Chapter Four

Experiments and laboratory Testing

4.1 Introduction:

In this section ,an intensive laboratory investigation was done, for the effect of high temperatures on hardened concrete mixes .preliminary testes of materials such as local ordinary Portland cement ,and Aggregates used in this Study have been carried out on college of Engineering lab at omdurman Islamic university and China Jiangsu committees company .

Moreover , large numbers of experiments concerning workability and compressive strength of concrete mixes , with and without adding super plastizers , have been done.

One group of cubes (15) without using of additives were casted in standard test moulds of 150 mm cubic –{according to BS1881:section 108and 116}{} with a compressive strength of concrete equal to 30 Mpa . Then these cubes are cured to 28 days and exposed to different Temperature degrees.

The other group of cubes (15) by adding a super plasticizer {appendix A} to concrete mixes were casted with a compressive strength of concrete equal to 40 Mpa . thus ,these cubes are cured to 28 days and exposed to different Temperature degrees .

Eventually , the results of these experiments are shown in the following tables and figures

4.2 Experimental program:

The purpose of this experimental work is to identify the applicability of compressive strength test to evaluate the deterioration of concrete and measure the compressive strength and that under the impact of elevated temperature on concrete.

Therefore, in order to examine the impact of elevated temperature on concrete's compressive strength and deterioration by using the compressive strength test; two grades of concrete were designed and casted with different mixes proportion and were selected and named as: Grade 40, Grade 30.

However, to investigate if there is any significant relation between compressive strength for mix design (1) see mix design sheet in table (4.2) and mix design (2) see mix design sheet in table (4.3) when the concrete is subjected to elevated temperature; each of the previous grades will contain a group of fifteen cubes are to be casted and cured for 28 days. Each group is divided into five sets namely as A, B, C, D and E and each set consisting of three cubes. then set (A) is to be direct tested for compressive strength at room temperature, the remaining sets (B, C, D and E) are to be subjected to elevated temperature at 100ºC, 100ºC, 200ºC, and 300ºC in times 45 minutes , 1.5 hours , 1.5 hours and 1.5 hours respectively , then will to be tested by compressive strength.

Table(4.1) : Mix design (1)

Variables / Cubes Group	Fcu (N/mm^2)	C^0	T (min)	Remark
A	30	-	-	Reference cubes
B	30	100	45	-
C	30	100	90	-
D	30	200	90	-
E	30	300	90	-

Table(4.2) : Mix design (2)

Variables / Cubes Groub	Fcu (N/mm^2)	C^0	T (min)	Remark
A	40	-	-	Reference cubes
B	40	100	45	-
C	40	100	90	-
D	40	200	90	-
E	40	300	90	-

In order to achieve the previous tests on the samples, the experimental procedures are outlined as following:

i. The Specification and properties of all materials and their tests will be performed according to British standard codes of practice.

ii. The design of mixes will be performed according to British code of practice BS 5238 and BS 8110 department of environment (DoE).

iii. Mix and cast all groups of cubes for both grade of concrete and cure in water for 28 days according to (BS 5238 and BS 8110).

iv. The crushing compressive strength test will also perform on one set (set A) for each grade also at room temperature.

v. The four sets (B, C, D and E) for each grades individually will be heated in an electrical Oven ,each set to specified temperature namely to 100ºC, 100ºC, 200ºC, and 300ºC in times 45 minutes ,1.5 hours , 1.5 hours and 1.5 hours respectively, each degree will maintain at rate of heating approximately to achieve the thermal steady state for the samples.

vi. The thermally treated sets will be allowed to cool down naturally to room temperature.

vii. Crushing compressive strength test will be performed on the sets

viii. The average value of compressive strength for each set for mix design (1) will compare with the average value that estimated from mix design (2) for each set before and after heating.

4.2.1 Concrete ingredients:

To prepare the two different concrete mixes, a single batch of each of the following materials was prepared:

1. **Cement:**

Locally available Ordinary Portland Cement produced in (Sakhr AL Sudan Cement Factory) according to the Sudanese standard and specification, and it specified as (ASTM Type-I Ordinary Portland cement).

The following laboratory tests on physical properties of cement were conducted:

i. **Consistence of standard paste**.

