BEHAVIOR OF HIGH-PERFORMANCE CONCRETE BEAMS WITH AND WITHOUT FIBER AS AFFECTED BY RIB GEOMETRY OF REINFORCEMENT BARS

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The need of high-performance concrete is increased in the recent years. Using steel of high grade and maximize the benefit of using these material become necessary, but these material were brittle and the failure also were brittle .So, fibers are used to enhance composite properties. The enhanced properties include tensile strength, compressive strength, elastic modulus, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics, and fire resistance. .There is little information in the available literature about the flexure behavior of high-performance and high-performance fiber-reinforced concrete beams with different rib geometry under partial bond

The main objective of this research is to study the effect of rib geometry for steel bars and fibers types on the flexure behavior of high-performance and high-performance fiber-reinforced concrete beams under partial bond, also Pattern of cracks, final mode of failure and deformational characteristics (deflection, slip, concrete strain and slope for beams) were investigated.

KEYWORDS: *Bond; High performance concrete; beams; behavior; rib geometry; steel, Fiber.*

1- INTRODUCTION

The behavior of hardened high-performance concrete (**HPC**) can be characterized in terms of its short-term (essentially instantaneous) and long-term properties. Short-term properties include strength in compression, tension, bond, and modulus of elasticity. The long-term properties include creep, shrinkage, behavior under fatigue, and durability characteristics such as porosity, permeability, freeze-thaw resistance, and abrasion resistance

The need of high-performance concrete is increased in the recent years. Using steel of high grade and maximize the benefit of using these material become necessary. So, different ribs are used for the bond strength between steel reinforcement and high-performance concrete, but these materials were brittle and the failure also was brittle.

So, fibers are used to enhance composite properties. The enhanced properties include tensile strength, compressive strength, elastic modulus, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics, and fire resistance concrete.

High-Performance Fiber-Reinforced Concrete (**HPFRC**) results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. Due to the superior performance characteristics of this category of(**HPC**), its use by the construction industry has significantly increased in the last 16 years. A very good guide to various portland cement-based composites as well as their constituent materials is available in a published book [Balaguru and Shah 1992][1]. The book provides information on fabrication, mechanical and long-term properties of concretes with short discrete fibers. It also covers special topics such as fiber reinforced cements and slurry-infiltrated fiber concrete. In 1992, the first international workshop on high performance fiber reinforced cement composites (HPFRCC) was held in Mainz, Germany [Reinhardt and Naaman 1992][2].

M. H. Harajli and M. E. Mabsout (2002)[3] have studied the effect of fibers on the bond strength of deformed bars embedded in concrete . They have reported that the use of fiber reinforcement significantly increases the development/splice strength and considerably enhances the ductility of bond failure. The increase in bond strength acquired using steel fibers may reach levels substantially larger than the maximum limit stipulated in the ACI building code for ordinary transverse reinforcement.

Experimental study on steel fiber-reinforced concrete beams were investigated by Magdy A. Tayel et al. (2003)[4] as follows :
1- The addition of steel fiber to a concrete mix has increased the hardened concrete compressive and tensile strengths.
2- The adding steel fiber in very small ratio 0.25% does not increase the concrete strengths.

The effect of rib geometry for steel reinforcement on bond of normal strength concrete study by Ali M.A. (2000)[5] found that the final mode of failure , cracking and ultimate load and deformation for cantilever-to-column connection effective by the relative rib area (α_{sb}) and development length . The geometry of the ribs can be expressed by the relative rib area α_{sb} described by Rehm [6] as **α_{sb}** (ratio of projected rib area normal to bar axis to the product of the nominal bar perimeter and the center-to-center rib spacing).

Since 1990, several studies have been conducted to investigate specifically the bond strength of reinforcement in high strength concrete. De Larrard et al. [1993][7] evaluated the bond strength between high strength concrete and reinforcing bars using the RILEM beam test. A high strength concrete with 28-day compressive strength of 95 MPa was used along with a normal strength concrete of 42 MPa as control. Three different sizes of deformed bars (10, 16, 25 mm) and one smooth bar (25 mm) were used. Based on several preliminary tests, the RILEM recommended bond (anchorage) length of 10 times bar diameter had to be reduced to 3 times to 2.5 times bar diameter for high strength concrete to ensure bond failure rather than yielding of reinforcement. The effect of rib geometry for steel reinforcement on bond characteristics and rotational capacity of exterior joints in structures of normal strength concrete study by Ali M. Abdallah (2000)[5] found that the bond stress increased by increased the relative rib area (α_{sb}). Also the values of the deflection and the slope at free end of cantilever

were increased with the decrease of the relative rib areas (α_{sb}) but the values of concrete strain; the rotation angle and the rotational capacity for the cantilever-to-column connection were decreased with the increase of the relative rib areas (α_{sb})

2-EXPERIMENTAL PROGRAM

Nine beams specimens were tested with steel diameters 16 mm and rectangular cross section equal to 12×30 cm^2, as shown in fig (1). The considered span for beams specimens were 240 cm for specimens. Strength of concrete (f_c) was 900 kg/cm^2. Bonded parts out the support (L_1) for steel reinforcement used in the tested beams were $5d_b$ for all beams specimens. The study takes into consideration the following parameters:

1- 1-Rib geometry and its relative rib area (α_{sb} for steel reinforcement used in the tested beams were 0.00, 0.062 and 0.10.
2- Types of fiber, two types of fibers (polypropylene, and harex steel fibers) were used for all specimens

The beams were tested and the average values of both cracking and ultimate loads were considered. The behavior includes the initiation of cracks and their propagation, the final mode of failure , the relationship between the applied flexural load and the maximum induced deformation ; in terms of deflection ,slip, strain and slope for (**HPC**) and (**HPFRC**) beams specimens reinforced with steel having variable relative rib area (α_{sb}) and different types of fibers were studied .

