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Shear Behavior of Fibrous High Strength Concrete Deep Beams Under Uniformly Distributed Loading.

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Abstract

This paper investigates the effect of the steel fiber and type of web reinforcement of high strength concrete on cracking behavior and deformation characteristics of deep beams under uniformly distributed load. The complete load-deflection response and the modes of failure were investigated experimentally. Eighteen beams of (600*300*100 mm) and nine cubes of (150*150*150 mm) in dimension were tested and compared with the same three series of different types of web reinforcement which contain different contents of fiber as additive. Results indicate that mid-span deflection decreases with increasing fiber content, while shear capacity increases, also test results indicate that type of web reinforcement produces no effect on formation of vertical cracks.

Keywords: - Deep beam; High strength concrete; Steel fiber; Shear capacity.

Introduction

Deep beams are usually loaded along the top edge, as in Fig. (1-a), with reactions provided at the bottom. However, in some cases, as the side walls of storage bins, the loads may be applied along the bottom edges, as in Fig. (1-b).Loads may be applied more or less uniformity throughout the depth, as in Fig.(1-c), by other deep beam members framing in at right angles and reactions may also be distributed throughout the depth [1] . The behavior of reinforced concrete deep beams is influenced by many factors, such as clear span/ depth ratio , shear span / depth ratio , type of loading , position of the load ,amount and type of web reinforcement , concrete strength inclusion of other materials, such as type and percentage of fiber reinforcement…. etc.

They studied the strength and behavior of fibrous reinforced concrete conti- nuous deep beams with particular reference to shear strength [2].

The experimental program consisted of testing 24 two-spans deep beams with three different fiber volume fractions of 0.25, 0.5 and 0.75% with variable shear span to depth ratios varied between (1.25 – 1.67).The same amount of longitudinal main reinforcements were used, with the, same arrangement for the vertical web stirrups, while the horizontal web reinforcement was changing from nil to one layer(two bar).

Results indicate that ,(i)- the horizontal shear web reinforcement was almost ineffective on strength, (ii)- the increase of steel fiber will increase the strength of beams by about 16% ,(iii)-the availability of discrete steel fiber will delay the formation and widening of cracks , (iv)- the deflection was decreased about 15% to 16% in linear elastic range and about 17% to 19% near failure and (v)- all the beams with horizontal shear reinforcement showed smaller deflections at both elastic and failure stages, of about 11% to 12% for both nonfibrous and fibrous beams compared with those without horizontal shear reinforcement.

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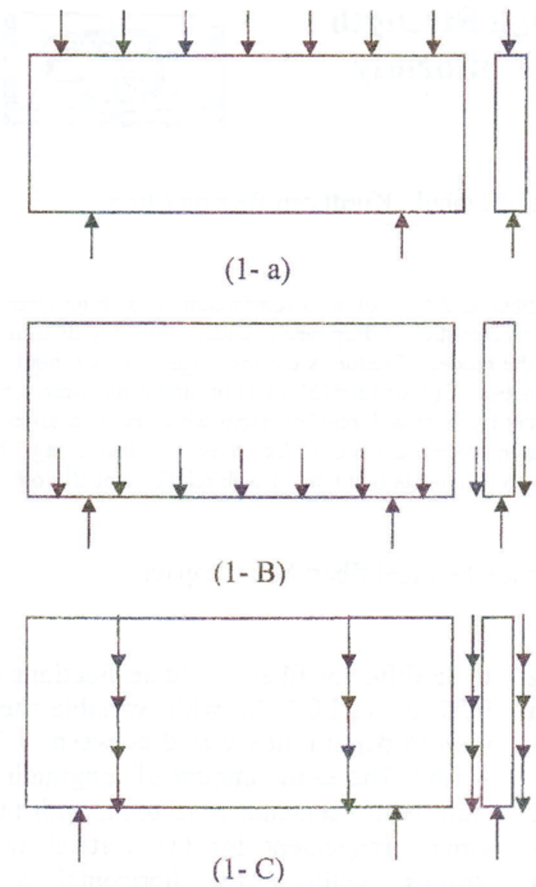

Fig. (1): Placement of loads on deep beams

They studied the experimentally the size effect in reinforced concrete deep beams [3].