For the determination of the initial and final setting time, cement paste of standard consistence should be used, therefore to determine the water content for any given cement to produce the desired consistence. The water content of standard paste is express as percentage by weight of dry cement.

ii. Setting time.

Setting time refers to the change from a fluid state to a rigid state, which refers to the gain of strength of a set cement paste. The setting process is accompanied by temperature change in the cement paste, initial set corresponds to a rapid rise in temperature and final set to the peak temperature.

Table (4.3): Setting time of cement

Test conducted	**Results**	**BS12-1996 Requirement**
Initial setting time	2 hrs. : 29 min.	Not less than 60 min.
Final setting time	4 hrs. : 42 min.	Not more than 10 hrs

ii. Compressive strength. Strength of hardened cement is the most obviously required for concrete uses, therefore, the compressive strength test is prescribed by all specifications for cement.

Table (4.4): Cement paste compressive strength

Test conducted	**Results**	**BS-11996Requirement**
Compressive strength (N/mm^2) 2 days	**1- 23.4 N/mm^2** **2- 24.1 N/mm^2** **3- 25.1 N/mm^2** **Average = 24.3N/mm^2**	**Not less than10N/mm^2**
Compressive strength (N/mm^2) 28 days	**1- 47.4 N/mm^2** **2- 48.1 N/mm^2** **3- 49.4 N/mm^2** **Average = 48.3N/mm^2**	**Not less than42.5N/mm^2**

2 Fine aggregate.

Valley fine (uncrushed aggregate) is obtained from (North Khartoum) nearby Khartoum Bahry area and specified as No.4 Nominal Maximum Size. The following laboratory tests were conducted on the fine aggregates: i. Sieve analysis according to (BS 882: 1992).

3 Course aggregate:

Crushed aggregate with maximum size of aggregate 20 mm were obtained from the local market (umdorman area) and the laboratory tests were conducted on the coarse aggregates.

4 Water.

Ordinary drinking water (tap water) was obtained from Khartoum area and no tests are required.

5 Chemical additive :

Used for sroc conplast sp 432ms with the specification following :

Conplast sp432ms is a chloride free , super plasticizing admixture based on selected sulphonated naphthalene polymers . its supplied as a brown solution which instantly disperses in water.

Conplast sp432ms disperses the fine particles in the concrete mix , enabling the water content of the concrete to perform more effectively . the very high levels of water reduction possible allow major increases in strength to be obtained .

Uses:

- to provide increased ultimate strength gain by significantly reducing water demand in a concrete mix
- to significantly improve the workability and retention of site mixed concrete without increasing water demand.
- To provide improved durability by increasing ultimate strength and reducing concrete permeability.

- Specifically developed for use in high quality concrete mixes utilizing cement replacement.

Advantages:

- Makes possible major reduction in water cement ratio which allows the production of high strength concrete without excessive cement contents.
- Increased workability levels are maintained for longer than with ordinary sulphonated melamine and naphthalene admixtures.
- Improved cohesion and particle dispersion minimizes segregation and bleeding and improves pump ability.
- Chloride free, safe for use in pre stressed and reinforced concrete.

Proportioning, mixing and casting of specimens :

The mix proportions were prepared according to British standards -BS 5238 and BS 8110 (DOE) - for the two mixtures with (w/c) ratio 0.47 and 0.49 and cement content 340 and 367 kg/ . The material used in design mixes were shown in the previous section.

It was not possible to match the higher strength grades (grade 40) and have practical workable mixes for these latter concrete grades, even though, an admixture (water reducer) had to be used and so (w/c) ratio was decrease in order to maintain a workable concrete with high strength. The principal criterion for the concrete workability was that it should be easily placed into the moulds without excessive vibration. The mixes design data sheets of all four grades are present in the following tables.