The beams were tested and the behavior includes the initiation of cracks and their propagation, the final mode of failure, the relationship between the applied load and the maximum induced deformation; in terms of deflection, slip, strain and slope for (HPC) beams reinforced with steel having variable relative rib area (α_{sb} were studied .
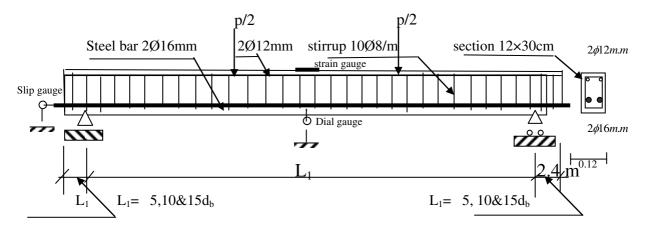

Fig.(1) : Details of R.C. Tested Beams

2.1- Materials:

2.1.1- High performance concrete (HPC):

Concrete mix design was made to produce high performance high strength concrete having 28-day cubic strength of 900 kg/cm^2. Concrete mix proportions are given in Table (1).

Table (1): concrete mix proportions

Cement kg/m^3	fine aggregate kg/m^3	Coarse aggregate kg/ m^3	Silica-fume kg/m^3	Super plasticizer (B.V.S.) Litre/m^3	Water liter/m^3
500	580	1200	110	17.5	140

Ordinary Portland cement was used (Assiut Cement). The coarse aggregate used was crushed basalt of 12mm nominal size. Local natural sand was used as fine aggregate; Super plasticizer (B.V.S.)type , with optimum dosage 17.5 litre/m^3 for concrete mix ; 110 kg/m^3 optimum dosage of silica fume with specific gravity 2.15

Steel Reinforcement:

Plain bars of normal mild steel(Sm &Sm* α_{sb} =0.000), its diameters 8 and 16 mm used for stirrups in RC beams and main steel as well as deformed bars of high tensile steel were used as longitudinal tension/compression reinforcements (B\S α_{sb} =0.062, EZ•AL2 α_{sb} =0.100& EZAL α_{sb} =0.060) , their diameters are 16 and 12mm in R.C. flexural members (beams) , are given in table (2)

Table (2): Mechanical and Geometrical Properties of Deformed Bars.

Group	Series	d_b (mm)	Specimens Notation	Relative Rib Area (α_{sb})	Yield stress (f_y) kg/cm^2	Ultimate stress (f_u) kg/cm^2	% Elongation % e
B and BF	B1-3 and BF-PP and BF-HS	16	Sm	0.000	3100	4600	28.6
			B\S	0.062	4600	6700	19.2
			EZ•AL2	0.100	4750	6900	18.5
Top steel		12	EZAL	0.060	4600	6700	22.0
Stirrups		8.0	Sm*	0.000	2900	4200	29.5

2.1.2 -High-performance fibers-reinforced concrete (HPFRC):

Six beams with high performance fiber reinforced concrete equal to 900 kg/cm^2 (with polypropylene and harex steel fibers), with the same material used of(**HPC**). Typical properties of various types of the non-metallic fiber (polypropylene fiber) and metallic fiber (harex steel fiber) are given in Table (3) and the shape of fibers as shown in fig.(2) . One fiber concentration was used in the specimens this was 1.0% by volume of the total mix

a-Polypropylene fiber   b-Harex steel fiber

Fig. (2): Shape of non-metallic and metallic fibers

Table (3) : Typical properties of fibers

Type of fiber	Diameter (μm)	Length (mm)	Density (gm/cm^2)	Tensile Strength kg/cm^2	Young's modulus kg/cm^2	Elongation (%)
Polypropylene	2-20	18	0.91	5000	50000	8-10
Harex steel	1000	32	7.8	20000	2000000	3

2.2 Test Procedure:

Nine beams of 28 days age were tested simply supported over a clear span of 2.4 m and were tested under two third-point loading. The available testing machine (EMS 60 tons Pu) was used in testing the beams specimens under static loading. Average values of 28-days concrete compressive strength determined from cubes of 15cm side length were (907, 900 and 918 kg/cm^2) for (**HPC**) beams without fibers, (**HPC**) beams with polypropylene fibers and harex -steel fibers respectively.

3-TEST RESULTS

3.1- Crack Pattern and Mode of Failure.

The cracks pattern and modes of failure are explained for the tested reinforced high-performance concrete (HPC) and high-performance fiber–reinforced concrete (HPFRC) beams. Three rectangular (**HPC**) beams and six rectangular (**HPFRC**) beams tested under static loading. Generally, two types of final failure mode can be distinguished according to the relative rib area (α_{sb}) and fibers types as follows: -

    (1) Bond failure.
    (2) Flexural failure.

The effect of the various parameters on the cracks and final modes of failure for beams will be discussed as follows.

3.1.1 Effect of relative rib area (α sb).

The following noted cracks for tested beams were observed as follows:

- The initiation of cracks were observed at smooth bar or small value of (α_{sb}) for specimens (B1,B1P,B1S)although they were observed for beams (B3,B3P,B3S) at greater value of (α_{sb})

- The width of cracks and spacing between it were significantly large for beams (B1, B1P, B1S) having smooth bars, but narrow for other beams having ribbed bars.

- The propagation of cracks for beams (B3,B3P,B3S)and (B2,B2P,B2S) were more than those compared for beams (B1,B1P,B1S).

- The major cracks were formed at the max .moment for all beams (at mid span of beams).

- The final modes of failure of beams (B1,B1P,B1S) with smooth bars were noticed to be bond failure , and for ribbed bars with rib area (α_{sb}) = 0062 , 0.010 as a beams (B2,B2P,B2S and B3) but were flexural failure for beams (B3P and B3S) .

3.1.2 Effect of fibers types

The following noted cracks for beams were observed as follows:

- The initiation of cracks was observed for beams without fibers (B1, B2, B3) although they were observed for beams with polypropylene. Fibers (B1P, B2P, B3P) and beams with harex steel fibers (B1S, B2S, B3S).

- The propagation of cracks for beams (B1S, B2S , B2S) were less than those compared for beams (B1P ,B2P, B3P) and beams (B1P ,B2P, B3P) were less than those compared for beams (B1, B2 ,B3).

- The major cracks were formed at the max moment for all specimens (at mid span of beams).

