Evaluation of Iraqi Cement in High Strength Concrete

Samir AL- Mashhadi **Muna Mohammed Karim**
Zaid Hameed Mageed
Babylon University, College of Engineering, Department of Civil Engineering

Abstract

This study is amid to evaluate the use of Iraqi cement in high strength concrete (HSC) by production methods and investigation the mechanical properties such as compressive strength and splitting tensile strength. Four types of local made cement with one type of imported cement were used in concrete mixes. High strength concrete were produced using cement, crushed aggregate, fine aggregate and Superplasticizer. A comparison is made of mechanical properties of high strength concrete made with different types of cements.

Experimental results showed that the higher compressive strength was gain at early ages of concrete mixes with imported cement while the compressive strength gain is lower at early ages of concrete mixes made with local made cement. Results showed that higher compressive strength gain at later ages of concrete mixes with local made cement till the compressive strength of these mixes reaches the compressive strength of concrete mix which contain imported cement at age of 90 days.

Compressive strength of the investigated concreted were ranged between (61 – 91) MPa, (45-86) MPa, (42-87) MPa, (37-85)MPa , (32-82)MPa and splitting tensile strength were (5.75-6.85)MPa, (4.1-6.5)MPa, (3.8-6.3)MPa, (3.2-6.1)MPa, (2.65-5.2)MPa for concrete mixes made with AlQaseem cement (imported cement), Taslooga cement, AlMuthana cement, Kerbala cement, and Kufa cement (types of local made cement) respectively.

الخلاصة

تهدف الدراسة إلى تقييم استخدام السمنت العراقي في إنتاج الخرسانة عالية المقاومة بطرق الإنجاز المتاحة ودراسة الخواص الميكانيكية مثل مقاومة الانضغاط ومقاومة شد الانشطار. تم استخدام أربعة أنواع من السمنت المحلي مع نوع واحد من السمنت المستورد في الخلطات الخرسانية. تم إنتاج خرسانة عالية المقاومة باستخدام السمنت والحصى المكسر والركام الناعم والمادة الملدنة. تم أجراء مقارنة بين الخواص الميكانيكية للخرسانة عالية المقاومة بأنواع مختلفة من السمنت .

أظهرت النتائج المختبرية ان تطور مقاومة الانضغاط يكون اكبر في الأعمار المبكرة للخلطات الخرسانية المنتجة من السمنت المستورد بينما تطور مقاومة الانضغاط كان بطئ في الأعمار المبكرة للخلطات الخرسانية ذات السمنت المحلي إلا إن مقاومة انضغاط الخرسانة التي تحتوي على السمنت المحلي تتطور بشكل ملحوظ في الأعمار المتأخرة حتى أنها تصل إلى مقاومة انضغاط الخرسانة التي تحتوي على السمنت المستورد بعمر 90 يوماً.

تراوحت قيم مقاومة الانضغاط للخرسانة عالية المقاومة (61− 91)ميكاباسكال، (45−86) ميكاباسكال، (42−87) ميكاباسكال، (37−85) ميكاباسكال، (32−82)ميكاباسكال ومقاومة شد الانشطار (5.75−6.85)ميكاباسكال، (4.1−6.5)ميكاباسكال، (3.8−6.3)ميكاباسكال، (3.2−6.1)ميكاباسكال، (2.65−5.2) ميكاباسكال للخرسانة المنتجة بسمنت القصيم (سمنت مستورد) ، سمنت طاسلوجة، سمنت المثنى ، سمنت كربلاء، وسمنت الكوفة (أنواع من السمنت المحلي) على الترتيب.

Introduction

High strength concrete (HSC) is defined as "All concrete with a compressive strength above the present limits in National codes i.e about 40 MPa and up to 130 MPa" **(ACI Committee 363, 1997)**, the term "High strength" has changed significantly over the years: at one time, 40 MPa was considered high strength concrete; Later one, 60 MPa was viewed as high strength concrete (HSC) (**Neville, 1995)**. However nowadays, high strength concrete (HSC) may be defined as that having an average compressive strength of 80 MPa and above **(Peter and Marios, 1993)**.

