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Imrovement Of Structural Properties For Reinforced Concrete Deep Beam Using Silica Fume With Polypropylene Fibers

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ABSTRACT

The objective of this study is to investigate the effect of silica fume and polypropylene fibers to gather on the mechanical properties of concrete and the improvement on general behaviour for deep reinforced concrete beams containing silica fume and polypropylene fibers. Properties studied include Silica fume content used was (0%, 10% and 20%) by replacement of equal weight of cement in concrete. Polypropylene fibers were added in (0%, 0.20% and 0.40%) by volume fraction of concrete. Totally three deep reinforced concrete beams specimens with cross-sectional dimension of (100X300)mmfor a length of 1000mm were tested. Out of which three beams provisional on the relation of shear span (a) to the active depth (d) .The (a/d) ratio was used (1) with different containing silica fume and polypropylene fibers with differents percentsge of replacement for silica fume and various Polypropylene fibers were addition

تحسين الخصائص الانشائية للعتبات الخرسانية المسلحة العميقة الحاوية على غبار السليكا بلأضافة الى الياف البولي بروبلين

الخلاصة

أن الهدف من هذا البحث هو دراسة تأثير غبار السليكا و الياف البولي بروبلين سوية على الخواص المتصلبة للخرسانة وايضا دراسة التاثير على سلوك العتبات الخرسانية المسلحة العميقة الحاوية على غبار السليكا و الياف البولي بروبلين . الخصائص التي درست تضمنت أستعمال غبار السليكا بنسب 0%،10%و20% على التوالي، وايضا اضافة بنفس الوقت الياف البولي بروبلين بنسب حجمية 0%و0.20%و0.40% ، حيث تم دراسة ثلاث عتبات مسلحة عميقة بمقطع داخلي(300X100)ملم وطول1000ملم تم اختبارهن ,بلأعتماد على نسبة فضاء القص (a) الى العمق الفعّال (d),حيث نسب(a/d) استخدمت وهي(1)، من خلال الفحص العملي للخواص المتصلبة للخرسانة بينت تحسن في الخصائص وايضا بينت الدراسة تحسن في سلوك العتبات الخرسانية المسلحة العميقة الحاوية على غبار السيليكا و الياف البولي بروبلين من خلال النتائج المختبرية من عرض التشقق و فحص القوة-الهطول وايضا فحص الأنفعال مقارنة للعتبة غير حاوية على غبار السليكا و الياف البولي بروبلين .

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Introduction

Now a days waste material creation is increasing which leads to problem of its management. Thus it emphasized on use of waste material as a partial replacement of locally available materials used in construction, so that can accumulation which in turn helps us to improve overall effectively protect our environment from waste economy Silica Fume concrete is prepared by replacing cement partially by specific amount of Silica Fume in concrete. which will improve its engineering properties. The use of Silica Fume for its pozzolanic properties and special particlesize characters render quality up gradation at no extra cost or may be even as reduced cost.

Silica fume is mentioned to as micro silica or summarized silica fume, but the term silica fume has become generally believed. It is a by-product of the manufacture of silicon and ferrosilicon alloys from high-purity quartz and coal in a submerged-arc electric furnace (Neville, 1995)[1]. Silica fume is a generous of mineral admixture which provides special characteristics to concrete such as; condensed penetrability, improved reinforcement corrosion defense, better resistance against sulfate and chemicals attack, developed mechanical enactments, improved tensile and flexural strengths and last but not the least heightened compressive strength of concrete. The control concrete sample showed the lowest compressive strength, while concrete sample containing 10% silica fume occasioned in highestcompressive strength as associated to rest of the samples.Duval and Kadri (1998)[2] in their research paper found that the compressive strength of concrete increases withthesilica fume content up to 20% and reaches a maximum for a 10% to 15% silica fume level.Mazloom et.al. (2003)[3] presented experimental results on the workability, strength and autogeneous shrinkage with different percentage of silica fume.Bhanja and Sengupta (2005)[4] investigated influence of silica fume on the tensile strength of concrete. The important finding was strength increases with silica fume addition but optimum replacement level was not constant which depends on the water-cementious material ratio of the mix.

