Evaluation Of Using Glass Fiber On Properties Of Self-Compacting Concrete

تقييم استخدام الألياف الزجاجية على خواص الخرسانة الذاتية الرص

Mohammed Karem Abd
Technical Institute-Babylon \ Lecturer

Abstract :-

This research aims to evaluate of using the glass fiber on the properties of fresh and hardened self compacting concrete (SCC).The work involves four mixes , the mix proportion of these mixes is(1:1.75:2),and water cement ratio is(0.4), superplasticizer of (5) % of cement content, limestone powder of (100Kg /m^3) ,and glass fiber (0,1,3,5)% of mixes volume respectively .

Slumpflow, L-Box and V-funnel tests are using to determine the workability of all mixes, the values of slump flow are (710,680,655,615)mm, the values of t_{50cm} are (2,3,3,5) second, the blocking ratio (H_2/H_1) values are (0.93, 0.87, 0.86, 0.82) and the flow time through the V-funnel are (6, 9, 11, 12) seconds respectively, the mechanical properties studied in this work are compressive strength with average value of six spacements are (28.6,29.2,29.8,31.5) , (47.3,48.7,51.3,54.7)N/mm^2 of (7,28) day ages respectively , and splitting tensile strength with average values of six spacements are (4.1, 4.3,4.6,5.1) , (5.2,5.8,6.1,6.5)N/mm^2 of (28,56) days ages respectively .

Flexural strength (Modulus Of Rupture)(MOR) was tested with average values of three spacements are (4.1,4.3,4.6,5.1) , (5.2,5.8,6.1,6.5)N/mm^2 of (28,56) day ages, for glass fiber ratio of (0,1,3,5)% respectively .

Keywords: Self-compacting concrete, Glass Fiber, Slumpflow, MOR

الخلاصة :-

يهدف هذا البحث إلى تقييم استخدام الألياف الزجاجية على خواص الخرسانة الذاتية الرص الطرية والمتصلبة وقد تم عمل أربع خلطات خرسانية ذاتية الرص وبنسبة خلط (2:1.75:1) وبنسبة ماء إلى الاسمنت (0.4) ونسبة ملدن متفوق (5)% من وزن السمنت ومادة ناعمة (الغبرة) (100كغم/م3) ونسبة ألياف (5,3,1,0)% من حجم الخلطة على التوالي .

تم فحص قابلية تشغيل الخلطات الخرسانية ذاتية الرص والتي استخدم فيها نسبة ألياف زجاجية (5,3,1,0)% وكان مقدار الانسياب (710 ، 680 ،655 ،615)ملم، وزمن انتشار الخرسانة t_{50cm} هو (2،3،3،5) ثانية، ونسبة الانسداد(H_2/H_1) في فحص (L-Box) هي (0.93، 0.87، 0.86، 0.82) وزمن الانسياب في فحص (V-funnel) هو (6، 9، 11، 12) على التوالي كما تم فحص مقاومة الانضغاط للخرسانة المتصلبة وكانت قيم معدل المقاومة لستة نماذج هي (28.6 ، 29.2 ، 29.8 ، 31.5) و (47.3 ، 48.7 ، 51.3 ، 54.7) نيوتن/ملم2 للأعمار (7 ، 28) يوم على التوالي كما تم فحص مقاومة الانفلاق وكانت قيم معدل المقاومة لثلاثة نماذج هي (4.1 ، 4.3 ،4.6 ،5.1) و (5.2 ، 5.8 ، 6.1 ، 6.5) نيوتن / ملم2 للأعمار (28 ،56) يوم على التوالي كما تم فحص مقاومة الشد (معامل التصدع) وكانت قيم هذا المعامل (معدل ثلاث نماذج) وبالأعمار (28 ، 56) يوم هي (4.1 ، 4.3 ، 4.6 ، 5.3)، (6.4 ، 6.6 ، 7.2 ، 7.5) نيوتن /ملم2 لنسب ألياف زجاجية (0،1،3،5) على التوالي .

الكلمات الدالة:- الخرسانة الذاتية الرص، الألياف الزجاجية، الانسياب، معامل التصدع

Introduction:-

One of the problems of a cement-based matrix is the inherently brittle type of failure which occrues under tensile stress systems or impact loading and in the construction industry a major reason for the growing interest in the performance of fibers in cement based materials is the desire to increase the toughness or tensile properties of the basic matrix[1].

The fiber types can be divided in tow main groups , these with module lower than the cement matrix , such as cellulose , nylon and polypropylene and those with higher module such as asbestos , glass , steel , carbon and Kevlar [1][2] .

The main factors controlling the theoretical performance of the composite material are the physical properties of the fibers and the matrix and the strength of the bond between the tow [3] .