In recent years, the construction industry has shown significant interest in the use of high strength concrete (HSC). This is due to the improvements in structural performance, such as high strength and durability, that it can provide compared to traditional, normal strength concrete (NSC). Recently, the use of high strength concrete, which was previously in applications such as bridges, off-shore structures and infrastructure projects, has been extended to high rise buildings. One of the major uses of HSC in buildings is for columns (**Kodur, 2003)**.

High strength concrete is a relatively recent development in concrete technology made possible by the introduction of efficient water- reducing admixtures and high strength cementitious materials **(John and Ban, 2003)**. The results of many recent tests on HSC shown that there are significant differences between the performances of high strength concrete compared with normal strength concrete**.**

High strength concrete is now used in many parts in the world, its growth is duo to the development in materials technology, its improved resistance to mechanical loads and environment conditions, so it has become an increasingly promising material**(Cetin and Carrasquillo, 1998).**

The increased use of high strength concrete on such construction projects can reduce the required concrete volume and amount of reinforcing steel. As the production of cement and steel is a very energy intensive process, the use of HSC would result in lower overall cost in building construction **(Wolsiefer, 1984)**.

High strength concrete material selection and mix proportioning are a more critical process than the design of normal strength concrete mixes. Each material, namely cement, sand, coarse aggregate, concrete admixtures, and pozzolans must be evaluated as to type, strength characteristics, grading, fineness, and interaction in combination with each other **(ACI Committee 363, 1997 and ACI Committee 211.4 R, 1993).**

The selection of cement is an important parameter affecting the ultimate value of compressive strength of high strength concrete. The selection of type and source of cement is one of the most important steps in the production of high strength concrete **(ASTM C917)** may be useful in considering cement sources. Variations in the chemical and physical properties of the cement affect the concrete compressive strength more the variations in any other single material **(ACI Committee 211.4 R, 1993).**

High-strength concrete shows higher rate of strength gain at early ages as compared with normal strength concrete, but at later ages the difference is not significant (**ACI Committee 363 ,1997**). The ratio of 7-day to 28-day strength were found between 0.8 - 0.9 for HSC and 0.7 - 0.75 for normal strength concrete. It seems likely that higher rate of strength development of high-strength concrete at early ages is caused by:

1. An increase in the internal curing temperature in the concrete due to the higher heat of hydration.
2. Shorter distance between hydrated particles in high-strength concrete. due to low water / cement ratio (low porosity).

Experimental Work

This research was designed to study the possibility of using of the local made cement to produce high strength concrete.

The test specimens used were (100mm) cubes and (100 *200 mm) cylinders. The compressive strength test was conducted according to **(BS 1881: Part 116: 1983).** The splitting tensile strength was determined according to **(ASTM C- 496).**

Materials and Mixes

Cement

Four types of cement were chosen from several cement factories in Iraq (represent the local made cement) with AlQaseem ordinary Portland cement (OPC) manufactured in Saudia Arabia **(**represent imported cement) were used in this work.

The chemical composition properties of different types of cement are shown in Tables (1) to (5) respectively and physical properties of different types of cement are shown in Tables (1-1) to (5-1) respectively. The results conform to the Iraqi specification **(IQS No.5/1984**). The tests were carried out in the testing cement laboratory of Babylon University**.**

Table (1) : Chemical analysis of AlQaseem ordinary Portland cement used.

Oxide	%	I.O.S. 5: 1984 Limits
CaO	62.23	_
SiO_2	20.78	_
Al_2O_3	4.9	_
Fe_2O_3	3.84	_
MgO	1.57	< 5.0
SO_3	2.50	< 2.8
Loss On Ignition (L.O.I)	3.7	< 4.0
Lime Saturation Factor (L.S.F)	0.89	0.66 - 1.02
Insoluble residue (I.R)	1.23	< 1.5 %
Free lime (F.L)	1.0	
Total	99.52	
Compound Composition	%	I.O.S. 5: 1984 Limits
C_3S	45.8	_
C_2S	25.02	_
C_3A	6.49	_
C_4AF	11.68	_

Table (1-1) : Physical Properties of AlQaseem ordinary Portland cement used.