Fibers in cement matrix are secondary reinforced material and acts as crack arrester which helps us to restrict the growth of flaws in matrix which prevents these from enlarging under land, into cracks which eventually leads to failure. Thus fiber reinforced concrete is concrete made of cement, fine and coarse aggregate and discontinuous discrete fibers, when two different kinds of materials with contrasting properties of strength and elasticity.The usually castoff fibers are steel, glass, polymeric, carbon, asbestos, and regular fibers. The polypropylene, polyethylene, polyester, acrylic, and aramid fibers are becoming popular these times. Polypropylene fibers, produced by the fibrillation of polypropylene films, have been castoff in Portland cement concrete since the late 1960s (Bentur and Mindess, 1990)[5]. With minimal lengths of 6, 12 or 18 mm, polypropylene fiber is the perfect explanation for concrete mixtures susceptible to plastic shrinkage, cracking and crazing. The failure mode of conventional concrete is mainly due to spalling, while the failure mode of fiber reinforced concrete is bulging in transverse direction. Aly concluded that the overall total shrinkage strain of concrete increases slowly but consistently with increase in volume (Alyetal.,2008)[6]. Mydin,Roohollah studied the flexural behavior of light weight Foamed Concrete bare to great temperatures with altered polypropylene fiber percentages in range of 0.2 to 0.6% of mix volume and presented enhanced consequences (Md Azree et al., 2012; and Roohollah et al., 2012)[7].Peng-Zhang explored in their effort that presence of polypropylene fiber significantly advances fracture toughness, lessening crack length and maximum mid-span deflection of the three-point bending beam specimens of concrete compound covering 15% fly ash and 6% silica fume (Peng and Qingfu, 2013)[8]. Consequence of polypropylene was more marked in tension than compression due to the adhesive and friction services between concrete and Polypropylene fibers. Researchers have premeditated cement concrete and polypropylene fiber reinforced concrete, however seeing reinforcing fibers and silica fume is an innovative approach.The persistence of this work to study the effect of polypropylene fibers and silica fume to gather on the mechanical properties of concrete and the improvement on general behaviour for deep reinforced concrete beams when studied the crack patteren, load-deflection and strains.

Objective is to investigate the consequence of half-done replacement of cement with Silica Fume in varying percentages (0% , 10% and 20% by weight of cement), and of polypropylene Fibers volume fraction was(0%,0.20% and 0.40%) for enhancement the mechanical properties concrete and general behaviour for deep reinforced concrete beams .

Materials

1. Fibers

High enactment polypropylene fibers were castoff in this investigation, as presented in table (1) indicates the usual assets of the recycled polypropylene fibers[9].

Table (1) Properties of the used polypropylene fibers

Chemical Base	**100% Polypropylene Fibers**
Specific gravity	0.91
Fiber length	12mm
Fiber Diameter	18micron
Aspect ratio	667
Water Absorption	NIL
Melting point	160 C
Ignition point	365 C
Acid Resistance	High
Alkali Resistance	100%
Tensile strength	(300-400) MPa
Chloride content	NIL
Young's modulus	(3500-3900) MPa
Surface area	250 2/kg

2. Silica Fume

A gray densified silica fume (which is a byproduct from the manufacture of silicon or ferro-silicon metal) was used, which was introduced from Sika company. Silica fume is an awfully fine powder, its elements are hundreds of periods minor than cement particles, continuously used in minor percentage either as incomplete replacement of cement or as an additive (as cast-off in the current effort) to develop concrete properties. Table (2), Chemical is given compositions of silica fume used in this research .The silica fume obeys to the supplies of ASTM C1240-04[10].

