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The Effect of Accelerated Curing on Compressive Strength of Self – compacting Concrete

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Abstract

The aim of this research is to study the effect of the process of accelerated curing on the compressive strength of Non - Vibrated Concrete. The study is divided into two parts the, first part including design of reference concrete containing 10% partial replacement of weight of cement, limestone powder (LSP), High Reactivity Metakaolin (HRM), and Ultra fine Fumed Silica (UFS), without Superplasticizer. The same mixes added with Superplasticizer have been exposed to conditions of moist curing for ages 28 & 56 days. Second Part , covered the study of compressive strength of the specimens of concrete mixes cube measuring (150mm) after exposure to accelerated curing cycle with three levels of temperature to include a wide range of change of temperature, according to the most important international standards and research which are (60 ℃ , 80 ℃ and 100 ℃) . Based on the results self-compacting concrete can be achieved during the one day accelerated curing at temperature of (80℃) for about 12- hour were reached (64 MPa). And the results that provided through mathematical equations derived from statistical analysis can be used to estimate the compressive strength of accelerated curing self-compacting concrete at 28 and 56 day.

الملخص

كان الهدف من هذا البحث هو دراسة تأثير الإنضاج المعجل على مقاومة الانضغاط للخرسانة الغير مرصوصة . تم تقسيم الدراسة إلى جزئيين الجزء الأول تصميم خلطات مرجعية تحتوي علي 10% استبدال جزئي من وزن السمنت ,من مسحوق الجير, الميتاكألين عالي الفعالية ومسحوق السليكا الناعم وبدون مضافات كيميائية .ونفس الخلطات السابقة الذكر, تم إضافة المضافات الكيميائية وتم تعريضها إلى ظروف الإنضاج في الماء للأعمار 28&56 يوم .

إما الجزء الثاني فشمل دراسة مقاومة الانضغاط للنماذج الخرسانيه(المكعب طول ضلعه 150 ملم) بعد تعريضها إلى دوره من الإنضاج المعجل إلى ثلاثة مستويات من درجات الحرارة لتشمل مدى واسع للتغير من درجات الحرارة وحسب توصيات اغلب المواصفات العالمية والبحوث (60 م° ,80 م°, 100م °) . من النتائج المستحصلة أن أفضل مقاومة انضغاط للخرسانة الذاتية الرص بعمر 1 يوم و بظروف الإنضاج المعجل بدرجة حرارة 80 م° و بفترة 12 ساعة حيث

بلغت (64) نيوتن/ملم^{2}.و من النتائج المستحصلة من خلال المعادلات الرياضية الناتجة من التحليل الإحصائي إلى إمكانية تقدير مقاومة الانضغاط لأعمار 28 و56 يوم من دورة الإنضاج المعجل .

1. Introduction:

Self-compacting concrete (SCC) developed in Japan in the late 1980 s is a relatively new material in civil engineering applications. It spreads into construction elements, e.g., highly congested reinforced column or wall, under its own weight and it provides good compaction without vibration. It has excellent deformability and high resistance to segregation [(1)]. SCC mixes usually contain superplasticizer, high content of fines and/or viscosity modifying admixture (VMA). Wetting concrete whilst the use of superplasticizer maintains the fluidity; the fine content provides stability of the mix resulting in resistance against bleeding and segregation. As fine materials (e.g. cement, pozzolans and filler) are substantial constituents of SCC, utilizations of fly ash (FA), silica fume (SF), ground granulated blast furnace slag (GGBS), or limestone filler in SCC contributes significantly to its fresh and hardened properties as well as to reducing its cost. Due to the enhanced rheological properties of SCC and its placing method (without vibration) into construction elements, it provides number of benefits both to the environment and to the contractors, e.g., faster construction, better surface finish, reduced noise level and safer working environment. It is estimated that using SCC may result in up to 40% faster construction than using PC concrete [(2)].

The major methods that exist for purpose of accelerating the curing process of concrete can be divided into two categories: physical processes and admixtures. Like most chemical reactions, the rate at which hydration occurs is very susceptible to temperature changes; with increased temperatures, the rate significantly increases. In concrete, this translates to the achievement of high early strengths; many precast manufacturers routinely achieve compressive strengths of 8, 300 psi in less than 24 hours, primarily through the use of elevated curing temperatures. The relationship between concrete strength gain and curing temperature has long been known. The implementation of elevated curing temperatures is a relatively straight forward process, and can be achieved without the need for a great deal of research and development. As a result, this is the primary method currently employed by commercial precast manufacturers. With recent advances in material technology, a number of admixtures (mineral and chemical) can be used, both directly and indirectly, as accelerating agents. However, compared with increased curing temperatures, the use of admixtures as accelerators can introduce numerous potential problems and difficulties [(3)].