- The final modes of failure of series (B1-3), (BF-PP) and (BF-HS) were noticed to be bond failure except beams B3P and B3S were flexural failure shown in figs (3), (4) & (5).
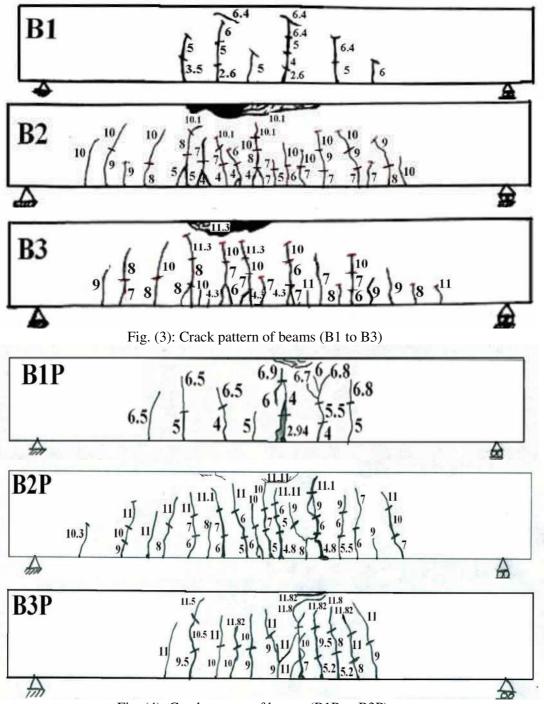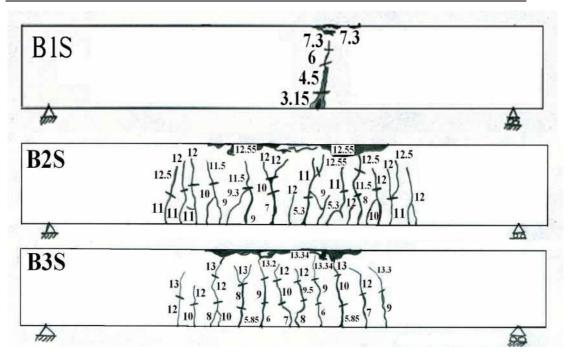

Fig. (3): Crack pattern of beams (B1 to B3)

Fig. (4): Crack pattern of beams (B1P to B3P)

Fig. (5): Crack pattern of beams (B1S to B3S)

3-2 Measured Deformations:

The flexural load-mid span deflection; the load-end slip; the load-concrete strain and the load-slope curves obtained from tests are shown in Fig. 4 to 12 . The effect of the various parameters on the load-mid span deformations characteristics will be discussed as follows.

3.2.1- Load – Mid Span Deflection:

The measured and theoretical values of mid span deflection are plotted versus the applied load from starting the loading up to failure of beams as shown in Fig. (6) . All plotted values indicated that the deflection increases as the applied load increases up to the ultimate load for all beams and then starting from the ultimate load, the beams started to show the sign of failure and the slope of the load- deflection curve becomes steep from top to bottom or horizontal straight line and the slip increased with or without decrease of the loads for beams with fibers .The relation between the applied load and the mid span deflection tends to be in linear or non linear relation depending on the applied load level , and the relation depend on the relative rib area (α_{sb}) , as well as the fibers types . The theoretical central deflection at all loads was calculated by using ACI [8]equations as($I_e=(M_{cr}/M_a)^3 I_g +(1-(M_{cr}/M_a)^3 I_{cr})$, $E_c=3320\sqrt{f'_c} +6900$ Mpa , $M_{cr} =(f_{ctr} .I_g)/y_{ct}$, $f_{ctr} =0.94\sqrt{f'_c}$ Mpa . $I_g =bt^3/12$, $y_{ct} =t/2$, b=12cm , t=30cm .
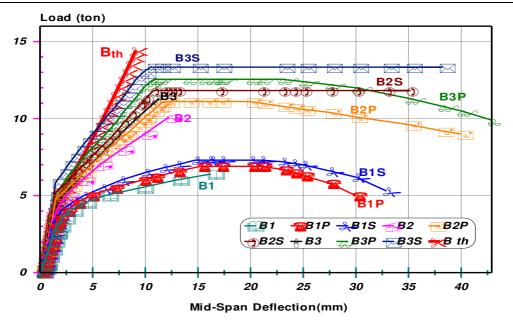
Fig. (6): Ultimate Load versus Mid-Span Deflection for Beams with and without Fibers

Effect of relative rib area (αSb).

The values of the applied load from beams test increased with the increases of the relative rib area (α_{Sb}). Generally the shape of the load-mid span deflection curve of tested beams for small relative rib area (α_{Sb}) differs from the shape of the load- mid span deflection curve of tested beams for high relative rib area (α_{Sb}).

Effect of fibers types

The values of the applied load at all values of deflections for beams having polypropylene fibers were more than that values of beams without fibers and the values of the applied load at all values of deflections for beams having harex steel fibers were more than that values of beams with polypropylene fibers. For high performance concrete, the mode of failure of beams without fibers were more brittle .But For high performance fibers reinforced concrete, the mode of failure of beams were ductile , as shown in figs. (6) .

3.2.2 Load – Slip relationship

Stresses for concrete and steel are transferred between the two materials if they work together in beams. The term "bond" is used to describe the means by which slip between concrete and steel is prevented or minimized wherever the tensile or compressive stress in a bar changes or not. Bond stresses must act along the surface of the bar to produce the change. Bond stresses are the longitudinal shearing stresses acting on the surface between the steel and concrete. Bond resistance of plain steel bars is largely dependent on adhesion between the bar and concrete. But even after adhesion

is broken, friction between the materials continues to provide a considerable bond resistance. Friction resistance is low for a smooth bar surface. Deformed bars have larger bond capacity because of the interlocking of the ribs with the surrounding concrete .The mechanism of bond is comprised of three main components: chemical adhesion, friction, and mechanical interlock between bar ribs and concrete.