Table (2) Chemical properties of silica fume

Oxide composition	**abbreviation**	**Oxide Content (%)**	**Limit of Specification Requirement (ASTM C 1240)**
Silica	SiO2	94.87	85.0 (min)
Alumina	Al2O3	1.18	-
Iron oxide	Fe2O3	0.09	-
Lime	CaO	0.23	-
Magnesia	MgO	0.02	-
Sulfate	SO3	0.25	-
Potassium oxide	K2O	0.48	-
Loss on ignition	L.O.I.	2.88	6.0(max)
Moisture content	-	0.48	3.0(max)

3. Cement

The cement used in this study is Iraqi conventional Portland cement (Taasluja) type (I). It is stored in airtight plastic containers to avoid exposure to different atmospheric conditions. This cement is tested and checked allowing to the Iraqi Standard Specification (IOS 5:1984) [11]. Tables (3) and (4) show the chemical and physical properties of this cement. It imitates to the Iraqi specifications.

Table (3): Chemical composition of the cement. *

Compound composition	**Chemical composition**	**Percentage by weight**	**Limits of IOS 5:1984**
Lime	CaO	62.00	_
Silica	SiO_2	21.00	_
Alumina	Al_2O_3	5.26	_
Iron Oxide	Fe_2O_3	3.00	_
Magnesia	MgO	2.70	<5
Sulfate	SO_3	2.10	<2.8
Loss on Ignition	L.O.I	1.10	<4
Insoluble residue	I.R	0.49	<1.5
Lime saturation factor	L.S.F	0.92	0.66-1.02
Main Compounds (Bogue's equation) percentage by weight of cement			
Tricalcium silicate (C_3S)		47.11	
Dicalcium Silicate (C_2S)		30.81	
Tricalcium Aluminate (C_3A)		8.87	
Tetracalcium Aluminoferrite (C_4AF)		9.12	

*Chemical testing laboratory in the College of Engineering. University of Basrah

Table (4): Physical properties of the cement.

Physical Properties	**Test result**	**Limit of IOS 5:1984**
Fineness using Blaine air permeability apparatus (m^2/kg)	312	≥230
Setting time using Vicat's instruments		
Initial (hrs:min.)	2:10	≥45 min
Final (hrs:min)	4:00	≤10 hrs
Compressive strength		
3 days (MPa)	20.5	≥15
7 days (MPa)	28.8	≥23

4. Fine Aggregate

The grading and amount of fine aggregate are important factors in the concrete. Natural sand from Al-Zubair region in Basrah city was used. The classifying of fine aggregate revealed in table (5) Specification No.45/1984[12]. Table (6) expressions the physical possessions of the used fine aggregate. The fine aggregate was with in zone (2) of Iraqi specifications No.45/1984[12]. Fineness modulus was 2.64.

5. Coarse Aggregate

Crushed gravel from Sanam mountain region in Basrah city with maximum size from (5)mm to (20) mm. Table (7) depend on the requirements of Iraqi specification No. 45/1984.Table (8) confirmations the specific gravity, chloride comfortable and absorption and sulphate.

Table (5): Grading of the fine aggregate.

No.	Sieve size (mm)	% Passing by weight	
		Test results	Limits of IOS No. 45/1984- Zone 2
1	10	100	100
2	4.75	99	90-100
3	2.36	90	75-100
4	1.18	75	55-90
5	0.60	53	35-59
6	0.30	17	8-30
7	0.15	2	0-10

Table (6): Physical properties of the fine aggregate.

Physical Properties	Test results	Limits of IOS No.45/1984
Specific gravity	2.65	-
Sulfate content(SO3) %	0.33	$\leq$ 0.5
Absorption %	1.1	-
Loose bulk density kg/m3	1645	-

Table (7): Grading of the coarse aggregate.

No.	Sieve size mm	Passing (%) by weight	
		Test results	Limits of IOS No.45/1984
1	20	100	100-95
2	14	80	-
3	10	37	30-60
4	5	2	0-10

Table (8): Properties of the coarse aggregate.

