Flexural Behavior of Reactive Powder Concrete with Hybrid Section T-Beams

Lect. Dr.Rafid Saeed Atea
(**Al-Furat Al-Awsat Technical University/Najaf Institute**)

Rafid 1980@ yahoo.com

ABSTRACT

Reactive powder concrete (RPC) is unique of the newest and greatest significant improvements in constructions field , it has usual excessive kindness happening current duration in the world owing toward its higher concrete properties , great ductility, durability, imperfect shrinkage penalties, great opposition to corrosion and abrasion. In this experimental investigation is carried out on the way to revision the flexural behavior of RPC with Hybrid Section T- Beams and the mechanical properties of this construction material. The experimental program included testing five beams to examine the things of steel fiber volumetric ratio, silica fume ratio, tensile steel ratio, hybrid section on flexural performance of RPC T-beams. The study was focused on determining the first crack load (P_{cr}), ultimate flexural strength (P_u), ultimate deflection (Δ_u), load-deflection behavior, letdown mode, strain supply across the depth of the beams and crack pattern at failure. The effects of steel fiber volumetric ratio and silica fume ratio were also considered in studying the mechanical properties of RPC mixes. Moreover, a study of hybrid beams exhibited that expending RPC happening web and normal concrete in flange efficiently enhances the enactment of T- beams in comparison with normal concrete T-beams and also studying hybrid beams exhibited that expending RPC happening flange and normal concrete in web efficiently enhances the enactment of T- beams in comparison with normal concrete T-beams.

Keywords: Reactive powder, Steel Fiber, Silica Fume

سلوك الانثناء لخرسانة المساحيق الفعالة للعتبات الهجينة بمقطع(T)

م.د. رافد سعيد عطية
جامعة الفرات الأوسط التقنية-المعهد التقني/ النجف

الخلاصة

خرسانة المساحيق الفعالة هي واحدة من أحدث وأهم التطورات في تكنولوجيا الخرسانة، لقد أوليت اهتمام كبير في السنوات الأخيرة في العالم نظرا لخصائصها الميكانيكية الفائقة مثل: المقاومة العالية ، المطيلية العالية ، المتانة العالية ، الانكماش المحدود ، المقاومة العالية للتآكل والتعرية في هذا البحث تم أجراء تحري عملي لدراسة سلوك الانثناء لخرسانة المساحيق الفعالة للعتبات الهجينة بمقطع (T) و الخواص الميكانيكية لهذه المادة الجديدة. تضمن البرنامج التجريبي اختبار خمسة عتبات لتحري تأثير كل من النسبة الحجمية للألياف الحديدية ، نسبة أبخرة السليكا، المقطع الهجين و على سلوك الانثناء لعتبات خرسانة المساحيق الفعالة بمقطع (T). تركزت الدراسة على إيجاد حمل التشقق الأولي ، سعة الانثناء القصوى ، الهطول الأقصى ، سلوك الحمل-الهطول ، نمط الفشل ، توزيع الانفعال على مدى عمق العتبات وشكل التشقق عند الفشل . تأثير النسبة الحجمية للألياف الحديدية و نسبة أبخرة السليكا أيضاً اعتمدا في دراسة الخواص الميكانيكية لخلطات خرسانة المساحيق الفعالة. بالإضافة لذلك فقد بينت دراسة العتبات الهجينة أن

استخدام خرسانة المساحيق الفعالة في الوتر والخرسانة العادية في الشفة حسنت بشكل كفوء أداء العتبات بمقطع T بالمقارنة مع عتبة الخرسانة العادية، وأيضا دراسة استخدام خرسانة المساحيق الفعالة في الشفة والخرسانة العادية في الوتر حسنت بشكل كفوء أداء العتبات بمقطع T بالمقارنة مع عتبة الخرسانة العادية.