The slip is plotted against the applied load from the starting of loading up to failure as shown in Fig. (7).
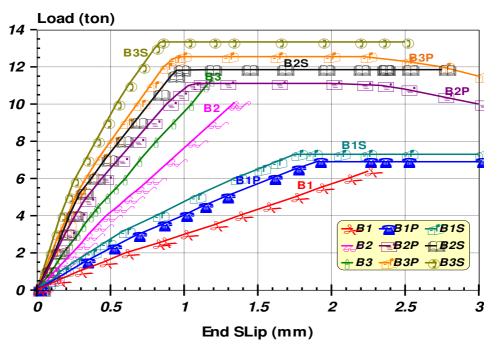

Fig. (7): Load - End slip relationship for beams with and without fiber**s**

Effect of relative rib area for steel (α sb):

The measured values of the slip for all tested beams indicated that the end slips decrease with the increase of the relative rib area (α_{sb}). Also, the loads increase with the increase of relative rib area (α_{sb}).
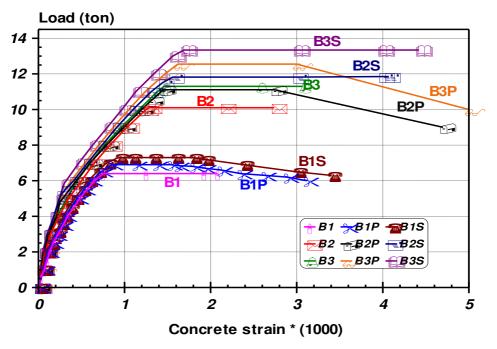
Effect of fibers types

The measured loads for beams series (BF-HS) having harex steel fibers were larger than that measured for series (BF-PP) having polypropylene fibers. A1so, the measured loads for series (BF-PP) having polypropylene fibers were larger than that measured for series (B1-3) without fibers as shown in Fig. (7). The measured end slip for bars steel of beams should be decreased due to used the fibers.

3.2.3 Concrete strain at the top compression zone for the beams.

The measured strain values are plotted versus the applied load from starting loading up to failure as shown in Fig. (8). Generally, the compressive concrete strain increases as

the applied load increases up to the ultimate loads .The rate of increases of compressive concrete strain due to applied load depends on the relative rib area (α_{sb}) and the fibers types, the effect of these parameters can be observed from such curves.

Fig(8): Load – Compressive concrete strain at top mid span relationship for beams with and without fibers

Effect of relative rib area (α_{sb}):

The measured values of the concrete strain for all tested beams in group (B) and (BF) decrease with the increase of relative rib area (α_{sb}).

Effect of fibers types

The measured values of compressive concrete strain for all tested beams for group (B) decrease with the used the fibers of group (BF) as shown in Fig. (8).

3.2.4 Load-Slope characteristics

The maximum measured slope at the center of hinged support of the beams is plotted versus the applied load from zero loading up to failure as shown in Fig.(9). Generally, the slope at the center of hinged support increases as the applied load increases up to limit of cracking load, beyond this limit a sharp decrease in the rate of increase of the ultimate slope was observed and after that increasing in the slope was accompanied with a slight increasing of the applied load up to ultimate load.

The effect of the studied variables on the load-slope will be discussed as follows: -

Effect of relative rib area ((α sb).

The values of slop for all tested beams in groups (B) and (BF) increase with the decrease of the value of relative rib area (α_{sb}) due to the increase of the bond between the steel and concrete of beams.

Effect of fibers types

The values of slop for all tested beams in groups (B) decrease with the used of fibers for beams in group (BF)as a result of increased in bond stresses between main steel and concrete for beams .
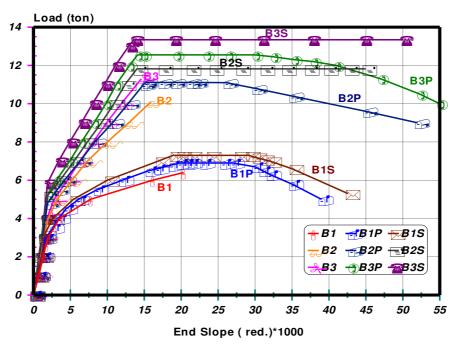

Fig.(9): Load - end slop relationship for beams with and without fibers

4- DISCUSSIONS OF RESULTS

This item describes and interprets the analysis of the obtained test results of the (**HPC**) and (**HPFRC**) beams. The analysis includes the relationship between the   values of the cracking and ultimate loads , slips , deflections , concrete strains and slope versus relative rib area of bars (α_{sb}) and fibers types used for beams .

4.1- cracking and ultimate loads

The theoretical values of the cracking load (P_{crth}) of beams (without fibers) can be determined according to (ACI 1995)[8] .

Where $M_{cr} = (f_{ctr} . I_g)/y_{ct}$, $f_{ctr} = 0.94\sqrt{f'_c}$ Mpa , $P_{crth} = 2.5 M_{cr}$.

Then $P_{crth} = 3.81$ ton   …………………………………………………….(1)

The theoretical values of the ultimate load (P_{uth}) can be determined according to the smallest value of the following cases(a)- due to bending ,(b)- due to shear or(c)-due to bond .The critical case was due to bending as follow by (ACI code 1995)[8]:

$M_n = A_s\, f_y\, d\, (1-0.59\rho f_y/f'_c)$ in-lb , $f'_c = 0.9 f_c$, $P_{uth} = 2.5 M_n$, $\rho = A_s/A_c$.

Then $P_{uth} = 2.7\, f_y\, (1 - 0.9\, f_y/10^5)$ kg………… ………………… (2)

The theoretical values of the ultimate load (P_{uth}) of beams (without fibers) were 8.14; 11.91 and 12.28 ton for beams reinforced by bars Sm; B\S and EZ•AL2 respectively.

The values of the experimental cracking (P_{cr}) and ultimate (P_u) loads for beams tested   are given in table (4).

Table (4): Values of cracking and ultimate loads for beams with and without fibers

Group No.	Series	Relative Rib Area (α_{sb})	Fiber Types	P_{cr} (ton)	P_u (ton)	Mode of Failure
B	**B1**	**0.00**	**Without Fibers**	**2.6**	**6.40**	**Bond Failure**
	B2	**0.062**		**4.0**	**10.10**	**Bond Failure**
	B3	**0.100**		**4.3**	**11.30**	**Bond Failure**
BF	**B1P**	**0.00**	**PP.F**	**2.94**	**6.9**	**Bond Failure**
	B1S	**0.00**	**HS.F**	**3.15**	**7.3**	**Bond Failure**
	B2P	**0.062**	**PP.F**	**4.8**	**11.11**	**Bond Failure**
	B2S	**0.062**	**HS.F**	**5.2**	**11.82**	**Bond Failure**
	B3P	**0.100**	**PP.F**	**5.3**	**12.55**	**Bond -Flexural Failure**
	B3S	**0.100**	**HS.F**	**5.85**	**13.34**	**Bond -Flexural Failure**

P_{cr} and P_u : Experimental values

Influence of Relative Rib Area (αsb)

The values of the cracking (P_{cr}) and the ultimate loads (P_u) for beams   tests increase with the increase of the relative rib area (α_{sb}) as shown in Fig.(10) and table (4) .
The values of the cracking and the ultimate loads for bars (B\S) and (EZ.AL2) compared to the corresponding values for bar (Sm) at different fibers were respectively as follows:
(a)-For cracking load
    For beams without fibers: The compared values were 153.9 and 165.4 %.
    For beams with polypro: Fibers the compared values were 163.2 and180.3 %.