1-1: The aim of this study:

The present study is aimed to:-

- Predication of the strength of SCC mixes at the 28 and 56 days from one day accelerated curing.
- Prediction of the best temperature to get the high strength from one day accelerated curing.
- Study the effect of the mineral admixtures on strength of one day accelerated curing SCC.

1-2: Research Significance:

The use of Self-Compacting Concrete (SCC) may help precast plant to produce high quality prestressed concrete members at reduced labor costs .concerns about the effect of SCC proportions on hardened properties have limited the wide spread use of SCC in precast concrete applications. Cubes were tested of compressive strength by accelerating curing depending on the different temperatures cycles of self-compacting concrete to predict the compressive strength 28 and 56 days from one day accelerating curing. The study of effect of mineral admixtures on properties of Self-Compacting Concrete by accelerated curing.

1-3: Accelerating Curing Cycle in Concrete:

A number of methods for proving accelerated strength have been proposed. these include applying heat to specimens by means of saturated steam, hot water, autoclaving, dry oven heat, electrical heat or autogenously [4] all of these methods use a curing cycle for this purpose as show in the Figure (1-1) for all concrete production adequate supply of moisture is essential to insure hydration of the cement .The accelerated curing cycle consist of four portions. All of these portions are completely interrelated. Any change in any portion of curing cycle may cause adverse effects in another portion of this cycle.

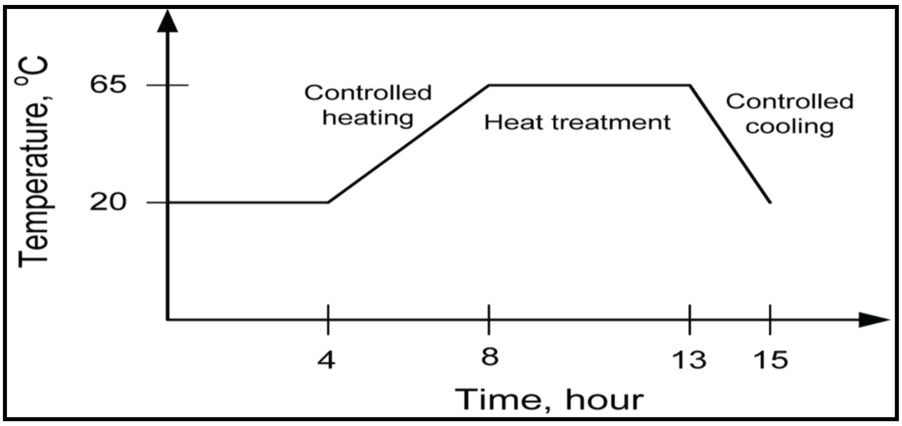

Figure (1-1): Typical idealized atmospheric steam curing cycle [4].

Schindler *et al.* [(5),] showed that, the Self-Consolidating Concrete, used in prestressed concrete application .Twenty one of SCC mixtures were made with varying W/C ratios, and sand to total aggregate ratio an cementations material type Ш, cement, flay ash ,ground –granular blast furnace slag, and silica fume , the accelerating curing temperature 65.6 °C for 18 hours ,the results compressive strength at SCC mixtures varied between (38 and 66 MPa), which slightly exceeded the target range (34 and 62 MPa). The two control mixtures had compressive strength values of (43 and 52 MPa).and the modulus of elasticity. Eighteen-hour Eci values of the SCC mixtures ranged from (32 and 41 GPa), while the two control mixtures had Ec*i* values (37 and 42 GPa). Fifty-six-day Ec values of the SCC mixtures ranged from (46 and 52 GPa), while the two control mixtures had 56-day Ec values of (45 and 48 GPa).

Alaa et al. [(6)] indicated that to study that the mechanical properties of SCC such as compressive strength, tensile strength and modulus of elasticity when exposed to cycles of elevated temperatures then treated in either water quench or air cooled. the variables included were the cycle temperature (20°C, 100°C, 150°C, and 200°C) and the treatmentty water quench or air cooled) at cement content of 500 kg/m^3 using ordinary Portland cement. Test results clearly show that a higher reduction in compressive, tensile strength and modulus of elasticity for SCC occur when exposed to cycles of elevated temperature then quenched in water. There was a significant increase in compressive strength, tensile strength and modulus of elasticity of SCC when cooled in air after exposing it to the same cycles of elevated temperatures.

