Mechanical Properties of High Performance Concrete Re-tempered in Different Ambient Temperatures

Prof. Dr. Shakir Ahmed Salih
Building and Construction Department
University of Technology

Lect. Ass. Moslih Amer Salih
Civil Department
Technical Institute of Babylon

Wisam Kurdi Al Foadi
M.Sc Civil Engineering
University of Technology

Abstract:

This paper studying some of the Mechanical properties of High Performance Concrete re-tempered by using G51 after 90 minute waiting at 3 different ambient temperature (23, 40, 57)starting from lab temperature to high temperature during casting which may simulate summer degree in Iraq. The comparative made with reference concrete in the same environment. HPC produced by adding High Reactivity Metakaolin after burning. Compressive strength, Ultrasonic Pulse Velocity, Splitting tensile and Flexural test was made for both reference and HPC mixes.

المستخلص:

في هذا البحث تم دراسة بعض الخواص الميكانيكية للخرسانة عالية الأداء المعادة التطبيع باستخدام مضاف جديد بعد ٩٠ دقيقة من الخلط وفي ثلاث درجات حرارة مختلفة °C (٥٧،٤٠،٢٣) بدأ من درجة حرارة المختبر وصولا إلى درجة حرارة عالية أثناء الصب والتي تمثل محاكاة لدرجة حرارة الصيف في العراق وذلك بالمقارنة مع خرسانة مرجعية بنفس الظروف. تم إنتاج الخرسانة عالية الأداء بإضافة أطيان الكاؤلين بعد حرقها.الفحوصات التي تم إجراؤها تتمثل بفحص الانضغاط وفحص الانفلاق ومعاير الكسر كما تم إجراء فحص الموجات فوق الصوتية للخرسانة.

Introduction:

The term High performance concrete (HPC) is a describing for concrete that meets special requirements of performance that cannot always be achieved using the conventional constituents and normal mixing properties, and curing practices. HPC is also a concrete in which certain properties are developed for particular application and environment. Examples of proportions that may be considered critical in an application are: easy of placement, compaction without segregation, early age strength long-term mechanical properties and low permeability. This type of concrete is note composed from just Portland cement, aggregate and water; it is also contain super plasticizers and supplementary cementing materials. The beneficial effect of using mineral admixtures as a partial replacement of cement on the transition zone between the surface of aggregate and cement paste is a key factor in the production of HPC [1], with the addition of cementation materials, the term (water/cement) ratio needs to be modified to (water/(cement+cementations materials))ratio it is now becoming common to quote both ratios when describing a concrete mix.

There is three interrelated steps to produce or design HPC [2]:

First: Selection of suitable ingredients-cement, supplementary cementing materials, aggregates, water and chemical admixtures.

Second: The relative Quantities of these materials should be determined in order to produce, as economically as possible, a concrete that has the desired rhelogical properties, strength and durability.

Third: Careful quality control of every phase of the concrete making process.

Materials

Cement:

Ordinary Portland cement (OPC) type (I) manufactured in Lebanon (Turabat Al Sabaa) (ASTM C150-2004) [3] was used throughout this investigation. It was stored in a dry place. The Chemical composition and physical properties of this cement are presented in Table (1) and (2) respectively. The results conform to the Iraqi Specification IQS 5/1984[4].

Table (1): Chemical composition and main compounds of the cement*

Oxide	% by weight	Limit of Iraqi Specifications
Calcium Oxide CaO	62.20	-
Silicon dioxide SiO_3	22.10	-
Aluminum oxide Al_2O_3	4.55	-
Ferrio oxide Fe_2O_3	3.34	-
Magnesium oxide MgO	2.32	5.0% (Max)
Sulphur trioxide SO_3	2.3	2.8% (Max)
Loss on ignition L.O.I.	1.54	4.0%(Max)
Insoluble residue I.R.	0.65	1.5 (Max)
Lime saturation factor L.S.F.	0.74	0.66-1.02
Main compounds Bogue's Equations	% by weight	Limit of Iraqi Specifications
Tricalcium silicate C_3S	44.64	-
Dicalcium silicate C_2S	29.69	-
Tricalcium aluminate C_3A	6.41	5.0 (Min)
Tetera calcium alumina ferrite C_4AF	10.16	-

* Both chemical and physical tests on cement were made by the National Center for Constructional Laboratories (NCCL).

Table (2): Physical properties of Portland cement*

Physical Properties	Test Results	Limit of Iraqi Specifications No.5/1984
Specific surface area (Blaine Method)	310	230 m2/Kg (Min)
Setting time (vicats method) Initial setting, hrs:min Final setting, hrr:min	 1:30 4:10	 0.45 hr (Min) 10 hrs (Max)
Compressive strength of mortar, MPa 3-day 7-day	 24.0 30.5	 15.0 MPa(Min) 23.0 MPa (Max)
Autoclave expansions, %	0.229	0.08 %(Min)

Fine Aggregate:

The fine aggregate used through this research is brought from Al-Ekadir region. It is tested to determine the grading and other physical properties. Table (3) and (4) shows the sieve analysis and physical properties of fine aggregate. Results indicate that the fine aggregate grading and sulfate content were within the requirement of Iraqi Specification (I.O.S.) No.45 1984, zone 3.

