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

Rafid Saeed Atea (rafid1980@yahoo.com)
University of Kufa

Original Article

Keywords: Reactive powder, Steel Fiber, Silica Fume

Posted Date: November 15th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1051508/v1

Abstract

Reactive powder concrete (RPC) is unique of the present 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, shrinkage, great opposition to corrosion and abrasion. In this experimental investigation is carried out on the way to revision the RPC flexural activity with Hybrid Segment T- Beams and the mechanical characteristics of this building material. In order to analyze the belongings of steel fiber volumetric ratio, silica fume ratio, tensile steel ratio, hybrid section on RPC T-beam flexural efficiency, the experimental program included testing five beams. The study was focused on determining the load-deflection behavior, letdown mode, strain supply across the depth of the beams and crack pattern at failure. The results of the volumetric ratio of steel fibers and the silica fume ratio were also considered in studying the mechanical properties of RPC mixes. Moreover, a study of hybrid beams showed that use of RPC web and normal concrete in flange efficiently improves the performance of T-beams compared to normal concrete T-beams with a percentage rise of 12 percent and hybrid beams have also shown that the use of RPC flange and normal concrete in web efficiently improves the display of T-beams associated to regular concrete T-beams with percentages increase of 28%.

1. Introduction

Reactive powder concrete (RPC) is unique to the knowledgeable and best significant improvements in concrete equipment, owing to its higher mechanical properties, it has developed excessive consideration in current years in the world [1, 2]. RPC is also known to make its more structural presentation as ultra-high enactment concrete. This includes large cement measurements, fine sand with a particle size of 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 Under static load, the flexural conduct of simply assisted RPC T-beams. 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 form 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, different silica fume fillings reaching from 0–40% were castoff in the mix sizes. In 2007, Gao [6] The properties of plain RPC and reinforced RPC fibers are influenced by expected Dynamic Loads. 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 adding 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 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. In 2010 Hannawayya [9] In addition to examining the flexural performance of RPC rectangular section beams, research database offered to study the effects of RPC on the concrete properties as a material, investigating that conclusion of the consequence of the volumetric ratio of steel fibers (Vf) and the content of silica fume On some important RPC properties, such as compressive strength, solidity uniaxial stress-strain relationship, tensile strength splitting and rupture module. This study offers an investigational revision of the Under a simple static load effect, flexural conduct of the simply supported RPC T-beams Hybrid Segment, as well as some significant RPC mechanical properties being studied. Four beams were verified in this study to exercise the effect of volumetric ratio of steel fibers (Vf), silica fume ratio (SF), hybrid section on the flexural performance of single reinforced RPC T-beams.

2. Materials

2.1

The significance of reactive powder using dissimilar arrangements proceeding the conduct of beams and, there is calculated normal concrete. Cement [10], sand [11], gravel [11], steel reinforcement [11] and traditional water are treated without any additives in the casting-off products.

2.1 Silica Fume:

A gray densified silica fume was cast-off, awfully fine dust, elements 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 (1), chemical is given conformations of silica fume castoff happening this research. The silica fume is compliant with ASTM C1240-04[12] supplies.

Table (1) :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 test have been performed in the materials test laboratory in the College of Engineering ,University of Kufa

2.2Superplasticizer (S.P.):

A great enactment concrete superplasticizer (entitled High Range Water Reduction Agent HRWRA) established, recognized as Glenium 51, castoff in this amendment [13].

Table (2) :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 °C
pH	6.6
Viscosity	128 ± 30 cps @ 20° C
Transport	Not classified as dangerous
Labeling	No hazard label required
Chloride content	None

*Supplied by manufacturer .

2.3 Steel Fibers:

High enactment steel fibers were castoff in this investigation [14], Its properties are described in table Properties (3).

Table (3) :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 .

2.4 Steel Bars:

Table (4) 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 (4) :Properties of steel bars

Diameter (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 casting the normal and the web into hybrid beams, cement, fine aggregate, coarse aggregate, and water were cast off. (Normal, RPC1, RPC2 and RPC3). Control sample in the form of cylinders and prisms were also cast from this mixture.

