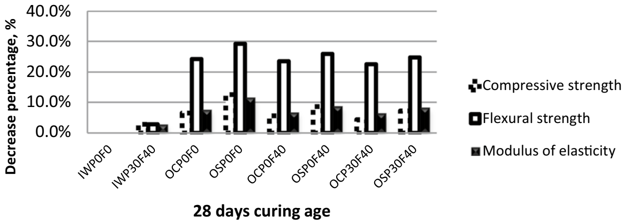

Fig. 10 Decrease % in compressive strength, flexural and modulus of elasticity for all concretes at 28 days curing age

the maximum decrease was in flexural strength (more than in compressive strength and modulus of elasticity). This behavior may be attributed to the micro-cracks and shrinkage cracks caused by hot weather.

From the results, it was obvious that there was minimum difference in compressive strength between samples cured via immersion in water and samples cured via curing compounds, which indicates the usefulness of curing compounds under hot weather conditions. Also, the influence of curing compound on strength and durability (i.e. absorption & length change properties) of concrete under hot weather was better than wet sheet. This behavior can be considered as a positive indication for regions where there is a severe scarcity of curing water.

From Table 4 and Fig. 9 and based on the decrease in length, it is obvious that shrinkage was increased for mixture cured by curing compound and wet sheet in hot weather, which may be due to micro-cracks caused by hot weather, but it was decreased for mixture with fly ash and date palm kernel shells replacements. This behavior is attributed to the fly ash reaction which leads to less water vaporization during shrinkage by exhausting more free water in the system (Harith 2018). This reinforces the conclusion that there is a lower porosity and finer pore structure for fly ash mix, which promotes losing water by self-desiccation and not by spreading to the circumference ambiance.

The same behavior was for absorption at 28 curing days as illustrated in Fig. 7, it is clear that absorption was increased for mixtures with PKS inside lab, but it is was decreased for the same mixtures outside the lab, and the maximum absorption was for mixtures without fly ash and PKS replacement cured by wet sheets outside the lab. This behavior may be attributed to the reduction in thermal cracks induced by the hot climate outside the lab, due to less thermal coefficient of PKS as compared with natural gravel, and by minimizing the heat of hydration of concrete by fly ash replacement.

Figure 6 shows that air dry density at 28 curing days was decreased for outside curing mixtures and mixtures with PKS replacement, but it was increased for mixtures cured inside the lab and mixtures with fly ash replacement. This may be due to cracks produced in hot weather and water evaporation. Also, it might be due to less specific gravity of PKS and pores refinement by fly ash replacement.

Figure 8 shows that the maximum slump values were for mixtures with 40% fly ash replacement. The average of slump flow values observed for fly ash mixes, mixes without fly ash and fly ash-PKS mixes were 710 mm, 700 mm and 695 mm, respectively. This behavior is due to the increase in workability by the lubrication influence of the globular shape particles of fly ash. This means that slump values were decreased for mixtures with date palm kernel shells replacement which is in agreement with (Alsalami et al. 2018), but increased for mixture with fly ash replacement.

Table 4 Compressive and flexural strengths, elasticity modulus, density, absorption, length change and flow value–average and min–max