Table: (3) Grading of Fine Aggregate

Sieve Size	Cumulative % passing	Limit of Iraqi Specification No. 45/1984/Zone 3
4.75	100	90-100
2.36	92.10	85-100
1.18	82	75-100
0.60	64.80	60-79
0.30	21	12-40
0.15	7.15	0-10

Table: (4) Physical Properties of Fine Aggregate

Physical Properties	Test Results
Bulk Density (kg/m3)	1721
Specific Gravity	2.35
Sulfate Content%	0.22%
Fineness Modulus	2.45
Absorption%	1.14%

Coarse Aggregate:

Crushed aggregate used as coarse aggregate of 9.5 mm maximum size used for all mixes. It was obtained from Al- Nebai source. Tables (5) and (6) show the grading and physical properties of coarse aggregate. It is conform of the Iraqi standard specification No.45/1984[5]

Table: (5) Crushed Course Aggregate

Sieve Size, mm	Cumulative % Passing	Limits of Iraqi Specifications No.45/1984
14	100	100
9.5	89	85-100
4.75	14	0-25
2.36	2.3	0-5

Table :(6) Physical Properties of Course Aggregate

Physical Properties	Test Results
Bulk Density (kg/m3)	1564
Specific Gravity	2.60
Sulfate Content%	0.11%
Absorption%	0.85%

High Performance Concrete Superplasticizer Admixture (Glenium 51)

Glenium 51, it is one of the new generations of copolymer based superplasticizer made for the production of high performance concrete. Glenium 51 matching with ASTM type A&F. It is different from conventional superplasticizers in that it is based on a unique carboxylic ether polymer with long lateral chains and that would greatly improve cement dispersion. At the start of the mixing process, electrostatic dispersion occurs but the presence of the lateral chains, linked to the polymer backbone, generate a steric hindrance. This steric hindrance stabilizers the cement particles capacity to separate and dispers. This mechanism provides flowable concrete with greatly reduced water demand [6]

The normal dosage of this superplasticizer that was recommended by the manufacturer was 0.5-0.8 liters per 100 kg of cement (cementitious materials) and dosage outside this range are permissible with trail mixes. Exact dosage rates depend on the type of effect required, quality of cement, aggregate, water cement ratio and ambient temperature there fore, in many cases it is advisable to carry out trail mixes. The technical description of Glenium 51 is given in Table (7), which was issued by the producer [7]

Table (7): Technical and Physical Description of Superplasticizer Glenium 51

Properties	Technical Description
Basis	Modified polycarboxylic ether
Form	Viscous liquid
Color	Light brown
Relative density	1.1 at 20C
Ph value	6.6 (chloride free)
Storage	Should be stored in original containers and at above 5C

*Glenium 51 produced by BASF the chemical company [7]

High Reactivity Metakaolin (HRM)

Kaolin clay is the raw material used in the manufacture of high reactivity metakalolin. Kaolin clay is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. The structure of the kaolin minerals is based on the combination of two layer structures. One layer, known as silica layer, is composed of silicon and oxygen atoms, and the second layer, known as the gibbsite layer, is composed of aluminum atoms and hydroxyl groups [8]. Previous studies indicated that kaolinite, after calcinations at specific temperature and under controlled conditions, forms high reactivity metakaolin (HRM) that exhibits Pozzolanic properties [9].

$$\underset{\text{Kaolinite}}{Al_2O_3.2SiO_2.2H_2O} \longrightarrow \underset{\text{Metakaolin}}{Al_2O_3.2SiO_2} + \underset{\text{Steam}}{2H_2O} \quad \text{……..(1)}$$

HRM is a reactive aluminosilicate pozzolan. When HRM reacts with calcium hydroxide (CH), a pozzolanic reaction takes place whereby new cementitious compounds, (C2 ASH8) and (C-S-H) are formed. These newly formed compounds will contribute to cementitious strength and enhanced durability properties of the system in place of the weak and soluble calcium hydroxide [10] [11].

$$OPC+H_2O \longrightarrow CSH+CH \quad \text{………(2)}$$
$$AS_2+CH \longrightarrow C_2ASH_8+CSH \quad \text{……..(3)}$$

HRM has shown promise as a product capable of expanding the application of high performance concrete. The availability of HRM highlighted the way for new application of high performance concrete and high durability cement-based products.

Chemical and Physical Properties of High Reactivity Metakaoline

Chemical composition of HRM is shown in Table (8), it comprises nearly 95% of (SiO_2+Al_2O_3+Fe_2O_3). The X-Ray diffraction analysis indicates that the HRM is a poorly crystalline material.

