Hisham K. Ahmed
Civil Engineering Department, Al-Esra'a University College, Baghdad, Iraq

Wasan I. Khalil
Building and Construction Engineering Department, University of Technology Baghdad, Iraq

Nada H. Jumaa
Reconstruction and Projects Office, Ministry of Higher Education and Scientific Research Baghdad, Iraq.
nadaalrubai@gmail.com

Received on: 29/09/2016
Accepted on: 23/02/2017

Effect of Impact Hot- Dry Weather Conditions on the Properties of High Performance Lightweight Concrete

Abstract- *The aim of this investigation is to produce high performance lightweight aggregate concrete in actual hot- dry weather conditions, and then study the combined effect of hot-dry weather conditions on the fresh properties of high performance lightweight aggregate concrete such as workability, initial and final setting time, measuring concrete temperature, and hardened concrete properties (compressive strength, splitting tensile strength and flexural strength, modulus of elasticity). The experimental program including the use of fixed mix proportions and was carried out in a typical Iraqi summer days (under actual conditions) of different times during the day, where the mean maximum temperature in shadow in July and August usually is more than 44° C and relative humidity of about 24 %, the results were compared with the specimens prepared and casted in laboratory and others in shadow site. The results indicate that as temperature rises, and relative humidity falls, the initial and final setting time were reduced, beside that actual drop in slump. The results also show that rising placing temperatures more than allowable concrete temperature that recommended in ACI 305 does not, as a rule, lead to lower strengths. The strength performance of concrete can remain unaffected by higher placing temperatures, or it can even improve over that at lower temperatures. Using pre-soaked lightweight aggregates (pumice) as internal water reservoirs for producing this type of concrete under actual hot-dry weather condition played positive role in improvement of concrete properties by compensate the evaporation of water due to the rising temperature and decreasing relative humidity, and provide additional moisture in concrete for a more effective hydration of the cement.*

Keywords- *should be included in a separate line immediately after the abstract. Maximum 6 keywords (words or phrases). The general and plural terms and multiple concepts should be avoided (avoid for example, "and" "of"). Enter keywords or phrases in alphabetical order, separated by commas.*

How to cite this article: H.K. Ahmed, W.I. Khalil and N.H. Jumaa, "Effect of Impact Hot- Dry Weather Conditions on the Properties of High Performance Lightweight Concrete," *Engineering and Technology Journal*, Vol.36, Part A, No. 3, pp. 262-273, 2018.

1. Introduction

Iraq is characterized by hot-dry weather and the summer is usually extended over several months. Hot-dry weather is described by high temperature (in the summer up to 40-50 ˚C during the day ,and 15-25 ˚C at night) , intensive direct solar radiation, low relative humidity (from below 20% in the afternoon to over 40% at night), and wind velocity generally low in the morning, rising towards noon to reach a maximum in the afternoon [1]. These sudden and continuous great changes in temperature and humidity accelerate the cracking of concrete due to expansion and contraction that can adversely affect the properties and serviceability of the hardened concrete, which cannot be, rectified later [2]. Conventional concrete suffer from certain deficiencies, one of these deficiencies is that it has a low strength-weight ratio. This makes concrete at an economic disadvantages when designing structural members. Attempts to overcome these deficiencies have been resulted in the development of special concrete types such as structural lightweight aggregate concrete, high-strength concrete and recently high-strength lightweight concrete.

Lightweight aggregate concrete (LWAC) has been used very successfully as a construction material for many years. There are worldwide environmental, economic and technical impetuses to encourage the structural use of LWC. The advantages of LWAC over normal weight concrete (NWC) are numerous and well known. It offers design flexibility and substantial cost savings by providing less dead load, thinner sections, smaller size structural members, longer spans, decreased story height, less reinforcing steel, lower foundation costs, reduced handling and forming costs, improved seismic structural response, better fire ratings, and has better shock and sound absorption, also LWC precast elements

https://doi.org/10.30684/etj.36.3A.4
2412-0758/University of Technology-Iraq, Baghdad, Iraq

offer reduced transportation and placement costs [3,4].

In recent years, the terminology "High-Performance Concrete" has been introduced in construction industry. High Performance Concrete (HPC) can be designed to give optimized performance characteristics for a given set of load, practice and exposure conditions consistent with the requirements of cost, service life and durability. HPC is now available as NWC and structural lightweight concrete (SLWC). Although the accessibility of NWC-HPC is almost common, the application of SLWC is also on the increase. There are limited information about the use of HPC in summer weather. The use of HPC in hot-dry weather conditions normally requires special precautions against excessive water evaporation. Because of the low w/c ratio of HPC, the low bleeding rates may result in plastic shrinkage cracking. In general, Portland cement concrete can develop problems and undesirable characteristics for both freshly and hardened mix when exposed to high ambient temperatures during mixing, transporting, casting, finishing, and curing [5, 6]. Impairment of quality and durability of concrete has been a well-established fact. Recent advances in materials technology have accelerated the development of higher strength concrete by using lightweight aggregates. The use of high performance lightweight aggregate concrete (HPLWAC) can reduce the self-weight of structure, higher strength/weight ratio, better tensile strain capacity, lower coefficient of thermal expansion and superior heat and sound isolation characteristics [3,7]. Concrete with these characteristics are desirable since it can offer substantial cost reduction. For this reason the applications of HPLWAC has been widely increased, and is become used in buildings and constructions. The researches in the range of present investigation were very rear , most of them were studied the effect of hot weather on the properties of normal strength concrete [5,6,8-16],several investigations have been made about the effect of hot weather conditions on the properties of the lightweight concrete[17-19] and high strength concrete [20-21]. Most of them were studied the influence of air temperature and relative humidity only (experiments in still air) that carried out in laboratory in an environmental chamber to simulated hot weather conditions. The aim of this study is to experimentally investigate the effect of hot-dry weather on the properties of HPLWAC under actual hot-dry weather conditions by using lightweight aggregates.