1. INTRODUCTION

Reactive powder concrete (RPC) is unique of the informed and best significant improvements in concrete equipment , it has established excessive consideration in current years in the world owing toward its higher mechanical properties [1,2]. RPC is also recognized as ultra high enactment concrete (UHPC) allowing to its more structural presentation. It involves of great measure of cement , fine sand with particle size less than 600 µm , silica fume , fibers, low w/c ratio (less than 0.2) , new generation of superplasticizers and on no account coarse aggregate[3]. RPC is quickly rising as an outstanding alternative to conventional concrete and even high strength concrete in many important structural submissions such as bridges, factories and power stations; therefore, there is increasing need to understanding the mechanical properties and structural behavior of this novel production material. Behavior of RPC beams is one of the fields which requires more studies because until this time there are quiet insufficient researches dealing with this field and there is surely absence of evidence about the analysis and design of RPC structural members. Therefore, this paper aims at studying experimentally and theoretically the flexural behavior of simply supported RPC T-beams under static load. In addition, some significant mechanical properties of RPC combination, are also experimentally recognized which institute data needed for the analysis and design of RPC structural members. Reactive powder concrete is a type of concrete which shows superior mechanical and durability properties, this goes to its elements (types and proportions), mixing efficiency, pressing after placing and curing regime. Each step of preparing RPC and each one of RPC components play key and significant part in getting high recital concrete[4] . In 2004, **Chan and Chu** [5] studied the conclusion of appearances in RPC, containing bond strength , pullout energy ,etc. Various silica fume contents ranging from 0% to 40% were used in the mix proportions Based on the results of bond strength and pullout energy, the optimal silica fume–cement ratio was found to be in between 20% and 30%, given the conditions of this experimental program .At the optimal silica fume dosage (30%), the pullout energy was increased by approximately 100%, whereas the bond strength was increased by 14%. The difference can be attributed to the dissimilar mechanisms of silica fume on supplement energy and on bond strength. In 2007, **Gao** [6] planned the influence of dynamic loads on the properties of plain RPC and fibers reinforced RPC. The test program included two types of case ; concrete cylinder with dimension height and diameter (150mm×75mm) and small beams with dimension depth, width and length (280mm×70mm× 70mm) with a span of 210mm, The addition of 1.5 %(by volume) of steel fiber significantly increased the flexure strength of RPC. However, there are no helpful belongings on solidity under quasi static and higher rate loading. In 2008, **Hoang et al** [7] considered guidance of ultra high by using steel fibers enactment concrete (modified RPC, the investigation consequences exhibited that flexural strength and hardiness of excessive enactment concrete is amended by adding of steel fibers. In 2010, **Prabha et al** [8] planned stress-strain properties of RPC under uniaxial compression. All the tests were approved out on concrete cylinder specimens of size (diameter=100 mm and height= 200mm) in the Universal Testing Machine. Two types of steel fibers ((L_f /d_f =6/0.16 and 13/0.16) and various dosages of steel fibers (0%,1% and 2% for 13mm, while 1%,2% and 3% for 6mm and a arrangement of 1% of 6mm and 1% of 13 mm and to end a amalgamation of 1% of 6mm and 2% of 13mm) were used in RPC mix. The trials also showed that the elastic modulus of RPC mixes was found to be 21 %(for 2%-6mm) to 24 %(for 2%-13mm) higher than that of RPC without fibers. It was settled that the ratio of ultimate to peak strain was the highest for fibers permutation of 2% 13mm and 1%6mm (4.65) following by 2%13mm (3.81) mix and 3% 6mm (3.73) mixes. The crack pattern confirmations realization of vertical cracks for lower percentages of small fibers reinforcement and diagonal cracks for higher percentages of fibers reinforcement. 3% of 6mm and 2% of 13mm seemed to be the optimal fibers contents for RPC as observed from the results gained in this revision. In 2010 **Hannawayya** [9] offered investigation to study the effects RPC on the concrete properties as a material as well as reviewing the flexural performance of RPC rectangular section beams. The investigational database involved investigating that conclusion of consequence steel fibers volumetric ratio (V_f) and the content silica fume (SF) on some imperative properties of RPC such as compressive strength, uniaxial stress-strain relationship in solidity, splitting tensile strength and modulus of rupture. Supplementary investigational trials were also directed to training the result of V_f, SF and longitudinal steel bar ratio (ρ) on the flexural behavior (in terms of load-deflection response, moment-curvature response, failure load and cracking pattern) of simply supported separately reinforced RPC beam having dimensions of 140×125×1400 mm under symmetrical two point load. This research offerings investigational revision on flexural behavior of simply supported RPC T-beams Hybrid Section under simple static load effect as well as studying some important mechanical properties of RPC. In this research, four beams were confirmed to exercise the consequence of steel fibers volumetric ratio (V_f), silica fume ratio (SF), hybrid section on the flexural performance of singly reinforced RPC T-beams.

2. Materials:

2.1 Cement:

The castoff in this effort is Iraqi conventional Portland cement (Taasluja) type (I). It is stowed in impermeable plastic containers to evade exposure to altered atmospheric conditions. This cement is tested and checked allowing to the Iraqi Standard Specification (IOS 5:1984) [10]. Tables (1) and (2) show the chemical and physical properties of this cement. It imitates to the Iraqi specifications.

Table (1): Chemical composition and main compounds of the cement

Oxide composition	abbreviation	Content by weight (%)	Limit of Iraqi Specification No.5/1984(10)
Lime	CaO	63.11	-
Silica	SiO_2	20.66	-
Alumina	Al_2O_3	5.13	-
Iron oxide	Fe_2O_3	3.36	-
Magnesia	MgO	2.32	5.0 (max)
Sulfate	SO_3	2.05	2.8 (max)
Loss on ignition	L.O.I.	2.39	4.0 (max)
Insoluble residue	I.R.	0.68	1.5 (max)
Lime saturation factor	L.S.F.	0.88	(0.66-1.02)%
Main compounds (Bogue's equation)			
Tricalcium Silicate	C_3S	54.72	-
Dicalcium Silicate	C_2S	18.25	-
Tricalcium Aluminate	C_3A	8.05	-
Tetracalcium aluminoferrite	C_4AF	10.21	-

Table (2) :Physical properties of cement used in this study*

Physical Properties	Test Results	Limits of Iraqi SpecificationNo.5/ 1984[10]
Specific surface area(Blaine method),(m^2 /kg)	320	230 (Min.)
Setting time (vicat's apparatus) Initial setting time (hrs: Min.) Final setting time (hrs : min.)	 1 : 50 3: 40	 0:45 (Min.) 10:00 (Max.)
Compressive strength (MPa) 3 days 7 days	 27.2 37.4	 15 (min) 23 (min)
Soundness (Autoclave method),%	0.22	0.8(max)

* Chemical and Physical tests analysis have been tested in the materials laboratory of the college engineering , University of Kufa

2.2 Fine Aggregate:

There are contain two types of fine aggregate are castoff in this revision:

1. For typical concrete combinations of this revision used typical sand from Al-Zubair region in Basrah city was used. The maximum size of this type (4.75mm) with pointed subdivision form and smooth. The arranging of this sort is revealed in Table (3). The consequences specified that the fine aggregate grading was within the supplies of the Iraqi description No.45/1984 (11). Table (4) shows the specific gravity, sulfate content, and absorption of fine aggregate.

2. For RPC is castoff very fine sand with maximum size (600µm). The classifying of fine aggregate revealed in table (6) Specification No.45/1984[11]. Table (6) expressions the physical possessions of the castoff fine aggregate .

Table (3): Grading of fine aggregate used for normal concrete compared with the requirements of No.45/1984[11]

Sieve Size IQ.S.23(mm)	Cumulative Passing %	Limits of No.45/1984[11]	
10(mm)	100	Zone(3)	Zone(4)
4.75	97	90-100	95-100
2.36	92	85-100	95-100
1.18	88	75-100	90-100
0.60	71	60-79	80-100
0.30	30	12-40	15-50
0.15	10	0-10	0-15

Table (4): Physical properties of fine aggregate*

Physical Properties	Test Result	Limit of Iraqi Specification No. 45/1984[11]
Specific gravity	2.7	-
Sulfate content%	0.09%	0.5% (Max)

***The tests have been performed in the materials test laboratory of the college engineering, University of Kufa**

Table (5) :Grading of very fine sand

Sieve Size(mm)	Cumulative Passing %	Limits of B.S. 882/1992 Limit of grading Zone(F)[11]
4.75	100	100
2.36	100	80-100
1.18	100	70-100
0.60	100	55-100
0.30	47	5-70
0.15	9	-------

Table (6): Physical and chemical properties of very fine sand

Physical Properties	Test Result	Limit of Iraqi Specification No. 45/1984[11]
Specific gravity	2.65	-------
Sulfate content%	0.07	0.5(Max.)