3.2 Reactive Powder Concrete Mixes:

Five RPC mixtures were castoff in this revision. The quantities of supplies of all mixes are reported in the table (5). The percentage of silica fume ratio (three percentages of silica fume as additive were used 15, 20 and 25 percent) and the volume ratio of steel fibers were the variables castoff in these mixes. The percentage of silica fume ratio (three percentages of silica fume as additive were used 15, 20 and 25 percent) and the volume ratio of steel fibers were the variables castoff (three volume ratios were considered 0, 1 and 2 percent).

Table (5): Properties of the various types of mixes for RPC

Mix♣	Cement kg/m³	Sand kg/m³	Silica Fume* %	Silica Fume kg/m³	w/cemen -titious	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 denotes the proportion of the fiber content (Vf) and the second number denotes the proportion of the silica fume content (SF).

* Percent of cement weight.

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

*** Percent of mix volume

3.3 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 (6). The beams were considered to have suitable sizes that can be industrial, controlled and established as informal as likely. 1300 mm in total distance and 160 mm in depth were the minimum lengths of the confirmed beams.. 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 (6): Beam details and concrete properties

Group No.	Parameter	Beam	Vf %	SF %	Tensile reinforcement	Concrete in section	Flange width(bf) (mm)
1	Changing in concrete of section	Normal	-	-	2φ12	Normal in all section	220
		RPC1	2	25	2φ12	RPC in all section	220
		RPC2	2	25	2φ12	RPC only in web	220
		RPC3	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.

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 :

Information of the specimens under charge were as follows: 100 mm cubes and 150 to 300 mm cylinder for concrete compressive strength test(fc ') were used for ASTM C39-03[17], flexural strength test(fr), the experiment is supported for ASTM C78-02[18], splitting tensile strength assessment(ft) is achieved on diameter and height dimensions (150 to 300) mm[18] .Concrete cylinders permitting ASTM C496-04[19], and with diameter and height (150 □ 300) mm for concrete cylinders permitting ASTM C469-02[20] for the dimension of the static elasticity modulus (Ec). All the observations in the table shown (7).

Table(7): Results of Hardened Concrete Tests' mechanical properties

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) on load-mid-span deflection:

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.

4.3 Patterns of Crack:

Usually, cracks in concrete are molded in parts wherever the tensile stresses arise and Exceeding the concrete's definite tensile strength. Cracks start at tension fiber in the central region of the sample for samples failing in flexure, hence all formed beams of this revision because of the cracking mechanism happening middle third of the beam, at the tension zone as shown in the figure through (3) Afterwards, photos of the crack patterns indicate the disappointment of the beams examined. When the crack reached the concrete upward, the numeral alongside the crack designated the load.

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 As revealed in numbers, each beam (4) to (7). These figures reveal that the distribution of strain remained roughly linear across the loading range in the compression field. The strain distribution was roughly linear at low loads in the stress zone and became nonlinear at greater loads due to cracking. Also it can be noted from these figures that the presence of steel fibers leads to increase ultimate concrete strain, the can be due to the improved operation of steel fibers in tension relatively than compression at together tension and compression zones, then the influence is additional important in the tension field.

5. Conclusions Based On Experimental Work Results

1. The result of the steel fibre volumetric ratio on the increase of ultimate deflection shows that increasing the volumetric ratio of the fibers of steel to 2 percent allows RPC T-beams that are more ductile and able to undergo significant deflections previously resonant potential of final load is achieved. These possessions are precisely essential structural supporters as it helps concrete to provide previous dissatisfaction with warning and stops unexpected failure.

2. Although the ultimate mid-span deflection increases through rising volumetric ratio of steel fiber, load-deflection curves of beams with a volumetric ratio of steel fiber (0, 1 and 2 percent) show that the deflection decreases at a specific load level by the increasing volumetric ratio of steel fiber at all loading stages due to an increase in stiffness.

3. The increase in the first crack load and final load for steel fiber RPC T-beams with an improved volumetric ratio is due to the fact that fibers limit development and extension of the cracks through the initial flexural cracks and conduct normal tensile to the concrete near the cracks. Throughout the post-cracking steps, this preserves the beam stability, so the beam resists better load and displays more deflection before disappointment. With a higher ratio of steel bars, higher ductility is achieved.

4.Silica fume with ratios from 15% to 25% has little consequence on the principal crack capacity, ultimate flexural and the mid-span deflection of RPC T-beams. On the other hand, with percentages of 17, 10 and 15 percent respectively, The principal crack load, the ultimate flexural strength and the ultimate deflection of the mid-span rise from 15 to 25 percent.