2. Experimental Program

I. Material

- *Cement*

Ordinary Portland cement (type 1) manufactured by Mass Bazian factory was used in this study. The chemical composition and physical properties of The cement are given in Tables 1. They are conformed to Iraqi specifications (I.Q.S) No. 5/1984.

- *Silica fume*

Silica fume was used known commercially as (Sika fume-HR); it was brought from Sika Company. The physical properties and chemical composition of the silica fume are given in Table 2. The results show that the silica fume used satisfies the requirements of ASTM C 1240-06.

Table1: Chemical composition and Physical properties of cement

Oxides composition	Content (%)	Physical properties	Test result	Limits of I.Q.S No.5/1984
CaO	65.8	Specific surface area Blaine methods (m^2/kg)	391	≥ 230
SiO_2	22.7			
Al_2O_3	5.59			
Fe_2O_3	3.28	Setting time (Vacats method)		
MgO	1.30	-Initial setting (h: min)	1:55	≥ 45 min
SO_3	2.75	-Final setting (h: min)	3:25	≤ 10 h
Na_2O	0.32	Compressive strength of mortar (MPa):		
MnO	0.10			
Loss on Ignition, (L.O.I)	1.05	3-days	23.7	≥ 15
		7-days	31.4	≥ 23
Insoluble residue	1.27	Soundness (Autoclave method),(%)	0.16	≤ 0.8
Lim Saturation Factor, (L.S.F)	0.88			

Table 2: Physical properties and chemical composition of silica fume (SF)

Physical Properties							Test results		ASTM C1240 limitations
Unite weight (kg/m^3)							3.00		-
The amount of SF remaining on a sieve of 45 µm, (%)							4.20		≤ 10
Accelerated Pozzolanic Strength Activity Index with Portland cement at 7 days, % of control.							126		≥ 105
Chemical composition									
Oxides composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	Loss on ignition	
Content (%)	0.15	90.65	4.53	1.56	2.0	0.02	3.39	2.86	

- *Fine aggregate*

Natural sand brought from Al-Ukhaider region was used as fine aggregate passing through sieve of 4.75 mm. The results indicate that the fine aggregate grading and the sulfate content conform to the I.Q.S No.45/1984 Zone 2 as shown in Table 3and 4.

Table 3: Grading of fine aggregate

Sieve size (mm)	Cumulative passing (%)	I.Q.S limits No. 45/1984
10	100	100
4.75	92	90-100
2.36	84	75-100
1.18	72	55-90
0.6	45	35-59
0.3	18	8-30
0.15	6	0-10
Fineness modulus : 2.72		

Table 4: Physical and chemical properties of the sand

Properties	Specification	Test results	Limits of Specification
Bulk specific gravity	ASTM C128-01[61]	2.60	-
Absorption, (%)	ASTM C128-01[61]	1.92	-
Dry loose unit weight, (kg/m^3)	ASTM C29-03 [62]	1620	-
Material finer than 0.075 mm sieve, (%)	(I.Q.S.) No. 45- 84[60]	1.16	5 (max. value)
Sulfate content as (SO_3), (%)	(I.Q.S.) No. 45-84 [60]	0.1	0.5 (max. value)

Also, lightweight fine aggregate (Pumice) was used as partial replacement by volume of the natural sand by percentage of 20%; this LWA was crushed by crusher machine. The gradation of pumice fine aggregate (PFA) was prepared as that of the natural sand.

- *Coarse lightweight aggregate*

The lightweight coarse aggregate (pumice) was used as fully replacement of normal coarse aggregate. Grading of pumice coarse aggregate (PCA) falls in the size designation of 12.5 to 2.36 mm in accordance to ASTM C 330-04.Physical properties of pumice lightweight aggregate are shown in Table 5.

Table 5: Physical properties of pumice lightweight aggregate

Property	Specifications	Result	
		Fine	coarse
Specific gravity	ASTM C127-88 ASTM C128-88	1.32	0.93
Absorption (%)	ASTM C127-88 ASTM C128-88	17.3	28.6
Dry loose-unit weight, (kg/m^3)	ASTM C29-89	968	672
Dry rodded- unit weight, (kg/m^3)	ASTM C29-89	1117	758

- *High range water reducing admixture: Super plasticizer*

A high range water reducing agent was used (commercially known as Sika Visco Crete -5930), and meets the requirements for superplasticizer (Sp)according to ASTM C -494 type G and F.

Π Mix proportions

Mix design is made in accordance with volumetric method ACI 211.2 [22]. The reference concrete mixture is designed to give at 28-day characteristic compressive strength of 40 MPa. The design was made to conform the requirement of SLWC, according to ACI Committee 213 classification [23]. Several trial mixes were carried out to select suitable mix of HPLWAC. This mix was conducted to get the proper weight of materials ensuring homogeneity and workability of the mixture and having a dry unit weight of 1908 kg/m^3 that is not exceeding the requirement of SLWC. Constant mix proportions were used throughout this investigation. The mix proportions are 1: 1.33: 0.84 (cement: sand: lightweight coarse aggregate) by weight. The weights of materials per (1.0) m^3 are shown in Table 6.

III. Mixing procedure

Mixing process was carried out in three series as follows:

Series one: In the filed under actual hot-dry weather conditions in the summer season at different hours of the day at (7:30am, 9:30am, 12:00 pm, 3:00pm). Before mixing, all concrete ingredients and mixer as well as molds were kept under sun radiation

Series two: Outside of the laboratory in the natural atmosphere during summer season under shadow site at (12:00) pm. namely (M Sh).

Series three: Represent reference mixture, mixing of materials carried out inside the laboratory where the temperature is 23± 2 and relative humidity (RH) about (65±5%), namely (M Ref).

Before mixing, the pumice aggregates was pre-soaked for 30 minutes in water and used after removal of excess surface water to produce the aggregate particles in state saturated surface dry (SSD) condition. A pan mixer of 0.1 m^3 capacity was used. PCA was added first to the drum followed by fine normal weight aggregate and PFA. All these materials were first mixed for 1 minute to get homogenous materials. The required cement and SF were mixed manually until a homogenous mixture was obtained, then they were added to the rotary drum. Two thirds of the water was added to the dry mixture and mixed for 1 minute. Finally the superplasticizer and one third of the remained water were stirred and added to the mixture. After that, the mixture was mixed for 6 minutes.