The research carried out by Bentz *et al.* [(1)] showed that curing conditions have significant effect on the degree of hydration of cement. They showed that for specimens (initially cured at 100 % RH for 6 or 12 h) exposed to 90% RH, hydration process discontinued as all remaining capillary water was lost due to evaporation. Whilst curing under sealed condition, in particular for concretes with w/c of 0.4 or over, or keeping the surface as saturated were adequate. As there are significant differences between conventional vibrated PC concrete and SCC, particularly during their early stages, knowledge of mechanical properties of SCC under different curing environments needs to be explored. Al-khafaji [(7)] explained that, the strength can be achieved by exposing concrete to the accelerating curing temperature 80°C for 12 hours duration only. The possibility to approach 95% of the ultimate conventional module at this age. Mathematical models, using non -linear estimation for predicated static modulus of elasticity from the dynamic modulus of elasticity. AL-Rawi [(8)]**,** stated that ,the curing temperatures 70 °C for different kind of cements and also different fineness , the best results for 28 days strength coincide with the lower loss of 28 days strength , if delay period was 4 hours and oh temperatures of 12 °C/ hour. ACI committee 517 reported, that several researchers have found the most effect are obtained when the concrete is cured at temperatures between (66 -82) °C [(4)]. The concrete institute of Australia reported cited [(8)], 80°C of low pressure steam curing for most effective results. The British standard, cited [(9)], stated that for most effective results maximum curing temperatures between (35 -85) °C.

2. Experimental Work:

2-1: Cement:

The cement used in this study is Tasloiga ordinary Portland cement type (I). This cement is tested and checked according to Iraqi Standard Specification (I.Q.S 5:1984) [10]. Tables (2-1) and (2-2) show the chemical and physical properties of this cement and used respectively .Results indicate that the available cement is conformed to I.Q.S 5:1984.

Table (2-1): Chemical Composition of Tasloja Cement.

Chemical Composition		
Oxides	Cement %	Iraqi Specification Limits I.Q.S 5/1984
CaO	63.46	---
SiO_2	19.94	---
AL_2O_3	4.67	---
MgO	2.86	5 % max.
Fe_2O_3	3.29	---
SO_3	2.30	---
L.O.I	3.32	---
I.R	0.72	---
L.S.F.	0.97	0.66-1.02
C_3S	39.28 %	
C_2S	32.63 %	
C_3A	11.98 %	
C_4AF	8.00 %	

Table (2-2): Physical Properties of Tasloja Cement.

Physical Properties			
Property		Result	Iraqi Specification Limits I.O.S 5/1984
Fineness by air permeability method (Blaine)		3015	Not less than 2300cm^2/gm
Initial Setting time		170 min	> 45min.
Final Setting time		407 min	< 10hrs.
Compressive Strength(MPa)	3-day age	30 MPa	> 15 MPa
	7-day age	42 MPa	> 23 MPa

2.2 Fine Aggregate: -

Natural sand from Al-Ukhaider region is used. Table (2-3) shows the grading of the fine aggregate and the limits of the Iraqi specification **No.45/1984** (11).Table (2-4) shows the physical properties of the fine aggregate that are performed by the National Center for Construction Laboratories (NCCL).

Table (2-3): Grading of Fine Aggregate.

Sieve size (mm)	% Passing by weight	Limits of the Iraqi specification No.45/1984 (zone 2)
4.75	100	90-100
2.36	92	75-100
1.18	82	55-90
0.60	59	35-59
0.30	27	8-30
0.15	7	0-10

Table (2-4): Physical Properties of Fine Aggregate.

Physical Properties	Test Results	Limits of the Iraqi specification No.45/1984
Specific gravity	2.60	---
Sulfate content	0.08 %	$\leq$ 0.50 %
Absorption	0.75 %	---

2.3: Coarse Aggregate:

Crushed gravel of maximum size 14 mm from Al-Niba`ee region is used. Table (2-5) shows the grading of this aggregate, which conforms to the Iraqi Specification No.45/1984 [11] the specific gravity, sulfate content and absorption of coarse aggregate are illustrated in Table(2-6).

Table (2-5): Grading of Coarse aggregate

Sieve size (mm)	% Passing by weight	Limits of the Iraqi specification No.45/1984
14	100	100
10	89	85-100
5	11	0-25
2.36	0	0-5

Table (2-6): Physical Properties of Coarse Aggregate

Physical Properties	Test Results	Limits of the Iraqi specification No.45/1984
Specific gravity	2.63	-
Sulfate content	0.06 %	$\leq$ 0.1 %
Absorption	0.63 %	-

2.4: Mineral Admixture:

2.4.1: Limestone powder (LSP):

This material is locally named as “Al-Gubra”. It is a white grinding material from limestone ($CaCO_3$) excavated from different regions in Iraq, and usually used in the construction processes. In this work, a fine limestone powder, grinded by blowing technique, has been used. The cost of grinding is very low, and the fineness of the gained material is very high. The chemical composition of LSP is listed in Table (2-7).

Table (2-7): Chemical Composition and Physical Properties of Limestone Powder*.