5. The part below the load mid-span-deflection curve of the With the growing RPC T-beam, volumetric ratio of steel fiber and constant tensile steel ratio.

6. When consuming RPC in the flange of the web with standard concrete for hybrid T-section beam, the main Crack load, ultimate strength of flexure and ultimate mid-span deflection with proportions rise by 22 percent for RPC1, 31 percent for RPC2 and 12 percent for RPC3 as associated with normal concrete T-beam show increase.

7. RPC shows upsurge ultimate flexural power in the first crack load and ultimate mid-span deflection trendy the web using In a flange, standard concrete for hybrid T-section beam with proportions increased by 82 percent for RPC1, 56 percent for RPC2 and 28 percent for RPC1 as associated with normal concrete T-beam. More than the situation of RPC in flange, RPC in the web prepares to efficiently improve concert of T-beams.

8. Multiple cracking is associated with cracking of RPC beams with higher Volumetric ratios of fibers made of steel, though beams through lower volumetric ratios of steel fibers are associated with localized cracking. The impact of the silica fume on the crack pattern is not apparent.

9.The presence of steel fibers in RPC gives some improvement to its compressive strength. Increasing volume fraction 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.

10. 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 result in growing the splitting tensile strength, as upsurges starting 15% , 20% then 25% increase by only 2.32% to 8.77% respectively.

11. 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.

12.The strain distribution crosswise 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 then the influence is more marked in the tension zone. The improved action of steel fibers in tension slightly than in compression and increasing in stiffness and modulus of elasticity.

Declarations

 The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Title page and Funding

1-Full name: Rafid Saeed Atea

2-Academic position or professional affiliations: Assistant Professor

3. Last Degree earned :(PhD/ Structural Engineering)

4.Nationality: Iraqi

5.Address: Iraq - Najaf .

6.Mobil number: 009647809392111

7. Email: rafid1980@yahoo.com

8. Name and address of affiliation: university of Kufa / College of Engineering

9. Name of supporting funds Organization: no funds

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.

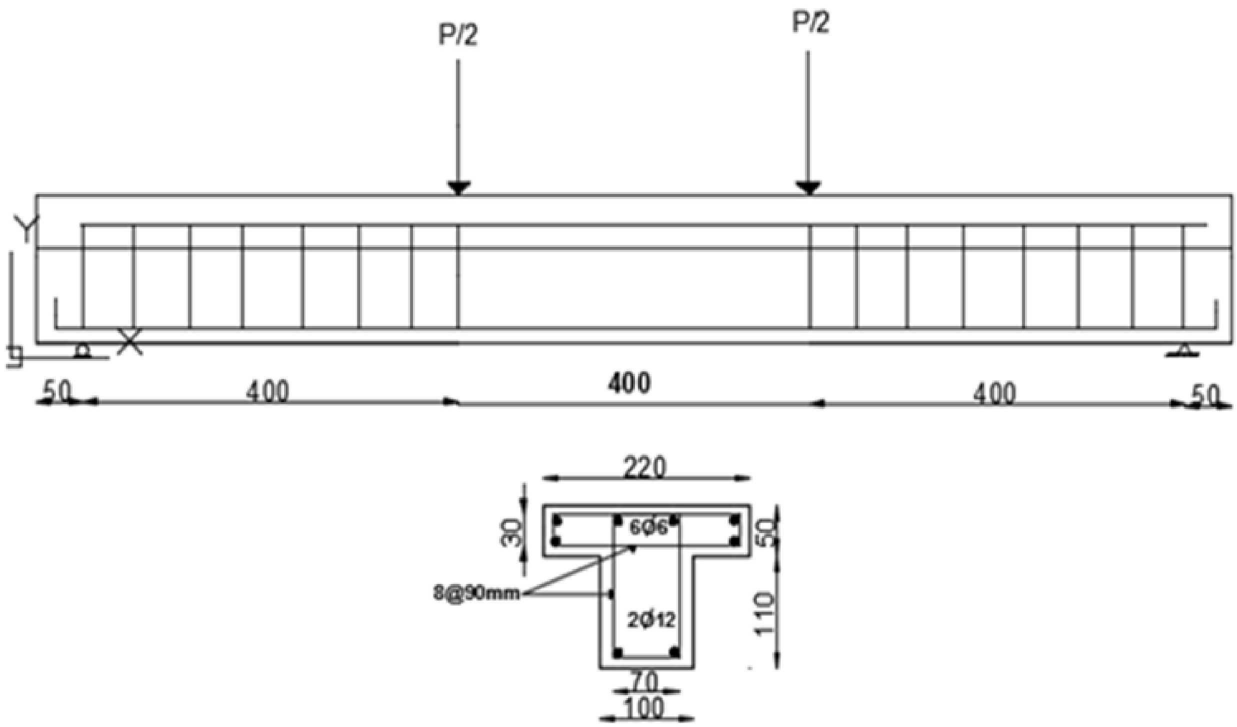
[17] ASTM C39/C39M-2003, “Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens”, Vol. 4.2, 2003, pp. 1-5 and B.S. 1881: Part 116: 1983, “Methods for Determination of Compressive Strength of Concrete Cubes”, January 1983, pp. 1-8.