Physical Properties	Test Results	I.O.S.5: 1984 Limits
Fineness, Blaine, cm^2/gm	3250	>2300
Setting Time :		
Initial hrs ; min	2;05	≥45 min
Final hrs ; min	3;45	≤10hrs
Compressive Strength MPa		
3-days	25.5	≥15
7-days	34	≥23

Table (2): Chemical analysis of Taslooga ordinary Portland cement used .

Oxide	%	I.O.S. 5: 1984 Limits

CaO	62.52	_
SiO_2	20.90	_
Al_2O_3	4.76	_
Fe_2O_3	3.92	_
MgO	2.71	< 5.0
SO_3	2.4	< 2.8
Loss On Ignition (L.O.I)	2.31	< 4.0
Lime Saturation Factor (L.S.F)	0.89	0.66 - 1.02
Insoluble residue (I.R)	1.03	< 1.5 %
Free lime (F.L)	1.4	
Total	99.52	
Compound Composition	%	I.O.S. 5: 1984 Limits
C_3S	45.55	_
C_2S	25.55	_
C_3A	5.98	_
C_4AF	11.93	_

Table (2-1) *:* Physical Properties of Taslooga Ordinary Portland cement used.

Physical Properties	Test Results	I.O.S.5: 1984 Limits
Fineness , Blaine , cm^2/gm	3250	>2300
Setting Time :		
Initial hrs ; min	1;45	≥45 min
Final hrs ; min	3;20	≤10hrs
Compressive Strength MPa		
3-days	24.0	≥15
7-days	33.5	≥23

Table (3): Chemical analysis of Al-Muthana Sulphate Resisting Portland cement used.

Oxide	%	I.O.S. 5: 1984 Limits
CaO	63.54	_
SiO_2	21.59	_
Al_2O_3	3.8	_
Fe_2O_3	4.8	_
MgO	2.71	< 5.0
SO_3	2.07	< 2.8
Loss On Ignition (L.O.I)	1.15	< 4.0
Lime Saturation Factor (L.S.F)	0.89	0.66 - 1.02
Insoluble residue (I.R)	0.82	< 1.5 %
Free lime (F.L)	1.34	
Total	99.59	
Compound Composition	%	I.O.S. 5: 1984 Limits
C_3S	51.37	_
C_2S	22.94	_
C_3A	1.95	_
C_4AF	14.60	_

Table (3-1) : Physical Properties of Al-Muthana Sulphate Resisting Portland cement

Physical Properties	Test Results	I.O.S.5: 1984 Limits
Fineness , Blaine , cm^2/gm	3200	>2500
Setting Time :		
Initial hrs ; min	2;10	≥45 min
Final hrs ; min	3;30	≤10hrs
Compressive Strength MPa		
3-days	21	
7-days	32	

Table (4):Chemical analysis of Kerbala Sulphate Resisting Portland cement used .

Oxide	%	I.O.S. 5: 1984 Limits
CaO	64.52	_
SiO_2	21.26	_
Al_2O_3	3.66	_
Fe_2O_3	5.12	_
MgO	1.85	< 5.0
SO_3	2.15	< 2.8
Loss On Ignition (L.O.I)	0.91	< 4.0
Lime Saturation Factor (L.S.F)	0.91	0.66 - 1.02
Insoluble residue (I.R)	o.83	< 1.5 %
Free lime (F.L)	1.4	
Total		
Compound Composition	**%**	**I.O.S. 5: 1984 Limits**
C_3S	57.34	_
C_2S	17.69	_
C_3A	1.03	_
C_4AF	15.58	_

Table (4-1) : Physical Properties of Kerbala.Sulphate Resisting Portland cement used

Physical Properties	Test Results	I.O.S.5: 1984 Limits
Fineness , Blaine , cm^2/gm	3250	>2500
Setting Time :		
Initial hrs ; min	2;05	≥45 min
Final hrs ; min	3;50	≤10hrs
Compressive Strength MPa		
3-days	21.5	≥15
7-days	30	≥23