Shanmugam and Swaddiwudhipong [4] carried out an experimental investigation to study the ultimate load behavior of steel fiber reinforced concrete deep beams and found that the addition of steel fibers results an increased failure loads and change in failure modes.

Much of the credit for the initial development of dispersed glass-fiber as reinforcement for cement must undoubtedly be given to the Russians[1].Birykovichetal who published a book in 1964 on the properties and basic methods of fabrication of the material .

Although glass fibers have been used in overlays to concrete pavements, there is relatively little published work on the physical properties of glass fiber concretes. This is because the research effort has been concentrated into the development of thin sheet products which require fine grained matrices [5].

However, alkali resistant glass fibers in concrete have been studied by Marsh and Clarc [6] for the limited condition of testing after (14) days and curing in air at 50 percent , and 23 ºC. Fiber lengths between 12mm and 50mm were used at volumes between (0.5) percent and (2.5) percent . Various mix proportions were examined using (10) mm maximum sized river gravel aggregate , water reducing admixtures and about (5) percent of entrained air [1] .

The use of fiber has gone through a quite big development in the last 30 years, Fiber Reinforced Concrete (FRC) constitutes one of the most relevant innovations in the filed of the special concrete [7] .

Fiber Reinforced Concrete (FRC) is often used in the structures to restrict cracks that originate from stresses caused by volume changes in combination with structural restraint , Cracking is a problem especially when high strength concrete , which is in herently brittle is used . Fiber in concrete provide a means of arresting crack growth and improving the load carrying capacity [8] .

Trials carried out by Warner (1995) with a variety of concrete samples of various types of fibrillated polypropylene fiber and glass fiber additions , examining flexural and compressive strength were carried out between 1 and 28 days from batching . The concrete as used by Warner was of an approximate compressive strength around 45 N/mm^2 with a (27) percent cement replacement of pulverized fuel ash and water cement ratio of 0.45 , fiber dosage was 0.9 Kg/m^3 [9] .

Initial bonding between the fibers and the concrete can be attributed to physical adhesion and also to static friction caused by the surface finish of the fiber.Chemical bonding(sometimes referred to as elastic bonding) between the fibers and the matrix .

In general friction plays an important role in confining stress increasing with the fiber deformation processes load to local mechanical interaction between fiber and matrix-involving a typical distribution of the load by the matrix [3][10] .

A number of efforts have been made to improve bond-slip characteristics of fiber in cement-based matrixes . These include matrix modifications such as slica fume and polymer additions [11] , and fiber modifications such as coating surface indenting and notching [12] . However , by farmost improvements in bond-slip characteristics are found to occur when fibers are mechanically deformed , such that they develop a positive anchorage in concrete [13] .

Fiber act as cracks arresters through the initial loading stages , and increase the energy required for crack propagation-what provides an increase in the strength . During the later stages of straining the fiber distribute the microcracking , thus increasing toughness and apparent strength [14] .

Fiber in concrete has found to improve several properties like tensile strength, cracking resistance, impact and wear resistance, ductility and fatigue resistance . Future development in the fild of fiber reinforced concrete was due to introduction of high strength fiber like glass and carbon fibers.

The initial studies showed deterioration of glass fiber due to corrosive alkali environment of the cement paste. The alkali resistant glass fiber, which is developed recently has overcome this defect and can be effectively used in concrete. The production of fiber reinforced concrete should always be considered in two well defined phases, the fresh and the hardened phases [7][15][16] .

Experimental Work:-

Involves the following statements:-

1- Materials used :-

• Cement:- Ordinary Portland cement (Tasluja) of 42.5 grades available in local market is used. And Tables (1) and (2) show the physical and chemical properties of cement according to Iraqi Standard Specifications No.5/1984 (IQS)[17] .

Table (1) Physical properties of cement

Test	Result	Limits of (IQS No. 5/1984)
Initial Setting Time	96	>=45min.
Final Setting Time	7.10	<=10hrs.
Compressive Strength at (3days)	16.3	>=15Mpa.
Compressive Strength at (7days)	24.9	>=23Mpa.

Table (2) Chemical properties of cement

Oxide	Result	Limits of (IQS No. 5/1984)
(SiO_2) %	19.5	
(CaO) %	62.3	
(Al_2O_3) %	4.56	
(Fe_2O_3) %	3.56	
(MgO) %	2.95	<=4%
(SO_3) %	2.59	<=2.5% if C_3A <5% <=2.8% if C_3A >5%
Loss on Ignition (L.O.I)	1.6	<=4%
Insoluble Residue (I.R)	1.23	<=1.5%
L.S.F	0.86	0.66-1.02
Free Lime	0.62	
(C_3S)%	57.45	
(C_2S)%	12.54	
(C_3A)%	6.06	
(C_4AF) %	10.83	

• Fine Aggregate :- Karbala quarries sand was used as fine aggregate its specific gravity of (2.63) and fineness modulus of (2.55) and the ratio of sulphate content was (0.2)% .The grading of the sand is compatible with zone (3) of fine aggregate grading according to the(IQS No.45/1984) [18] and Table (3) below illustrates its gradiation .