They tested 12 large and medium size specimens with overall height (h) ranging from 500 to 1750mm and effective span from 1500mm to 4520mm to failure under symmetrical two-point top loading .

The beams had compressive cylindrical strength of about 40MPa and main steel ratio of 2.6%. Test results reveal that the ultimate shear strength is size – dependent and Bazants law can best describe this size effect. On the other hand, the diagonal stress is hardly size – dependent, besides the shear span to height ratio a/h has a significant influence on the failure mode.

Larger deep beams are more brittle in comparison with smaller ones.

After comparing with ACI code, they found that ACI code prediction model do not have uniform safety margin.

Larkutzing[4] investigated the ultimate shear behavior of normal strength (NSC) as well as

high strength concrete (HSC) by loading a beam at 4 points with a total span of 1540mm.

The cross-section was rectangular with a height of 200mm and a width of 300mm with clear shear span of 520mm too. After testing of the 3 beams series (the natural strength concrete (NSC) and the high strength concrete (HSC) beams without fibers, and one NSC beam with 40 kg/m³ of steel fibers), he found that ,when 40 kg/m³ of steel fiber are added to NSC, the shear capacity goes up sharply.

The shear strength surpasses the ultimate bending capacity of the test beam. It fails by crushing at the compressive zone. After the strengthening of the beams of the first series at the compressive zone with strong reinforcement, the ultimate shear strength did not reach the bending capacity. Atypical ordinary shear collapse behavior could be observed.

They investigated the effect of inclusion of steel fibers in concrete on crack and deformation characteristics of deep beams for various spans to depth ratio [5]. Twelve beams, simply supported under single point loading were casted and tested under gradually increasing load at their centers.

The results indicate that, the inclusion of steel fibers significantly reduces the cracking and deformation behavior of plain concrete deep beams by resisting tensile stresses. Comparisons were made among the varied span to depth ratio of beams within the same series too.

They investigated the strength and behavior of deep beams at different ages [6].
Forty prisms of deep beams of (600*300*75mm) in dimensions were casted and divided into two series. The first series was reinforced with steel fibers of different aspect ratios of (62.5,83.33 and 100%) while the second series the beams were reinforced with different types of web reinforcement (horizontal ,vertical and grids). Saeed results conclude the followings (i)-the strength of deep beams increased with time,(ii)-the strength of deep beam reinforced with steel fiber is increased, (iii)- the effect of aspect ratio of steel fiber on strength of deep beam decreased with time and (iv)- the strength of deep beam reinforced with diagonal web steel was highly increased for different ages when compared with beams without diagonal web reinforcement and steel fiber contents.

Table(1): Specimens Details*

Series	Beam No.	Main Steel Reinf.	Web Reinf.		Fiber Content%
			H.Reinf	V.Reinf.	
B	1BOF	2 Φ12mm	----------	----------	0
	2BOF	2 Φ12mm	----------	----------	0
	1B1.5F	2 Φ12mm	----------	----------	1.5
	2B1.5F	2 Φ12mm	----------	----------	1.5
	1B3F	2 Φ12mm	----------	----------	3
	2B3F	2 Φ12mm	----------	----------	3
BH	1BHOF	2 Φ12mm	3Φ10mm	----------	0
	2BHOF	2 Φ12mm	3Φ10mm	----------	0
	1BH1.5F	2 Φ12mm	3Φ10mm	----------	1.5
	2BH1.5F	2 Φ12mm	3Φ10mm	----------	1.5
	1BH3F	2 Φ12mm	3Φ10mm	----------	3
	2BH3F	2 Φ12mm	3Φ10mm	----------	3
BHV	1BHVOF	2 Φ12mm	3Φ10mm	3Φ10mm	0
	2BHVOF	2 Φ12mm	3Φ10mm	3Φ10mm	0
	1BHV1.5F	2 Φ12mm	3Φ10mm	3Φ10mm	1.5
	2BHV1.5F	2 Φ12mm	3Φ10mm	3Φ10mm	1.5
	1BHV3F	2 Φ12mm	3Φ10mm	3Φ10mm	3
	2BHV3F	2 Φ12mm	3Φ10mm	3Φ10mm	3

* Nine control cubes were prepared (i.e., 3 cubes for each percentage of fiber).