Table (5): Chemical analysis of Kufa ordinary Portland cement used

Oxide	%	I.O.S. 5: 1984 Limits
CaO	61.95	_
SiO_2	20.92	_
Al_2O_3	6.02	_
Fe_2O_3	3.12	_
MgO	3.33	< 5.0
SO_3	2.57	< 2.8
Loss On Ignition (L.O.I)	1.71	< 4.0
Lime Saturation Factor (L.S.F)	0.87	0.66 - 1.02
Insoluble residue (I.R)	0.66	< 1.5 %
Free lime (F.L)	1.23	
Compound Composition	**%**	**I.O.S. 5: 1984 Limits**
C_3S	33.96	_
C_2S	32.84	_
C_3A	10.67	_
C_4AF	9.49	_

Table (5-1) *:* Physical Properties of Kufa ordinary Portland cement used .

Physical Properties	Test Results	I.O.S.5: 1984 Limits
Fineness , Blaine , cm^2/gm	3010	>2300
Setting Time :		
Initial hrs ; min	2;00	≥45 min
Final hrs ; min	3;20	≤10hrs
Compressive Strength MPa	21.0	≥15
3-days	27.0	≥23
7-days		

Aggregate

The fine aggregate used was Al-Ekhaider natural sand zone 2 with fineness modulus of 2.9. The grading, physical and chemical properties of fine aggregate conform to Iraqi specification **(IQS No. 45 /1984).**

Crushed gravel obtained from AL-Nebai source was used as coarse aggregate. The maximum coarse aggregate size was chosen to be 14 mm.

Superplasticizer

High range water reducing agent (HRWR) called Glenium 51 (Sulfonated melamine–formaldehyde) was used in this work. This superplasticizer is conformed to **(ASTM C-494)** classified as type F, it has acceleration effect on the HSC. The dosage for Glenium 51 was 0.8 liters per 100 Kg of cement. The typical properties are shown in Table (6). The superplasticizer was added to the mixing water before the addition to the mixes.

Table (6) : Typical Properties of Super plasticizer.

Form	Viscous liquid
Colour	Light brown
Relative density	1.1 @ 20ºC
pH	6.6
Viscosity	128 cps @20ºC
Transport	Not classified as dangerous
Labelling	No hazard label required
Dosage	0.5 to 0.8 liters per 100 Kg of cement

Mix Design and Proportion

One mix of concrete was investigated in this work, namely 80 MPa at age (28) days. The proportions of the concrete mixes are summarized in Table (7). The high strength concrete was made under controlled laboratory conditions with a constant water cementitious materials ratio (0.3) and designed to give a characteristic compressive strength of (80) MPa.

All concrete mixes contain the same materials, the difference between concrete mixes was source of cement.

Table (7): Mix Proportions

Weight proportion Cement: Sand: Gravel	W/C ratio	Mix proportion kg/m3 Cement :Sand :Gravel: Water	Superplasticizer (liter/100 kg Cement)
1.0 : 1.2 : 1.8	0.3	550 : 660 : 990 : 165	0.8

Mixing Casting and Compacting of Fresh Concrete

The concrete was mixed using an electrical drum type mixer with a maximum capacity $0.1m^3$. The total mixing time was about 7 min.

The concrete mix was cast in the molds in two layers for cubes, three layers for cylinders, finally the molds were leveled by hand trawling. The concrete mixes were fully compacted on a vibrating table. The vibration time to reach full compacting was decided upon the stopping of air bubbles immigration from the surface of fresh concrete .

Testing of hardened Concrete

Compressive Strength Test

For the hardened concrete, the compressive strength test was carried out according to **(BS. 1881: part 116:1983)**, using a digital testing machine of 2000 kN maximum capacity. Three cubes (100 mm) were tested for each mix at each age for the determination of compressive strength.

Splitting Tensile strength

The splitting tensile strength was determined according to **(ASTM C496-86)** specification. Each splitting tensile strength value was the average of two specimens.