X-Ray Diffraction analysis for HRM

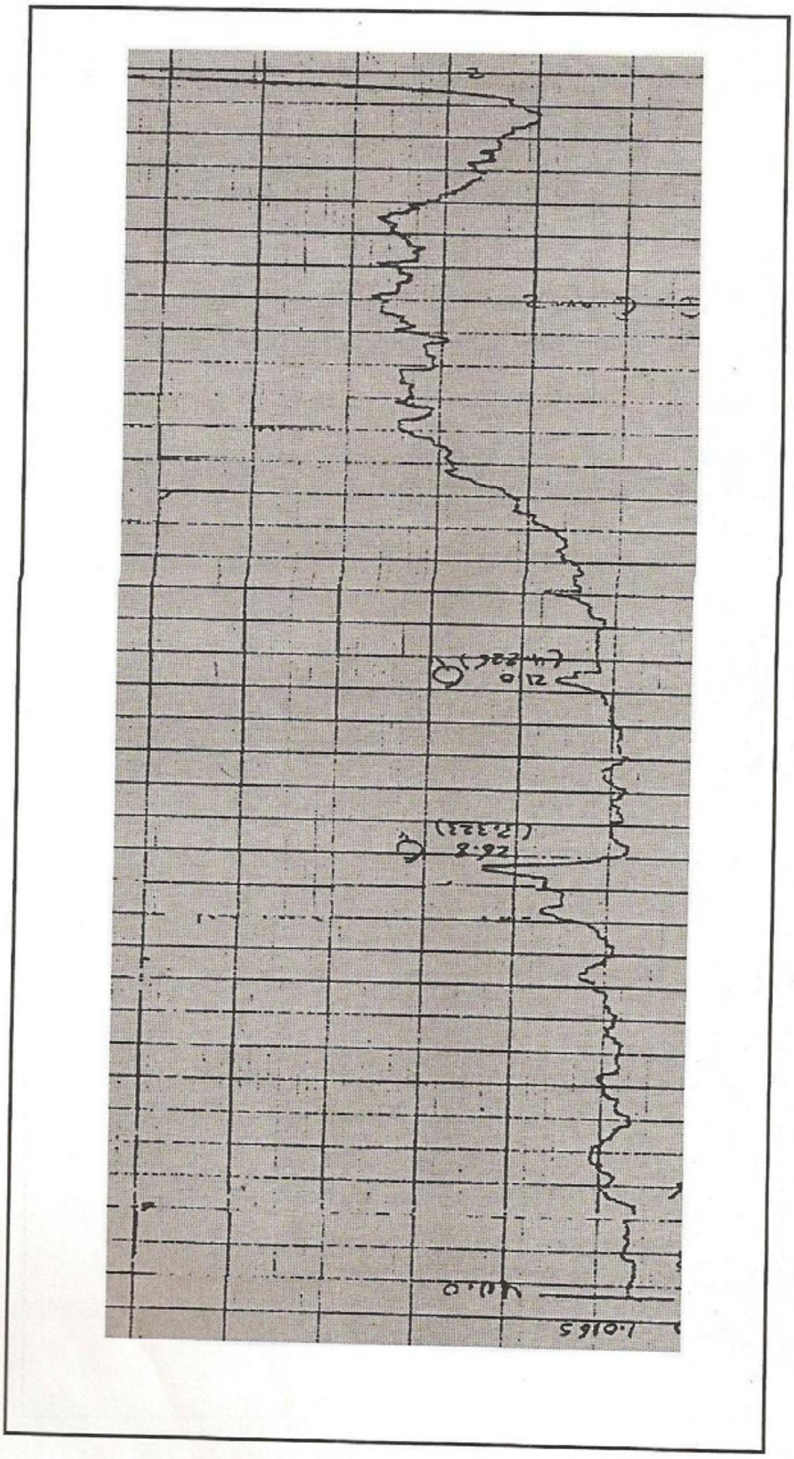

Table (8): Chemical Analysis of High Reactivity Metakaoline*

Oxides Composition	Oxide Content % by weight	Pozzolan Class N ASTM C270
SiO_2	51.32	
Al_2O_3	41.71	70% Min.
Fe_2O_3	2.31	

CaO	3.0	
MgO	0.17	
Na_2O	0.03	1.5Max
SO_3	-	4%Max
L.O.I	4.49	10 Max

* National Center for Constructional Laboratories (NCCL).

Physical Properties of High Reactivity Metakaoline

Physical properties of HRM are shown in Table (9). The specific gravity of HRM was determined using standard Le-chatelier flask according to ASTM C188-1984[12]. This is found to be (2.67), Fineness was determined by blain air permeability method in accordance with ASTM C204-1984[13]

Table (9): Physical Properties of High Reactivity Metakaoline

Physical Properties	HRM	Pozzolan Class N
Specific Gravity	2.67	Max 5%
Fineness	$655 m^2/kg$	-
Physical form	Powder	-
Color	Off- white	-
Pozzolanic Activity Index	104.6	75 Min

Pozzolanic Activity Index of high reactivity metakaoline:

For Pozzolanic Activity Index measurement, mortar mix was prepared according to ASTM C311- 87 [14], all mortars consist of one part of Cement or cementitious materials and (2.75) sand by weight. High reactivity metakaoline cement mortars contain 8% HRM as a partial replacement by weight of cement was tested. The w/c or w/cementitions materials were adjusted to maintain equal flow of 110±5for all mortars in 25 drops of the flow table. Another sample of metakaoline was produced without the stage of final grinding. Table (10) shows w/c or w/cm ratio and Pozzolanic activity index, for various mixes.

Three cubes 50mm specimens were molded from each type of mortar. After molding the specimens were placed in the moist cabinet maintained at temperature of 23±2ºC and relative humidity of more than 90% for 24 hours. After that the cubes were demolded and placed in containers made of light- tinned sheet metal and having a capacity of three cubes.

The containers were sealed, air tight and then stored at 38±2ºC for 27 days. Before testing the specimens were allowed to cool to Lab temperature.

The Pozzolanic activity index (P.A.I.) with Portland cement was determined as follows:

P.A.I.=(A/B)*100

Where:

A: average compressive strength of test mix cubes.

B: average compressive strength of reference mix cube.

Table (10): Pozzolanic Activity Index and w/c for tested mortars.