2.3 Coarse Aggregate:

typical concrete, Smooth type maximum size 14mm attained from Sanam mountain region in Basrah city was castoff as coarse aggregate. Table (7) confirmations grading of coarse aggregate which conforms to the Iraqi specification No.45/1984 [11]. Table (8) illustrates the specific gravity; sulfate content and absorption of coarse aggregate.

Table (7) :Grading of coarse aggregate

Sieve Analysis (mm)	Cumulative Passing %	Limit of Iraqi Specification No. 45/1984[11]
20(mm)		100
14	100	90-100
10	87	50-85
5	16	0-10
2.36	2.2	-----------

Table (8): Physical and chemical properties of coarse aggregate*

Physical Properties	Test Result	Limit of Iraqi Specification No. 45/1984[11]
Specific gravity	2.67	-
Sulfate content	0.035%	≤ 0.1%

***The tests have been performed in the materials test laboratory of the college engineering , University of Kufa**

2.4 Silica Fume:

A gray densified silica fume was cast-off, which was introduced from Sika company. Silica fume is an awfully fine dust, its elements are periods minor than cement atoms, continuously cast-off in minor percentage all as incomplete replacement of cement or as an preservative (as cast-off in the current effort) to develop properties. Table (9), chemical is given conformations of silica fume castoff happening this research .The silica fume obeys to the supplies of ASTM C1240-04[12].

Table (9): chemical properties of silica fume*

Oxide composition	abbreviation	Oxide Content (%)	Limit of Specification Requirement (ASTM C 1240)[12]
Silica	SiO_2	94.87	85.0 (Min.)
Alumina	Al_2O_3	1.18	-
Iron oxide	Fe_2O_3	0.09	-
Lime	CaO	0.23	-
Magnesia	MgO	0.02	-
Sulfate	SO_3	0.25	-
Potassium oxide	K_2O	0.48	-
Loss on ignition	L.O.I.	2.88	6.0(max)
Moisture content	-	0.48	3.0(max)

***The tests have been performed in the materials test laboratory of the college engineering , University of Kufa**

2.5 Superplasticizer (S.P.):

A great enactment concrete superplasticizer (entitled High Range Water Reduction Agent HRWRA) established, which is recognized commercially as Glenium 51, is castoff in this revision. Glenium 51 is unrestricted from chlorides and obeys with ASTM C494 type a [13]. Table (10) shows the properties of Glenium 51.

Table (10): Properties of Glenium 51*

Form	**Viscous Liquid**
Commercial name	**Glenium 51**
Chemical composition	**Sulphonated melamine and naphthaline formaldehyde condensates**
Subsidiary effect	**Increased early and ultimate compressive strength**
Form	**Viscous liquid**
Color	**Light brown**
Relative density	**1.1 gm/cm^3 at 20 ^{o}C**
pH	**6.6**
Viscosity	**128 ± 30 cps @ 20^o C**
Transport	**Not classified as dangerous**
Labeling	**No hazard label required**
Chloride content	**None**

***Supplied by the manufacturer**

2.6 Steel Fibers:

High enactment steel fibers were castoff in this investigation, Allowing to ASTM-A820-04 [14], this type of steel fibers is classified as (Type I). Its properties are listed in Table (11).

Table (11): Properties of steel fiber*

Configuration	Property	Specification
	**Description**	**Hooked**
	Length	**30 mm**
	Diameter	**0.375 mm**
	Density	**7800 kg/m^3**
	Tensile strength	**1800 MPa**
	Modulus of elasticity	**200GPa**
	Aspect ratio(L_f/D_f)	**80**

***Supplied by the manufacturer**

2.7 Water:

Conventional water is process without any additives

2.8 Steel Bars:

insignificant diameter (ϕ12mm) were castoff as tension reinforcement, while (ϕ6mm) warped steel bars were castoff as stirrups and (ϕ6mm) as oblique reinforcement of flange. The tensile experiments for all these bars are recorded in Table (12). from each nominal diameter are tested to define the average yield stress (f_y) and the ultimate strength (f_u). The investigation consequences of bars (ϕ12mm) satisfy ASTM A615 requirements [15].The test results are, as follows:

Table (12) :Properties of steel bars

Diameter (steel bar) mm	f_y (MPa)	f_u (MPa)	Elongation %
12	513	643	12
8	446	621	10
6	376	495	6.3

3. Concrete Mix Design:

Two forms of concrete mixtures were cast-off in this study:

3.1 Typical Concrete Mix:

A typical concrete mixture involving of cement, fine aggregate, coarse aggregate, and water were cast-off to cast the normal and web in hybrid beams (Normal, PRC1, PRC2 and PRC3). Control sample in the form of cylinders and prisms were also cast from this mixture. The (w/c) of this combination was 0.45 and the sizes of cement, fine aggregate and coarse aggregate were 1:1.5:3 (by weight) respectively.

3.2 Reactive Powder Concrete Mixes:

Five RPC mixtures were castoff in this revision. Supplies quantities of all mix are recorded in table (13). Several mix proportions were tried to get maximum compressive strength conferring to ASTM C39[16] .The variables castoff in these mixes were the percentage of silica fume ratio (three percentages of silica fume as additive were used 15, 20 and 25%) and the volume ratio of steel fibers (three volume ratios were considered 0, 1 and 2%).