P.D.Zararisl [7] described a theory in which the shear failure of reinforced concrete of deep beams under two-point or a single point loading with shear span to effective depth ratio (a/d) between 1.0 and 2.5, is due to a crushing of concrete in compression zone with a restricted depth above the tip of the critical diagonal crack. Simple expressions are derived for the restricted depth of the compression zone, as well as, for the ultimate force of deep beams with and without web reinforcement .The derived formuli from this analysis were verified by comparisons to extensive sets of experimental data from literature for deep beams with various strengths of concrete , main steel ratios, and shear span to depth (a/d) ratios between 1.0 and 2.5.This paper studied the shear behavior of high strength concrete (HSC) on model beams supported at two ends and subjected to uniformly distributed loading with variables, such as, web reinforcement type and steel fiber content.

Experimental Programme

A total of 18 beams specimens (600*300*100mm) and 9 control cubes of (150*150*150mm) in dimension were cast and tested at 28 days, as in Table (1).

Testing Materials

Ordinary Portland cement and crushed river aggregates were used. Sand of fineness modulus of 2.9 and gravel of maximum size of 19mm as coarse aggregate were used. The concrete mix proportion was 1:1:2 by weight with water cement ratio of 0.4 kept for all specimens. A plasticising retarding (ChemoPlast RP1), was used to improve the workability, the rate of addition was about 1.2 lit/100kg cement. Steel fiber of plain rectangular section with aspect ratio equal to 32 and its yield strength of 420 MPa were used. Longitudinal reinforcement consists of 2 bars of Ø12mm of 378 MPa yield strength were used at the bottom of beams and 3 bars of Ø10mm were used as web reinforcement placed horizontally and vertically in the beam. The beams were casted taking special care to ensureuniform distribution of fibers and to prevent them from balling up.

Specimens Details

Tests were carried out on 18 beams (600*300*100mm) in dimension. All the beams had constant clear span of 500mm and a span to depth ratio of 2.0. The beams were divided into three series as follows ;(i)- (B) series, which consisted of 6 beams reinforced only for bending (2Ø12mm),(ii)- (BH) series which consisted of 6 beams reinforced for bending and web reinforcement (horizontal only), and (iii)- (BHV)series which consisted of 6 beams reinforced for bending and web reinforcement (horizontal and vertical). Placing and vibrating of concrete was implemented externally which contain steel fiber of 0%, 1.5% and 3.0%, as in table (1). Nine control cubes of (150*150*150mm) in dimensions (i.e., 3 cubes for each group) were prepared.

Testing Procedure

The beams were tested under gradual uniform increase of loading at the top of testing beam. Fig.(2) shows the compression machine used for the tests. A dial gauge of (0.002mm) in accuracy was fixed at the lower part of base platform to measure the mid-span deflection. Surface strains on concrete were measured with mechanical type demec gauge of (0.002mm) in accuracy at every stage of loading.Aluminum discs with 10mm diameter and a 1.5mm diameter holes were fixed at left and right sides from the center of tested beam and at a distance of 75mm from top and bottom surface. Fig. (3) Shows the test setup and arrangement of demec discs on beams.