For beams with Harex-steel fiber: The compared values were 165 and 185.7%.

(b)-For ultimate load

For beams without fibers: The compared values were   157.8 and 176.6 %.

For beams with polypro: Fibers: The compared values were 161 and 181.9%.

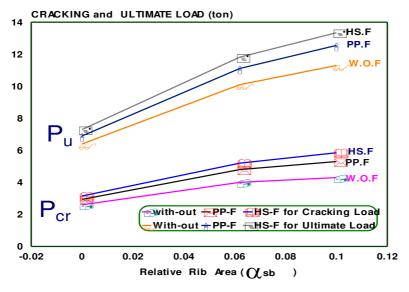For beams with H. steel fibers: The compared values were162 and 182.7 %.

Fig. (10): Cracking and ultimate loads versus relative rib area of steel bar for beams

Influence of Fibers Types

The values of the cracking (P_{cr}) and the ultimate loads (P_u) for beams tests were more for beams with harex steel fibers than beams with polypropylene fibers , also the before loads for beams with polypropylene fibers were more than beams without fibers, as shown in Fig. (11) The values of the cracking (P_{cr}) and ultimate (P_u) loads for beams **HPFRC** with harex-steel and polypropylene fibers compared to the corresponding values for beams **HPC** without fibers for bars (Sm) ,(B\S)and (EZ.AL2) were respectively as follows:-

(i) For cracking load

For bar (Sm): the compared values were 113.07 and 121.15%.

For bar (B\S): the compared   values   were   120.0 and   130.0 %.

For bar (EZ.AL2): the compared values were 123.2 and   136.04%.

(ii) For   ultimate load.

For bar (Sm): the compared values were 107.8 and 114.08 %.

For bar (B\S): the compared values were 110 and 117.03   %.

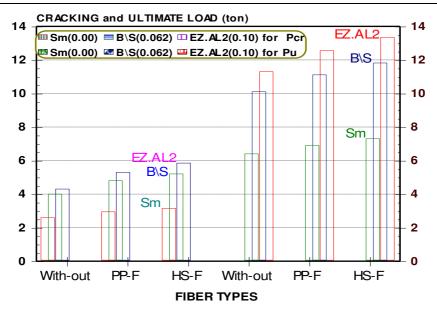For bar (EZ.AL2): the compared values were 111.06 and 118.05 %.

Fig. (11): Cracking and ultimate loads versus fiber types for beams with fiber

4.2- Deformations:

The values of the obtained deformation at cracking (P_{cr}) and the ultimate loads (P_u) for beams tests are given in tables (5),(6), (7) and (8). The values of this deformation depend on the relative rib area (α_{sb}) , as well as the fibers types.

4.2.1- Mid-Span Deflections:

The values of deflection and the loads are considerably affected by the following parameters, as shown in figs.(12) and table (5).

Influence Of Relative Rib Area (αsb)

At the constant deflections, the loads increase with the increase of relative rib area (α_{sb}). The loads were increased by different percentage ranged from 30% to 57 % for deflections=0.5mm. Whereas these increases ranged from 33% to 71.4 % for deflections = 5 mm.

At the cracking loads, the deflection increases with the increase of the relative rib (α_{sb}) due to increase of the cracking   loads and constant the stiffness of beams. The deflection was increased by different percentage ranged from 14.2 % to 21 %.

At the ultimate loads, the deflection decreases with the increase of the relative rib (α_{sb}). The deflection was decreased by different percentage ranged from 23.3 % to 30.3 %.

The reduction of the values of the defection for the beams reinforced with steel bar (EZ.AL2) , (B\S) having (α_{sb} = 0.10 , 0.062) may be due to the increase of the bond strength and the decrease of the slip resulting from the increase of the relative rib area (α_{sb}) and the decrease in number, length and width of cracks. Therefore, the stiffness of

these beams were more than the corresponding stiffness for beams reinforced with steel bar (Sm) having (α_{sb} = 0.00).

Table (5): Values of experimental deflection at cracking and ultimate loads and the load at different deflection

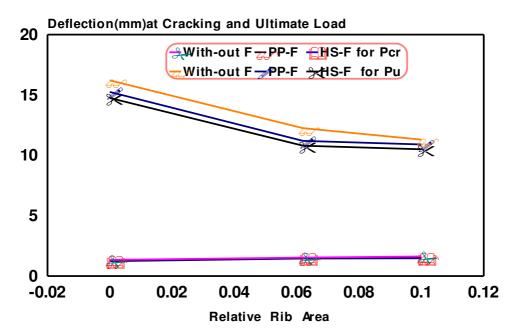| Group No.	Series	Fiber Types	Relative Rib Area (α_{sb})	Load (ton) at Deflection		Deflection (mm) at P_{cr} (δ_{cr})	Deflection (mm) at P_u (δ_u)
				0.5mm	5mm		
B	B1	**Without Fiber**	0.000	0.87	4.72	1.34	16.21
	B2		0.062	1.16	6.6	1.53	12.25
	B3		0.100	1.30	7.12	1.62	11.3
BF	B1P	**PP.F**	0.000	1	5.07	1.27	15.25
	B2P		0.062	1.36	7.07	1.48	11.7
	B3P		0.100	1.57	8	1.53	10.9
	B1S	**HS.F**	0.000	1.2	5.25	1.23	14.75
	B2S		0.062	1.56	7.56	1.45	10.8
	B3S		0.100	1.78	9	1.47	10.5

Fig (12):Deflection at cracking and ultimate load versus relative rib area for beams

Influence of Fibers Types

At the constant deflections, the loads increase with used the fiber in reinforced concrete. The loads were increased by different percentage ranged from   15 % to 37.9 % for deflections=0.5mm. Whereas these increases ranged from 7.1   % to 26.4 % for deflections=5mm.