Table (13) :Properties of the different types of RPC mixes

Mix♣	Cement kg/m³	Sand kg/m³	Silica Fume* %	Silica Fume kg/m³	w/cementitious	S.P. ** %	Steel Fiber*** %	Steel Fiber kg/m³
M0,25	1000	1000	25	250	0.2	1.7	0	0
M1,25	1000	1000	25	250	0.2	1.7	1	78
M2,25	1000	1000	25	250	0.2	1.7	2	156
M2,20	1000	1000	20	200	0.2	1.7	2	156
M2,15	1000	1000	15	150	0.2	1.7	2	156

♣ The letter M denotes Mix; the first number indicates the percentage of steel fiber content (Vf) and the second number indicates the percentage of silica fume (SF).

*** Percent of cement weight.**
**** S.P.: Superplasticizer, percent of binder (cement + silica fume) weight.**
***** Percent of mix volume**

3.3 Mixing Procedure:

RPC was varied by consuming a horizontal turning mixer with (0.1 m^3) ability obtainable in the structures laboratory, College of Engineering, Kufa University. Then the involvement process was stopped to shovel the mix by hand and then restarted for 3 additional minutes. This stage was recurrent in three cycles to assure the homogeneity of the combination. After the third cycle, steel fibers were all added by hand although involvement was integrated for 3 minutes. The total partying time was about 25-30 minutes. The normal concrete was mixed using the same mixer according to the conventional mixing of normal concrete.

3.4 Experimental Program:

In this research, four samples were established to revision the effect of (Vf), (SF) , hybrid section on the flexural conduct of singly reinforced RPC T-beams. The beams were separated as listed in table (14). The beams were considered to have suitable sizes that can be industrial, controlled and established as informal as likely. The minimal lengths of the confirmed beams were 1300mm in total distance and 160mm in depth. The web was completed with effective depth and 100mm width, the flange was prepared with 50mm thickness , 220mm flange width, clear span of 1200mm for all beams confirmed underneath exploit of two point loads, the space between two point loads was reserved constant at (400 mm).

Table (14): Beam details and concrete properties

Group No.	Parameter	Beam	V_f %	SF %	Tensile reinf.	Concrete in section	Flange width(b_f)(mm)
1	Changing in concrete of beam section	Normal	-	-	2φ12	Normal in all section	220
		RPC 1	2	25	2φ12	RPC in all section	220
		RPC 2	2	25	2φ12	RPC only in web	220
		RPC 3	2	25	2φ12	RPC only in flange	220

3.5 Hybrid Section

Two beams (RPC2 and RPC3) were castoff to explore inspiration incompletely using RPC on conduct T-beams equally contrast with completely RPC sample (RPC1) and typical sample (Normal), figure (1) shows details of cross-sectional .

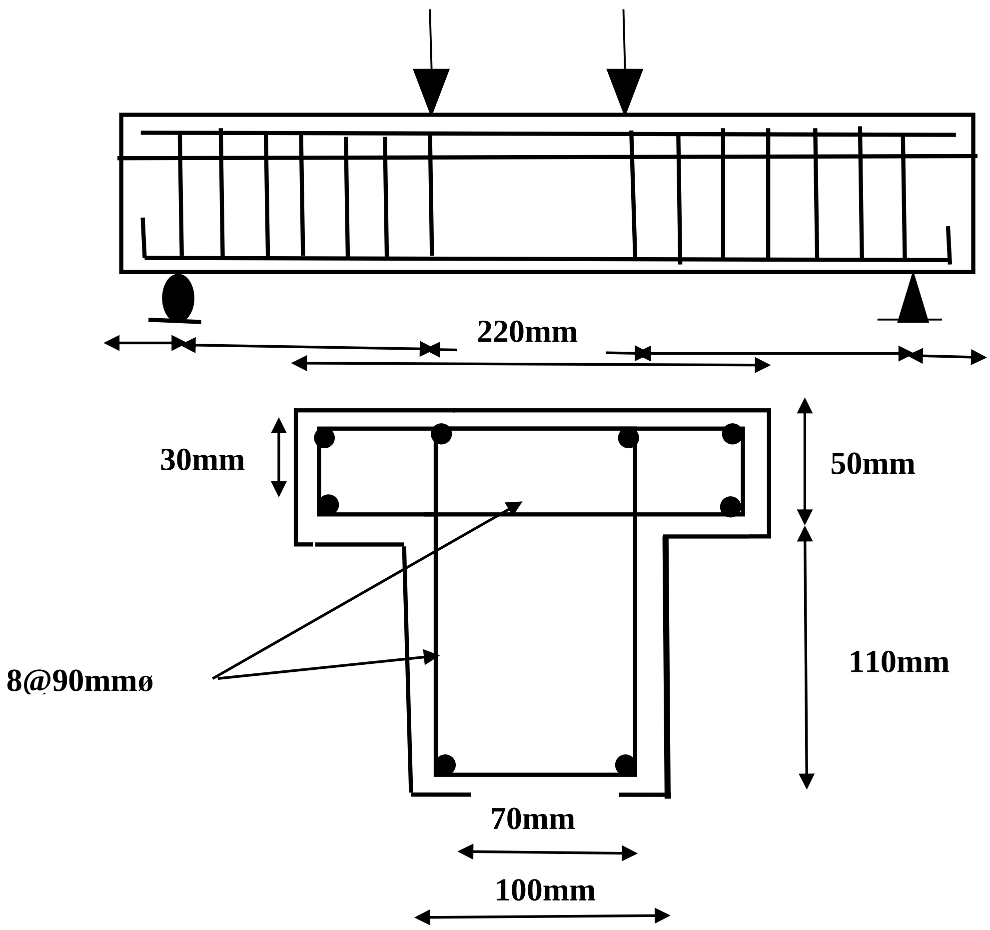

Figure (1) Details of cross-sectional dimensions and reinforcement of beams (Normal, RPC1, RPC2 and RPC3).

4. Experimental Results and Discussion

The consequences of the investigational experiments approved out in this research to observe and assess the flexural performance of RPC with Hybrid Section T-Beams as well as revising the manual properties of RPC. Belongings of three constraints on the flexural behavior of RPC with Hybrid Section T- Beams, comprising: steel fiber volumetric ratio (V_f), silica fume ratio (SF), hybrid section. The possessions were premeditated in expressions of load deflection curves, principal crack load, ultimate load, strain dissemination across the depth of the beam at dissimilar load stages, type of beam failure and crack form.