Physical properties	Test results	Limits of IOS No.45/1984
Specific gravity	2.65	-
Sulfate content(SO3)	0.073 %	≤ 0.1 %
Chloride content(Cl)	0.092 %	≤ 0.1 %
Absorption	.65 %0	-
Loose bulk density kg/m3	1500	-

6. Water

Tap water was used in this work .

Experimental Work

1. Concrete Mixes

Reference concrete mix was considered in agreement with ACI 211.1 -91 [13] shown in Table(9) to obtain a least compressive strength of 25MPa at 28days without any admixtures(BM25). The others way combinations were approved out to define the silica fume contented and fibers(BM30) and (BM40).

Table (9):Concrete mix materials

Mix symbol	**BM(25)**	**BM(30)**	**BM(40)**
Cement(kg/m3)	**390**	**390**	**390**
Water(kg/m3)	**195**	**195**	**195**
Fine aggregates(kg/m3)	**610.10**	**610.10**	**610.10**
Coarse aggregates(kg/m3)	**1073.4**	**1073.4**	**1073.4**
Water cement ratio	**0.50**	**0.50**	**0.50**
Silica Fume%	**0**	**10**	**0.20**
Fibers%	**0**	**20**	**0.40**

2. Mixing of Concrete

The mixing progression was executed in a pan type mixer of (0.1 m3)capacity. The inner superficial of the blender was prepared and moisturized before substituting the materials. The dry residents of the reference concrete mixture were located in the blender and diverse for about 1.5 minutes to trace a firm dry mix. Then, the compulsory quantity of water was additional, the entire mixture components were mixed for about 2minutes pending a uniform concrete mix was achieved .
For great enactment concrete, the prerequisite quantity of silica fume was diverse with the cement before the supplementary to the mixer to confirm uniform dispersal of silica fume. The dry components (cement, silica fume, sand, and gravel) were employed in mixer and mixed for about 1.5 minutes to achieve a unvarying dehydrated mix .The same procedure of involvement was passed out for the fiber reinforced concrete mixtures, excluding that the fibers were extra by hand after all involvement

radiant was carefully varied, and the mixing was then sustained for(2-3) minutes to attain a unchanging supply of fibers during the concrete mix.

Manual of Hardened Properties Trials

1. Compressive Strength of Concrete (f′c)

Figure (1) was concluded affording to Standard 150 mm cubes and (150*300 mm) cylinders were used according to BS 1881: part 116and ASTM C39-03[14] respectively, trial was piloted at ages of 7 days, 28 days.

Figure(1):compressive strength test

2. The modulus of rupture Test of Concrete(fr)

modulus of rupture is supported out by expending (100 x 100 x 500 mm) prisms, burdened at 450mm span with two points packing. The experiment is permitted out consenting to **ASTM C78-02** [15],spending three concrete prisms and the middling of three consequences is embraced. This processing showing as follows:-

$f_r = PL/bd^2$ 1)

where:-

f_r: modulus of rupture, MPa.

P: maximum load, N.

L: clear span length, mm.

b: width of specimen, mm.

Figure(2): Flexural strength test.

3. Splitting Tensile Strength of Concrete (ft)

cylinders of 150 mm x 300 mm were primed allowing to the **ASTM C496-04**[16]. Three samples are confirmed at age of 28 days and the middling rate of these samples is firm and noted, the cylinders is intended using the following equation:

$f_t = 2P/ \pi D L$.(2)

f_t: splitting tensile strength, (MPa).

P: Maximum applied load, (N).

D: diameter of specimens, (mm).

L: length of the specimens, (mm).