[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

Figures



*all dimensions in mm

Figure 1

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

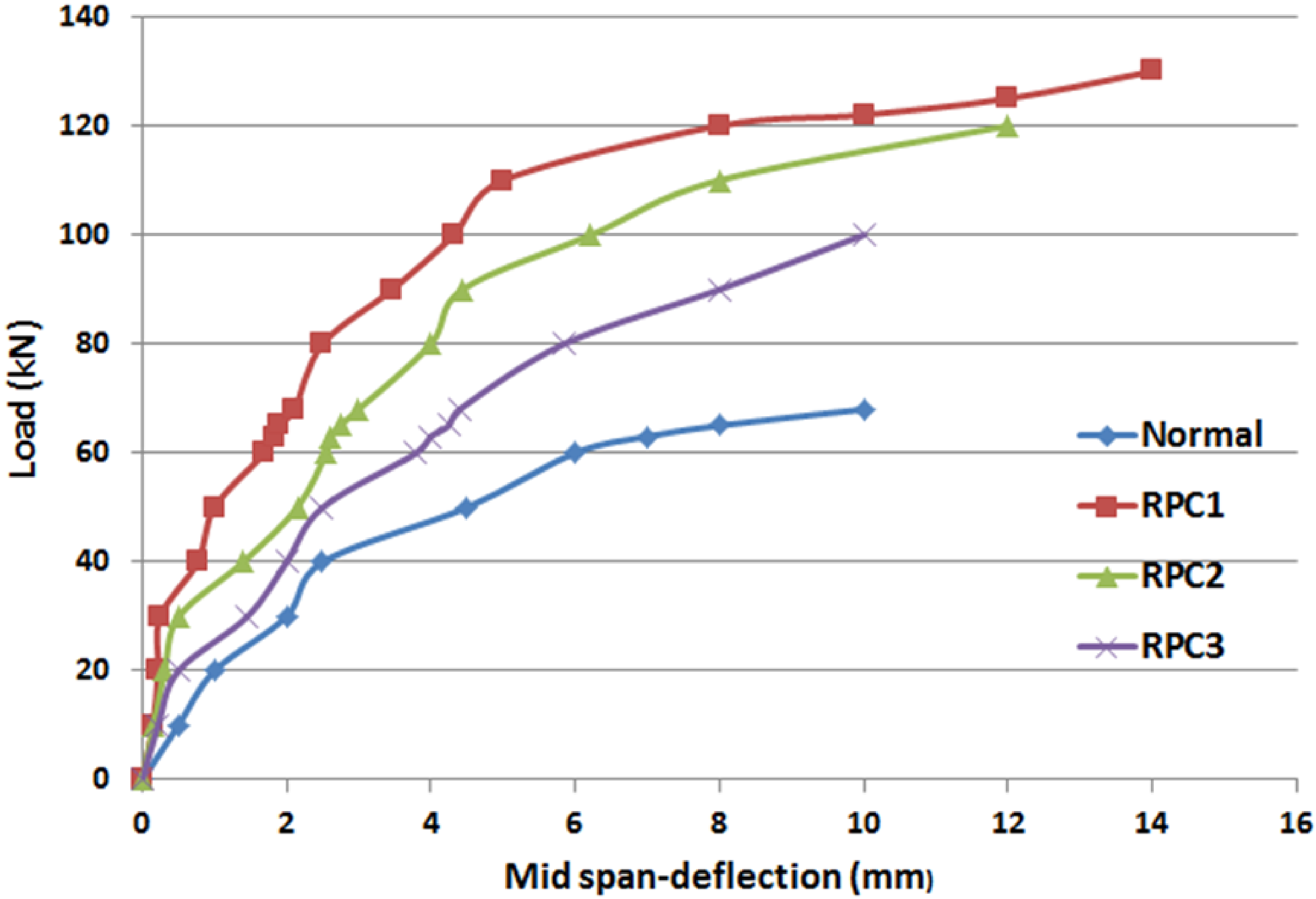


Figure 2

Effect of hybrid section on load deflection curves of T-beams