Table (3) Gradiation of fine aggregate

Sieve Size (mm)	Passing (%)	Limits of (IQS No.45/1984) (%)
10	100	100
4.75	96	90-100
2.36	88.3	85-100
1.18	79.2	75-100
0.6	63.5	60-79
0.3	16.1	12-40
0.15	1.8	0-10

- Coarse Aggregate:- Al-Nibaee crushed aggregate is used with a maximum aggregate size (20mm) . Its specific of gravity was (2.67) and sulphate content was (0.03) % . Table (4) below shows its gradiation which conforms to (IQS No.45/1984) [18] .

Table (4) Gradiation of coarse aggregate

Sieve Size (mm)	Passing (%)	Limits of (IQS No.45/1984) (%)
37.5	100	100
20	95.6	90-100
10	34.4	30-60
5	3.2	0-10

- Filler :- Additions are commonly used in SCC due to the need for substantial contents of fine particles .All additions conforming to the EN Standards are suitable . Limestone dust filler is used . The filler is measured according to (BS 7979) and Table (5) shows the properties of limestone powder .

Table (5) Chemical properties of Limestone Powder

Oxide	Test Result (%)
CaO	51.6
SiO_2	1.64
Al_2O_3	0.85
Fe_2O_3	0.23
MgO	0.26
SO_3	3.41
L.O.I	41.3

- Admixture:-The most important admixture are the superplasticizers (high range water reducers) , (Hyperplast PC 711) used with a water reduction greater than 20% . This admixture helps to provide very good homogeneity and reduces the tendency to segregation , and Table (6) shows technical properties of superplasticizer According to (ASTM C494 Type G) [19] .

Table (6) The technical properties of the superplasticizer

Main Action	Concrete Superplasticizer
Subsidiary Effect	Hardening retarder and flowable concrete mixes
Fire	Non-flammable
Color	Light yellow liquid
Freezing point	-10 ºC
Specific gravity	1.09
Chloride content	Nil
Air entrainment	Typically less than 2%

- Fiber:- The glass fiber used are Reinforced Aluminum F oil (glass wool , water proofing bitumen membrane , thermal insulation), with density (1Kg/m^3), diameter (12microns), length (25microns) .
- Water:- Tab water was used for mixing and curing .

2-Mix Design: -

There is no unique mix design solution for the production of (SCC) and a wide variety of materials have been used (Domone et al) . Water/binder ratio are generally less than (0.5) and mixes have lower coarse aggregate content and higher paste content than conventional concrete [20] . Admixture and concrete addition such as limestone powder contribute to both increases in workability and segregation resistance . Four mixes were designed according common mix design method for (SCC) [21]. The proportion of the SCC mixes are shown in Table (7) below .

Table (7) The proportion of the SCC mixes

Property	Comments
Water Content Admixtures	Typically range (160-180)Kg/m^3 superplasticizer used
Binder	Typically range (450-550)Kg/m^3
Water/binder ratio	0.3-0.36
Aggregate	Both gravel and crushed rock used up to (20)mm nominal size is common

3- Mixing Of Concrete :-

Four mixes were prepared , the first a reference mix was without any glass fiber , the second , third and fourth mixes contained (1,3,5)% glass fiber by volume of concrete mix respectively .

The concrete was mixed according to Swedish Cement and Concrete Research Institute [21]. Table (8) shows the contents of the four mixes.

Table (8) The contents of the mixes

Fiber Ratio %	Water/Cement ratio	Superplastisizer %	Limestone Content Kg/m^3	Gravel Content Kg/m^3	Sand Content Kg/m^3	Cement Content Kg/m^3	Mixing Ratio
0	0.4	0	0	830	750	400	2:1.75:1
1	0.4	5	100	830	750	400	2:1.75:1
3	0.4	5	100	830	750	400	2:1.75:1
5	0.4	5	100	830	750	400	2:1.75:1

4-Laboratory Tests :-

- Workability :-The property of the fresh concrete is related entirely to the mobility of the concrete .

The slumpflow test utilizes a British Standards slump cone, which is filled in one layer without compaction. Typical values lie between (600 and 800) mm. This is the t_{50} value , which measures the time taken to reach a spread of (500)mm. the acceptable value of passingability ratio (H_2/H_1) is normally (0.8-1), and V-funnel test is used to determine the segregation of concrete, the time of flow through the V-funnel for SCC mixes is (6 and 12)seconds.