Chemical Properties	
Oxides	Content %
SiO_2	1.38
Fe_2O_3	0.12
Al_2O_3	0.72
CaO	56.1
MgO	0.13
SO_3	0.21
L.O.I	4.56
Physical Properties	
Fineness by air Permeability method (Blaine)	3100 cm^2/gm
Specific gravity	2.60

***** The test is carried out in the National Center for Constructional Laboratories and Research.

2.4.2: High reactivity Metakaolin (HRM):

High reactivity Metakaolin (HRM) is an aluminum silicates pozzolan produced by clinking the kaolin (a fine, white, clay mineral that has been traditionaiiy used in the manufacture of porcelain) at temperatures of (700-900) ^oC. Locally available fine grain size kaolin clinks in laboratory using the burning kiln of clinkering ability up to 1200 ^oC. Kaolin is burned at 700 ^oC for whole one hour then left to cool down.

Pozzolanic Activity Index (P.A.I) of HRM with Portland cement is determined according to ASTM (311-89) [12]. The chemical and physical properties of HRM are listed in Table (2-8).

Table ***(2- 8): Chemical and physical properties of HRM*.***

Chemical Properties		
Oxides	**Content %**	**Pozzolanic class N**
SiO_2	51.34	70 % Min.
Fe_2O_3	2.30	
Al_2O_3	33.4	
CaO	3.00	
MgO	0.17	
SO_3	0.15	4% Max.
L.O.I	7.8	10% Max.
Physical Properties		
Specific Gravity	2.62	5% Max.
Fineness (Blaine) m^2/g	19000	---
Pozzolanic Activity Index	150	75

- Test was carried out at State Company of Geological Survey and Mining.

2.4.3: Ultra fine Silica Fume (SF):

Silica fume is a mineral admixture composed of ultra fine, amorphous glassy spheres of silicon dioxide (SiO_2), produced during the manufacture of silicon or ferrosilicon. This process involves the reduction of high purity quarts in electric arc furnaces at temperatures of over 2000 ^{o}C. Silica fume forms when SiO gas, given off as the quarts reduce, mixes with oxygen in the upper parts of the furnace. Here the SiO oxides to SiO_2, condensing to the pure spherical particles of silica fume that form the major part of the smoke or fume from the furnace. Hence the alternative names for the material- condensed silica fume or micro silica [13]. Tables (2-9) show chemical analysis and chemical requirement limits of the ASTM C 1240.

Table (2-9) Chemical analysis and Chemical requirements of SF *

<table>
<tr><th>Oxide composition</th><th colspan="2">Oxide content %</th></tr>
<tr><td>SiO_2</td><td colspan="2">95.95</td></tr>
<tr><td>Al_2O_3</td><td colspan="2">0.02</td></tr>
<tr><td>Fe_2O_3</td><td colspan="2">0.01</td></tr>
<tr><td>Na_2O</td><td colspan="2">0.00</td></tr>
<tr><td>K_2O</td><td colspan="2">0.07</td></tr>
<tr><td>CaO</td><td colspan="2">1.21</td></tr>
<tr><td>MgO</td><td colspan="2">0.01</td></tr>
<tr><td>SO_3</td><td colspan="2">0.22</td></tr>
<tr><td>L.O.I.</td><td colspan="2">2.5</td></tr>
<tr><td colspan="3">Chemical requirements of SF ASTM C I240</td></tr>
<tr><td>Oxide composition</td><td>Limit of specification requirement of SF ASTM C 1240</td><td>SF</td></tr>
<tr><td>SiO_2, min. %</td><td>70</td><td>95.95</td></tr>
<tr><td>Moisture content, max. %</td><td>3</td><td>0.8</td></tr>
</table>

*Test was carried out at the National center of Geological Survey and Mining.

3. Concrete mixtures:

Mix design of SCC must satisfy the criteria of filling ability, passing ability and segregation resistance. The mix design method used in the study is according to EFNARC 2002 [(14)], and then the proportions of materials are modified after obtaining a satisfactory self-compactability by evaluating fresh concrete tests. Eight concrete mixture types were used, four References concrete, without suprerplastazer (S.P) name (RC), it used limestone powder (LSP) replacement of cement weight, mix name (RCL) ,High Reactive Metakaolin (HRM) name (RCM) and ultra silica fume(USF) mix name (RCF) , minerals admixture 10% replacements from cement weight . The other four are mixes SCC, it used limestone powder, High Reactive Metakaolin and ultra silica fume replacement of 10 % of cement weight ,as mineral admixtures mixes name (SCCL,SCCM,SCCF) respectively. as show Details of Mixes in table (3-1).

Table (3-1): Details of Mixes.

Mix	Water l/m³	Cement kg/m³	Limeston Powder kg/m³	High Reactivity Metakaolin kg/m³	Silica Fume kg/m³	Fine aggregate kg/m³	Coarse aggregate kg/m³	S.P l/m³	Water/ powder Ratio
RC	270	500	---	---	---	970	780	---	0.54
RCL	273	450	50	---	---	970	780	---	0.54
RCM	280	450	---	50	---	970	780	---	0.56
RCF	284	450	---	---	50	970	780	---	0.56
SCC	170	500	---	---	---	970	780	5.0	0.35
SCCL	170	450	50	---	---	970	780	5.0	0.35
SCCM	170	450	---	50	---	970	780	6.4	0.35
SCCF	170	450	---	---	50	970	780	6.9	0.35

*S.P=superplasticizer dosage.