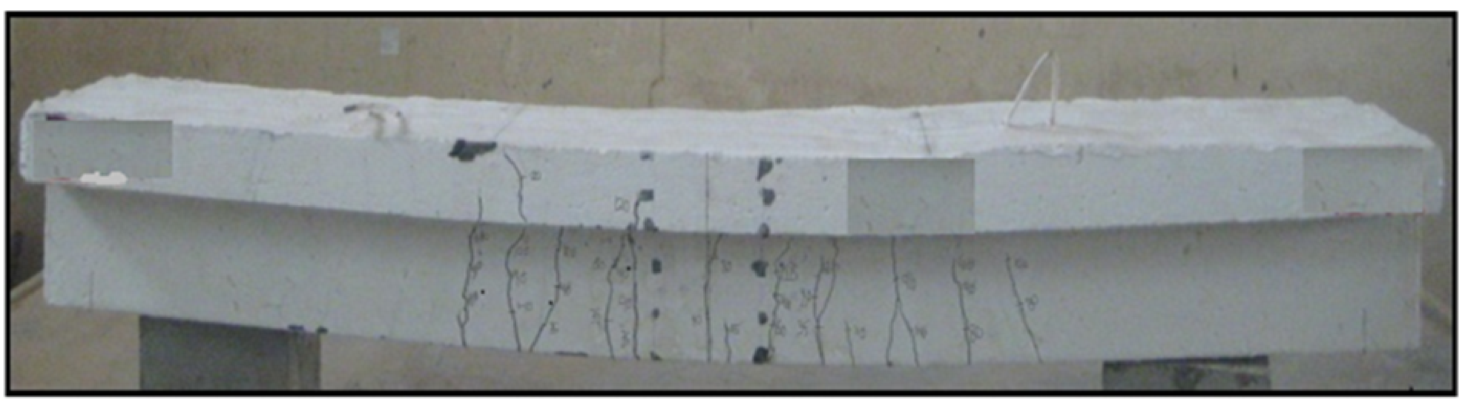


Figure 3

Effect of hybrid section on Crack pattern of T-Beams

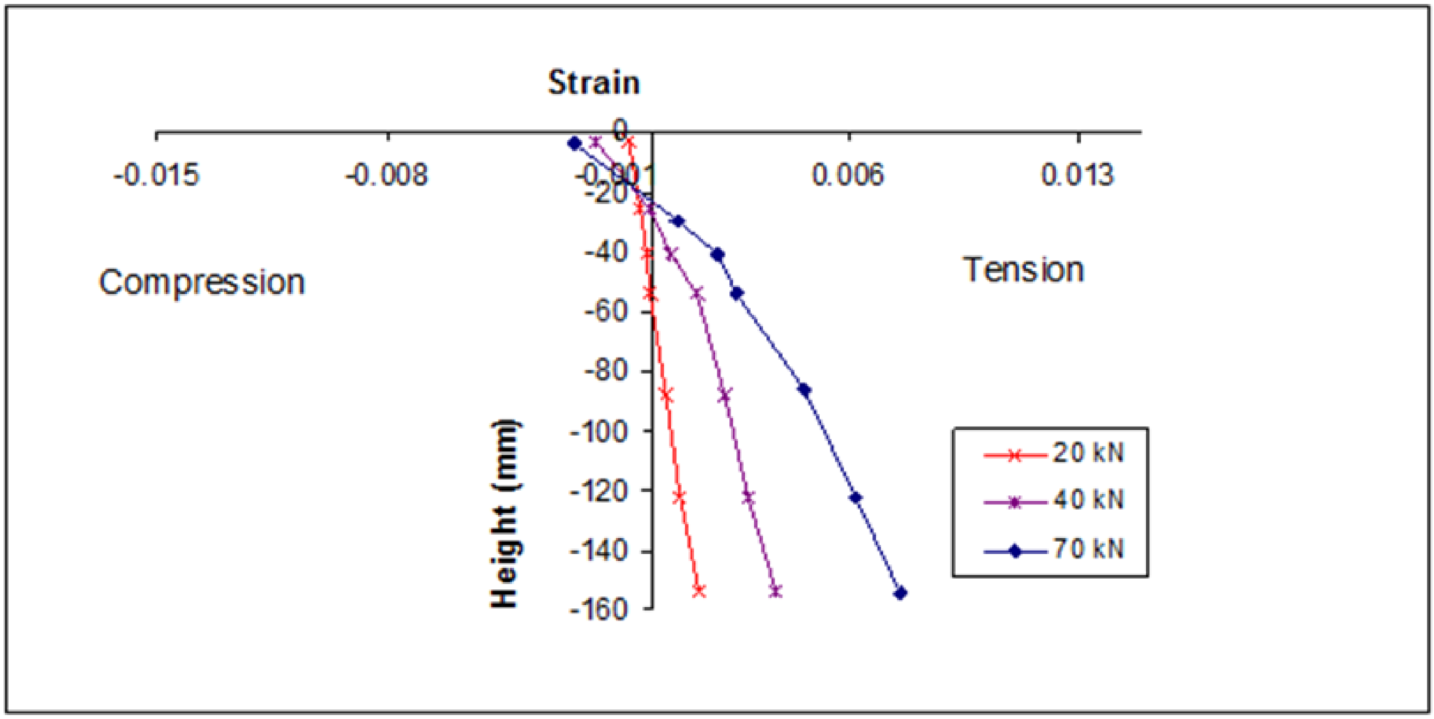


Figure 4

Strain distribution at section mid-span of beam (Normal)