- Compressive Strength :- In order to evaluate usual concrete compressive strength (150mm cubes) specimens are used . After (7,28) days of standard curing in saturated water at (23ºC + 3 ºC) , specimens is then placed between the two platens of a testing machine and the load is applied at a defined rate until failure
- Splitting Tensile Strength :- In order to avoid using such a big and heavy concrete specimens many people prefer to ineasure the splitting tensile strength of concrete because it requires the use of less than (15Kg) of concrete for (150*300)mm specimens .
- Flexural Strength:- Prisms , nominally (150*150*520)mm were cast according to (BS 1881 Part 118:1983) prisms were moist cured in a similar manner as the cubes .Using two-point loading machine with capacity of (200KN). Each value of Modulus Of Rupture (MOR) is the average of results of tests of three prisms .

Results and Discussion:-

1) The effect of fiber volume on the slumpflow, blocking ratio, time flow of the typical mixes are shown in Table (9) and Figure (1),(2) and (3)from which it can be seen that , the slumpflow of fiber from (710)mm for reference mixture to (680,655,615)mm of concrete mixtures[1] ,t_{50cm} values are (2 to 5) second, the blocking ratio (H_2/H_1) value are (0.93, 0.87, 0.86, 0.82) and the flow time through the V-funnel are (6, 9, 11, 12) seconds respectively which is used in it proportions of glassy fibers (1,3,5)% and owing to the reason that the mixture which are used in it glassy fibers need increasing quantity of water to moisten glassy fibers and for increasing internal cohesive friction

among concrete mixture constituents. This agreed with held Swamy [2] and Hannant [1] view which is saying that the operative ability of mixture is minimized whenever the concentration of fibers is maximized [3].

2) The Tables (10, 11, 12) and Figures (4,5,6) the effect of using for glassy fibers on the compressive strength ,splitting tensile strength and modulus of rupture for self-compacting concrete . In which compressive strength is increased with magnitudes (0.02,0.04,0.1) and (0.03,0.08,0.15) from the referential mixture for the ages (7,28) days respectively. As well as the splitting tensile strength is increased at the magnitudes (0.04,0.12,0.24) and (0.11,0.17,0.25) for the ages (28,56)days respectively and modulus of rupture is increased at the magnitudes(0.048,0.12,0.24) and (0.03,0.125,0.17) from the referential mixture and for ages (28,56) days respectively in the using of glassy fibers proportion (1,3,5)%respectively and this agreed with held Hannant [1] view .Which saying that the failure is occurred usually when the fiber under loading reached its ultimate strength , and the fibers absorbed capacity of bearing in a relatively large quantity , cracks are minimized as well as they are used as a joining material for the concrete mixture constituents . The concrete is continued in the bearing of maximizing tensile stresses , the material is behaved semi elastic behavior which is observed in the filed with cementations material ,or mortar, and concrete which is supplied with provisions or the concrete which is contained sufficient continued fibers volume which is reinforced with glassy fibers . The composition is failed when the fibers are broken at cracks besides a little with pull-out of the fibers .

Table (9) Result of fresh concrete mixes

Mix Notation	Slump Flow (mm)	t_{50cm} second	L-Box H_2/H_1	V-funnel second
0% Fiber	710	2	0.93	6
1% Fiber	680	3	0.87	9
3% Fiber	655	3	0.86	11
5% Fiber	615	5	0.82	12

Table (10) Compressive strength of concrete cubes

Mix Notation	Compressive Strength (Mpa.) (average of 6 samples)	
	Age (day)	
	7	28
0% Fiber	28.6	47.3
1% Fiber	29.2	48.7
3% Fiber	29.8	51.3
5% Fiber	31.5	54.7

Table (11) Splitting tensile strength of concrete cylinder

Mix Notation	Splitting Tensile Strength (Mpa.) (average of 6 samples)	
	Age (day)	
	28	56
0% Fiber	4.1	5.2
1% Fiber	4.3	5.8
3% Fiber	4.6	6.1
5% Fiber	5.1	6.5

Table (12) Modulus of rupture of concrete beams

Mix Notation	Modulus Of Rupture (Mpa.) (average of 3 samples)	
	Age (day)	
	28	56
0% Fiber	4.1	6.4
1% Fiber	4.3	6.6
3% Fiber	4.6	7.2
5% Fiber	5.1	7.5