3.1: Specimens Casting and Curing procedures:

In this study, four mixes (References mixes specimens) were cast on a vibrating table, results to optimum compactions. The SCC specimens were cast without any vibration. The specimens are most cured for four hours (preset period) .These specimens are immersed in the accelerated curing, heated electrically, in curing tank. Temperature is controlled at the required levels (60˚C, 80˚C and, 100˚C).The rate rise is 30˚ C / h which represents a moderate rate of temperature rise. The period of curing at the maximum temperature is about (12±1) hours. At the end of curing time, the heater is switched off automatically by electrical timer. Specimens are removed from curing tank , as shown in figure (3-1),three 150 mm cube are tested the compressive strength while the remaining cubes are stored in normal curing tank for 28 days and 56 days.

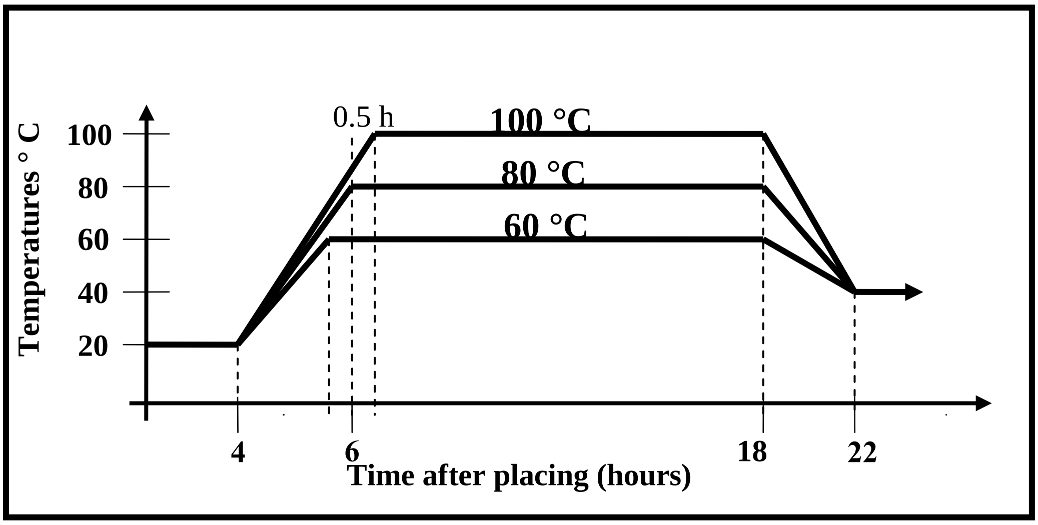

Figure (3-1): The accelerating curing cycle made by the researcher.

4. Results and Discussions:

4.1 Properties of Fresh concrete:

In order to achieve the test properties of fresh concrete .Reference concrete mixture (RC, RCL, RCM, and RCF) were tested slump test only. Self-compacting concrete mixes (SCC ,SCCL,SCCM,SCCF) must require of three characteristics of filling ability , passing ability and segregation resistance ,that respond to test Slump flow, T50 ,L-Box test and V-funnel test respectively . Results as shown in table (4-1). The results obtained of experimental work the dosage of SP used in SCC depend on the mineral admixture types due to their different fineness, particle shape and size. Mix SCCL gave better workability compared to mixes (SCC, SCCM, SCCF) gave decrease the workability .The results were agreed with Truckele and Altuntas [16].

Table (4-1): Results of fresh concrete properties

Mix	Slump/Slump flow (mm)	T50 (sec.)	V-funnel		L-BOX (H_2/H_1)
			TV (sec.)	Tv 5 (sec.)	
RC	75	---	---	---	----
RCL	72	---	---	---	---
RCM	70	---	---	---	---
RCF	70	---	---	----	---
SCC	750	4.0	3.5	4	0.94
SCCL	760	3.5	3.0	3.5	0.96
SCCM	720	4.5	5	7	0.91
SCCF	710	4.5	5	8	0.90

4.2: Hardened SCC Properties:-

4.2.1: Compressive Strength for Normal Curing Condition:

Three cubes are tested at each and the results are shown in Table (4-2) and Figure (4-1) for reference mixes and SCC mixes. The results of compressive strength was about (40.2-85) MPa for all mixes, these gave good results about strength development for reference and SCC mixes. It is seen that, using S.P chemical admixture increase of compressive strength about (13-23) %at 28 &56 day for all mixes. The effect of mineral admixture as replacement 10% for cement weight gave increase in strength about (10, 15) % for RCM& RCF compared of RC and (6, 19) % for SCCM, SCCF compared of SCC, But mixes contented LSP gave low compressive strength about (11, 17) % for mixes RCL and SCCL. The increase in strength in system of concrete containing pozzolanic materials play an important role improving the aggregate–past bound through the densification of the transition zone and formation of more silicate hydrates [9]. The LSP was not contain pozzolanic materials that contributes little to the strength of concrete, the LSP appropriate improve workability [16].