IV. Preparation of specimens

A specially prepared timber molds were used they were tightened thoroughly. After mixing process, the fresh concrete was casted in the molds, with approximately equal layers of 50mm for all the specimens and consolidated by means of vibrating table for a sufficient period. This was attained within 15 to 20 second; care should be taken to avoid segregation of the LWA.

A number of standard test specimens of different sizes were casted to investigate the various parameters.

- A total of 90 cubes 100mm were casted for testing compressive strength and fresh and dry air density, also 10 cubes for measuring concrete temperature were prepared.
- 12 Cubes of 150 mm for testing initial and final setting time of concrete.
- 90 Prisms of 100*100*400 mm were used for flexural strength test.
- Splitting tensile strength test was conducted on 90 cylinders of 100*200 mm.
- 18 cylinders of 150*300 mm were used to determine static modulus of elasticity

V. Curing of the test specimens

After 24 hours from casting, the specimens were demolded submerged in water tank and cured for 13 days in the same conditions of casting as referred in each series, then removed from water and left outside exposure to natural atmosphere condition until the time of test, while specimens of series three left in laboratory conditions until the time of test.

VI. Tests

The following tests and measurements were conducted on prepared mixtures:

a- The measurement of fresh concrete density carried out according to ASTM C138.

b-The temperature of different concrete mixtures casted at different times of the day measured in a practical manner immediately after casting by using embedded Copper Constant Thermocouples type T inside the specimen and Data Logger to measure concrete temperature during the first 24 hours .As well as calculating generated concrete temperature of freshly mixed concrete theoretically by means of measuring concrete ingredients temperature [24] using the following equation:-

$$T= \frac{0.22(Ta\ Wa+TcWc)+Tw\ Ww}{0.22(Ww+Wc)+Ww} \quad (1)$$

Where:-

T: The temperature of the freshly mixed concrete.

T_a, T_c, T_w: represents temperatures in C° of aggregates, cement and water respectively.

W_a, W_c, W_w: denotes to mass of aggregates, cement and water respectively per unit volume of concrete.

c- The workability of all concrete mixes was measured at different times by using slump test immediately after mixing in accordance with test method ASTM C-143. The (w/cm) ratio for mixture casted under actual hot weather conditions and laboratory was adjusted to have workability of slump ranged from 100 to 40 mm. On the other hand ,M-12:00,M-3:00 of slump 45, and 40 mm ,respectively have a good workability due to use the admixture superplasticizer.

d -According to the method described in ASTM C 403, the determination of initial and final setting time of concrete, by means of penetration resistance measurements on mortar sieved from the concrete mixture was used, using proctomotar penetrometer device**.**

e- Oven dry density was performed in accordance with ASTM C567-14 at age of 28 days.

f- Compressive test was carried out according to BS.1881: part 116.

g- Splitting tensile strength test was performed according to ASTM C 496.

h- Flexural strength test was carried out in conformity with ASTM C78-03.

These tests were carried out using a hydraulic testing machine type ELE digital testing with capacity of 2000 KN. Specimens were tested at the age of 3,7,28,90,and 180 days.

i- Axial compressive stress-strain relationships were determined; the chord– modulus of elasticity method was followed, as recommended by ASTM C469-02.

2. Results and Discussion

I. Concrete Temperature

Table7 shows the variation of weather conditions especially the high temperature and the reduction in the relative humidity (RH) with the progress of daily hours and reflects the actual atmosphere conditions of hot day in July and August. The variation of weather conditions also reflects the temperature of concrete ingredients and the produced concrete as shown in Table 8, it can be seen that the actual temperature of the concrete specimens is somewhat higher than that computed according to Eq. (1) due to the mechanical work done in mixing, and because of the development of the heat of wetting and hydration of cement [24].

As shown from Figure 1 it can be seen that initial concrete temperature of all specimens except that casted at 7:30am.was higher than the allowable temperature recommended ACI 305amounting 35°C [26].The figure show also that the peak concrete temperature for specimens casted at(7:30) am. was 60° C and happened after 8:30 h from casting i.e. at 4:00 pm. ,while the peak temperature of specimens casted at(9:30)am. was 66 °C which occurred after 8:00 h from casting, namely at 5:30 pm., whereas peak temperature of specimens casted at 12:00pm. of value 57.3 C° and happened after 7:30 h from casting that is less period than that of specimens casted at (7:30-9:30) am. due to the raising of air temperature and falling RH and impact of sun radiation. Also the peak temperature of specimens casted at 3:00 pm. was 52.8 ° C and occurred after 6:00 h from casting i.e. at 9:00 pm. this refer that this mixture exposure to sun radiation for short period about 4:30 h .

On the other hand, Figure 1 also illustrate the effect of sun radiation in rising concrete temperature when compared specimens casted in shadow site at 12:00 pm. and other casted at the same time but under the effect of direct sun radiation ,the peak temperature of shadow mixture was 45.2°C , and occurred after 8:30 h from casting. Therefore, that whenever possible, it is desirable to place the concrete in the coolest part of the day and preferably at a time such that the ambient temperature will rise following the setting of the concrete, that is, after midnight or in the early hours of the morning[24]. From previous study [9] it can be seen that peak temperature of normal weight concrete for specimens casted at 9:30 am.under actual hot weather conditions about 57 °C and happened after 4:30 from casting, while generated temperature from investigated HPLWAC specimens was more about 66° C, but occurred after 8:00 h from casting, this is because the amount of cement used was high about 572kg/m^3, moreover heat of hydration generated due to the presence of silica fume which increases the rate of heat evolution due to its accelerating effect on cement hydration, though the total heat liberated, is somewhat decreased as silica fume is substituted for cement [27]. On the other hand, using pre-soaked lightweight aggregates (pumice) as internal water reservoirs delayed the rising of concrete temperature, and provides additional moisture in concrete for a more effective hydration of the cement.