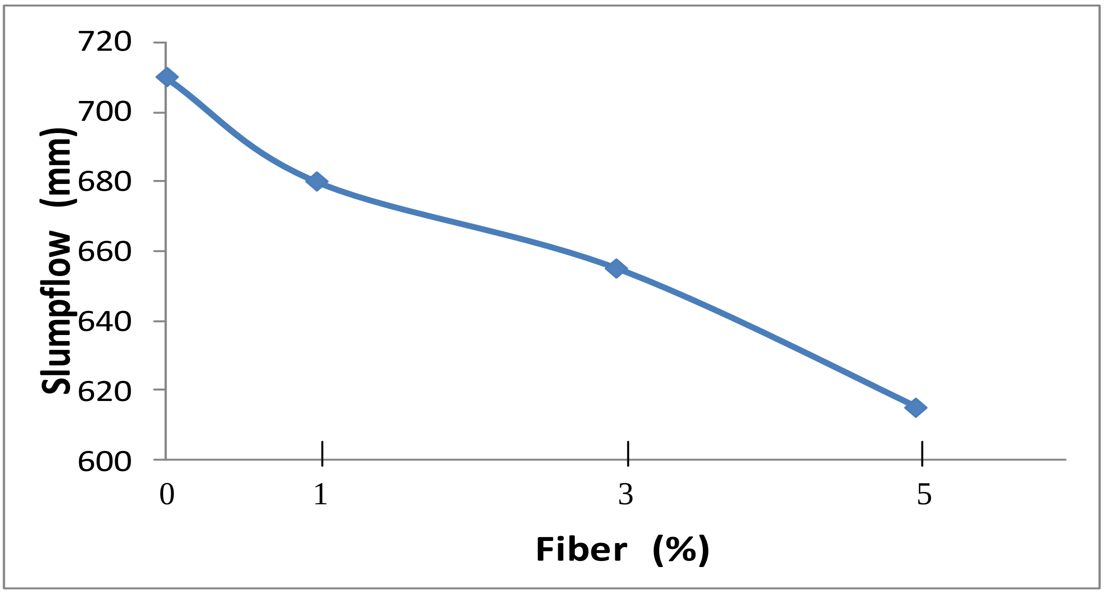

Figure (1) : Relation Between Fiber Ratio and Slumpflow

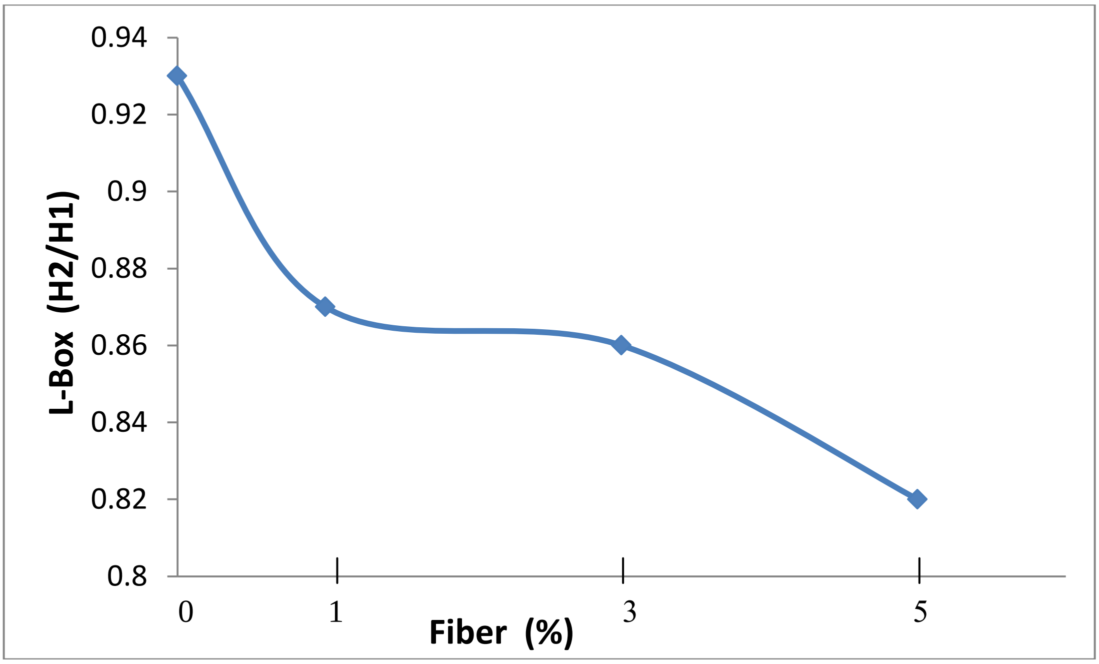