The splitting tensile strength was calculated as follows:

$$F_{sp} = 2P / \pi DL$$

where

F_{sp}= splitting tensile strength, (MPa)

P= maximum applied load, (N)

D= diameter of concrete cylinder, (mm)

L= length of concrete cylinder, (mm)

Results and Discussion

Compressive Strength

The compressive strength test results of the concrete specimens (cube 100 mm) were tested at age (7, 28, 60 and 90 days), the results of tests and development of compressive strength gain are shown in Table (8) and Figure (1) .

It can be shown that the compressive strength at 7days are 61, 45, 42, 37, 32 MPa of series CMQ, CMT, CMM, CMKr and CMKu respectively, whereas at 90 days are 91, 86, 87, 85, 82 MPa. It can be seen that series made with Iraqi cement have low compressive strength at early ages, whereas their compressive strength develops at higher rate at later ages. The rate of development of compressive strength between 28 and 90 days for series CMQ concrete was increasing by about (12%), for series CMT concrete by about (26%), for series CMM concrete by about (38%), for series CMKr concrete by about (49 %) and for series CMKu concrete by about (71%).

From these results it can be concluded that the Iraqi cement when it used in high strength concrete experienced a major increase in compressive strength between 28 and 90 days. The mane reason of this phenomenon is the chemical composition of Iraqi cement : high content of C_2S, low content of C_3S and low of Lime Saturation Factor as shown in tables 1 to 5 compared with the imported cement.

Table (8) :- Compressive Strength (MPa)of the Concrete Mixes .

Mix Notation	**Compressive Strength (MPa) Age (days)**			
	7	28	60	90
CMQ(1)	61	81	84	91
CMT(2)	45	68	80	86
CMM(3)	42	63	78	87
CMKr(4)	37	57	74	85
CMKu(5)	32	48	71	82

(1) : Concrete mix with AlQaseem cement.
(2) : Concrete mix with Tasloga cement.
(3) : Concrete mix with AlMuthana cement.
(4) :Concrete mix with Kerbala cement .
(5) : Concrete mix with Kufa cement.

Splitting Tensile Strength

The tensile strength governs the cracking behavior and affects other properties such as stiffness and durability of concrete. The tensile strength is determined either by direct tensile test or by indirect tensile tests such as flexural or split cylinder tests **(Carrasquillo et - al , 1987).**