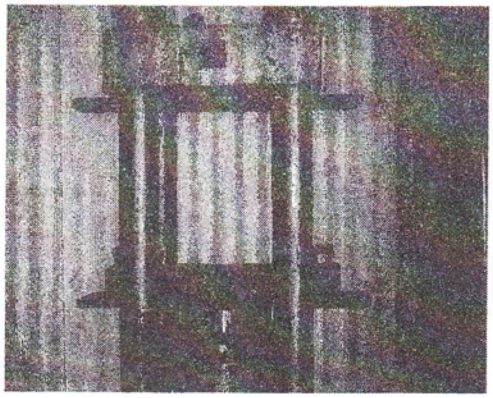

Fig. (2): Testing Machine of Beams

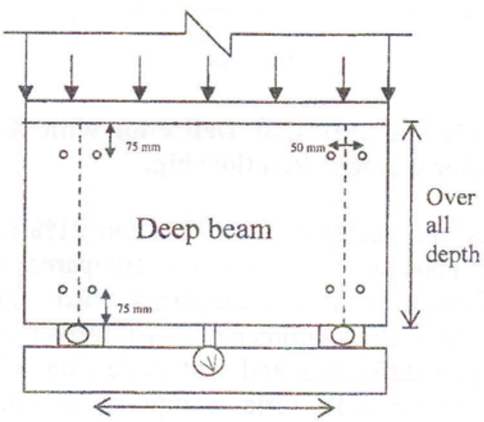

Fig.(3):Test Setup and Arrangement of Demec Disc on Beam.

Results and Discussion

In a deep beam under uniformly distributed loading, the entire load is transferred to the supports. Almost, in all specimens, the first cracks were observed at maximum positive moment (flexure cracks) and extended vertically upward .These cracks stopped after loading of above 50% of failure load. Shear cracks then appeared at the supports and extended vertically upward, finally beam failure was occurred by crushing of the concrete along the vertical cracks in either of two supports.

Fig. (4) shows the cracks pattern after beam failure.

Fig.(5) show that the effect of fiber content on compressive strength of concrete is small. The increase of strength was 3.5% and 4.5% for 1.5% and 3% fiber content compared to nonfibrous concrete respectively.

Table (2) and Fig.(6) show that the effect of fiber content on shear capacity was clear obviously as well as type of web reinforcement . For B series, the increase in shear capacity was 3% and 22% for fiber content of 1.5% and 3% compared to nonfibrous concrete respectively.

For BH series, the inclusion of fiber content of 1.5% and 3% increased the shear capacity by 10% and 15% compared to nonfibrous concrete respectively. For BHV series, the effects of fiber content of 1.5% and 3% increased the shear capacity by 9% and 12% compared to nonfibrous concrete respectively, also, we noticed that type of web reinforcement will effect on shearstrength capacity too, and that capacity will be increased for BHV series compared to other series.

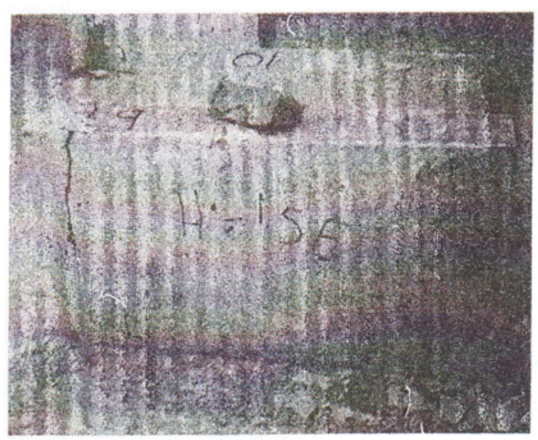

Fig. (4): Cracks Pattern and Position

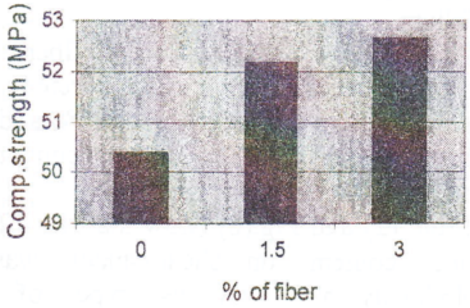

Fig. (5):Compressive Strength and % Fiber Content Relationship.