Figure (2) : Relation Between Fiber Ratio and L-Box (H_2/H_1) ratio

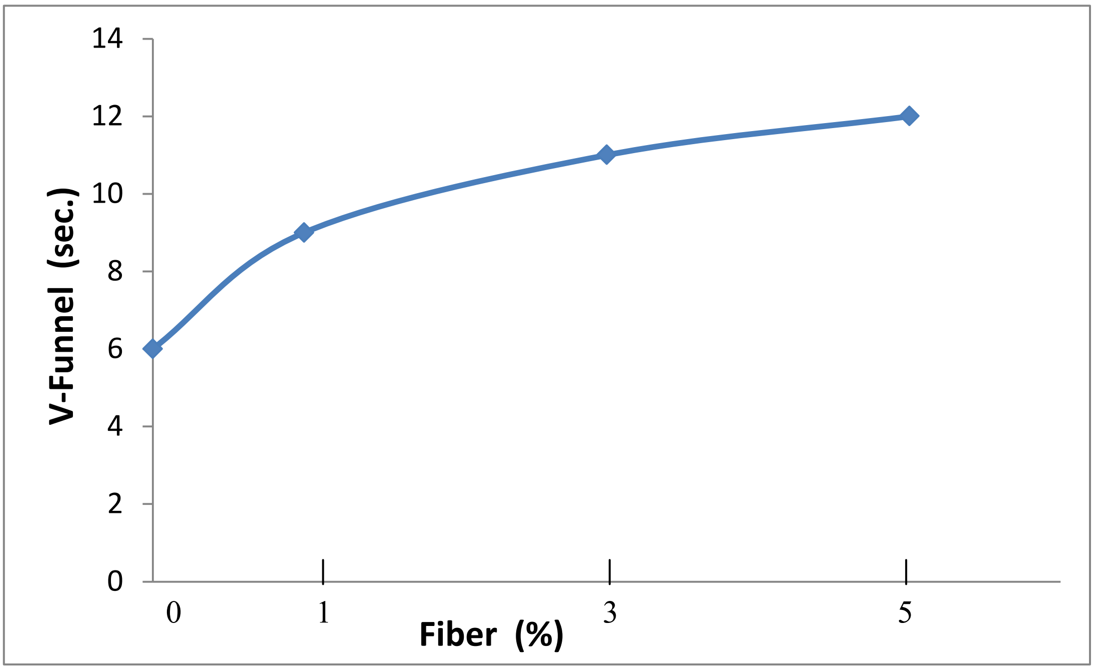

Figure (3) : Relation Between Fiber Ratio and time flow of (V-funnel)