Mix. NO.		1	2	3	4	5	6	7	8
Mix. ID		IWP0F0 Average (Min. – Max.)	IWP30F40 Average (Min. – Max.)	OCP0F0 Average (Min. – Max.)	OSP0F0 Average (Min. – Max.)	OCP0F40 Average (Min. – Max.)	OSP0F40 Average (Min. – Max.)	OCP30F40 Average (Min. – Max.)	OSP30F40 Average (Min. – Max.)
Compressive strength (MPa)	7 days	49.4 (48.8-51)	53 (51-54)	54.9 (53-56)	50.6 (50-51)	55.5 (54-56)	53.4 (52.3-55.4)	56.4 (54.8-57.6)	54.4 (53.4-56.3)
	28 days	70 (69-72)	68 (67-69.2)	65.5 (64-67.4)	61.2 (60.2-62.4)	66.1 (65.4-66.3)	64 (63.1-65)	67 (66-70)	65 (63-66)
	56 days	80 (79-83)	76 (74-77)	71 (70-71.9)	67 (66.2-68.5)	72 (70-73)	70 (68-70.2)	73.5 (73-74)	70.5 (69.8-71)
	90 days	88 (87-90)	85 (84.3-86.9)	80 (78-80.5)	75 (74.6-77)	81 (80-82.7)	79 (70-78.3)	83.5 (83-85)	80.2 (80-81)
	180 days	95.3 (94-97)	92 (90-92.9)	87.3 (85.6-88)	82.3 (80-84)	88.3 (85-89)	86.3 (86-88)	90.8 (89.5-91)	87.5 (87.1-88)
Flexural strength (MPa)	7 days	2.62 (2.41-2.76)	2.8 (2.51-3)	3.04 (2.93-3.28)	2.7 (2.53-2.91)	3.09 (3-3.86)	2.92 (2.64-3)	3.16 (3-3.39)	3 (2.71-3.12)
	28 days	6.92 (6.71-7)	6.72 (6.53-6.81)	5.24 (5.04-5.52)	4.9 (4.03-5.05)	5.29 (5-5.65)	5.12 (5-5.36)	5.36 (5.08-5.56)	5.2 (5.12-5.57)
	56 days	8.2 (8-8.43)	7.79 (7.53-8)	6.39 (6-6.56)	6.03 (6.01-6.12)	6.48 (6.03-6.61)	6.3 (6.02-6.45)	6.62 (6.53-6.86)	6.35 (6.08-6.67)
	90 days	11.09 (11-11.58)	10.71 (10.28-10.86)	8.33 (8.15-8.95)	7.85 (7.51-7.94)	8.42 (8.28-8.65)	8.23 (8-8.47)	8.66 (8-8.73)	8.34 (8.03-8.68)
	180 days	11.89 (11.18-12)	11.48 (11.31-11.69)	9.13 (9.01-9.42)	8.65 (8.35-8.89)	9.22 (9-9.57)	9.03 (9.01-9.29)	9.46 (9.32-9.78)	9.14 (9-9.45)
Modulus of elasticity (GPa)	7 days	29 (28-30)	31.11 (30-32)	30.83 (30.49-32.57)	29.28 (29.26-31)	31.16 (30.35-32.19)	30.39 (30.22-32)	31.27 (31.11-33)	30.55 (30.25-32.49)
	28 days	38.78 (38.52-40)	37.67 (36-38.28)	35.83 (35.44-37)	34.28 (33-36.61)	36.16 (35.92-37.26)	35.39 (34.18-36.83)	36.27 (35.52-37.17)	35.55 (35-37.14)
	56 days	45.71 (44.92-46.84)	43.42 (43-45.12)	42.71 (42.52-43.56)	41.32 (40.12-42.98)	43.17 (43.13-45)	42.47 (43-44.75)	43.46 (40.94-44.72)	42.43 (41.28-44.19)
	90 days	48.66 (48.44-49.52)	47 (45-48)	46.04 (46-47.85)	44.35 (42.88-45.96)	46.49 (44.98-47.84)	45.81 (44.23-47.12)	47.08 (46.15-48.27)	45.99 (45-45.89)
	180 days	51.66 (50.63-53.14)	49.87 (48.86-51.08)	49.04 (49-50.41)	47.35 (46.51-50.21)	49.49 (48.85-51.11)	48.81 (47.92-50.16)	50.08 (49.91-51.96)	48.99 (47.35-50.74)
Air dry density (Kg\m^3)	28 days	2443 (2441-2444)	2440 (2439-2442)	2441 (2440-2442)	2440 (2439-2441)	2445 (2444-2446)	2444 (2442-2445)	2438 (2437-2440)	2437 (2436-2438)
change in length (decrease) mm/m	28 days	0.0261 (0.0260-0.0263)	0.0386 (0.0385-0.0389)	0.0445 (0.0443-0.0446)	0.0859 (0.0857-0.0860)	0.0422 (0.0420-0.0423)	0.056 (0.055-0.058)	0.0399 (0.0396-0.0400)	0.0491 (0.0490-0.0494)
Absorption (%)	28 days	1.5 (1.2-1.6)	1.6 (1.5-1.8)	1.69 (1.62-1.7)	1.79 (1.73-1.8)	1.67 (1.61-1.69)	1.71 (1.7-1.85)	1.63 (1.61-1.65)	1.7 (1.65-1.72)
Flow Values (mm)	Mean Value	180	178	180	180	183	183	178	178