From Fig. (7), the maximum mid- span deflection for B series were decreased by 5% and 3% for fiber contents 1.5% and 3% than nonfibrous concrete respectively.For BH series , the decrease was 6.2% and 10% for fiber content 1.5% and 3% compared to nonfibrous concrete respectively . For BHV

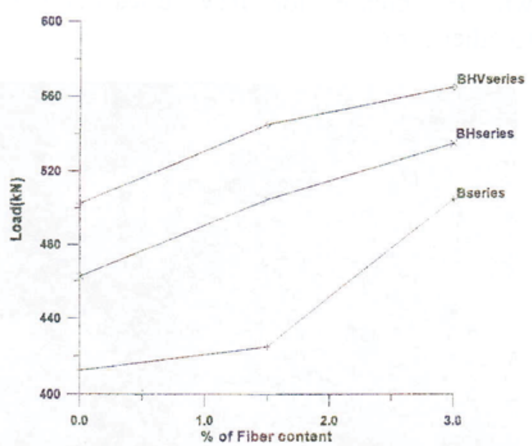

Fig.(6): Fiber Content and Shear Capacity Relationship.

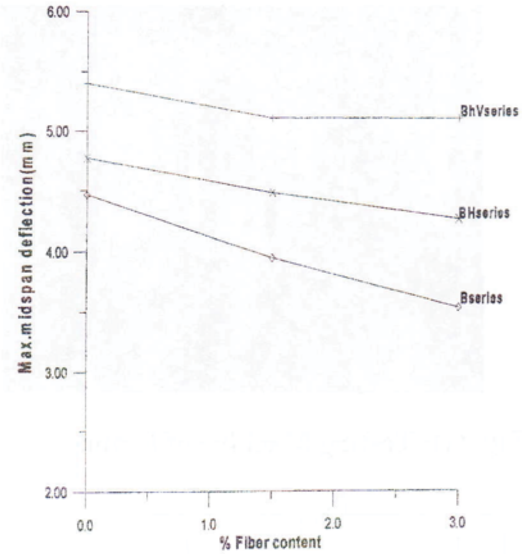

Fig. (7): Max.Midspan Deflection with % of Fiber Content Relationship.

series, the decrease was 12% and 21% for fiber content 1.5% and 3% compared to nonfibrous concrete respectively, also , the type of web reinforcement will effect on midspan deflection and that deflection will reduced for BHV series compared to other series.

Concrete strains were measured on the front side surface of the beams at the specified positions. As cracks formed and propagated, the concrete strain increases rapidly. Table (3) shows the results of strains at three stages of loading (100,200 and 300 kN) for all beams respectively. The results show not any variation between fibrous and nonfibrous deep beams and also shows that, the difference among different series is not quite varied.

Table(2) Results of Maximum shear capacity for different % fiber content

Type of Reinf.	%of Steel Fiber.								
	0%			1.5%			3%		
	Max.Load Applied (kN)			Max.Load Applied (kN)			Max.Load Applied (kN)		
	1st	2nd	Average	1st	2nd	Average	1st	2nd	Average
B series	405	420	412.5	450	400	425	500	510	505
BHseries	450	475	462.5	510	500	505	520	550	535
BHVseries	500	505	502.5	550	540	545	560	570	565

Table(3) Results of strains at desired position for different series at specified loads

% of Fiber	Type of Reinf.	Sample No.	Strain $*10^{-4}$ mm/mm					
			Applied Load (kN)					
			100		200		300	
			U.Demec	L.Demec	U.Demec	L.Demec	U.Demec	L.Demec
0	B	1B	1.2	-4.4	3	-3	16	18
		2B	-0.4	0	0	6	-1	60*
	BH	1BH	1.6	0.8	1.6	1.6	1.6	-2
		2BH	6	-1.6	-3.2	1.6	-8	4
	BHV	1BHV	2	0.8	0	0	-1.6	1.2
		2BHV	0.4	0	12	52*	80*	140*
1.5	B	1B	0	0	2.4	-16	12	-20
		2B	1.6	6	8	28	4	120*
	BH	1BH	-2	0.8	-1.6	8	48*	20
		2BH	1.2	1.6	3.2	12	4.8	24
	BHV	1BHV	-2.4	-0.4	-2.4	0	-4	1.2
		2BHV	2	2.8	2	100*	12	180*
3	B	1B	-0.4	0	0	-2.8	0.4	-2
		2B	2.4	2.8	60*	88*	128*	180*
	BH	1BH	-1.2	-6	-3.6	-4.8	12	28
		2BH	1.2	0.8	1.6	4.4	5.2	24
	BHV	1BHV	1.6	1.2	2.4	2	6	3.6
		2BHV	0.4	0	0	0.8	-1.2	100*