Index	HRM% by weight of cement	w/c or w/cm ratio to give flow 110+_5	P.A.I.
M	-	0.57	-
HRM8	8	0.57	103.2

HRM15	15	0.58	97.3
HRM25	25	0.59	92.0

Experimental Work:

The aim of this work is to study the influence of temperature and re-tempering on mechanical properties of high performance concrete in comparative with reference concrete subjected to the same environments. Reference concrete mix designed to have 48 MPa at 28 day. Mix design was made according to the British Method. [15][16] Cement content was 500 kg/m^3 and proportion of the mix was (1:1.1:1.88) by weight.
For High Performance Concrete, the quantity of High Reactive Metakaoline that used in mixes was chosen according to the Pozzolanic activity index test that performed to the Metakaoline. High performance concrete has 40 kg/m^3 HRM used as a replacement by weight of cement.

Mixing of Concrete:

The mixing process was performed in a pan type mixer of 0.1m3 capacity to mix concrete. The constituents of reference concrete were placed in the mixer such that the cement was placed over gravel and sand. The dry materials were well mixed for about (2) minutes to attain a uniform mix. The required quantity of tap water was then added and the whole constituent were mixed for other (2) minutes.

This procedure was used for reference concrete except that the required quantity of HRM powder was mixed with cement using porcelain mill so that the lumps of HRM particles were completely broken, this operation was continued to 20 minutes to insure that HRM particles were thoroughly dispersed between cement particles. The required amount of mixing water is added and the superplasticizer was then added to the mixing water and the solution was stirred to maintain uniform solution. Table (11) showing all concrete mixes that used is this paper.

Table (11): Concrete Mixes Symbols

Mix Symbol	Details
R1	Reference Concrete Direct Casting
R2	Reference Concrete Direct Casting
R3	Reference Concrete Direct Casting
R1G1	Reference Concrete re-tempered with G51- 90 minute waiting
R2G2	Reference Concrete re-tempered with G51- 90 minute waiting
R3G3	Reference Concrete re-tempered with G51- 90 minute waiting
HPC1	High Performance Concrete Direct Casting
HPC2	High Performance Concrete Direct Casting
HPC3	High Performance Concrete Direct Casting
HG1	High Performance Concrete Re-Tempered with G51- 90 minute waiting
HG2	High Performance Concrete Re-Tempered with G51- 90 minute waiting
HG3	High Performance Concrete Re-Tempered with G51- 90 minute waiting

Results and Discussions:

Compressive Strength Test:

This test determined according to the B.S. 1881: part 116/1989 by using 100mm cubes. Results for compressive strength test are presented in Table (12) and Figures (1, 2, 3 and 4). All specimens (Reference Concrete and High Performance Concrete) showed continuous exhibitions for compressive strength with age progress. This behavior is due to the continuity of hydration process which forms new hydration products within the concrete mass. High performance concrete showed higher compressive strength from reference concrete in all ages (7, 28 and 56 day) for all specimens and in different ambient temperature (23ºC, 40ºC, 57ºC). This behavior can be attributed to the cement content and the presence of high reactive metakaoline and superplasticizer effect with the agent G51, on the other side, there is a reduction in compressive strength results up to 56 days with the increase of ambient temperature from 23ºC to 57ºC and this is can be attributed to the rapid initial hydration which seems to form hydration products of poorer physical structure, probably more porous, so that a large proportion of the pores will always remain unfilled and according to the gel/space ratio, that will give lower strength compared with a less porous from products slowly hydrating.

Table (12): Compressive Strength Test Results

Mix	Temp	Mix Condition	G51	Compressive Strength (MPa)		
				7	28	56
R1	23ºC	Direct Cast	-	59	71	89
R2	40ºC	Direct Cast	-	63	76	87
R3	57ºC	Direct Cast	-	64	73	82
R1G1	23ºC	90 minute waiting	0.26	62	78	92
R2G2	40ºC	90 minute waiting	0.36	65	81	90
R3G3	57ºC	90 minute waiting	0.42	69	82	88
HPC1	23ºC	Direct Cast	-	66	80	92
HPC2	40ºC	Direct Cast	-	68	79	89
HPC3	57ºC	Direct Cast	-	70	78	86
HG1	23ºC	90 minute waiting	0.36	73	89	97
HG2	40ºC	90 minute waiting	0.48	76	86	94
HG3	57ºC	90 minute waiting	0.62	77	84	91

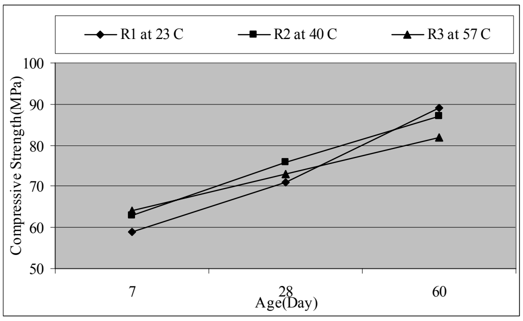

Figure (1): Compressive Strength test for Reference Concrete with direct cast

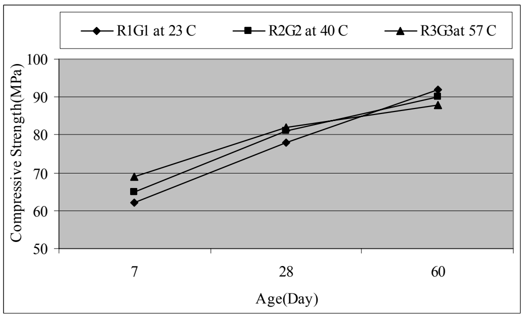

Figure (2): Compressive Strength test for Reference Concrete with 90 minute waiting