4.1 Mechanical Properties of RPC :

Device cases were equipped commencing the same mixture of non fibrous and fibrous concrete for each column specimen. The details of the control specimens were as following: Cubes of 100 mm and cylinder 150× 300mm for compressive strength test of concrete(fc') were used conferring to ASTM C39-03[17], flexural strength test(fr) (modulus of rupture) is approved out by consuming (100 x 100 x 500 mm) prisms, the experiment is supported out allowing to ASTM C78-02 [18], splitting tensile strength assessment(ft) is achieved on a dimensions with diameter and height (150×300) mm concrete cylinder allowing to the ASTM C496-04[19],and with diameter and height (150×300) mm for concrete cylinders for dimension of static modulus of elasticity (Ec) allowing to ASTM C469-02[20]. all the results shown in table(15).

Table (15) :Results of Mechanical Properties of Hardened Concrete Tests

No.of mix	Mix type	Steel fiber Vf %	Silica fume SF %	(fc') (MPa)	(ft) (MPa)	(fr) (MPa)	(Ec) (MPa)
1	M0,25	0	25	92.52	6.71	6.3	37481
2	M1,25	1	25	113.53	11.95	14.7	42469
3	M2,25	2	25	124.95	16.29	19.0	45024
4	M2,20	2	20	120.45	15.24	18.1	44751
5	M2,15	2	15	114.33	14.86	17.4	44529
6	M-normal	-	-	27.04	2.88	3.5	25641

4.2 Effect of Concrete Type (Hybrid Section):

To reading the talent of consuming typical concrete composed with RPC in the equivalent section to save part high cost of RPC and to achievement the benefits of the two materials in best technique, four beams were established.

Figure (2) shows the load-mid-span deflection of Normal, RPC1, RPC2, and RPC3.

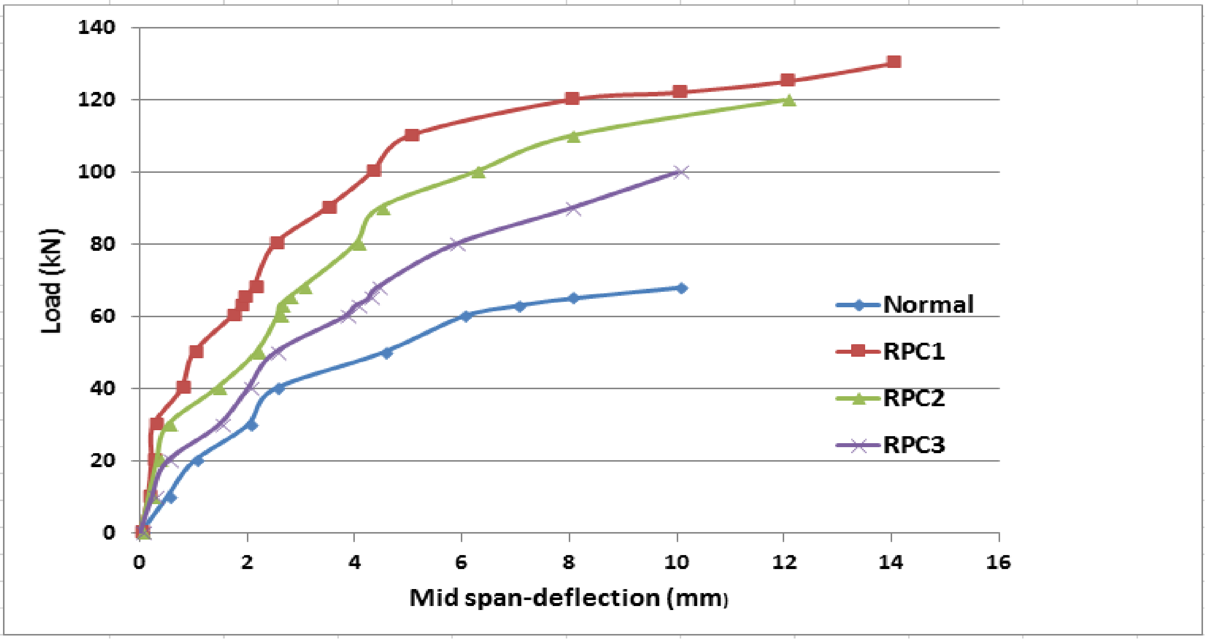

Figure (2): Effect of hybrid section on load deflection curves of T-beams

4.3 Crack Patterns:

Generally cracks in concrete are formed at sections wherever the tensile stresses exist and exceed the definite tensile strength of concrete. For samples failing in flexure, cracks initiate at the tension fiber in the central region of the sample, thus all established beams of this revision due to creation of cracking at tension zone in middle third of the beam as shown in figure through (3) which show photographs of the crack patterns afterward the disappointment of the tested beams. The numeral alongside the crack designated the load when the crack entered the concrete upwards.