Table (4.5): concrete mix design (1) Grade 30 without additive

Stage item	**Reference or calculation**	Values
1.1 Characteristic strength	specified {30 N/mm^2 }at 28 days	
		Proportion defection 2.5 percent
1.2 Standard deviation	Fig 1	8 N/mm^2 or no data ……. N/mm^2
1.3 Margin	Cl	(k=1.96× 8 = 15.68 N/mm^2
1.4 Target mean strength	C2	30 + 15.68 = 46 N/mm^2
1.5 Cement type	specified	OPC
1.6 aggregate type: Coarse		Crushed
Aggregate type: fine		Crushed
1.7 free water/cement ratio	table 1 Fig 2	0.47 ⎫ Use the lower value
1.8 Maximum free water/ cement ratio	specified	0.55 ⎭
2.1 Slump or V.B	specified	Slump 10-30 mm or V.B
2.2 Maximum aggregate size	specified	20 mm
2.3 Free-water content	Table 3	160 kg/m^3
3.1 Cement content	C3	160 ÷ 0.47 = 340 kg/m^3
3.2 Minimum cement content	specified	320 kg/m^3
3.3 Maximum cement content	specified_ kg/m^3_ use if greater than item 3.1 and	
Calculate item 3.4		
3.4 Modified free-water / cement ratio		

o4.1 Relative density of aggregate (SSD)		2.6 Known/ assumed
4.2 Concrete density	Fig 3	2400 kg/m^3
4.3 Total aggregate content	C4	2400-160-340= 1900 kg/m^3

5.1 grading of fine aggregate		Percentage passing 600 an sieve	70%
5.2 Proportion of fine aggregate	C5	fig 4	27%
5.3 fine aggregate content		0.27 × 1900 = 512 kg/m^3	
5.4 Coarse aggregate content	C5	1900 – 512 = 1387 kg/m^3	

Quantities	Cement (kg)	Water (kg or L)	Fine aggregate (kg)	Coarse aggregate (kg)
Per m^3 (to nearest 5 kg)	340	160	513	1387
Per trial mix of ….. m^3	2.754	1.296	4.155	11.235

Table (4.6): concrete mix design (2) Grade 40 with additive

Stage item	Reference or calculation	Values
1.1 Characteristic strength	specified {40 N/mm^2} at 28 days	
		Proportion defection 2.5 percent
1.2 Standard deviation	Fig 1	10 N/mm^2 or no data ……. N/mm^2
1.3 Margin	Cl	(k=1.96× 10 =1 9.6 N/mm^2
1.4 Target mean strength	C2	40 + 19.6 = 59.6 N/mm^2
1.5 Cement type	specified	OPC
1.6 aggregate type: Coarse		crushed
Aggregate type: fine		Uncrushed
1.7 free water/cement ratio	table 1 Fig 2	0.49] Use the lower value
1.8 Maximum free water/ cement ratio	specified	0.55
2.1 Slump or V.B	specified	Slump 10-30 mm or V.B
2.2 Maximum aggregate size	specified	20 mm
2.3 Free-water content	Table 3	180 kg/m^3
3.1 Cement content	C3	180 ÷ 0.49 = 367 kg/m^3
3.2 Minimum cement content	specified	320 kg/m^3
3.3 Maximum cement content	specified_ kg/m^3_ use if greater than item 3.1 and	
Calculate item 3.4		
3.4 Modified free-water / cement ratio		
o4.1 Relative density of aggregate (SSD)		2.6 Known/ assumed

4.2 Concrete density	Fig 3	2400 kg/m^3
4.3 Total aggregate content	C4	2400-180-367= 1860 kg/m^3
5.1 grading of fine aggregate	Percentage passing 600 an sieve	70%
5.2 Proportion of fine aggregate	fig 4	27%
5.3 fine aggregate content	C5	0.27 ×1860 = 502kg/m^3

5-4 Additive(Type Sp 432*dos)

Quantities	Cement (kg)	Water (kg or L)	Fine aggregate (kg)	Coarse aggregate (kg)	Additive (Liter)
Per m^3 (to nearest 5 kg)	370	180	502	1350	60
Per trial mix of ….. m^3	3.4	1.12	4.121	11.10.25	

5.4 Coarse aggregate content	C5	1860 – 502 = 1350 kg/m^3

4.2.2 Curing and testing of specimens:

Cubic specimens having the dimensions of 150 mm in length and 150*150 mm in cross section were prepared and the specimens were cast in order of 15 cubes at a time for both grade. The concrete was casted in a horizontal pan and paddle mixer and compacted within their moulds by standard -16 mm diameter. Sufficient concrete was produced for both mixes to allow for slump test on concrete in fresh state. Paddle mixer the moulds that filled with concrete were kept at lab room allowing the concrete to harden for 24 hours before de-molding and placing in water. The specimens were kept in water for curing process for a further 28 days before testing.