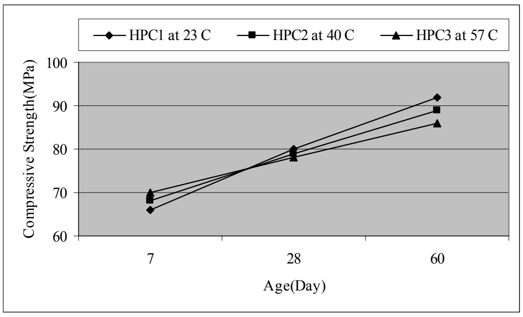

Figure (3): Compressive Strength test for High Performance Concrete with direct cast

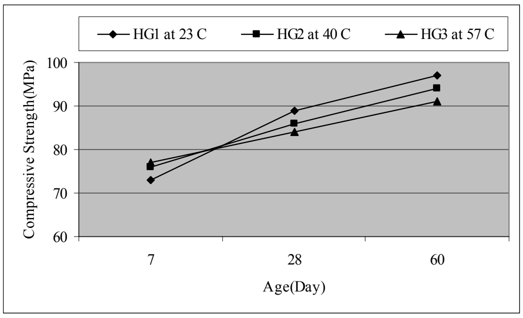

Figure (4): Compressive Strength test for High Performance Concrete with 90 minute waiting

Splitting Tensile Strength Test:

The tensile splitting strength determined according to the B.S.1881: part 117/1989 by using (100*2000 mm cylinders. Results for splitting tensile strength are presented in Table (13) and figures (5, 6, 7 and 8). We can notice that reference concrete and high performance concrete exhibit continuous increase in splitting strength starting from (7 days) to (56 day) because of continuity of hydration process. From all results it is clear that high performance concrete gives splitting strength higher than the reference concrete and that behavior due to the Pozzolanic reaction which reduce the micro cracking and strengthening the transition zone through the pore size and grain size refinement process, however the superplasticizer G51, tends to deflocculates and disperse the cement and High reactive metackoline agglomerates into individual particles. There is a greater statistical chance of intermeshing between the hydration products and the aggregate with the progress of hydration mechanism to make a system of higher internal integrity and hence superior tensile strength.

Table (13) shows that concrete mixes after 90 minute waiting before casting and retempered with superplasticizer give higher splitting tensile strength rather than concrete mixes with direct casting. All mixes showed increase in the splitting tensile strength with the increase of casting temperature from (23 ºC to 57 ºC) but it is decreases with the increase of the temperature at the age of 60 day.

Table (13): Splitting Tensile Test Results

Mix	Temp	Mix Condition	G51	Splitting Tensile (MPa)		
				7	28	56
R1	23ºC	Direct Cast	-	3.26	4.5	5.33
R2	40ºC	Direct Cast	-	3.67	4.71	5.23
R3	57ºC	Direct Cast	-	3.51	4.55	5.04
R1G1	23ºC	90 minute waiting	0.26	3.66	4.75	5.4
R2G2	40ºC	90 minute waiting	0.36	3.85	4.58	5.17
R3G3	57ºC	90 minute waiting	0.42	4.02	4.73	5.05
HPC1	23ºC	Direct Cast	-	3.72	4.82	5.48
HPC2	40ºC	Direct Cast	-	3.8	4.45	5.2
HPC3	57ºC	Direct Cast	-	3.89	4.32	4.75
HG1	23ºC	90 minute waiting	0.36	4.61	5.35	5.85
HG2	40ºC	90 minute waiting	0.48	4.7	5.01	5.58
HG3	57ºC	90 minute waiting	0.62	4.8	5.11	5.33

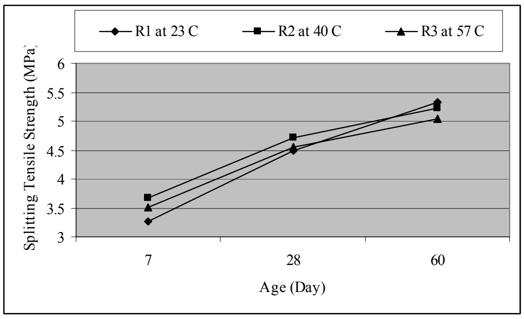

Figure (5): Splitting Tensile Strength test for Reference Concrete with direct cast

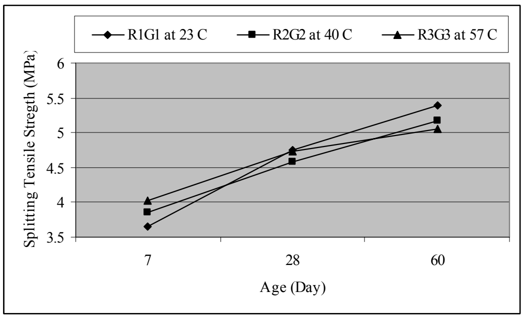

Figure (6): Splitting Tensile Strength test for Reference Concrete with 90 minute waiting time