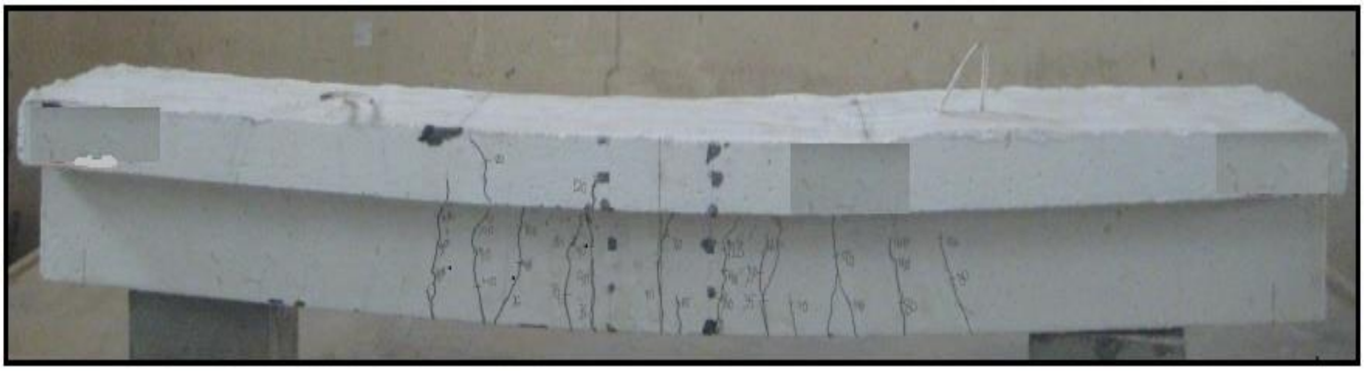

Figure (3): Effect of hybrid section on Crack pattern of T-Beams

4.4 Strain Distribution:

The strains in the concrete at midspan section of the tested beams were unrushed at seven unlike stages above the depth every beam as revealed in figures (4) to (7).

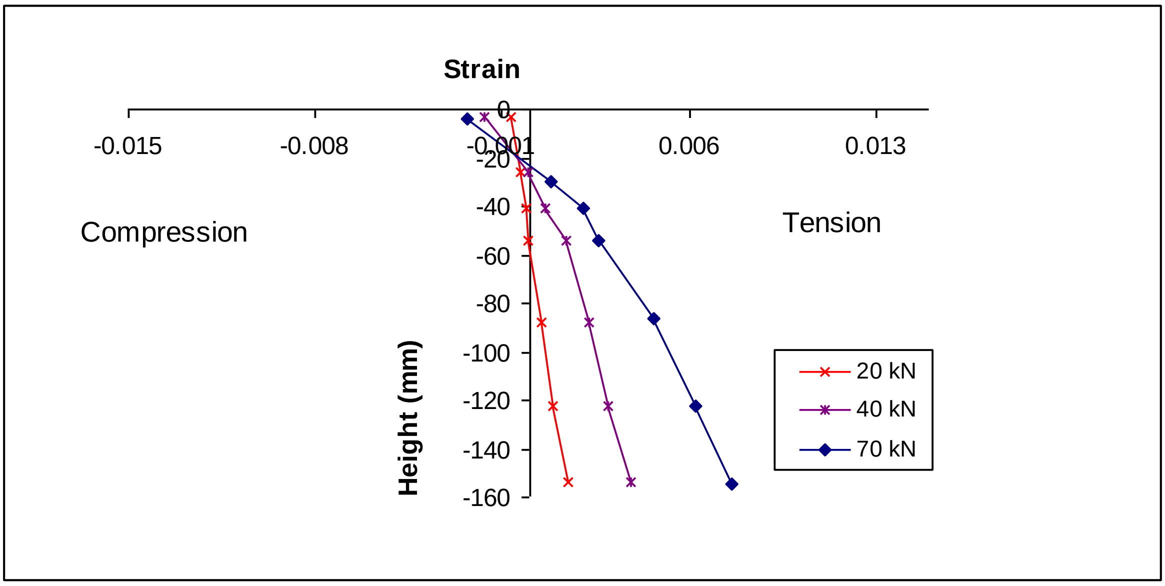

Figure (4): Strain distribution at section midspan of beam (Normal)

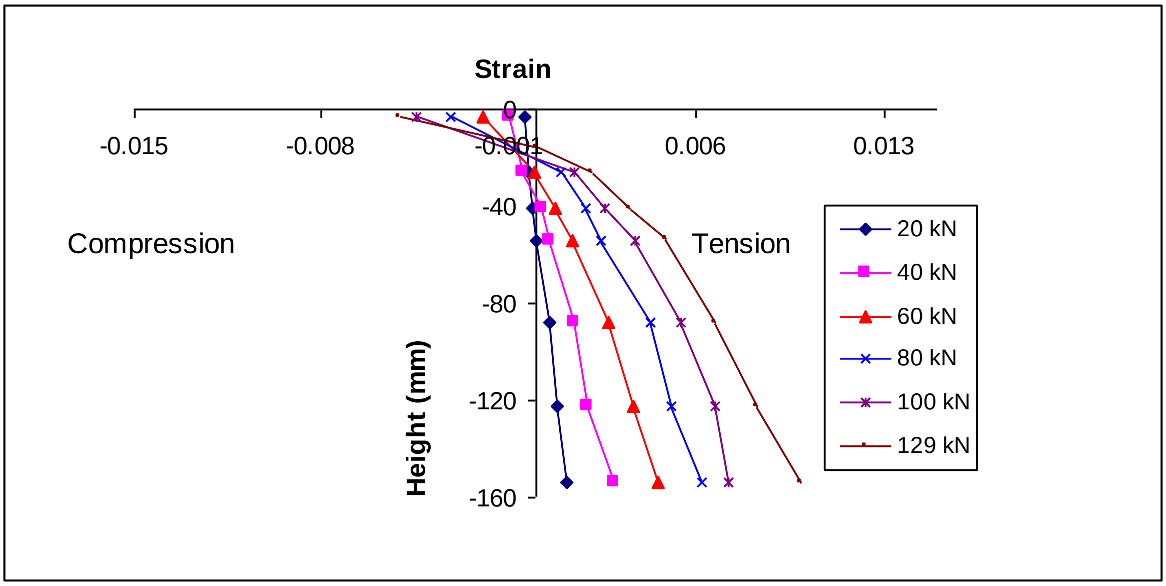

Figure (5): Strain distribution at section midspan of beam (RPC1)