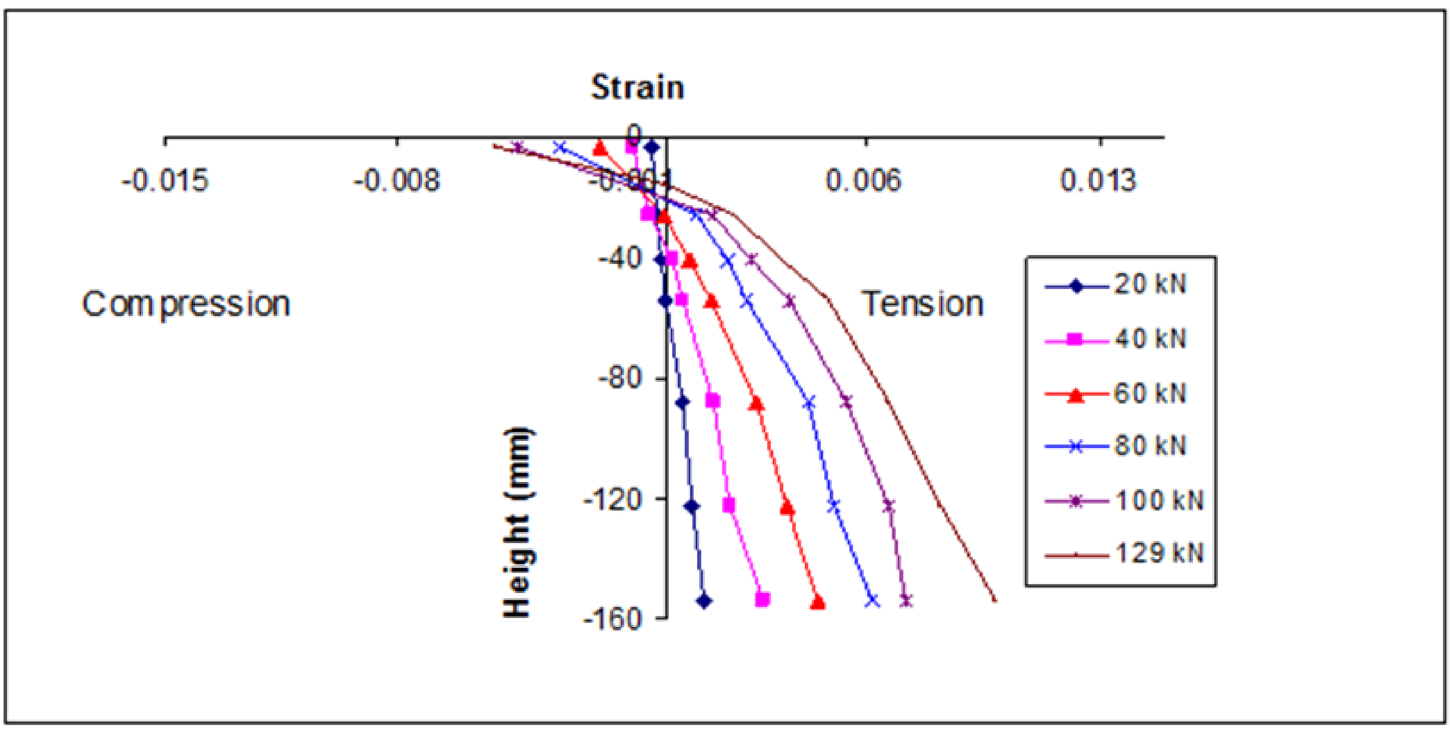


Figure 5

Strain distribution at section mid-span of beam (RPC1)