At the cracking load, the deflections decrease with used the fiber in reinforced concrete .The deflections were decreased by different percentage ranged from 3.27 % to 9.3 %.

At the ultimate loads, the deflections decrease with used the fiber in reinforced concrete. The deflections were decreased by different percentage ranged from 3.5 % to 11.84 %.

The decrease of deflections for increases used the fiber in reinforced concrete resulting to decrease the slip and increase the bond strength which accompanied with decrease length and width of cracks. Therefore, the stiffness of these parameters with used the fiber in reinforced concrete were more than those for beams without fiber, as shown in Fig. (13).
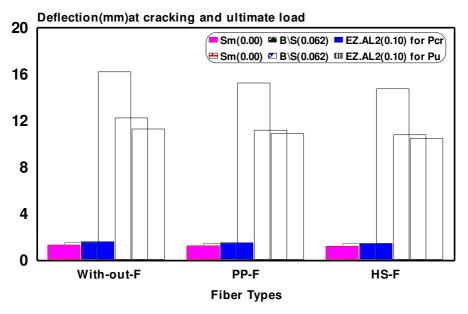

Fig. (13): Deflection at cracking and ultimate load versus Fiber Types for beams

4.2.2- End Slip of Steel

The values of slip at the cracking and the ultimate loads and the loads are considerably affected by the following parameters:-

Influence Of Relative Rib Area (αsb)

At constant slip, the loads increase with the increase of the relative rib area (α_{sb}) due to increase of the bond strength (f_b). The loads   were increased by different percentage

ranged from 112.5% to 317% for slip=0.025mm. Whereas these increases ranged from 110 % to 285%   for slip =0.25 mm.

At constant loads, the slip decreases with the increase of the relative rib area (α_{sb}) due to increase of the bond strength (f_b).

At the cracking and the ultimate loads, the slip decreases with the increase of the relative rib area (α_{sb}). The slip were decreased by different percentage ranged from 50.4% to56.9 % for the cracking loads and ranged from 47.1% to 52% for the ultimate loads the decreased due to increase of the bond strength and the decrease in number, length and width of cracks. Therefore, the stiffness of the cross-section of beams was increased, as shown in Fig. (14) and Table (6).

Influence of Fibers Types

At the constant slip, the loads increase with used the fiber in (**HPC**).The loads were increased by different percentage ranged from 50% to163%for slip= 0.025 mm .Whereas these increases ranged from 56%to102.7 % for slip = 0.25mm.

At the cracking load, the slip decrease with used the fiber in (**HPC**).The slip were decreased by different percentage range ranged from17.3 % to38.3 %.

At the ultimate load, the slip decrease with used the fiber in (**HPC**).The slip were decreased by different percentage range ranged from 15.56% to 37.5%.

The measured end slip for beams series (BF-HS) having harex- steel fibers were less than that measured for series (BF-PP) having polypropylene fibers . A1so, the measured end slip for series (BF-PP) having polypropylene fibers were less than that measured for series (B1-3) without fibers. The measured end slip for bars steel of beams should be decreased due to used the fibers, as shown in Fig. (15) and   table (6).

Table (6): Values of slip at cracking and ultimate loads and the loads at different slip

Group No.	Series	FIBER TYPES	Relative Rib Area(α_{sb})	Load (ton) at Slip (mm)		Slip (mm) at P_{cr}	Slip(mm)at P_u
				0.025	0.25		
B	B1	Without fiber	0.000	0.08	0.75	0.81	2.25
	B2		0.062	0.17	2.05	0.47	1.34
	B3		0.100	0.24	2.65	0.40	1.19
BF	B1P	**PP.F**	0.000	0.12	1..17	0.67	1.90
	B2P		0.062	0.36	3.86	0.32	1.09
	B3P		0.100	0.5	4.8	0.28	0.96
	B1S	HS.F	0.000	0.16	1.5	0.58	1.75
	B2S		0.062	0.41	4.51	0.29	0.95
	B3S		0.100	0.63	5.85	0.25	0.84

Slip(mm) at cracking and ultimate load
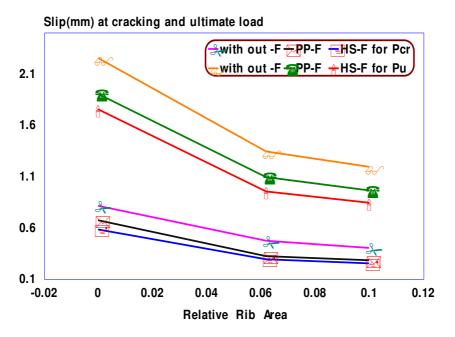
Fig. (14): Slip at cracking and ultimate load versus relative rib area of steel bar for beams

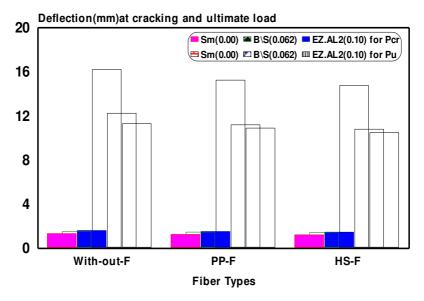**Deflection(mm)at cracking and ultimate load**

Fig. (15): Deflection at cracking and ultimate load versus Fiber Types for beams

4.2.3-Concrete Strain

The values of concrete strain are measured at top compression zone corresponding to the relative rib area (α_{sb}), fiber types for loads at (0.07and 0.7) strain, cracking and ultimate loads in table (7).

Table (7): Values of concrete strain at cracking and ultimate loads and loads at concrete strain = 0.07 , 0.7 m/m .