Figure (3):Splitting tensile strength test

4. Static Modulus of Elasticity Test(Ec)

cylinders of 150 mm x 300 mm were primed affording to the are allowing to **ASTM C469-02**[17]. Figure(4) was conquered from stress strain diagram using compressometer gage ,to evade impairment of challenging gage, all cases are examined up to 0.5 f'_c approximately. The slope of the conventional line drawn from origin to the point of 0.4 f'_c signifies the modulus of elasticity, consequently it is considered by the resulting formula:

$E_c=(S_2 - S_1)/(\varepsilon_2 - 0.00005)$ (3)

Where:

E_c= static modulus of elasticity, MPa

S_2 = stress corresponding to 40 % of ultimate load, MPa

S_1 = stress corresponding to a longitudinal strain (0.00005), MPa and

ε_2= longitudinal strain produced by stress $S2$.

Figure(4):Static modulus of elasticity test.

Experimental Results of Concrete

Investigational database of structural performance involves of casting and testing samples

Table(10):Variation of hardened properties with age 28 day (cement replaced by Silica Fume and Polypropylene Fibers volume fraction).

Mix No.	% Silica Fume	% Fibers	f_{cu} MPa	f′c MPa	f_t MPa	f_r MPa	E GPa
BM(25)	0	0	33	25	1.797	2.774	22.59
BM(30)	10	0.20	**42**	**31**	3.026	5.604	27.25
BM(40)	20	0.40	53	**40**	3.957	5.862	31.021

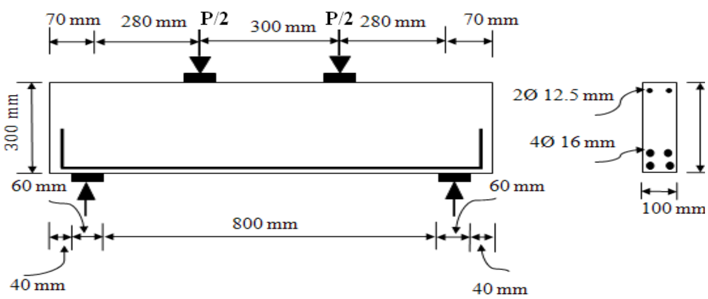
Investigational Program of Structural Performance

The database of structural behavior involves of casting and testing three specimens (3) beams. All the beams failed in shear and with shear span/effective depth (a/d) of (1).For each beams made with concrete mixes having compressive strength about 25, 30 and 40 MPa respectively.

Casting, Curing and Test Set-up of Beams Failed in Shear

Three reinforced beams considered to fail in shear without stirrups are reported. Three variables were investigated to appearance their possessions on the ability of beam to resistance the shear of the beams: the shear span-to-depth ratio (a/d) of (1), and concrete strength (fc') o f (25, 30 and 40) MPa. The beams details are offered in Figure(5) .

For all beam specimens, the cross section was100 mm wide and 300 mm in depth, , the longitudinal tensile reinforcement is constant 4 bars with diameter of 16 mm, and two bars 12mm diameter were used in compression zone to fix the stirrups at ends.The overall length was 1024 mm, with clear span 824mm for beams with (a/d) equal to (1).



Figure(5): Rectangular Deep Beam

1. The casting and curing Procedure for the shear beams as of the flexural beam specimens, as well as test set up with a few differences as follow:

   i. The rate of loading 10 kN per step for the beams .
   ii. The first flexural crack load in middle region was recorded as well as the first diagonal crack load, especially in test the beams with (a/d =1). At the end of each step of testing process, cracks were sketched and crack-width measured using a microscope for the two types of cracks.
   iii. Concrete strains were measured at the face of the specimens using strain targets were glued at the face of the specimens at the middle of the shear spans, and arranged as crosses to represent the concrete strains in direction of principle stresses in the shear spans. Also in mid-span, it were glued in location of top and bottom longitudinal reinforcement Figure(5).