4.2.3 Slump test results:

- Mix design (1) without additives (slump test) = 13 cm
- Mix design (2) with additives (slump test) = 14.2 cm

4.2.4 Compressive strength results:

The first mix was ordinary concrete without Additive with a compressive strength of 30N/mm^2.

These specimens were divided into 5 groups and the number of each group consisted of 3 cubes

1. The first group (A) as reference ones has been tested and results were recorded directly.
2. The second group (B) was exposed to a temperature of 100^{o}c at 45 minutes, thus the specimens were tested and results were recorded.
3. The third group was exposed to a temperature of 100 ^{0}c at 1.5 hours , thus the specimens were tested and results were recorded.
4. The forth group was exposed to a temperature of 200^{0}c at 1.5hours , , thus the specimens were tested and results were recorded.

5. The fifth group was exposed to a temperature of 300^0c at 1.5 hours, thus the specimens were tested and results were recorded.

Table (4.7): Result of compressive strength for mix (1)

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	935	41.4
2	150*150*150	22500	1130	50.2
3	150*150*150	22500	1050	46.6
Average				46.1

Table (4.8): Result of compressive strength for mix (1) in degree{ 100^0c / 45 min}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	880	39.1
2	150*150*150	22500	910	40.4
3	150*150*150	22500	900	40
Average				39.8

Table (4.9): Result of compressive strength for mix (1) in degree{ 100^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	650	28.9
2	150*150*150	22500	805	35.8
3	150*150*150	22500	780	34.7
Average				33.1

Table (4.10): Result of compressive strength for mix (1) in degree{ 200^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	710	31.6
2	150*150*150	22500	680	30.2
3	150*150*150	22500	640	28.4
Average				30.1

Table (4.11): Result of compressive strength for mix (1) in degree{ 300^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	670	29.8
2	150*150*150	22500	675	30
3	150*150*150	22500	610	27.1
Average				29

The second mix is the high strength concrete with additive, with target compressive strength of 40N/mm^2

The specimens for mix design (2) were divided into 5 groups and the number of each group consisted of 3 cubes .

1. The first group as reference ones has been tested and results were recorded directly.
2. The second group was exposed to a temperature of 100^{o}c at 45 minutes, thus the specimens were tested and results were recorded.
3. The third group was exposed to a temperature of 100 ^{0}c at 1.5 hours , thus the specimens were tested and results were recorded.
4. The forth group was exposed to a temperature of 200^{0}c at 1.5hours , , thus the specimens were tested and results were recorded.
5. The fifth group was exposed to a temperature of 300^{0}c at 1.5 hours, thus the specimens were tested and results were recorded.

Table (4.12): Result of compressive strength for mix (2)

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	1110	49.3
2	150*150*150	22500	980	43.6
3	150*150*150	22500	1130	50.2
Average				47.7

Table (4.13): Result of compressive strength for mix (2) in degree{ 100^0c / 45 min}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	775	34.4
2	150*150*150	22500	655	29.1
3	150*150*150	22500	730	32.4
Average				32

Table (4.14): Result of compressive strength for mix (2) in degree{ 100^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	610	27.1
2	150*150*150	22500	560	24.9
3	150*150*150	22500	580	25.9
Average				25.9

Table (4.15): Result of compressive strength for mix (2) in degree{ 200^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	480	21.3
2	150*150*150	22500	520	23.1
3	150*150*150	22500	495	22
Average				22.1

Table (4.16): Result of compressive strength for mix (2) in degree{ 300^0c / 1.5 hour}

Sample No	**Actual size (mm)**	**contact area (load area) (mm^2)**	**Breaking NG load (KN)**	**Compressive Strength (N/mm^2)**
1	150*150*150	22500	375	16.7
2	150*150*150	22500	455	20.2
3	150*150*150	22500	330	14.7
Average				16.5