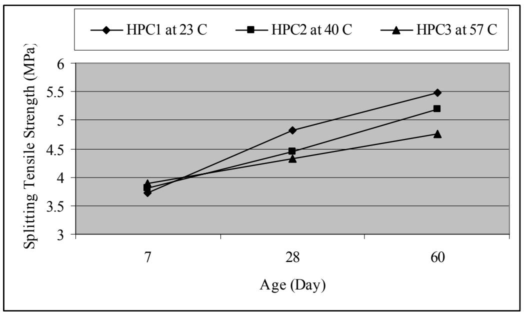

Figure (7): Splitting Tensile Strength test for High Performance Concrete with direct cast

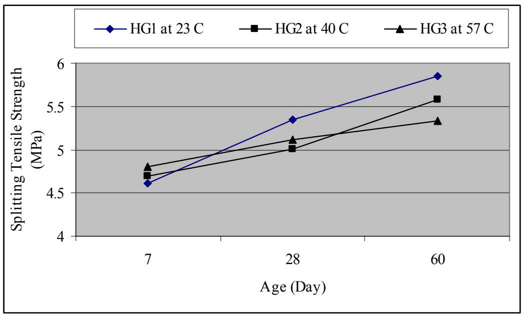

Figure (8): Splitting Tensile Strength test for High Performance Concrete with 90 minute waiting time

Flexural Test:

Simply supported prisms (100*100*400), has been used in this study to conduct the test according to the B.S. 1881: part 118/1989.All results for flexural test are presented in Table (14) and plotted in figures (9, 10, 11 and 12). These results showing that high performance concrete HPC exhibited a slight increase in flexural strength more than reference concrete. This behavior can be attributed to the reaction [Pozzolanic Reaction] between **High Reactivity Metakaoline** and the calcium hydroxide results during cement hydration. This reaction contributes the densification of the concrete matrix and strengthening the transition zone which reducing the microcracking leading to a significant increase in flexural strength.

Reference concrete mixes with waiting time 90 minute and high performance concrete in the same conditions (all retempered with superplasticizer) show a considerable increase in flexural strength and this is referred to the lower porosity associated with the reduction in w/c or w/cm ratios of such mixes and consequently better transition zone and also the Pozzolanic influence of high range metakaoline lead to increase the microstructure of the specimen and improve its mechanical properties.

From all results we can notice that flexural strength at early ages increase with the increase of ambient temperature and in the same time the strength started to decrease with the increase of ambient temperature.

Table (14): Flexural Test Results

Mix	Temp	Mix Condition	G51	Flexural Test (MPa)		
				7	28	56
R1	23ºC	Direct Cast	-	7.11	8.48	9.48
R2	40ºC	Direct Cast	-	7.23	8.55	9.41
R3	57ºC	Direct Cast	-	7.35	8.46	9.3
R1G1	23ºC	90 minute waiting	0.26	7.26	8.6	9.68
R2G2	40ºC	90 minute waiting	0.36	7.34	8.69	9.6
R3G3	57ºC	90 minute waiting	0.42	7.45	8.58	9.52
HPC1	23ºC	Direct Cast	-	7.29	8.69	9.6
HPC2	40ºC	Direct Cast	-	7.34	8.6	9.53
HPC3	57ºC	Direct Cast	-	7.45	8.57	9.39
HG1	23ºC	90 minute waiting	0.36	7.4	8.7	9.8
HG2	40ºC	90 minute waiting	0.48	7.49	8.73	9.74
HG3	57ºC	90 minute waiting	0.62	7.61	8.65	9.5

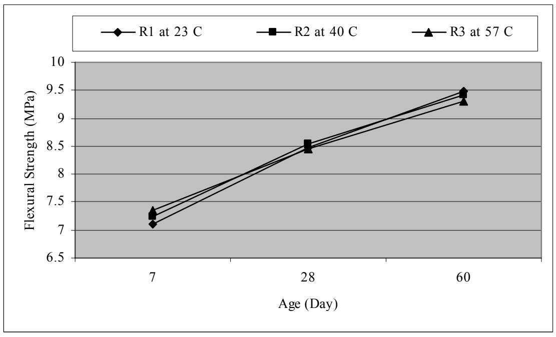

Figure (9): Flexural Strength test for Reference Concrete with direct cast

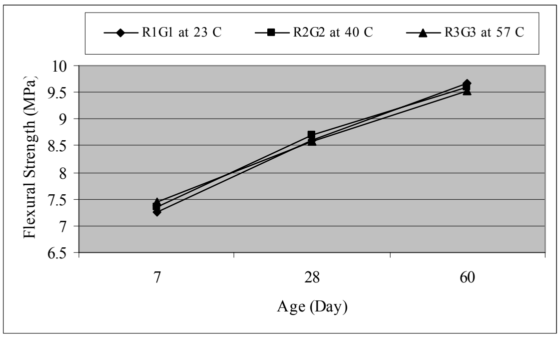

Figure (10): Flexural Strength test for Reference Concrete with direct cast

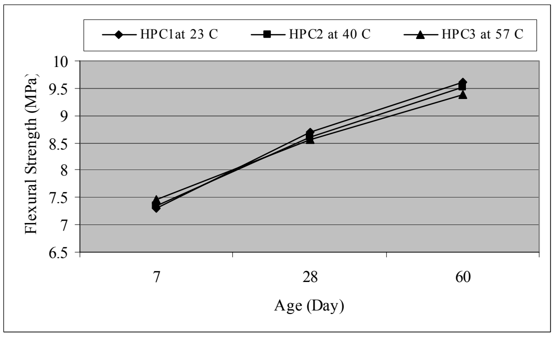

Figure (11): Flexural Strength test for High Performance Concrete with direct cast