Group No.	Series	Fiber types	Relative Rib Area(α_{sb})	Load (ton) at Strain(m/m)		Strain $*10^3$ at P_{cr}	Strain $*10^3$ at P_u
				0.07	**0.70**		
B	B1	Without fiber	0.000	1.0	6.2	0.18	0.75
	B2		0.062	1.75	7.28	0.24	1.29
	B3		0.100	2.0	7.59	0.25	1.46
BF	B1P	PP.F	0.000	1.2	6.38	0.20	0.85
	B2P		0.062	2	7.53	0.25	1.45
	B3P		0.100	2.25	8	0.28	1.62
	B1S	HS.F	0.000	1.5	6.6	0.21	0.93
	B2S		0.062	2.2	7.76	0.26	1.56
	B3S		0.100	2.4	8.41	0.30	1.69

The values of concrete strain at the cracking and the ultimate loads and the loads are considerably affected by the following parameters:-

Influence of Relative Rib Area (αsb)

At constant strain, the loads increase with the increase of the relative rib area (α_{sb}). The loads were increased by different percentage ranged from 46.7% to100% for strain =0.07mm. Whereas these increases ranged from 17.4% to 27.4% for strain =0.7mm. The increased due to decreased slip, length and width of cracks and increased

At the cracking loads, the concrete strain increases with the increase of the relative rib (α_{sb}). The concrete strain was increased by different percentage ranged from 23.8% to 42.8 %.

At the ultimate loads, the concrete strain increases with the increase of the relative rib (α_{sb}). The concrete strain were increased by different percentage ranged from 67.8 % to 94.7 % .

The increase of the values of concrete strain at cracking and ultimate loads for beams reinforced with steel bar having more relative rib area (α_{sb}) may be due to the bond strength increase and decrease of the slip between main steel and concrete for beams resulting from the decrease in length and width of cracks . Therefore, the stiffness of these beams were more than the beam with main steel having less relative rib area (α_{sb}) , as shown in fig.(16).

Influence of Fibers Types

At the constant values of concrete strain, the loads increase with used fiber in (**HPC**). The loads were increased by different percentage ranged from 20% to 50% for strain = 0.07.Whereas these increases ranged from 3% to1.8 % for strain = 0.7mm.

At the cracking load, the strain increase with used the fiber in (**HPC**).The strain were increased by different percentage range ranged from4.16 % to 20 %.

At the ultimate load, the strain increase with used the fiber in (**HPC**).The strain were increased by different percentage range ranged from 10.95% to24% .

At the cracking and ultimate loads , the values of concrete strain, increase for beams with polypropylene and harex-steel fibers than beams without fibers .Also the values of concrete strain, increase for beams with harex-steel fibers than beams with polypropylene fibers than beams without fibers .

The increase of the values of concrete strain at cracking   and ultimate loads for beams with polypropylene and harex-steel fiber may be due to the bond strength increase and decrease of the slip between main steel and concrete resulting from the decrease in length and width of cracks. Therefore, the stiffness of these beams were more than the beam without fiber, as shown in Fig. (17).
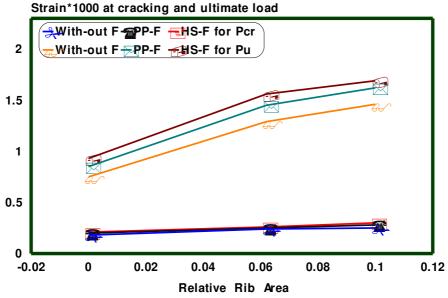

Fig.(16): Strain at cracking and ultimate load versus relative rib area for beams.

4.2.4- End Slop of Beams

The measured values of slope at the support of thr beams corresponding to the point of maximum slope at cracking and ultimate loads are recorded in table (8).The values of slope at the cracking and the ultimate loads and the loads are considerably affected by the following parameters:-

Influence of Relative Rib Area (αsb)

At constant slope the values of loads increase with the increase of the relative rib area (α_{sb}). At the cracking loads, the slope of beam at the support increases with the increase of the relative rib area (α_{sb}) due to the increase of the cracking loads and constant the stiffness cross-section of the beam. At the ultimate loads, the slope of beam at the support decreases with the increase of the relative rib area (α_{sb}) due to the decrease of

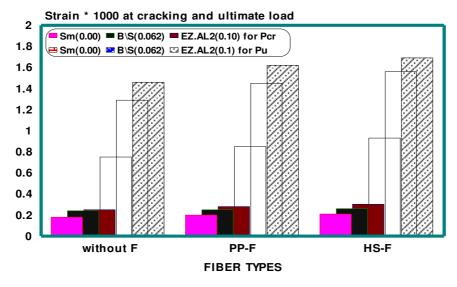slip and the increase of bond strength which causes a decrease in length and width of cracks , as shown in fig.(18).

Fig. (17): Strain at cracking and ultimate load versus fibers types for beams

Table (8): Values of slope at cracking and ultimate loads and the loads at different slope.

Group No.	Series	Fibers Types	Relative Rib Area(α_{sb})	Load (ton) at Slope (radian)		Slope $* 10^3$ at P_{cr}	Slope $* 10^3$ at P_u
				0.001	0.01		
B	B1	**Without Fiber**	0.000	1.50	5.27	1.68	20.3
	B2		0.062	2.0	8.0	1.98	15.9
	B3		0.100	2.15	9.05	2.1	14.6
BF	B1P	PP.F	0.000	1.55	5.67	1.60	19.75
	B2P		0.062	2.21	8.71	1.91	15.2
	B3P		0.100	2.56	10.38	1.98	14.14
	B1S	HS.F	0.000	1.76	6	1.56	18.85
	B2S		0.062	2.47	9.46	1.88	13.99
	B3S		0.100	2.7	11.78	1.91	13.65

Influence of Fibers Types

At constant slope **t**he values of loads for beams increase with used the fiber due to increase of the bond strength and decrease of slip which causes decrease in length, width of cracks and increase the stiffness cross-section of the beam.

At the cracking   load **t**he values slope for beams increase with used the fiber due to increase o f cracking   load and constant of the stiffness cross-section of the beam. The reduction of the values of slope at ultimate loads for beams with harex-fiber are due to increase of the bond strength and   decrease of slip which causes decrease in length, width of cracks and increase the stiffness cross-section of the beams, as shown in Fig. (19).
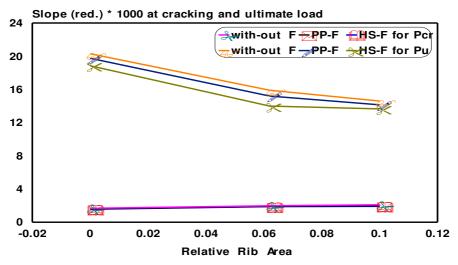

Fig. (18): Slope at cracking and ultimate load versus relative rib area of steel bar for beams.
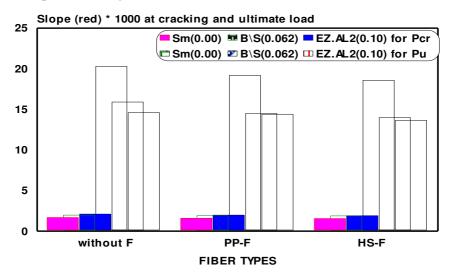

Fig. (19): Slope at cracking and ultimate load versus fiber types for beams.