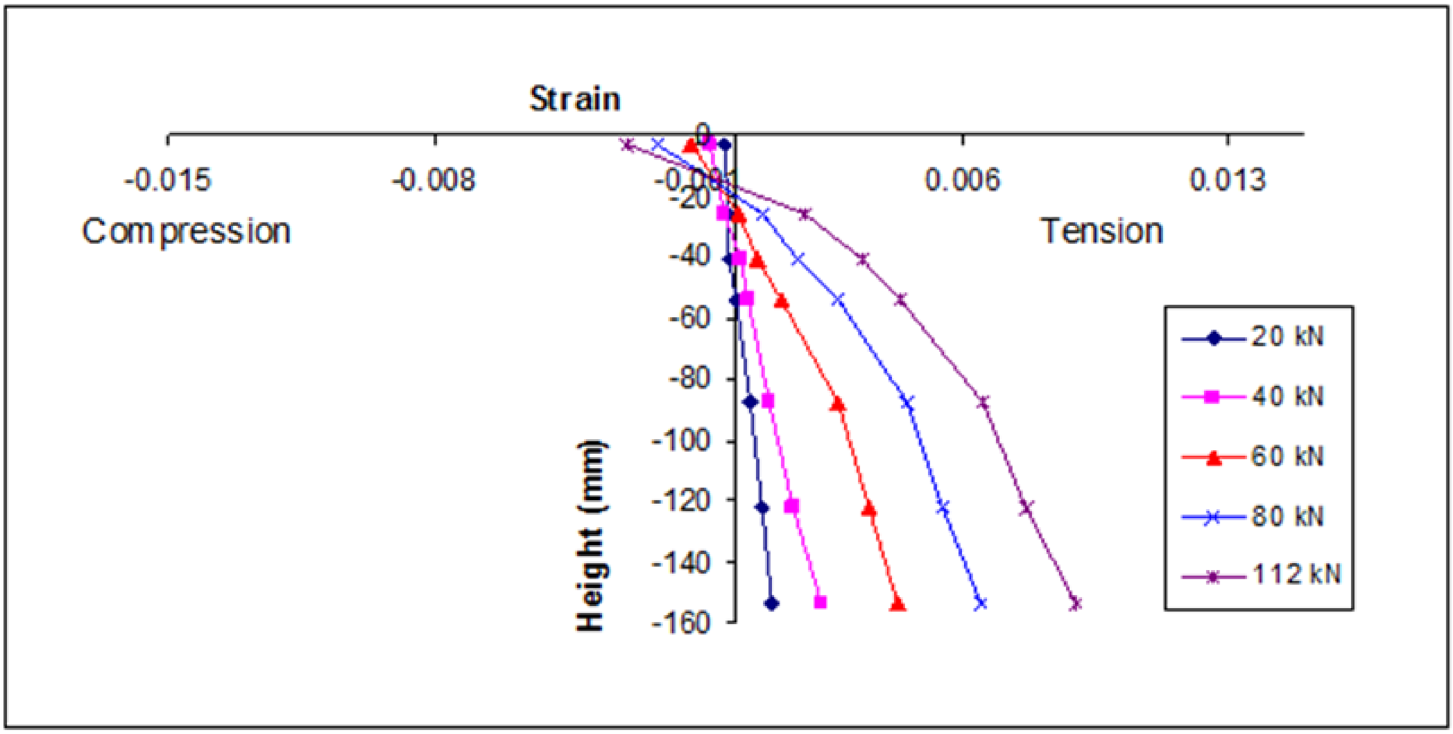


Figure 6

Strain distribution at section mid-span of beam (RPC2)