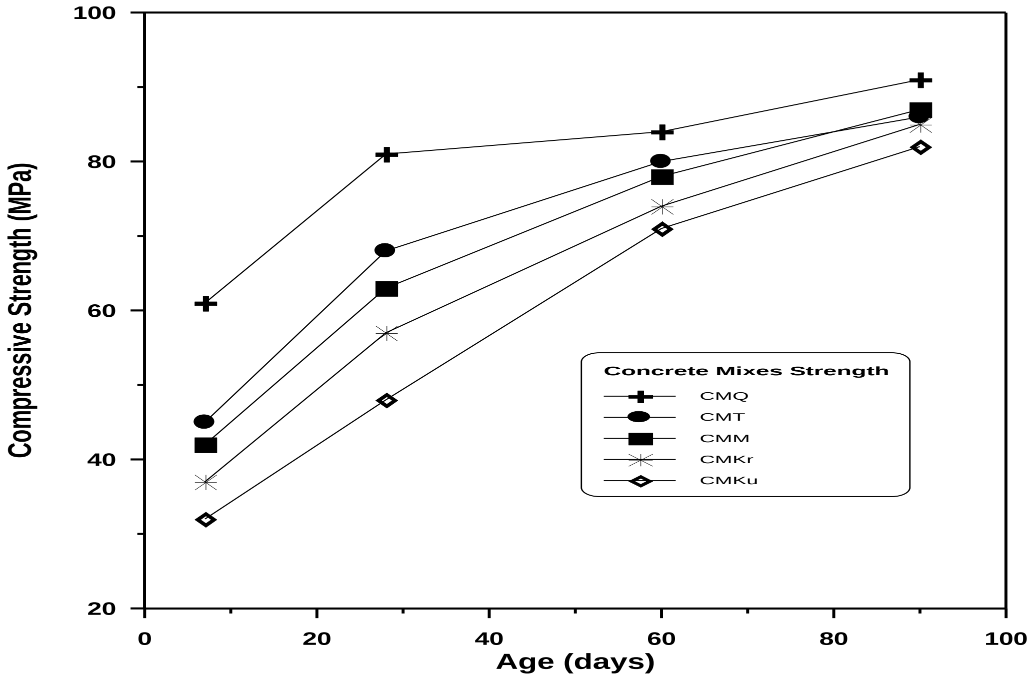

Figure (1) : Development of Compressive Strength of Concrete mixes

experimental work. The results of tests at age (7, 28, 60 and 90) days are shown in Table (9) and plotted in Figure (2).

The tensile strength of concrete for series CMQ concrete ranged between (5.75 – 6.85) MPa, (4.1 – 6.5) MPa for series CMT, (3.8 – 6.45) for series CMM, (3.2-6.1)MPa for series CMkr and (2.1 – 3.2) MPa for series CMKu .

It is clear from Figure (2) and Table (9) that the rate of development of tensile strength between 28 and 90 days are around (8.7%), (22.6 %), (24%), (37%) and (42.5%) for series CMQ,CMT,CMM, CMKr and CMKu respectively.

Table (9) :-Results of Splitting Tensile Strength (MPa)of the Concrete Mixes

Mix Notation	**Splitting tensile strength (MPa) at Age (days)**			
	7	28	60	90
CMQ	5.75	6.3	6.6	6.85
CMT	4.1	5.3	6.0	6.5
CMM	3.8	4.8	5.5	6.3
CMKr	3.2	4.45	5.2	6.1
CMKu	2.65	3.65	4.26	5.2

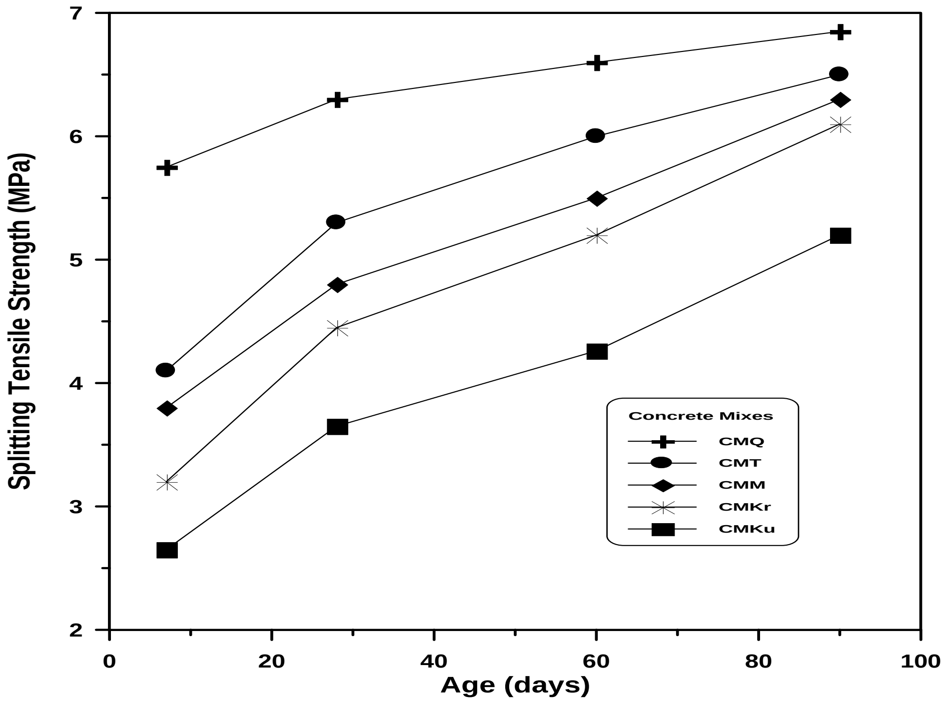

Figure (2) : Development of splitting tensile strength of concrete mixes .