2. Instruments and Test Procedure

Three simply supported deep beams were established up to failure at Al-Basrah University Laboratory using 2000 kN capacity hydraulic testing machine . During the test, the applied load and the conforming deflections at mid-span were measured from the trying machine and the dial gauges (reading to 0.01mm); then, the outputs from each trial beam were collected and castoff in intrigue the load-deflection curves. Longitudinal strains, over depth of concrete layer at shear-span, as presented in figure (6), were measured using demec gauge and the extensometer as shown in figure (10). All experiments were approved out primarily under the complaint of load control of 10 kN increments, which was then concentrated to 5kN nearby to the ultimate load. The equivalent investigation procedure was trailed for all beams. At the creation of each trial, a small load was useful (about 2kN) to bench the supports and stuffing system, then the load was unconfined and replenishing was carried out in a slow rate. For both sides of beam were painted white to depiction the establishment of cracks. The positions of the optical crashes in the concrete and loads, at which these are molded, were noted.

Figure (6) Photograph of a control rectangular deep beam with testing machine

Experimental Results and Discussion

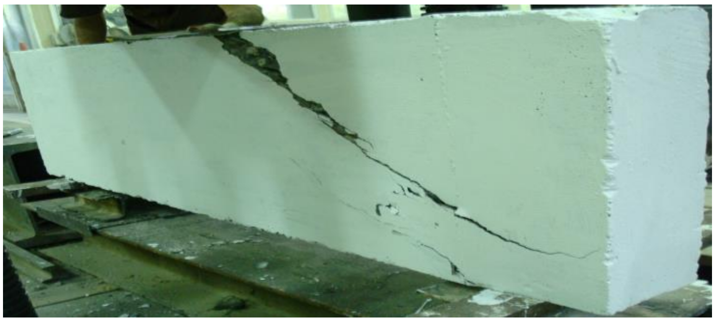
The chief impartial of the existing investigation study is to inspect consequence silica fume and polypropylene fibers on the conduct and load resounding ability of supported and reinforced concrete deep beams, the test results contain load resounding abilities s, load versus mid-span deflection curves, shear crack patterns and concrete strains.

1. Ultimate load.

The three deep beams tested in this study. The ultimate load and percentage increase in ultimate load with respect to reference beam (BM25)are shown in Table (11) . The alike mode of failure occurred for all deep beams. This mode was a diagonal shear crack which affected located in the shear zone at ultimate load level presented in Figure(7).

Table (11): Ultimate Loads of the Beam Specimens

Beam designation	Ultimate applied load (kN)	Percentage increase in ultimate load with respect to reference beam
BM(25)	200	------
BM(30)	320	60%
BM(40)	332	66%



Figure(7) Shear crack pattern after testing deep beam

2. Load Versus Mid-Span Deflection Results

From the load deflection curves of tested deep beams, it can be observed that the load versus mid-span deflection response can be divided into three stages of behavior.. It can also be noted that the strengthened deep beams failed suddenly and exhibited no ductility as shown in Figure(8).

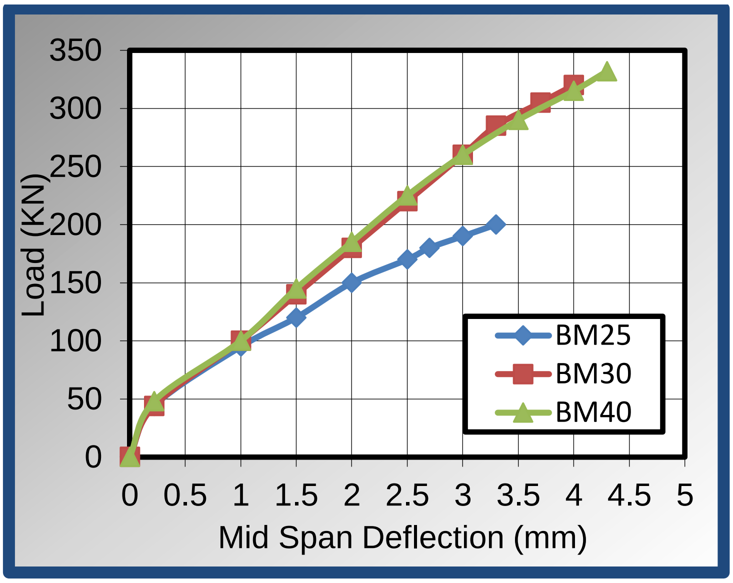


Figure (8): Experimental load versus mid- span deflection curve

3. Concrete Cracking

For each load increase, crack width of the main motivated crack at mid-depth of the beam was restrained by means of crack detection pocket microscope, figure (9) confirmation load versus crack width for all established beams.