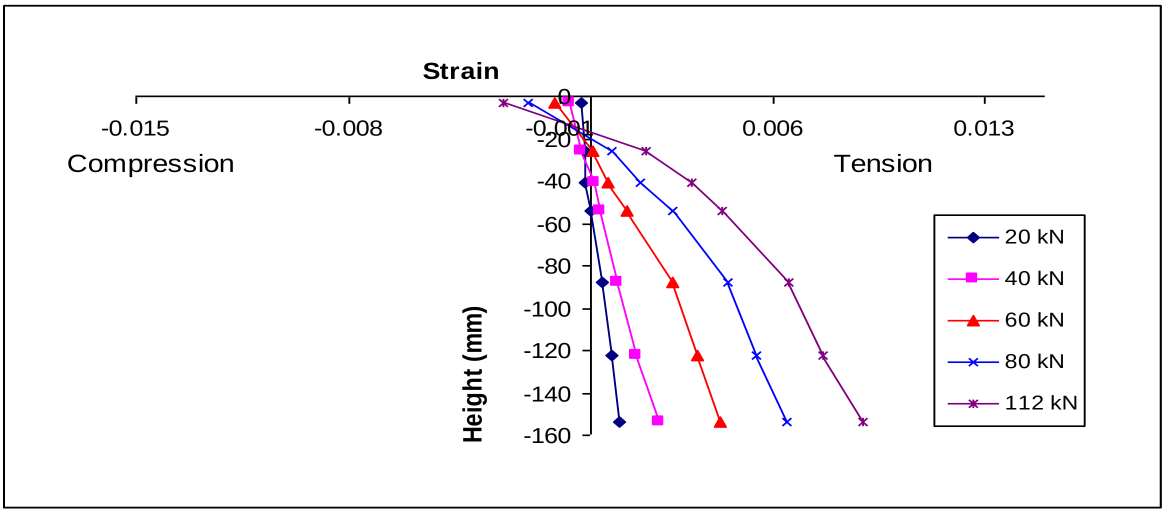

Figure (6): Strain distribution at section midspan of beam (RPC2)

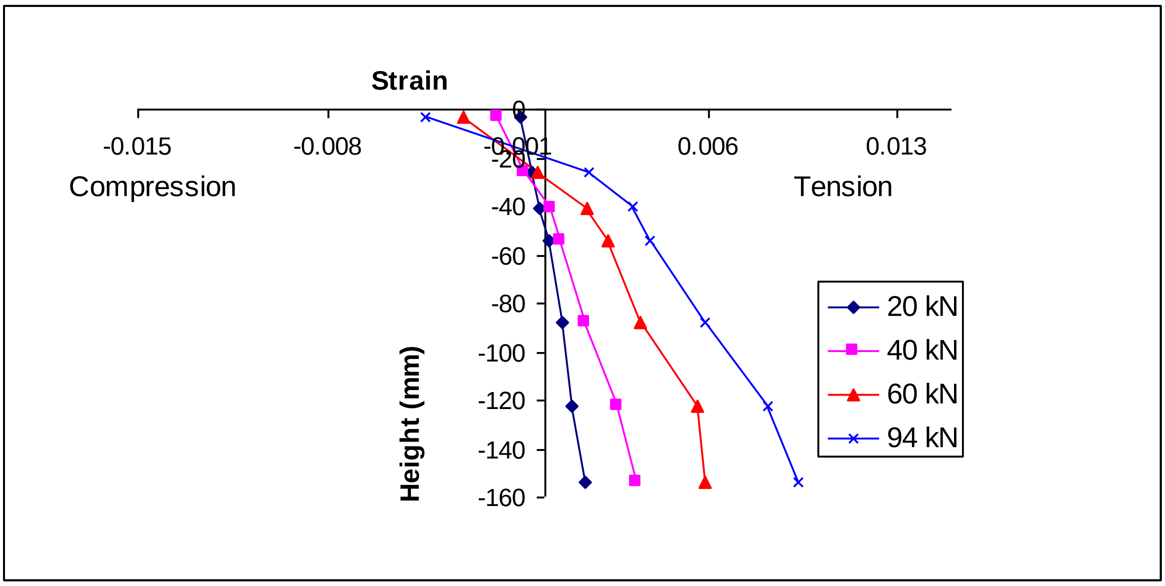

Figure (7) :Strain distribution at section midspan of beam (RPC3)

5. Conclusions Based on Experimental Work Results:

1. Influence of steel fiber volumetric ratio on the increase of ultimate deflection reveals that increasing steel fiber volumetric ratio to 2% makes RPC T-beams more ductile and capable of undergoing large deflections before attainment final load resonant ability. This possessions is exact significant structural supporters as it permits concrete to provide warning previously disappointment and avoids unexpected collapse.

2.Although the ultimate midspan deflection increases with increasing steel fiber volumetric ratio, the load-deflection curves of beams with (0, 1 and 2%) steel fiber volumetric ratio reveal that at a particular load level, the deflection decreases with increasing steel fiber volumetric ratio at all stages of loading, due to increasing in stiffness.

3. The increases in first crack load and ultimate load for RPC T-beams with increasing steel fiber volumetric ratio belong to the reason that fibers across the initial flexural cracks restrict growth and extension of the cracks and transmit regularly tensile to the concrete nearby the cracks. This maintains the beam reliability all over the post-cracking steps, therefore the beam resist better load and exhibits more deflection previously disappointment. A larger ductility is achieved with a higher ratio of steel bars.

4.Silica fume with ratios from 15% to 25% has little consequence on the principal crack capacity, ultimate flexural and the midspan deflection of RPC T-beams. On the other hand, growing ratio from 15 to25%, the first crack load, the ultimate flexural strength and the ultimate midspan deflection increase with percentages of 17, 10 and 15% respectively .

5.The part below load midspan-deflection curve of RPC T-beam increases with increasing steel fiber volumetric ratio and tensile steel ratio constant.

6. Main crack load, ultimate flexural strength and the ultimate midspan deflection with percentages increase of 22%, 31% and 12% respectively as compared with normal concrete T-beam, when using RPC in the flange with normal concrete in web for hybrid T-section beam show increase

7.Using RPC in the web with normal concrete in the flange for hybrid T-section beam show increase in the first crack load, ultimate flexural strength and the ultimate midspan deflection with percentages increase of 82%, 56% and 28% respectively as compared with normal concrete T-beam. Therefore, using RPC in the web does effectively enhance the performance of T-beams more than the case of RPC in flange.

8. Cracking of RPC beams with higher steel fiber volumetric ratios is associated with multiple cracking, while beams with lower steel fiber volumetric ratios are associated with localized cracking. Effect of silica fume on the crack pattern is not evident.