Table 6: Selected mix design proportion

Concrete ingredients	Cement (kg/m^3)	Normal Sand +PFA (kg/m^3)	PCA (kg/m^3)	Water + SP (kg/m^3)	Sp (by wt. of cement) (%)	SF (kg/m^3)	w/cm (%)
Contents	572	763	482	188	1.5	57.2	0.32

Table7: Average weather conditions at different hours in the field site during the time of casting HPLWAC specimens in July and August

Time of casting	Temperature Measured in Shadow(°c)	Measured Rh(%)	Forecast wind speed[25] (m/sec)	Forecast sun radiation[25] (calorie/cm^2/h)	Temperature measured under sun radiation(°c)
7:30 am.	33.2	26	3	45	35.7
9:30 am.	38.6	17	4.5	63	41.9
12:00 pm.	48	13	6	69	55
3:00 pm.	52.1	10	6	51	58.4

Table 8: Temperature of concrete ingredients

Time of casting	Temperature (°C)					Concrete temperature(C)		Air temperature(°C)	
		Fine agg.							
	Coarse agg.	Sand	LWA	Cement	Water	Experimental	Theoretical	Under sun radiation	In shadow
7:30 am.	34.2	33.6	35	33.1	31.8	34.1	33	35.7	33.2
9:30 am.	37.4	36.2	37.4	37.6	33.2	38.2	35.7	41.9	38.6
12:00 pm.	44.7	42.4	43.6	41.8	38.8	44.3	41.4	55	48
3:00 pm.	46.7	46.7	47.5	44.2	39.8	46.4	44.1	58.4	52.1
12:00 pm. (shadow)	39.6	37.3	38	36.4	34.8	41.6	39.4	-	48

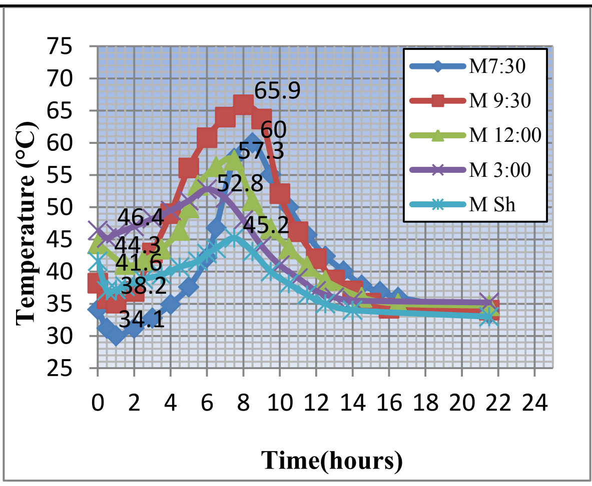

Figure 1: Temperature of HPLWAC casted at different hours of the day

Π Workability

The relation between the workability of HPLWAC represented by the slump and the actual hot-dry weather conditions showed in the Table 9, where the workability decreased by high temperature and decreased relative humidity. It has been noted that the initial concrete temperature effects on the workability of concrete and the amount of water required for a given slump due to evaporation. It can be seen also that the reduction in the slump of mixtures carried out under sun radiation which referred (M7:30, M9:30, M12:00 and M3:00) was (20, 35, 55, and 60) % respectively compared with laboratory mixture (M Ref). While the reduction in slump for mixture carried out in shadow site at 12:00 pm namely (M Sh) compared with (M12:00) conducted under sun radiation was about 53%.

Table 9: Slump of HPLWAC specimens casted at different hours of the day in hot dry weather conditions

Mix designation	w/cm (%)	Slump (mm)	Air temperature measured	RH (%)	Concrete temperature (°C)
M Ref	0.32	100	21	65	22.4
M 7:30	0.36	80	38	16	34.1
M 9:30	0.36	65	46	14	38.2
M 12:00	0.36	45	55	10	44.3
M 3:00	0.36	40	58.4	8	46.4
M 12:00(Sh)	0.36	95	44	14	41.6

III. Initial and Final Setting Time of Concrete

The relationship between penetration resistance and time to determine the initial and final setting time of HPLWAC were illustrated in Figure 2 and Table 10.These data show that, in general as the temperature rises and relative humidity falls, the initial and final setting time were reduced.

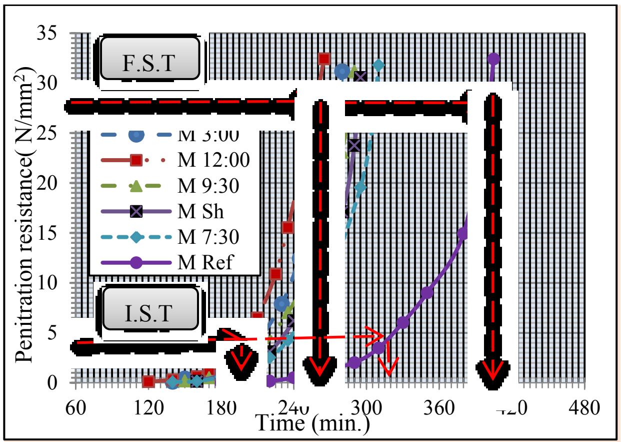

Figure 2: The relationship between penetration resistance and time for specimens casted at different hours under actual hot –dry weather conditions

From Figure 2 and Table 10 it can be seen that initial and final setting time for specimens casted at 12:00pm. under sun radiation was (3:15) h. and (4:17) h. respectively, that less than that for the same mixture but casted in shadow site the initial setting time was (3:42) h. and final setting time was (4:42)h. i.e. the initial and final setting time decreased by about 12% due to the effect of sun radiation. While from pervious study [9] the initial and final setting time of normal weight concrete casted at 12:00 pm. under actual hot-dry weather conditions was less than that of current study it is about (2:15) h and (3:39) h, this may be attributed to the internal reservoir of water, which is stored in porous lightweight aggregate (pumice), that it is delayed the time of setting concrete.