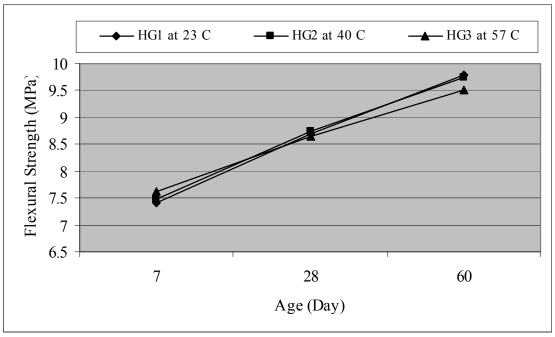

Figure (12): Flexural Strength test for High Performance Concrete with 90 minute waiting

Ultrasonic Pulse Velocity Test:

This test was determined according to the B.S. 1881: part 203 and ASTM C597-83, using (100*100*400) mm prisms.

The Ultrasonic pulse velocity (UPV) technique is used as a means of quality control of products which are supposed to be made of similar concrete: both lack of compaction and change in the water/cement ratio would be easily detected [17] and according to [17][18][19] it is useful to assess concrete uniformity, crack and voids detecting also it gives a good information about micro-cracks zone size, crack growth and the interior structure of the concrete elements. The results obtained in this test are shown in Table (15) and presented in Figures (13, 14, 15 and 16).

The velocity of the waves for all specimens increased in a slightly way with age progress starting from 7 days up to 56 day which means that this increase because of the progress of the hydration process which produce hydration products and decrease the void space in the concrete mass. The increase in the gel/space ratio causes a rise in wave speed, since the velocity of ultrasonic through materials is larger than that if it transfer through space and according to that the increase in the concrete mass within the same volume increases the ultrasonic velocity.

Through figures (11, 12, 13 and 14) high performance concrete gives ultrasonic pulse velocity higher than the reference concrete. High Reactive Metackaoline has a clear effect on the ultrasonic pulse velocity and this behavior is attributed to the Pozzolanic activity of HRM. This effect of HRM lead to increase the density of the transition zone and that will lead to higher velocity for mixes contain HRM

Table (15): Ultrasonic Pulse Velocity Results

Mix	Temp	Mix Condition	G51	U.P.V. (Km/s)		
				7	28	60
R1	23ºC	Direct Cast	-	3.97	4.38	4.75
R2	40ºC	Direct Cast	-	4.06	4.41	4.76
R3	57ºC	Direct Cast	-	4.1	4.44	4.79
R1G1	23ºC	90 minute waiting	0.26	4.09	4.45	4.82
R2G2	40ºC	90 minute waiting	0.36	4.16	4.48	4.84
R3G3	57ºC	90 minute waiting	0.42	4.21	4.5	4.77
HPC1	23ºC	Direct Cast	-	4.09	4.48	4.79
HPC2	40ºC	Direct Cast	-	4.15	4.53	4.71
HPC3	57ºC	Direct Cast	-	4.22	4.65	4.85
HG1	23ºC	90 minute waiting	0.36	4.21	4.63	4.96
HG2	40ºC	90 minute waiting	0.48	4.27	4.56	4.91
HG3	57ºC	90 minute waiting	0.62	4.3	4.69	4.98

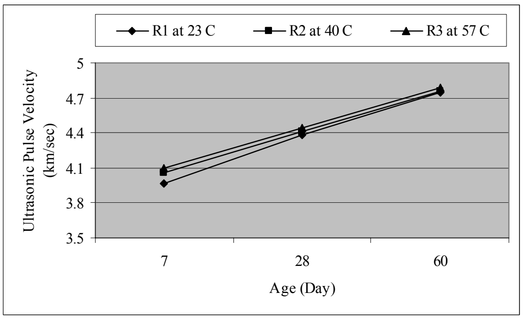

Figure (11): Ultrasonic Pulse Velocity test for Reference Concrete with direct cast

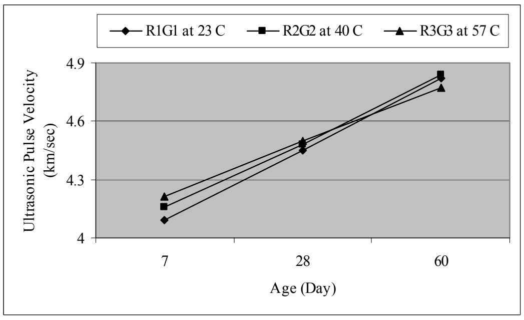

Figure (12): Ultrasonic Pulse Velocity test for Reference Concrete with 90 minute waiting time

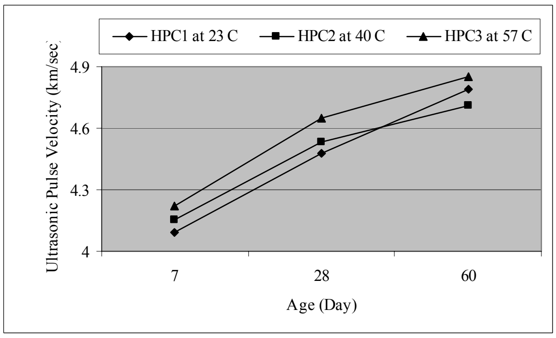

Figure (13): Ultrasonic Pulse Velocity test for High Performance Concrete with direct cast