Table (4-2): Results of Compressive strength concrete mixes for Normal curing.

Mix	28-day	56-day
RC	45.0	54.2
RCL	40.2	48.3
RCM	50.7	60.1
RCF	53.0	65.0
SCC	59.0	65.8
SCCL	48.9	57.5
SCCM	62.7	74.8
SCCF	73.0	85.0

4.2.2: Compressive Strength for Accelerating Curing Condition:

The compressive strength for accelerated curing conditions are shown in Table (4-3) ,these results are versus the different temperatures for all mixes at 1-day accelerating curing age , 1-day accelerating curing age plus 27 day normal curing and 1- day accelerating curing age plus 55 day normal curing . At 1-day accelerating curing age, it noticed that, increase about (17-21) % for reference concrete and (5-10) % for SCC mixes at 60 - 80 ˚C curing temperatures. While no fixed various fixed results at 100˚C curing temperatures. It is noticed that ,the effect the pozzolainc materials on accelerating curing is clear that mixes SCCF gave high strength about 27 % at 60 ˚C, 100˚C while 23 % at 80˚C , the mix SCCM gave high strength about (11-14) % , and SCCL gave lower strength about (19-20) % compared with SCC without mineral admixtures . At 1-day accelerating curing at 60 ˚C curing temperatures, mixes reference concrete gave low strength about (41, 47, 38, 36) % compared to normal curing at 28 days for reference concrete, and mixes (SCC,SCCL,SCCM,SCCF) gave low strength about (25 ,26,19,18)% respectively . It clear that there is a high beneficial effect of S.P using for SCC mixes than reference concrete. On 80 ˚C curing temperatures, the best results gave high strength about (25, 36, 26, 22) % for reference concrete, while for SCC mixes (17, 22, 12, 11) % for SCC, SCCL, SCCM, SCCF compared to normal curing at 28 days. The percentage of increases at 100˚C curing temperatures; was various between at 60 ˚C and 80 ˚C curing temperatures record values of strength . The mixes SCC strength gain is about (80) % of normal compressive strength on the 80˚C curing temperature in additions to (±7) tolerances, while reference concrete gain is about 70% (±7). The curing temperatures 60˚C gave about 75 %, 55% for reference concrete at (±5) tolerances. The accelerated curing temperatures of boiling water gave about (66%) for reference concrete while 76% for self-compacting concrete mixes. It is noted that the SCCF gave higher strength with different temperatures and SCCM mix low about 16 % compared to SCCF the attributed to silica ratio and fineness alter silica fume.

At 28 &56 day accelerated curing increasing curing temperatures from 60˚C to 80 ˚C leads to about (4%) and (3%) decrees at temperatures 100˚C for all mixes at 28 days age. The percentage increase slightly decreased at 56 days. The strength increased about 2% and decreased 3% for all mixes.

Table (4-3): Compressive strength of concrete mixes for Different Accelerating curing temperatures

Mix	Curing Temperatures (˚C)	1-day	28-day	56- day
RC	60˚C	26.7	44.3	53.3
RCL		21.5	43.7	46.5
RCM		32.7	50.0	59.4
RCF		34.9	54.5	64.3
SCC		44.2	58.5	63.4
SCCL		36.0	50.2	55.3
SCCM		50.6	64.1	71.0
SCCF		60.0	74.2	83.7
RC	80˚C	33.7	46.1	54.2
RCL		25.8	44.8	48.3
RCM		37.4	52.3	60.2
RCF		41.5	56.5	65.7
SCC		49.0	60.0	66.2
SCCL		38.0	50.5	57.5
SCCM		55.0	65.8	73.5
SCCF		64.2	75.6	84.2
RC	100˚C	30.4	44.5	53.4
RCL		25.8	43.5	47.0
RCM		35.4	51.7	60.0
RCF		37.8	55.2	65.1
SCC		46.1	58.7	64.8
SCCL		37.0	51.4	57.0
SCCM		53.5	64.3	73.5
SCCF		63.0	75.5	85.0

4-3: One day accelerating curing compressive strength versus 28 and 56 day normal strength:

As mention earlier , it would be tremendous an advantage to be able to predict the 28 days strength as well as 56 day strength in some cases within few hours of concrete placing. It found the relation between the accelerating curing strength and its normal strength at 28 day and 56 day for SCC mixes. Based on the statistical analysis the relationship between the 1-day accelerating curing with 28 day normal curing as shown in figure (4-3) the relationship was uniform the curve, and the relationship correlation coefficient value was high R = 0.97

$fc^{-}_{(28\ day)} = 0.8004\ fc^{-}_{(1\text{-}day\ acce)} + 21.528$ …….(R=0.97) ………. Eq.4-1

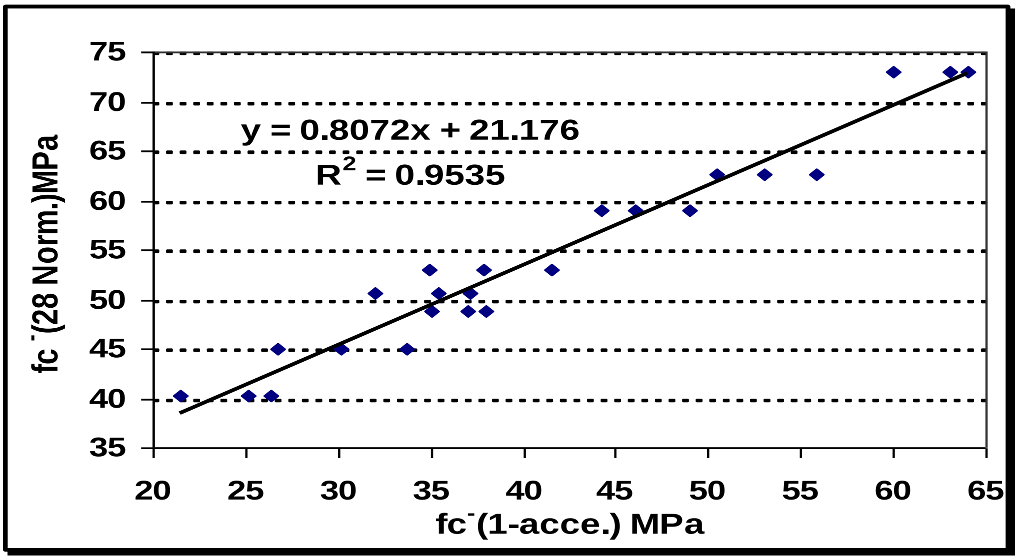

Figure (4-3): 28 days Normal Compressive Strength versus (1- day) Accelerated Strengths for different Curing Temperatures.

The correlation above separates for the different curing temperatures, as shown in Figures (4-4) for the curing temperatures (60˚C, 80˚C and 100˚C) respectively.

It's noticed that, the correlation coefficient value results better than accelerating curing cycle at the separate as shown in figure (4-4) and expressions that showed below are found to be valid for each specified curing temperatures.

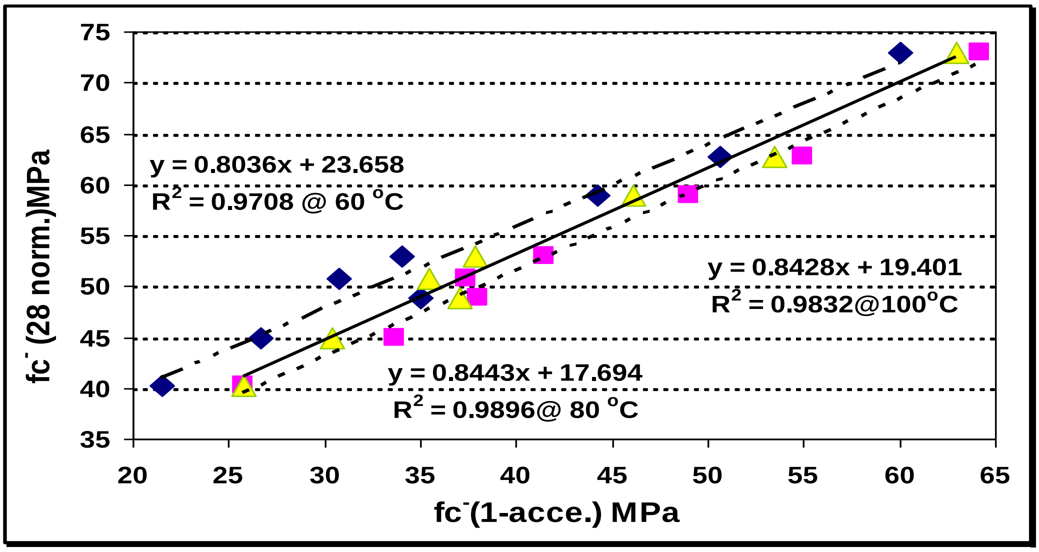

Figure (4- 4): 28 days Normal Compressive Strength versus (1- day) Accelerated Strengths for different Curing Temperatures.