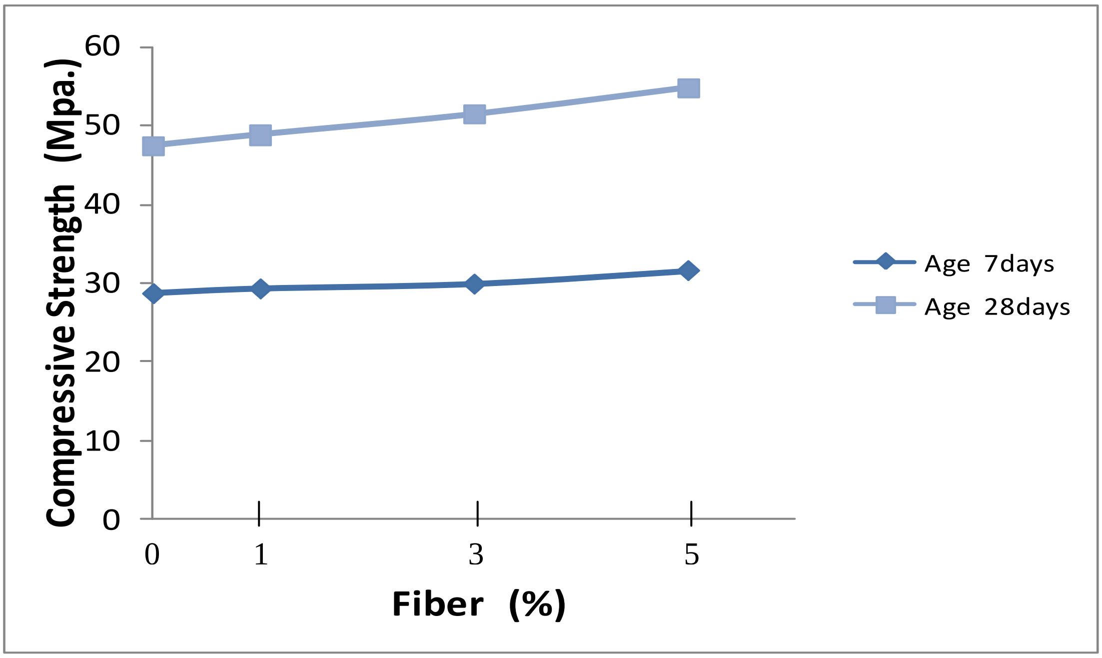

Figure (4) : Relation Between Fiber Ratio and Compressive Strength

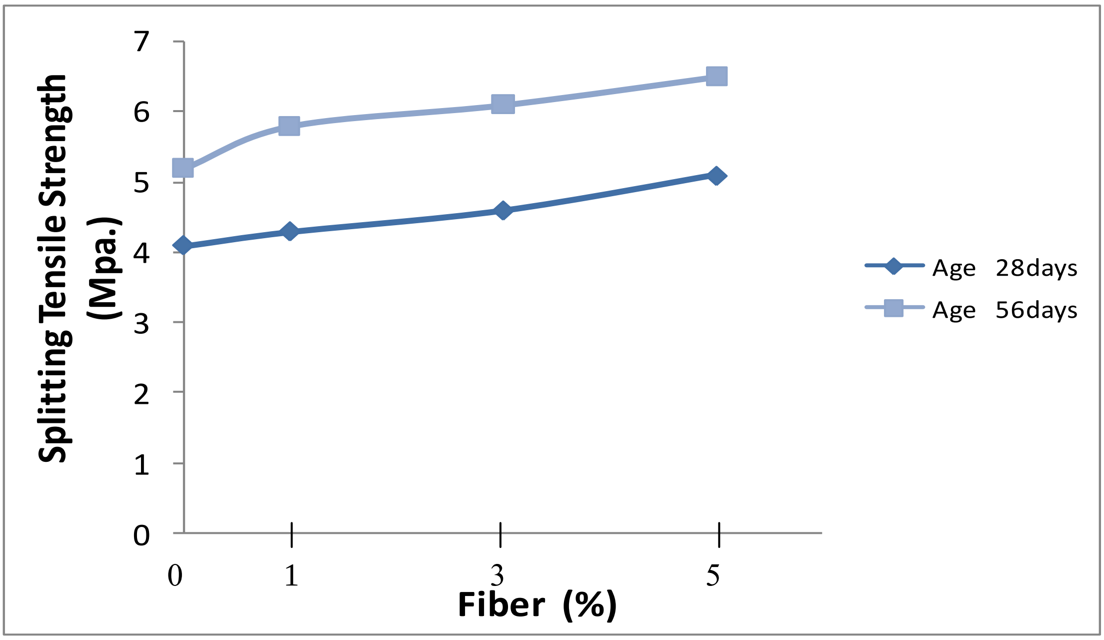

Figure (5) : Relation Between Fiber Ratio and Splitting Tensile Strength

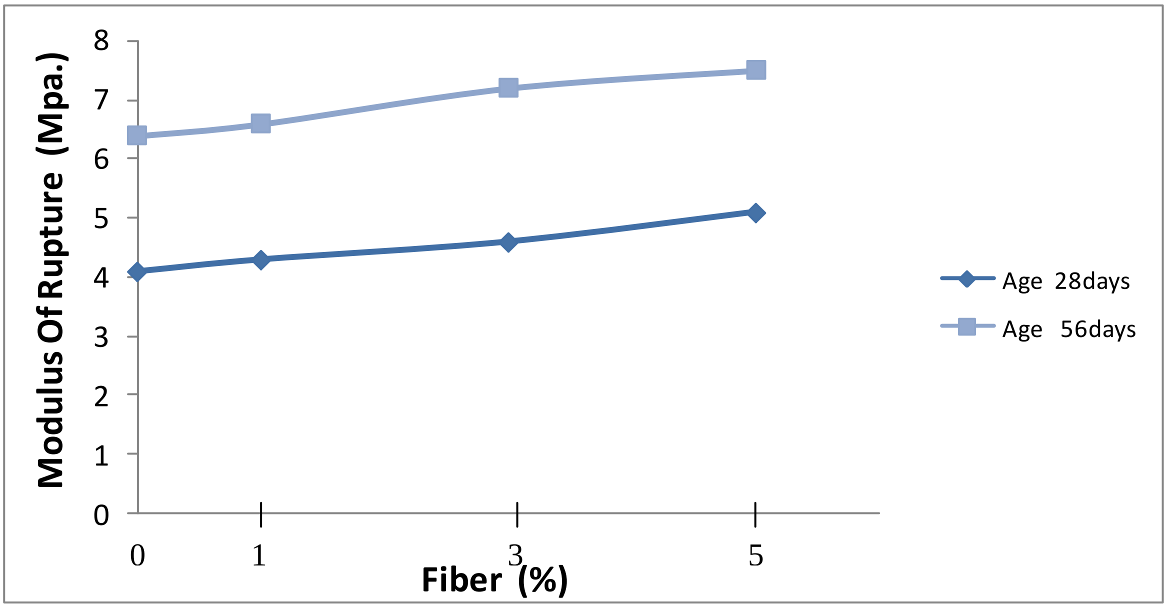

Figure (6) : Relation Between Fiber Ratio and Modulus Of Rupture

Conclusions and Recommendations:-

1) The result of concrete workability test, showed that the adding of glass fiber would reduce the value of slumpflow, t_{50cm}, blocking ratio of L-Box test and time flow of V-funnel test, but these results would remain within the standard classification.
2) Hardened concrete inspection results show the increasing of compressive and splitting strength and modulus of rupture (MOR) when using of glassy fibers and this increment is proportionate directly with volume of fibers which are used.
3) it is recommended to use glassy fibers in the self-compacting concrete (SCC) for the reason of it has a positive affect in the improvement of concrete properties .

References:-

1) Hannant D.J.,“Fiber Cement and Fiber Concrete”,1978,Wily Interscience Publication .
2) Swamy R.N. and Stavrides H., “ Some Properties Of High Workability Steel-Fiber Concrete ”, 1975 , Construction press Ltd. , 197-208 .
3) Hughes B.P. and Fattuhi N.I. , “ Fiber Bond Strength in Cement and Concrete ”,1975, Magazin of Concrete Research 27(92),pp 161-170 .
4) Shanmugam N.E. and Swaddiwudhipong S. , “ Strength of Fiber Reinforced Concrete deep beams containing openings ” , 1988 , International Journal of Cement Composites and light weight concrete , No.1,10, pp 53-60 .
5) Aveston J. , Cooper G.A. and Kelly A. , “ Single and Multiple Fracture the properties of fiber Composite ” , 1971 , Conference proceedings of N.P.L. Conference , IPC Science and Technology press Ltd. , pp 15-24 .
6) Marsh H.N. and Clarke L.L. , “ Glass Fibers in Concrete ” ,1974 , ACI Publication S.P.44 ,Fiber reinforced concrete , pp 247-264 .
7) Allen H.G. , “ Glass Fiber Reinforced Cement , Strength and Stiffiness ” ,1975 , CIRIA Report 55 .
8) Majumdar A.J. , “ The role of the interface in glass-fiber reinforced cement ” , May 1974 , BRE Current paper cp 57/74 .