Table10: Initial and final setting time of concrete specimens casted at different hours

Mix designation	Initial setting (I.S) (h:min)	Final setting (F.S) (h:min)
M Ref	310 (5:10)	400 (6:40)
M 7:30	230 (3:50)	308 (5:08)
M 9:30	213 (3:33)	285 (4:45)
M 12:00	195 (3:15)	257 (4:17)
M 3:00	207 (3:27)	278 (4:38)
M 12:00(Sh)	222 (4:55)	292 (4:52)

IV Compressive strength

The compressive strength results at age (3,7,28,90 and 180) days of HPLWAC specimens casted at different hours of the day under actual hot-dry weather conditions are shown in Table 11,which shows that the early age strength (3 and 7) days of specimens (M 7:30) casted at air temperature 35.7° C , RH 26%,and an initial concrete temperature was (34.1)°C that does not exceed allowable concrete temperature recommended in ACI 305 [26], are nearly the same strength of specimens (M Ref) where air temperature about 21° C and RH 65%. The percentage of increase of specimens (M 7:30) is only (2.7, and 3.1) % relative to that of (Ref) specimens. At 28 day and at later ages (90 and 180) days, the compressive strength of specimens (M7:30) decreased by about (4.2, 10.3, 11.0) % respectively compared to that specimens (M Ref).

Specimens M(9:30, 12:00,and3:00) have initial concrete temperature about (38.2,44.3, and 46.4) °C respectively, which are higher than allowable concrete temperature, resulted in an increase in strength at 3 and 7 days by about (8.0,10.4,and 5.0)% and (8.8,12.3, and 6.3)% respectively, compared with (M Ref).Also from Figure 3 it is evident that 28 day strength of specimens(M9:30) slightly higher than that of (M Ref) by about 2%, while it decreased at later ages 90, and 180 days by about (5.0, and 6.3)%respectively. Whereas 28 day compressive strength of specimens (M12:00) is still more than that of (M Ref), the percentage increase was 5.3%. At later ages 90 and 180 day the strength marginally decreased by about (2, and 3.8)% respectively, compared to (M Ref).While specimens (M3:00) the strength decreased by about (1.0,7.6, and 8.7)% at (28,90, and 180) day respectively, relative to that (Ref) specimens.

On the other hand, the percentage increase in compressive strength at age 7 days of specimens casted at (7:30am., 9:30 am, 12:00pm. and 3:00pm) was(4.6,4.9,5.8,5.4) % respectively, compared to the 3-day strength, while (Ref) specimens the percentage increase is 4.2%.

Whereas the percentage increase in 28-day strength of specimens M(7:30, 9:30, 12:00,and 3:00) compared to the 7-day strength ,it is about (19.9,20.9,21.0, and 20.1)% respectively, while (M Ref) was 29%, also for the same specimens, 90-day strength increased by about (8.3,7.8,7.5, and 8)% compared to 28-day strength, whereas (M Ref) the percentage increase was higher ,it is about 15.7%. The results also have shown that the percentage of increase in strength during 2 month less than that during 21 day. These values typically less than that for normal weight concrete. Of course, the strength development in LWC is limited by the inherent strength of aggregate. These results are in agreement with the finding of Al-Khaiat and Haque [17]. Also the percentage increase in 180-day strength compared to the 90-day is (4.4, 3.8, 3.5 and 4.1)% and for (M Ref) is 6.5%,this mean that the gain in strength at 28 day and later ages for (M Ref) was higher than that for specimens casted and cured under hot weather conditions, and this in agreement with other researchers [24,28,29] who reported "Concretes mixed, placed, and cured at elevated temperatures normally develop higher early strengths than concrete produced and cured at lower temperatures, but strengths are generally lower at 28 days and later ages".

It can be seen also from Table 10 the strength of specimens (M12:00) more than that of specimens (M Sh) in all ages, the percentage increase was (3.0, 4.0, 7.0, 6.2 and 5.8)% at (3, 7, 28, 90 and 180) respectively, but (M Sh) had higher strength at early ages at (3and 7)days compared with(M Ref) by about (7.1and 8.0)% but it is nearly the same strength at 28 day, (M Sh) decreased by about (1.5)%. While at (90 and 180) day the strength of (M Sh) decreased approximately (7.8, 9.0)% respectively. Therefore, during the early stage of curing, the compressive strength of concrete casted and cured at the high temperature is greater than that casted and cured at lower temperature. However, with rapid hydration, hydration products do not have time to become uniformly distributed within the pores of the hardening paste. In addition, "shells" made up of low permeability hydration products build up around the cement grains. The non-uniform distribution of hydration products leads to more large pores, which reduce strength, and the shell impedes hydration of the unreacted portion of the grains at later ages [29].

Table 11: Compressive strength of HPLWAC specimens casted at different hours under actual hot–dry weather conditions

Mix Designation	Compressive strength(MPa) at age (days)				
	3	7	28	90	180
M Ref	33.7	35.1	45.3	52.4	55.2
M 7:30	34.6	36.2	43.4	47	49.1
M 9:30	36.4	38.2	46.2	49.8	51.7
M 12:00	37.2	39.4	47.7	51.3	53.1
M 3:00	35.4	37.3	44.8	48.4	50.4
M 12:00 (Sh)	36.1	37.9	44.6	48.3	50.2

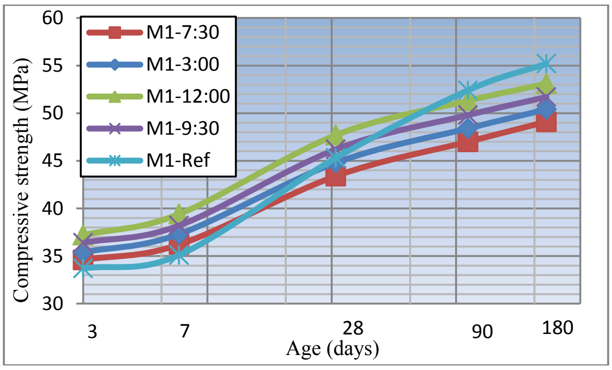

Figure 3: Compressive strength development of HPLWAC specimens casted at different hours of the day under actual hot dry weather conditions