4 Conclusions

1. Curing methods are important for high-performance concrete. Given that environmental conditions are difficult to control. Curing methods should be tested in hot weather to obtain satisfactory results.
2. The best curing method after immersion in water was curing compounds.
3. For concrete with fly ash and date palm shells replacements in areas with a scarcity of freshwater, curing by water immersion can be replaced by other methods, such as curing compounds or wet sheet, since no significant difference in mechanical properties was observed when compared with concrete cured by water immersion method.
4. The maximum decrease in percentages due to curing mixtures via wet sheets instead of curing them via immersion in water was 29.2%, 12.6 and 11.6% for flexural strength, compressive strength and modulus of elasticity, respectively, at 28 days of curing age.
5. The maximum decrease in percentages due to curing mixtures via curing compounds instead of curing them via immersion in water was 24.3%, 6.4 and 7.6% for flexural strength, compressive strength and modulus of elasticity, respectively, at 28 days of curing age.
6. The method of partial replacement of concrete components with fly ash and date palm shells is very important in hot weather as it works to increase the strength as well as reduce the cost and contributes to waste disposal.
7. Decrease in length (shrinkage) increased for mixture cured by curing compound and wet sheet in hot weather but decreased for mixture with fly ash replacement and date palm kernel shells replacement. The same behavior was observed for absorption.
8. The maximum absorption percentage was 1.79% at 28 days of curing for mixture cured via wet sheets without fly ash or PKS replacement (OSP0F0).
9. The minimum value of air dry density at 28 days of curing was 2437 kg/m^3 for mixture cured via wet sheets with 30% PKS and 40% FA (OSP30F40), as PKS plays a good role in reducing the density.
10. There was no significant difference in the values of air-dry density of the concretes cured in different conditions. The decrease percentages in density between mixtures cured by immersion in water and by curing compound were 0.08% for concrete (with 0% FA and 0% PKS replacement), 0.04% for mixtures cured by curing compound and by wet sheet curing (with 0% FA and 0% PKS replacement).
11. The samples cured by curing compound manner for all properties generated approximately less standard deviation than other curing methods showing that the manner is dependable.

References

A'Court C (1960) "Discussion of ref. [2]", Proc. Inst. C.E., London, Vol. 15, pp,.170–181.

Abbas Alsalami ZH, Harith IK, Dhahir MK (2018) Utilization of dates palm kernel in high performance concrete. Journal of Building Engineering 20:166–172

ACI 305 (2015) 1M-14 Specification for Hot Weather Concreting. Am Concr Inst

Alamri AM (1988) Influence of curing on the properties of concrete and mortars in hot climates PhD thesis, Leeds University, U.K.

Al-sallami ZHA, Marshdi QSR, Mukheef RAAH (2019) Effect of cement replacement by fly ash and epoxy on the properties of pervious concrete. Asian J Civil Eng, 1–10.

Arafah AM, Al-Haddad MS, Al-Zaid RZ (1995) Efficiency of concrete curing in Riyadh area. Proceeding of the International Conference on Concrete under Severe Conditions, CONSEC '95, Sapporo, Japan, 2 –4 August 1995, E&FN SPON, Hongkong, Wellprint Production, V2,1995, 890–897.

ASTM C618 (2002) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. Am Soc Test Mater

ASTM C78–84 (2003) Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third Points Loading. Annual Book of ASTM Standard, 04(02)

ASTM C150 (2005) Standard Specification for Portland Cement. Am Soc Test Mater

ASTM C157/C157M (2004) Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete. Am Soc Test Mater.

ASTM C469 (2002) Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression. Am Soc Test Mater.

ASTM C490 (2004) Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete. Am Soc Test Mater.