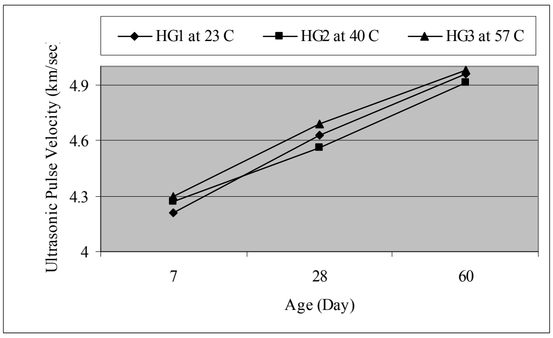

Figure (14): Ultrasonic Pulse Velocity test for High Performance Concrete with 90 minute waiting time

Conclusions:

1. Quantity of Superplasticizer admixture increased with the increase of temperature in both direct casting and 90 minutes waiting time for re-tempering.
2. Compressive strength of High performance concrete is higher than that of reference concrete in direct casting condition at all temperatures and at all ages.

The increase at age of 28 days was 10.23% at 23°C, 4% at 40°C and 6.4% at 57°C.

3. Compressive strength of High performance concrete retempered with G51 after 90 minutes waiting was higher than that of reference concrete at all ages and at all temperatures. The increase at age of 28 days was 12.36% at 23°C, 5.81% at 40°C and 2.8% at 57°C.
4. Re-tempering concrete after 90 minutes and using G51 showed an increase in splitting tensile strength. The increase was between (16.25-20.61) % with age of 7 days and (7.44-11.21) % at age of 28 days and between (5.3-8) % at age of 56 days for the three different degrees.
5. Flexural strength of HPC is higher than that for reference concrete at direct cast condition and with re-tempering after 90 minutes of waiting time at three different temperatures.
6. High performance concrete has a good performance for Ultrasonic Pulse Velocity as compared with reference concrete at the same age.
7. Re-tempering concrete after 90 minute waiting time and using G51 showed increase in Ultrasonic pulse velocity .
8. Mixes that are retempered by G51 give higher strength and higher Ultrasonic Pulse Velocity than mixes with direct casting.
9. Velocity of transferring the ultrasonic pulse increased with the increase of ambient temperatures.
10. Ultrasonic pulse velocity in different ambient temperatures increased with the progress of age for all specimens.
11. More test needed to study the relation between compressive strength results and Ultrasonic pulse velocity.

References:

1. M.S.j.Gani, "Cement and Concrete", Faculty or Engineering, Monash University, Victoria, Australia, 2003.
2. S. Mindess, "High Performance Concrete: Properties and Application", Department of Civil Engineering, University of British Columbia, Vanocouver. Canada.
3. ASTM, Specifications, C150-04, "Standard Specifications for Portland Cement", Vol. 04.02, 2004.
4. المواصفة القياسية العراقية رقم (٥) لسنة ١٩٨٤ "الاسمنت البورتلاندي" الجهاز المركزي للتقييس والسيطرة النوعية.
5. المواصفة القياسية العراقية رقم (٤٥) لسنة (١٩٨٤) ركام المصادر الطبيعية
6. Degussa, Construction Chemicals, "Glenium 51 Technical Data Sheet", 06/97 MBT-ME Revised 06/2005.
7. BASF the chemical company www.basf-cc.com.au
8. Ryan, W., "Properties of Ceramic Raw Materials", Pergaman Ltd., Second Edition, 1978, pp.113.
9. Justice, J.M., "Evaluation of Metakaolin for Use as Supplementary Cementitious Materials", M.Sc. Thesis, Georgia Institute of Technology, April 2005, pp.134.
10. Advanced Cement Technology, LLC, "High Reactivity Metakaolin (HRM) Engineering Material Admixture for Use with Portland Cement", www.sales@metakaolin.com 2002, pp.5.
11. Swamy, R.N., "Cement Replacement Materials", Concrete Technology and Design, Vol.3, 1986, pp.257.

12. ASTM C188-84, "Density of Hydraulic Cement", Annual Book of ASTM Standard American Society for Testing and Materials, Vol.04.01, 1984.
13. ASTM C204-84, "Standard test method for fineness of Portland Cement by Air Permeability Apparatus", Annual Book of ASTM Standard American Society for Testing and Materials, vol.04,01, 1989, pp.157-162.
14. ASTM C311-87a, "Standard Test Method for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland Cement Concrete", Annual Book of ASTM Standard, Vol.04-02, February 2003, pp.182-186.
15. الخلف، د. مؤيد نوري، ويوسف ، هناء عبد "تكنولوجيا الخرسانة" صفحة ٤٤٨-٤٨٩، ١٩٨٤
16. Brithish Standard Institute “Methods of Testing Concrete” BS 1881, London 1852.
17. Al-Khalil, I.K., “ Durability of High Performance Self Compacting Concrete Exposed to Chloride and Sulfate Solution”, M.Sc. Thesis, University of Technology, July 2005, pp.90.
18. الفحوص غير الاتلافية للخرسانة، مفيد عبد الوهاب السامرائي وزين العابدين رؤوف محمد ص، ٦٩
19. Jones, R. “The non-destructive testing of concrete”, Magazine of Concrete Research, No.2. June 1949, pp 67-78