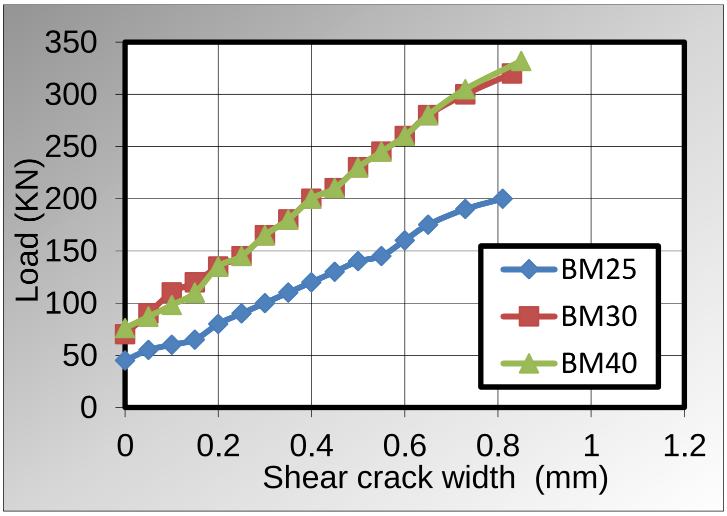


Figure (9): Load versus crack width of deep beams

4. Concrete Strain

The measured Diagonal concrete strains at points located at shear span of tested beams were measured by using a mechanical type Demec Gauge (Lc= 0.002 mm). It was used to measure surface concrete strain at every stage of loading. Aluminum discs with a 10 mm diameter and a 1.5 mm diameter hole at the centre, pasted on the face of the beam as plotted in Figure (10). The length and stage of loading was noted. To distinguish the regions at which the strain was measured, they were marked as A, B, C, and D, and at every loading stage, the development of determining and marking the straining was sustained up to the letdown of the beams. Detecting and measuring the cracks near the demecs were also done in Figures (11to13). From the experiment consequences, it can be realized that the relation was linear at low load levels, but it became nonlinear for all regions as the load increased at earlier stages due to cracking in concrete.