ASTM C642 (2006) Standard Test Method for Density, Absorption, and Voids in Hardened Concrete. ASTM International, West Conshohocken

Bentur A, Goldman A (1989) Curing effects, strength and physical property of high strength silica fume concretes. J Mater Civil Eng 1(1):46–58

Ben-Yair M (1971) The effect of chlorides on concrete in hot and arid regions. Proc Int Rilem Symposium on Concrete and Reinforced Concrete in Hot Countries, B.R.S., Haifa, Israel, I, 1971, pp. 109–120.

Bonavetti V, Donza H, Rahhal V et al (2000) Influence of initial curing on the properties of concrete containing limestone blended cement. Cem Concr Res 30(5):703–708

BS (1989) 1881- Part 4. Method for Determination of Compressive Strength of Cement Mortar, British Standard

Bushlaibi AH, Alshamsi AM (2002) Efficiency of curing on partially exposed high-strength concrete in hot climate. Cem Concr Res 32(6):949–953

Da Nóbrega ACV, Mouret M, Cassagnabere F, Le VA (2018) Improved 28-day compressive strength of SCC mixed and cured in hot weather: non-conventional behavior. Constr Build Mater 173:650–661

BS EN 12350–5, Testing fresh concrete. Part 5: Flow table test, 2009.

Guneyisi E, Gesoglu M, Ozturan T et al (2009) Estimation of chloride permeability of concretes by empirical modeling: considering effects of cement type, curing condition and age. Constr Build Mater 23:469–481

Harith IK (2018) Study on polyurethane foamed concrete for use in structural applications. Case Stud Construct Mater 8:79–86

IQS (Iraqi Specification) (1984) No.45, Aggregate from Natural Sources for Concrete and Construction, Baghdad.

IQS (Iraqi Specification), No.5/1984, Portland Cement.

Jaegermann CH, Glucklich J (1971) Effect of exposure of fresh concrete to high evaporation and elevated temperatures on the long-time properties of hardened concrete. Proc. Int. Rilem Symp. on Concrete and Reinforced Concrete in Hot Countries, B.R.S., Haifa, Israel, II, 1971, pp. 383–426.

Khatib JM, Mangat PS (2002) Influence of high-temperature and low-humidity curing on chloride penetration in blended cement concrete. Cem Concr Res 32(11):1743–1753

Liu B, Luo G, Xie Y (2018) Effect of curing conditions on the permeability of concrete with high volume mineral admixtures. Constr Build Mater 167:359–371

Mehta PK, Monteiro PJ (2006) Concrete: microstructure, properties, and materials (No. Sirsi) i9780071462891).

Nadesan MS, Dinakar P (2017) Mix design and properties of fly ash waste lightweight aggregates in structural lightweight concrete. Case Stud Construct Mater 1(7):336–347

Nasir M, Al-Amoudi OS, Maslehuddin M (2017) Effect of placement temperature and curing method on plastic shrinkage of plain and pozzolanic cement concretes under hot weather. Constr Build Mater 15(152):943–953

Neville AM (1983) Properties of Concrete, 3rd edn. Pitman, London

Popovics S (1986) Effect of curing method and final moisture condition on compressive strength of the concrete. ACI J 83(4):650–657

Ramezanianpour AA, Malhotra VM (1995) Effect of curing on the compressive strength, resistance to chloride-ion penetration and porosity of concretes incorporating slag, fly ash or silica fume. Cem Concr Compos 17(2):125–133

Ridgley T (1959) An investigation into manufacture of high Strength concrete in a tropical climate. Proc Inst CE London 13:23–24

Sajedi F, Razak HA, Mahmud HB, Shafigh P (2012) Relationships between compressive strength of cement–slag mortars under air and water curing regimes. Constr Build Mater 1(31):188–196

Tsui L (1971) An investigation on time-strength relationship of concrete in Hong-Kong. Proc Int Rilem Symp On Concrete and Reinforced Concrete irr Hot Countries, B.R.S Haifa, Israel 2:297–307

Zeyad AM (2017) Effect of curing methods in hot weather on the properties of high-strength concretes. J King Saud Univ Eng Sci 31(3):218–23