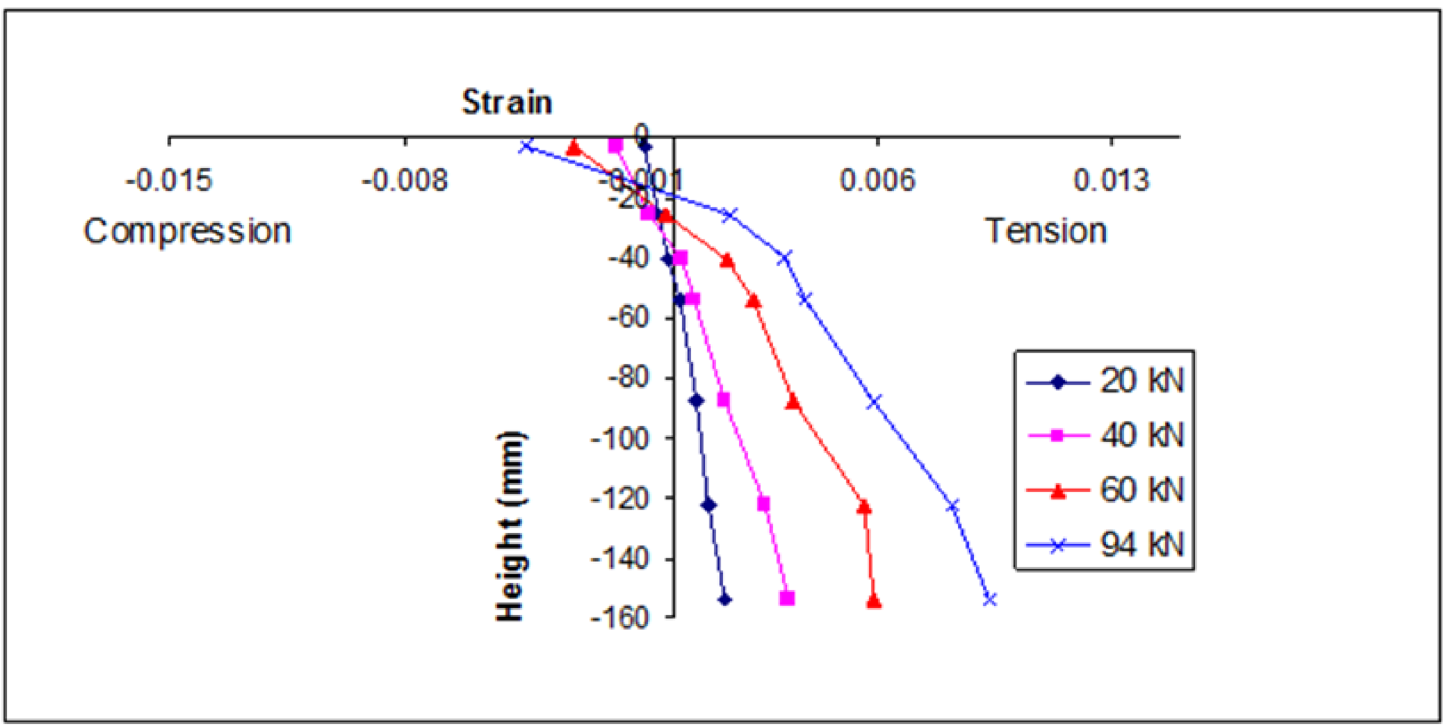


Figure 7

Strain distribution at section mid-span of beam (RPC3)