$fc^{'}_{(28\ day)} = 0.8036\ fc^{'}_{(1\ \text{-accel.})} + 23.658$ (R=0.98) Temp. 60˚C **Eq.4-2**

$fc^{'}_{(28\ day)} = 0.8443\ fc^{'}_{(1\ \text{-accel.})} + 17.964$ (R=0.99) Temp. 80˚C **Eq.4-3**

$fc^{'}_{(28\ day)} = 0.8428\ fc^{'}_{(1\text{-accel.})} + 19.401$ (R=0.99) Temp. 100˚C **Eq.4-4**

It is apparent that the relationships mentioned are linear and correlation coefficient is high. These equation agrees weel with some researchers [16, 17] and al-Rawi [8]**.** These agreements and indicates the efficiency of accelerated curing cycle test and chosen to get the best temperature results to predict to 28 day strength from 1 day accelerating curing cycle for self-compacting concrete. When accelerating strength versus their normal curing 56 day age, the correlation coefficient (0.96) lower than those obtained from 28 days (o.99). The effect curing temperatures also indicated the correlation coefficient the expression to as follows

$fc^{'}_{(56\ day)} = 0.8556\ fc^{'}_{(1\text{-accel.})} + 29.618$ (R=0.96) ……………… **Eq.4-5**

Figure (4-5) represents that the relationship is linear. This equation does not agree with equation AL-Khafaji [18] drived from his studies of high strength concrete .

Finally the predicted values of normal strength are under or over estimated from those observed strength within about ± (5) MPa

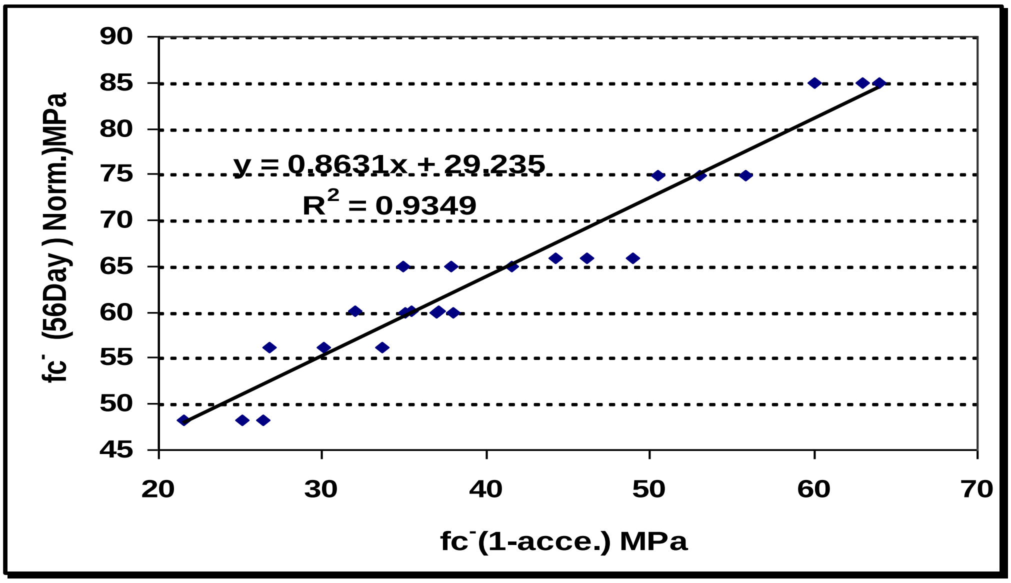

Figure (4- 5): 56 days Normal Compressive Strength versus (1- day) Accelerated Strengths for different Curing Temperatures.

5. Conclusions

Based on the test results presented in this study, the following conclusions can be drawn

1. Accelerating curing at 60 ˚C gives about (75) % compressive strength from 28 day normal curing strength while curing temperatures of (80 -100) ˚C gives about (80-76) % accelerating compressive strength respectively.
2. Accelerating curing at 80˚C enhances the strength about (4) % at the age 28 days compressive with respect to 28 days normal curing strength. And decrease (3) % for similar manner occurs on the 100˚C accelerating curing.
3. The best temperatures for the accelerated curing are found to be equal to 80˚C.
4. It is found that dosages of suprerplastazer change with mineral admixtures types in using 10 % replacement of cement weight as ultra silic fume increasing dosage and high reactive metakaolin while using limestone powder same suprerplastazer dosage compared to SCC without mineral admixtures. The limestone powder improved from the fresh properties of SCC mixes.
5. It is found that the percentage of increases and decreases in the compressive strength of age of 56 days is about 3% and 2% respectively.
6. It is found a good correlation between 1-day accelerated curing with 28 day and 56 day with correlation coefficient (0.97 & 0.99) for 24 cubes tested.

7. It is found that mixes containing ultra silica fume 10% replacement of cement gives a higher compressive strength than other mixes.

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