SUMMARY AND CONCLUSIONS

i- For high-performance concrete (HPC)

(1) The final mode of failure for high-performance concrete (**HPC**) beams was bond failure and the mode of failure bond failure& bond-flexural failure depend on the

rib geometry ($\propto_{sb}$) for the steel bar for high-performance fiber reinforced concrete (**HPFRC**) beams

(2) The first cracking load was early observed at small values of relative rib areas ($\propto_{sb}$) for beams.

(3) The width of cracks and spacing between it were significantly increased with the decrease of both relative rib areas ($\propto_{sb}$) for beams.

(4) The major cracks were formed at the maximum moment for all beams.

(5) For increase the relative rib areas($\propto_{sb}$) increases the cracking and the ultimate load and concrete strain at cracking and the ultimate load also increases the deflection and slope at the cracking load but decrease slip at the cracking and the ultimate load .

(6) Increasing the relative rib areas ($\propto_{sb}$) from 0.0 to 0.062 increases the cracking and the ultimate load by about 48 % and 62.3 % respectively. Also for increasing the relative rib areas ($\propto_{sb}$) from 0.062 to 0.10 increases the cracking and the ultimate load by about 9 % and 11.75 % respectively.

ii- For high-performance fiber reinforced concrete (HPFRC)

(1) The first crack was early observed for (HPFRC) beams with bars having smaller values of relative rib area (αsb).

(2) The width of cracks and spacing between it were significantly large for beams having smooth bars, but narrow for other beams having ribbed bars. The propagation of cracks for beams with ribbed bars were more than those compared for beams with smooth bars

(3) Adding fibers to the concrete mix improves the crack propagation patterns for all tested (HPFRC) beams.

(4) The values of the cracking and the ultimate loads were increased with the increase of the relative rib areas (αsb).

(5) Adding fibers to the concrete of (HPC) beams showed consistent higher first cracking and the ultimate loads than those without fibers .Also adding harex steel fibers to the concrete of (HPC) beams showed consistent higher first cracking and ultimate loads than those for beams with polypropylene fiber.

(6) The values of the deflection, strain, slip and the slope at free end of beams were decreased with the increased of the relative rib areas (αsb).

(7) Adding fibers to the concrete of (HPC) beams showed smaller deflection, strain, slip and the slope values than beams without fibers; also, those are less for beams with harex- steel fibers than beams with polypropylene fibers.

(8) The addition of fibers to a concrete mix has greatly improved its ductility by increasing both the strains at max loads, and the ultimate strains under compressive stresses.

(9) HPFRC beams (with fibers)showed smaller crack widths and numbers compared with HPC beams (without fibers) at the same loading levels, also beams with harex steel fibers showed smaller crack widths and numbers compared with beams with polypropylene fibers at the same loading levels.

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سلوك الكمرات الخرسانة عالية المقاومة التي تحتوي ولا تحتوي

علي الألياف متأثرة بهندسية النتوءات

في الآونة الأخيرة ظهرت الحاجة لاستخدام الخرسانة ذات المقاومة العالية و لذا أصبح من الضروري استخدام حديد التسليح عالي المقاومة وللاستفادة من أقصى مقاومة لصلب التسليح و كذلك الخرسانة ذات المقاومة العالية لذا فان الأمر يتطلب قوة تماسك كافية   بين الحديد و الخرسانة مما يستلزم إن يحاط   سطح حديد التسليح بنتوءات تكفل تولد قوى التماسك الكافية . ونظرا لاختلاف هندسية النتوءات لأنواع حديد التسليح المختلفة فقد ظهرت الحاجة لمعرفة اثر هذا الاختلاف علي سلوك العناصر الإنشائية من الخرسانة عالية المقاومة   ونظرا لان الخرسانة ذات المقاومة العالية مادة قصفة وغير ممطولية لذا احتاجت الخلطة إلي بعض الإضافات لتحويلها الى مادة ذات ممطولية . ونظرا لقلة المعلومات المتوفرة عن سلوك الكمرات الخرسانة عالية المقاومة و الكمرات الخرسانة عالية المقاومة ذات الألياف مع الأخذ في الاعتبار بعض المتغيرات التي تؤثر على هذا السلوك وهى المساحة النسبية للنتؤ فى وجود تماسك جذئى لنهايات الحديد .

و تم ذلك بإجراء اختبار عدد 9 كمرات خرسانية ذات مقاومة عالية و 3 كمرات بدون ألياف و 3 كمرات بها ألياف البولى بروبلين و 3 كمرات تحتوى على ألياف الهاركس و ذات قطاع   12×2سم 30 و تسليح   رئيسي 16 مم وعلوي 12مم   كانت أطوال العينات المختبرة240 سم+   5 مرات قطر السيخ و قد تم الأخذ في الاعتبار العوامل التالية :

1-هندسية النتؤات والمساحة النسبية للنتؤ لحديد التسليح المستخدم في عينات الاختبار وقيمها هي (0.0 -0.062 -0.10) .

2- نوع الألياف المستخدمة (ألياف البولى بروبلين و ألياف الهاركس)

3. تم استخدام رتبة واحدة من الخرسانة عالية المقاومة و كانت قيمتها هي (900 كجم/سم2) 0

والهدف الرئيسي من هذه الدراسة هو محاولة الوقوف على تأثير هندسية النتوءات و نوع الألياف علي سلوك الكمرات الخرسانة عالية المقاومة و الكمرات الخرسانة عالية المقاومة ذات الألياف   مع الأخذ في الاعتبار بعض المتغيرات التي تؤثر على هذا السلوك وهى المساحة النسبية للنتؤ .

وقد تم التوصل لنتائج هامة في هذا البحث من حيث أن طراز الانهيار و سلوك الكمرات الخرسانة عالية المقاومة ة تعتمدا على هندسية النتؤات لأسياخ الحديد المستخدم و كذلك نوع الألياف المستخدمة .