Conclusions

Based on the tests of present study, the following conclusions can be drown :

1. With careful proportioning and mixing, High strength concrete can be produced with available local materials.

2. The sulphate and ordinary Iraqi cement when it used in high strength concrete experienced a major increase in compressive strength between 28 and 90 days.

3. The selection of cement is an important parameter affecting the ultimate value of compressive strength for high- strength concrete.

4. Variations in the chemical composition and physical properties of the cement affect the compressive of high strength concrete.

5. For the considered mix properties, the compressive strength at ages (28- 90) days, ranged between (81-91)MPa for concrete mixes with ALQaseem cement, where as, (68-86) MPa ,(63-87)MPa, (57-85)MPa, and (48-82)MPa for concrete mixes with Tasloga cement, AlMuthana cement, Kerbala cement and Kufa cement respectively.

6. For the considered mix properties, the splitting tensile strength at ages (28-90) days, ranged between (6.3 - 6.85) MPa for concrete mixes with ALQaseem cement,(5.3-6.5) MPa, (4.8- 6.3) MPa, (4.45- 6.1) MPa, and (3.65- 5.2) MPa for concrete mixes with Tasloga cement, AlMuthana cement, Kerbala cement and Kufa cement respectively**.**

7. Higher compressive strength gain at early ages of concrete mixes with imported cement while the compressive strength gain is lower at early ages of concrete mixes with local made cement**.**

References

ACI Committee 363 **"State –of –the Art Report on high –strength concrete"** Journal of American concrete Institute. Detroit Vol.81., No .4, July – August 1997, pp.364-411.

ACI Committee 211.4R **" Guide for Selecting Proportions for High – Strength Concrete with Portland Cement and Fly Ash"** ACI Material Journal Vol. 90 , No. 3, May – Jun 1993, pp.272-283.

ASTM (C917)**, "Standard Method of Evaluating of Cement Strength Uniformity from a Single Source"**, American Society for Testing and Materials, Vol. 17, 1995, pp.3.

ASTM (496 - 86), **" Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens",** American Society for Testing and Materials, Annual Book of ASTM Standards, V. 04. 02, 1989, PP. 32-34 .

ASTM C 494/C 494M – 1999a, "**Standard Specification for Chemical Admixtures for Concrete"**, Vol. 04.02, 1999, pp.1-9.

BS.1881, part 116, **"Method for Determination of Compressive Strength of Concrete Cubes",** British Standards Institution, 1989, 3pp.

Carrasquillo, R. L., Nillson, A. H., and Slate, F. O. **"Properties of High Strength Concrete Subjected to short – term – loads"** ACI Journal Proceeding 78No .3, May – Jun, PP. 171 -178, 1987.

Cetin, A., and Carrasquillo, R. L. **"High – Performance Concrete: Influence of Coarse Aggregates on Mechanical Properties"**, ACI Material Journal VOL. 95 , No .3 ,May – Jun , 1996.pp.44-49.

Iraqi Organization of Standards, **IOS 5: 1984**, for Portland cement.

Iraqi Organization of Standards, **IOS 45: 1984**, for Aggregate**.**

John, N. and Ban, S. C., **"Advance concrete technology"** Department of civil Engineering Imperial College London Chp.3, 2003.

Kodur, V. R. ; Sultan, M. A**., "Structural Behavior of High Strength Concrete Columns Exposed to Fire"** NRCC-41736, http://irc-cnrc.gc.ca/ircpubs, October, 2003 **pp**. 1-11.

Neville, A.M. **"Properties of Concrete"** Fourth and final Edition, Wiley, New York and Longman, London, 1995.

Peter, D, and Maries, S. **"**An **approach to the proportioning of High Strength Concrete Mixes"** Concrete International, September – October 1993, pp .26-31.

Wolsiefer, J. **"Ultra High –Strength Field Peaceable Concrete with Silica Fume Admixture"** Concrete International Vol. 16, No.4, April 1984, pp.25- 31.