V. Splitting tensile strength

Table 12 and Figure 3 show the relationship between splitting tensile strength and age of HPLWAC specimens casted at different hours under actual hot weather conditions. Generally, the results indicate that the pattern of the behavior of all specimens in splitting tensile strength is similar to that of the compressive strength. The figure show also that the splitting tensile strength at early ages (3 and 7) days of specimens M(7:30, 9:30, 12:00,and3:00)was higher than that of reference specimens, the percentage increase at 3 days was (4.9, 11.3, 16.2 and 7.6)% respectively, and at 7 days the percentage increase was(5.2, 12.7, 18.7 and 8.4)% respectively, compared with reference specimens .On the other hand, the results at 180 days of age, the splitting tensile strength of specimens (M Ref) was higher than that of specimens (M 7:30, M 9:30, M 12:00 and M 3:00) by about (15, 9.1, 5.3 and 12.8)% respectively. Form Table 11 the splitting tensile strength of specimens (M 12:00) higher than that of specimens (M Sh) at all ages , the percentage increase at (3, 7, 28, 90 and 180) days was (5.3, 6.7, 8.4, 7.1 and 5.6)% respectively . The relationship between the compressive strength and the splitting tensile strength of specimens at age 28 and 180 days are presented in Table 12. These results show that the splitting/compressive strength ratios range between (9.47% to 9.97) % and (9.28% to 9.72%) respectively. These results are in agreement with findings by Sampebulu [19] where the tensile strength of high strength lightweight aggregate concrete about (8.3) % of its compressive strength when ambient temperature was 40°C.

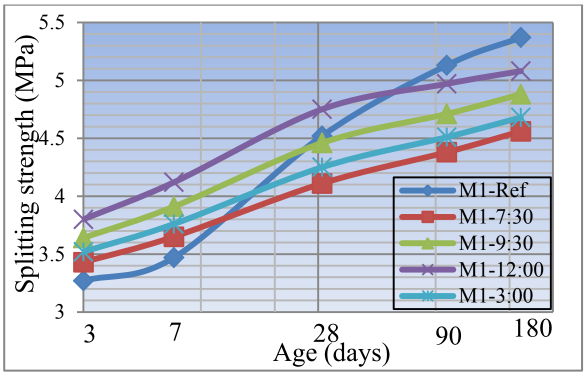

Figure 3: The relationship between splitting tensile strength and age of HPLWAC specimens casted at different hours under actual hot-dry weather conditions

VI. Flexural strength (Modulus of Rupture)

The development in the ultimate flexural strength (modulus of rupture) value of HPLWAC specimens over a period of 180 days hot-dry weather conditions exposure is included in Table 13 .The results demonstrate that maximum modulus of rupture (M.O.R) for specimens casted under actual hot weather conditions was for specimens (M 12:00) at all ages, while the minimum M.O.R was for specimens (M7:30) which initial concrete temperature was less than allowable concrete temperature (35) °C, the percentage of increase in M.O.R of specimens (M 12:00) at age (3,7,28,90and 180)days compared to that (M7:30) was (7.2, 9.2, 10, 10 and 9.6)%respectively, whereas specimens (M Ref) has M.O.R less than that of specimens (M7:30) at early ages, but it increased at later ages. The percentage of increase in M.O.R at (3 and 7) days of specimens M (7:30, 9:30, 12:00 and 3:00) compared to (M Ref) is (2.6, 7.2, 10.1 and 5.7) % and (3.2, 9.4, 11.4 and 5.8) % respectively. Whereas the M.O.R at 28 day of specimens M(7:30, and 3:00) slightly decreased by about (4.6, and 1.9)% respectively, while M.O.R of specimens(M9:30) approach to that of (Ref) specimens, the percentage increase is only 1.7 % , while specimens (M 12:00) slightly higher by about (5)% .At later ages (90 and 180) day ,the percentage decrease of M.O.R of specimens M (7:30, 9:30, 12:00 and 3:00) compared to (M Ref) was (12.3, 6.2, 3.5 and 9.7)% , and (12.5,6.6,4.2 and 13.5) % respectively. The results also show that the percentage decrease in M.O.R at later ages of specimens M 12:00 compared to (M Ref) was insignificant. On the other hand, M.O.R of specimens (M 12:00) was higher than that of specimens (M Sh) at all ages, the percentage of increase was (5.2, 6.7, 8.4, 7.1 and 5.6)% respectively, this behavior may be attributing to same reason as referred to previously when discussion compressive strength.

The results demonstrate also from Table 13 that all concrete specimens exhibited a continuous increase in M.O.R with increasing ages, but there has been a marginal degradation in the M.O.R of specimens (M 3:00) from the age of 90 days to 180 days by about 1.6%. This reduction can be attributed to the initiation of microcracking and the introduction of tensile stresses due to drying shrinkage of the specimens during exposure. These results are conformable to the findings by Haque et.al [18].

Table 13: Modulus of rupture of HPLWAC specimens casted at different hours under actual hot -dry conditions

Mix Designation	Modulus of rupture (MPa) at age (days)				
	3	7	28	90	180
M Ref	5.43	5.65	7.25	8.37	8.61
M 7:30	5.57	5.84	6.92	7.34	7.53
M 9:30	5.82	6.18	7.37	7.85	8.04
M12:00	5.98	6.38	7.61	8.08	8.25
M 3:00	5.73	5.98	7.11	7.56	7.44
M12:00 (Sh)	5.78	6.11	7.16	7.86	8.04

Table 12: Splitting tensile strength of HPLWAC specimens casted at different hours under actual hot weather conditions

Mix Designation	splitting tensile strength(MPa) at age (days)					Splitting tensile strength/compressi	Splitting tensile strength/compressi
	3	7	28	90	180		
M Ref	3.27	3.47	4.52	5.13	5.37	9.97	9.72
M 7:30	3.43	3.65	4.11	4.38	4.56	9.47	9.28
M 9:30	3.64	3.91	4.46	4.71	4.88	9.65	9.43
M 12:00	3.8	4.12	4.75	4.97	5.08	9.95	9.56
M 3:00	3.52	3.76	4.25	4.51	4.68	9.48	9.28
M 12:00(Sh)	3.61	3.86	4.38	4.64	4.81	9.82	9.58