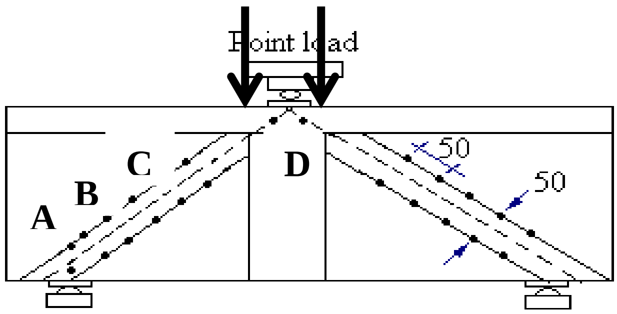


Figure (10): Locations of demec point in test beams

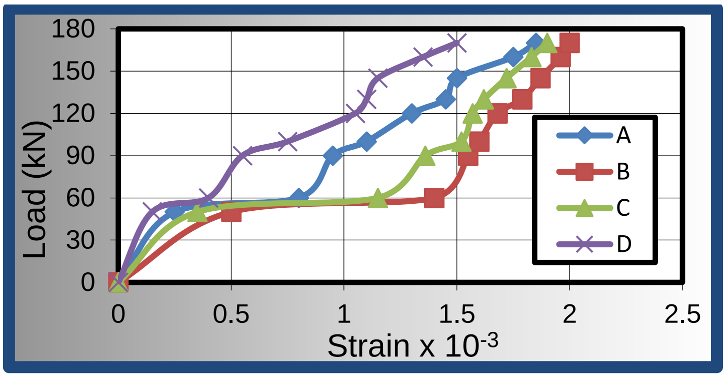


Figure (11): Concrete load- strain curve for(BM25) beam

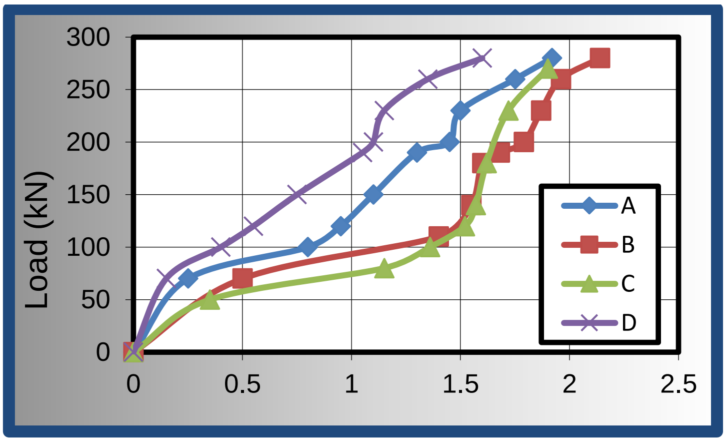


Figure (12): Concrete load- strain curve for (BM30)beam

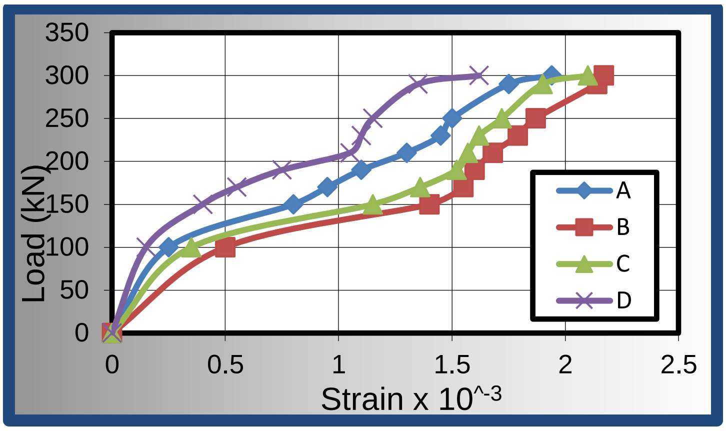


Figure (13): Concrete load- strain curve for(BM40)beam

CONCLUSIONS

The conclusions can be drawn on the basis of current study are:

1.The hardened properties of concrete are measured in mixes containing Silica Fume with polypropylene Fibers. Results demonstrated that in general, all concrete specimens exhibited increases in compressive strength, splitting and modulus of elasticity.

2.The addition of replacement of cement with Silica Fume in varying percentages (10%) and (20%) by weight of cement, and of polypropylene Fibers volume fraction was(0.20%, and 0.40%) to the concrete at 28 days to the causes increases in the in compressive strength, splitting and modulus of elasticity the increases were(63.2%,11.6%,11.3% and 32.8%) respectively concrete at 28 days containing 20% silica fume by weight of cement and 0.40 polypropylene Fibers volume fraction.

3. For beams intended to fail in shear,the beams prepared by Silica Fume and polypropylene Fibers(BM30,BM40) presented upper ultimate load paralleled with control beam(BM20), the increases were(60% and 66%) respectively.

4. A harder load-deflection retort is detected for deep beams supported with Silica Fume and polypropylene Fibers as related with retort of control deep beam

5.The numeral of cracks(flexural and shear) in reinforced deep beams was lower than the similar unstrengthened beams.

6. The reducing in the width of cracks due to attendance of Silica Fume and polypropylene Fibers is happened. The middling reduction is about 35 % of the crack width of the control deep beams at ultimate load levels.

7. Increasing the amounts of Silica Fume and polypropylene for deep beams reasons to reduction in deflection and width of cracks.

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