* Cracks failure

Conclusions

1- Shear capacity (load) at failure of B series is increased by 3% and 22% while deflection (i.e.,max.midspan) is decreased by 5 % and 5.7% for 1.5% and 3% fiber content compared to nonfibrous concrete respectively.

2- Shear capacity (load) at failure of BH series is increased by 10 % and 15% while deflection (i.e.,max.midspan) is decreased by 6.2% and 10% for 1.5% and 3% fiber content compared to nonfibrous concrete respectively.

3-Shear capacity (load) at failure of BHV series is increased by 9% and 12% while deflection (i.e., max. midspan) is decreased by 12% and 21 % for 1.5%and 3% fiber content compared to nonfibrous concrete respectively.

4- All beams exhibited large deflection at failure than normal concrete , indicating high ductility and energy absorption property , therefore, the deflection is a major design limitation.

5- Type of web reinforcement will effect on shear capacity and span deflection . The use of combination of horizontal and vertical web reinforcement leads to improve the shear capacity(increase) and the midspan deflection (decrease).

6- Type of web reinforcement have no effect on formation of vertical cracks.

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ڕەوشتی بەرهەڵستی برین لە كەمەرەی كونكریتی قوڵ و داڕێژراو بە ریشاڵی ئاسنین لەژێر كێشی چوون یەكدا

سامر حیكمەت حەننا، پیمانگای تەكنیكی دهۆك، بەشی ئەندازیاری، هەرێمی كوردستان / عێراق

پوختە

ئەم لێكۆڵینەوەیە كاریگەری ڕێژەی ریشاڵی ئاسنین و چۆنیتی دانانی شیشی ئاسن بۆ بەرهەڵستی برین لەسەر كەمەرەی قوڵی بەهێز كە باركراوە بە كێشی چوون یەك، هەروەها جۆری شكانەكەی. بۆ ئەم مەبەستەش ١٨ نموونە تێست كراوە لەم كەمەرانە (٦٠٠*٣٠٠*١٠٠ مام). ئەنجامەكان ڕوونیانكردەوە كە زیادكردنی ریشاڵی ئاسنین دەبێتە هۆی كەمكردنەوەی چەمانەوە و زیادكردنی بەرهەڵستی ئەم كەمەرانە بۆ هێزی برین .

سلوك العتبات الخرسانية المسلحة العميقة عالية المقاومة و المعززة بالالياف الفولاذية للقص و المعرضة لاحمال الموزعة بانتظام.

ثامر حكمت حنا، المعهد التقني دهوك، قسم الهندسة، اقليم كوردستان / العراق

الخلاصة

يهدف البحث الى دراسة تاثير نسبة الالياف الفولاذية ونوع حديد التسليح الوتري لخرسانة عالية المقاومة على نمط الفشل والتشوهات للعتبات العميقة والمعرضة الى احمال موزعة بانتظام. تم صب وفحص ١٨ نموذج من الجسور العميقة (١٠٠*٣٠٠*٦٠٠) ملم بالاضافة الى ٩ نماذج من المكعبات (١٥٠*١٥٠*١٥٠) ملم وبنسب مختلفة من الالياف الفولاذية (٠٪ و ١,٥ ٪ و ٣٪) بالاضافة ثلاثة انواع من حديد التسليح الوتري . اظهرت النتائج ان زيادة نسبة الالياف ادى الى تقليل الاود وزيادة المقاومة القصوى للعتبات في القص في حين ان نوع التسليح الوتري لايؤثر على شكل ونوع الفشل .

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وەرگرتن لە ٤ / ١١ / ٢٠٠٥ دا و پەسەندكردن لە ١٩/١١/٢٠٠٦دا.