VII. Static Modulus of Elasticity (Es)

The results of static modulus of elasticity (Es) of HPLWAC specimens at age of 28- day casted at different hours of the day under actual hot-dry weather conditions are shown in Table 14.It can be seen that modulus of elasticity ranged from (24.35-20.64) GPa, and static modulus of elasticity at age 28 days of specimens casted at 7:30 am. lower than that of specimens (M 9:30,M 12:00,M 3:00), the percentage of decrease was(9.4,13.5,and2.5)% respectively, although the initial concrete temperature of M 7:30 was about 34.1°C ,that is less than that allowable concrete temperature recommended ACI 305[27]but it was exposed to sun radiation for long period ,while other specimens have initial concrete temperature higher than allowable temperature as shown previously from Table 8,also these results demonstrate that modulus of elasticity of (M12:00) more than other specimens. On the other hand, modulus of elasticity of specimens casted at 12:00 pm. under sun radiation higher than that casted in shadow site, the percentage of increase was 13%.This behavior may be attributed that (M 12:00)have higher compressive strength than other specimens due to it is higher initial concrete temperature resulted in a rapid hydration reaction. The modulus of elasticity of concrete is a function of compressive strength and normally Es increases with the increase of compressive strength. These results are in agreement with results obtained by Hossain [31]. In general the enhancement in the results of modulus of elasticity of HPLWAC specimens may be due to the improvement in the interfacial transition zone enhanced the hydration process because of internal curing of lightweight porous aggregate (pumice), and absence of shrinkage-induced microcracking.

Most of the international standards take into account that modulus of elasticity of LWC depends on the compressive strength and the density. The tests conducted so far with different aggregates confirm both influences. Various building codes have provided empirical equations relating Es and compressive strength. The test results of modulus of elasticity are comparable to the values calculated according to the Eq. (2) suggested in ACI -213 [23] expression of:

$$E_s = 0.043\ \rho^{1.5} \sqrt{f_c} \qquad (2)$$

where:

E_s: static modulus of elasticity (MPa)

ρ: concrete density(Kg/m^3)

f_c : cylinder compressive strength

and using equation (3) according to BS [32] , expression of:

$$E_s = 1.7\ \rho^{2} f_c^{\ 0.3} \qquad (3)$$

Where:

f_c : cub compressive strength

It can be seen that the better estimate of the E_s value against measured value has been obtained using ACI formula, while British Standard formula give underestimated values of elastic modulus. The observed difference between measured values and calculated value using ACI formula is ranged from (2 to11) %, while the difference ranged from (7 to 25)% when using BS formula. This is because these equations applied for specimens casted and cured under laboratory conditions, while measured specimens exposed to actual hot-dry weather conditions, also modulus of elasticity for lightweight aggregate concrete is significantly affected by moisture.

Table 14: Modulus of elasticity of HPLWAC specimens at age 28 days

mix designation	f_{cub} (MPa)	Es Experimental (Gpa)	Es (ACI)Formula, (Gpa)	Es (BS)Formula, (Gpa)
M Ref	45.3	24.35	21.88	19.51
M 7:30	43.4	20.64	20.20	19.26
M 9:30	46.2	22.79	21.15	19.55
M 12:00	47.7	23.87	21.65	19.86
M 3:00	44.8	21.18	20.78	19.45
M 12:00(Sh)	44.6	21.13	20.54	19.38

3.Conclusions

The following conclusions can be drawn from the results and discussion presented from this investigation:

1. There is pronounced effects of hot-dry weather conditions on the reduced workability of concrete, and increased the need to mixing water. The reduction in the slump of specimens (M7:30, M9:30, M12:00 and M3:00) was (20, 35, 55, and 60 %) respectively compared with (M Ref), and 53% for (M Sh) comparatively to that (M12:00).However this type of concrete showed very good workability and compatibility by using optimum dosage of superplacticizer.
2. The initial and final setting times are both reduced with the rise in temperature and decreasing relative humidity, its accelerating effect on the rate of stiffening the concrete.
3. Rising placing temperatures more than allowable concrete temperature that recommended in ACI 305 amounting 35°C does not, as a rule, lead to lower strengths. The results indicate that the compressive strength, splitting

tensile strength and modulus of rupture of specimens casted at 12:00 pm. under actual hot-dry weather conditions more than that other specimens (M 7:30,M 9:30,M 3:00) at all ages.

4- The compressive ,and splitting tensile strength, and modulus of rupture performance results of specimens (M 12:00) that casted and cured under actual hot-dry weather and exposed to sun radiation was more than that for specimens of shadow site at all ages. While strength performance of reference specimens was slightly more than that of specimens (M 12:00) at later ages.

5. The results indicate there are no negative effects on the modulus of elasticity of specimens casted and cured under actual hot-dry weather conditions.

6.Using pre-soaked lightweight aggregates (pumice) as internal water reservoirs of producing HPLWAC under actual hot-dry weather condition played main role in improvement concrete properties by compensate evaporation of water due to high temperature and reduced relative humidity, and provide additional moisture in concrete for a more effective hydration of the cement.

References

[1] R. Shalon, "Report on Behaviour of Concrete in Hot Climate, Part I," *Materials and Structures*, Vol.11, No.62, pp. 127-131, March-April 1978.

[2] O.S.B. Al-Amoudi, M. Maslehuddin, M. Shameem, and M. Ibrahim, "Shrinkage of Plain and Silica Fume Cement Concrete Under Hot Weather," *Cement and Concrete Composites*, Vol. 29, No .9, pp. 690–699, 2007.

[3] K.S. Harman, "Engineering Properties of Structural Lightweight Concrete," Carolina Stalite Company – United States, 2007.