9.The strain distribution across the depth of the mid-span section of RPC beams is around line happening compression zone during the stuffing variety, while in the tension region,it is roughly linear at squat load levels and converts nonlinear at greater load levels owing to cracking. Also the presence of steel fibers leads to an growth in the final concrete strain values at together tension and compression zones but the influence is more pronounced in the tension zone. This can be credited to the enhanced action of steel fibers in tension slightly than in compression and increasing in stiffness and modulus of elasticity.

10.The presence of steel fibers in RPC gives some improvement to its compressive strength. Increasing Vf from 0% to 1% and 2% resulted in an increase in compressive strength of the order 20% and 33% respectively. Although silica fume is a smaller amount operational; growing silica fume ratio starting 15% to 20% and 25 % increases the compressive strength of RPC by only 5% and 8.5% respectively.

11. Under compressive load the failure of nonfiberous RPC is of explosive and brittle nature, while the failure of RPC with steel fibers exhibits ductile behavior. Steel fibers result in more closely spaced cracks, reduces the crack width and improves resistance to deformation.

12. Steel fibers obligate a important consequence on tensile strength of concrete. As steel fibers proportion upsurges from 0% to 1% and 2%, the splitting tensile strength of RPC upsurges by 75% and 139% separately. Silica fume has a minor effect in growing the splitting tensile strength, as upsurges starting 15% , 20% then 25% increase by only 2.32% to 8.77% respectively.

13. Steel fibers have also a significant effect in increasing the modulus of rupture of RPC. As soon as steel fibers ratio rises starting 0% to 1% and 2% modulus of rupture of RPC rises by 129% to 198 % respectively. However silica fume appearances tiny consequence happening the modulus of rapture. As rises from 15% to 20% and 25 rises by only 4% and 9% respectively.

14. The strain distribution across the depth of the mid-span section of RPC beams is nearly direct in the compression region during the course of the charging variety, however happening the tension zone, it is nearly linear at short load levels and develops nonlinear at higher load levels owing to cracking. Also the presence of steel fibers leads to an rise in the ultimate concrete strain values at together tension and compression zones but the influence is more pronounced in the tension zone. This can be recognized to the enhanced action of steel fibers in tension reasonably than in compression.

References

1- Richard, P. and Cheyrezy, M., "Reactive Powder Concrete with High Ductility and 200-800 MPa Compressive Strength", ACI SP144-24, 1994, pp. 507-518.

2- Collerpardi, S ., Coppola, L., Troli, R. and Collepardi, M., "Mechanical Properties of Modified Reactive Powder Concrete", Proceedings fifth CANMET/ACI International conference on superplasticizers and the chemical admixtures in concrete, Rome. Italy. Farmington Hills, MI: ACI publication SP-173, 1997, pp. 1-21.

3- Richard, P. and Cheyrezy, M., "Composition of Reactive Powder Concrete", Cement and Concrete Research, Vol. 25, No. 7, 1995, pp. 1501-1511.

4- Shaheen, Ehab. and Shrive, Nigel. G., "Optimization of Mechanical Properties and Durability of Reactive Powder Concrete", ACI Materials Journal, November-December 2006, pp.444-451.

5- Gao, X.,"Mix Design and Impact Response of Fiber Reinforced and Plain Reactive Powder Concrete", M.Sc. Thesis, School of Civil, Environment and Chemical Engineering, RMIT University, August 2007, 73p.

6- Hoang, K., H., Phat, H., B., Hien, L., V., D., "Influence of Types of Steel on Properties of Ultra High Performance Concrete", The 3rd ACF International Conference-ACF/VCA, 2008, pp. 347-355.

7- Tai, Y., S.," Uniaxial Compression Tests at Various Loading Rates for Reactive Powder Concrete ", Theoretical and Applied Fracture Mechanics, No. 52, 2009, pp. 14-21.

8- Prabha, S., L., Datta, J., K., Neelamegam, M., and Seshagiri Rao, M., V., "Study on Stress-Strain Properties of Reactive Powder Concrete under Uniaxial

Compression" , International Journal of Engineering Science and Technology, Vol.2(11) , 2010, pp. 6408-6416.

9- Hannawayya, S., P., Y., "Behavior of Reactive Powder Concrete Beams in Bending", Ph.D. Thesis, Building and Construction Engineering Department, University of Technology, Baghdad, 2010, 239p.

10.IraqiStandardsNo.5/1984,"Ordinary Portland cement" Ministry of Housing and Construction, Baghdad, 2004

11- Iraqi Standards No.45/1984, "Aggregate from Natural Sources for Concrete and Construction", Ministry of Housing and Construction, Baghdad, 2004.

12- ASTM C1240-04, "Standard Specification for the Use of Silica Fume as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout", Vol. 4.2, 2004, 6p.

13- ASTM C494/C494M-1999a, "Standard Specification for Chemical Admixtures for Concrete", Vol. 4.2, 1999, 9p.

14- ASTM A 820/A 820M-04 " Standered Specification for Steel Fiber for Fiber-Reinforced Concrete " , 2004,pp.1-4.

15- ASTM A615/615M-05a, "Standard Specification for Deformed and Plain Carbon Structural Steel Bars for Concrete Reinforcement", Annual Book of ASTM Standards, Vol.01.02, 2005.

16- ASTM A615/615M-05a, "Standard Specification for Deformed and Plain Carbon Structural Steel Bars for Concrete Reinforcement", Annual Book of ASTM Standards, Vol.01.02, 2005.

17-.ASTM C39/C39M-2003, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", Vol. 4.2, 2003, pp. 1-5 and B.S. 1881: Part

116: 1983, "Methods for Determination of Compressive Strength of Concrete Cubes", January 1983, pp. 1-8.

18-.ASTM C78-02, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-point Loading)", Vol. 4.2, (2002), pp. 1-3.

19-.ASTM C496/C496M-04, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens", Vol. 4.2, (2004), pp. 1-5.

20-.ASTM C469-02, "Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression", Vol. 4.2, (2002), pp. 1-5