9) Warner F. , “ Fiber Enhanced Concrete ” , 1995 , States of jersey public services Department , st. Hellier , pp 1-22 .
10) Ganzalo M.B. ,Fernando U.N. , Osman G. and Witold B. , “ Mechanical Properties of Polypropylene-Fiber reinforced concrete after gamma irradiation ” , 2011 ,Composites ,part A42 ,pp567-572 .
11) Gopaiautnam V.S. and Shah S.P. , “ Sottening Response of Concrete in Direct Tension ” , 1984 , Technological Institute Report , Northwestern University , Evanston .
12) Hillerborg A. , “ Theoretical Basis of a Method to Determine the Fracture Energy G_F of concrete ” ,1985 , RILEM Technical Committee 50 .
13) Jensen J.J. and Bjerkeli L. , “ Effect of Water Pressure on Concrete Structures ” , Water Absorption Static Strength and Strain Development Tests , SINTEF Report , STF65 , F87037 .
14) Kurtz S. and Balaguru P. , “ Post rack Creep of Polymeric Fiber-reinforced Concrete in Flexure ” ,2000 , Cenc Concr Res. (90-183) .
15) Neville A.M. , “ Properties Of Concrete ”, 2000 , 5th and final edition , Pitman , London .
16) Sravana P. , Srinivasa Rao P. and Seshadri Sakhar T. , “ Flexural Behaviour of Glass Fiber Reinforced Concrete Slabs ” ,2010 ,Conference on (Our World in Concrete and Structures) .
17) Central Organization for Standarization and Quality Control , “ Iraqi Standard Specification (IQS) No.5/1984 Ordinary Portland Cement ” ,Baghdad , Iraq .
18) Central Organization for Standarization and Quality Control , “ Iraqi Standard Specification (IQS) No.45/1984 Natural Aggregate Using in Concrete and Building ” ,Baghdad , Iraq .
19) ASTM C494-04, 2004 , “Standard and Specification For Chemical Admixtures For Concrete ”, Annual Book of ASTM Standards ,Vol. 02,04 pp.271-279 .
20) Ozawa K., Maekawa K. , Kunishima K. and Okaamura H. , “High Performance Concrete Based On The Durability Of Structures ” ,1989 ,Proceeding of the 2nd East Asia –Pacific Conference On Structural Engineering and Construction , Chiang-Mai .
21) Orjan Peterson ,“Preliminary Mix Design ” , 1998 , Final Report of Task 1, Swedish Cement and Concrete Research Institute ,pp 1-41 .