[4] http://www.stalite.com/PDF/Engineering properties.PDF

[5] L. Gunduz, L. Ugur, "The effects of different fine and coarse pumice aggregate/cement ratios on the structural concrete properties without using any admixtures, " *Cement and Concrete Research*, Vol. 35, pp. 1859–1864, 2005.

[6] A.F. Abbasi, A.J. AL-Tayyib, "Effect of Hot Weather on Pulse Velocity and Modulus of Elasticity of Concrete ". *Materials and Structures*, Vol. 23, pp. 334-340, 1990.

[7] B.H. Ahmadi, "Initial and Final Setting Time of Concrete in Hot Weather," *Materials and Structures,* Vol. 33, pp. 511-514, October 2000.

[8] S.H. Ahmad, and R. Barker, "Flexural Behavior of High Strength Lightweight Concrete Beams," ACI Structural Journal, Vol.88, No.1, pp.69-77, January-February 1991.

[9] R. Shalon, and D. Ravina, "Plastic Shrinkage Cracking," *ACI Journal*, Proceedings Aprial, Vol.65, No. 1,pp.282-291, 1968.

[10] H.K. Ahmed, "The Effect of Hot-dry weather on Some Properties of Normal Concrete and Containing Pozzolana," Magazine of Building Research, No.1, pp.5-19, 1982.

[11] M.A. Samarai, S. Popovics, and V.M. Malhotra, "Effect of retempering with superplasticizer on the properties of fresh and hardened concrete mixed at higher ambient temperature", in 'Superplasticizers and other Chemical Admixtures', ACI Symposium, Ottawa, Canada, ACI SP119, 1989.

[12] Z. Berhane, "The Behaviour of Concrete in Hot Climates". *Materials and Structures*, Vol. 25, pp. 157-162, 1992.

[13] S.H. Alsayed, and M.A., Amjad, "Effect of Curing Conditions on Strength, Porosity, Absorptivity, and Shrinkage of Concrete in Hot and Dry Climate". *Cement and Concrete Research*, Vol. 24, No. 7, pp. 1390-1398, 1994.

[14] A. Arafah, R. Al-Zaid,and M. Al-Haddad, "Influence of Non-Standard Curing on the Strength of Concrete in Arid Areas," *Cement and Concrete Research*, Vol. 26, No. 9, pp. 1341-1350, 1996.

[15] AL-Khaiat, H., Fattuhi, N., "Long –Term Strength Development of Concrete in Arid Conditions". *Cement and Concrete Composite*, Vol. 23, pp.363-373, 2001.

[16] M. Mouret, A. Bascoul, and G., Escadeillas, "Strength Impairment of Concrete Mixed in Hot Weather: Relation to Porosity of Bulk Fresh Concrete Paste and Maturity," *Magazine of Concrete Research*, Vol.55, No. 3, pp. 215–223 June 2003.

[17] H. Suyun, and O. Taekeun, "Effect of Mixing and Placing in Hot Weather on Hardened Concrete Properties," *International Journal of Concrete Structures and Materials*, Vol.7, No.2, pp.165–174, June 2013.

[18] H. Al-Khaiat and M.N. Haque, "Effect of Initial Curing on Early Strength and Physical Properties of a Lightweight Concrete," *Cement and Concrete Research*, Vol. 28, No. 6, pp. 859–866, 1998.

[19] M.N. Haque, H. Al-Khaiat, and O. Kayalib, "Long-term strength and durability parameters of lightweight concrete in hot regime: importance of initial curing," *Building and Environment*, Vol. 42, pp. 3086–3092, 2007.

[20] V. Sampebulu, "Increase on Strengths of Hot Weather Concrete by Self-Curing of Wet Porous Aggregate," *Civil Engineering Dimension*, Vol. 14, No. 2, pp. 92-99, September 2012.

[21] A.H. Bushlaibi, A.M. Alshamsi, "Efficiency of Curing on Partially Exposed High-Strength Concrete in Hot Climate," *Cement and Concrete Research*, Vol. 32, No.6, pp. 949–953, June 2002.

[22] H. EL-Chabib, and A. Ibrahim, "The performance of high-strength flowable concrete made with binary, ternary, or quaternary binder in hot climate," *Construction and Building Materials*, Vol.47, pp.245–253, 2013.

[23] ACI Committee 211, "Standard Practice for Selecting Proportion for Structural Lightweight Concrete," (ACI 211–2–98), pp. 1–20, Reproved 2004.
[24] ACI Committee 213, "Guide for Structural Lightweight Aggregate Concrete," American Concrete Institute, Farmington Hills, USA, 2003.
[25] A. M. Neville, "Properties of Concrete", Longman Group UK Limited, 4th and final ed., pp. 673-674, 2005.
[26] http://www.accuweather.com/en/iq/Baghdad/207375 /hourly weather forecast for Baghdad Iraq.
[27] ACI Committee 305, "Specification for Hot Weather Concreting," An ACI Standard, American Concrete Institute, pp. 1-8, March 2007.
[28] ACI Committee 234, "Guide for the Use of Silica Fume in Concrete," American Concrete Institute, 2006, pp.1-63.
[29] P. K. Mehta, and J. M. P. Monteiro, "Concrete Microstructure, Properties, and Materials, Prentice-Hall, INC,"3rd ed., New Jersey, pp. 1-684, 2006.
[30] K.A. Schindler, and B.F. McCullough, "The Importance of Concrete Temperature Control during Concrete Pavement Construction in Hot Weather Conditions," A paper offered for publication at the Annual Meeting of the Transportation Research Board. Washington, D. C .January 2002.
[31] A.A. Almusallam, "Effect of Environmental Conditions on the Properties of Fresh and Hardened Concrete," *Cement and Concrete Composite*, Vol. 23, No. 4-5, pp. 353-361, 2001.
[32] K.M.A. Hossain, "Properties of Volcanic Pumice Based Cement and Lightweight Concrete," Cement and Concrete Research, Vol. 34, No.2, pp. 283- 291, 2004.
[33] British Standard Institution, BS 8110, part 2 "Structural Use of Concrete," 1985.