Structural Behavior Of Self-Compacting Concrete Reinforced T-Beams

Prof. Dr. Mohammed M. Salman
AL-Mustansiriya University
College of engineering
Civil Engineering Dept.
mmsalman٥٦@yahoo.com

Asst. Prof. Dr. Mohammed M. Rasheed
AL-Mustansiriya University
College of engineering
Civil Engineering Dept.
mohammed_rasheed٧٢@yahoo.com

Yahya S. Khudhair
AL-Mustansiriya University
College of engineering
Civil Engineering Dept.
kingconger٢٠٠٠@yahoo.com

Abstract

The study is concerned with the structural behavior of (١٢) reinforced T-shaped cross-section beams made of self-compacting concrete under flexural with two types of fibers (polypropylene and steel fibers). Compression and tensile strengths, deflection, ductility and cracking behavior are considered. Experimental results are compared with these evaluated based on the (ACI ٣١٨ – ٠٨). The variables studied are reinforcing ratio (%ρ) (between %٤,٤٩٠٧ - ٪٦,٠٤٣٤) using different sizes of reinforcing steel bars (Φ ٢٥mm, Φ ٢٠mm, Φ ١٦mm, Φ ١٢mm, Φ ٦mm, Φ ٤mm, and Φ ٦mm wire mesh), in addition to two fibers, [polypropylene (RHEO-FIBERS®) and steel fibers (FIBERFORCE®) at a rate of [(١kg/m^٣) & (٠,٥٪)], respectively. The tested T-Beams were categorized into three groups, each group includes (٤) T-Beams of different steel ratios (ρ %). In Group (G ١), polypropylene fibers were used. In Group (G ٢), steel fibers were used. The reference group (G ٣) is with the same reinforcement ratios as in the previous two groups.

It was concluded that using polypropylene fibers (RHEO-FIBERS®)in addition to (١kg/m^٣) in self-compacting concrete (SCC) improves the cracking control, ductility by ($\Delta\mu_d$ = ٠,٥٨٤٦ – ٤,٠٥١٤). However, fibers have minor effect on the deflection behavior of T-Beams. On the other hand, when steel fibers type (FIBERFORCE® steel fibers) of a volume rate of (V_f = ٠,٥٪ of concrete volume V_c) are used in combination with self-compacting concrete, affects the flexural behavior of T-Beams (reducing deflection, increasing ultimate loads' by (١١,٠٢٪ - ١٦,٨٠٪) and improving the ductility by ($\Delta\mu_d$ = ٤,٩٢٣٢ – ١٢,١٢٣٨), but it has a minor effect on reducing the crack width.

Keywords: *Self-Compacting Concrete; T-Beam; Steel Fibers; Polypropylene Fibers; Superplasticizer; Silica fume; Limestone Powder; Flexural Behavior; Cracking Behavior; Deflection; Ductility Factor.*

السلوك الإنشائي للعتبات الخرسانية الذاتية الرص ذات المقاطع بشكل حرف (T)

الاستاذ د.محمد مصلح سلمان	الاستاذ المساعد د.محمد محمد رشيد	يحيى صابر خضير
الجامعة المستنصرية	الجامعة المستنصرية	الجامعة المستنصرية
كلية الهندسة	كلية الهندسة	كلية الهندسة
قسم الهندسة المدنية	قسم الهندسة المدنية	قسم الهندسة المدنية

الخلاصة:

أن هذا البحث يهدف ألى دراسة السلوك الأنشائي للعتبات الخرسانية ذات المقاطع بشكل حرف (T) بعدد (١٢ عتب) والمسلحة بنوعين من الألياف (ألياف البوليمر وألياف الحديد) , وأن دراسة هذا البحث تتضمن برنامج عملي شامل ، مع الأخذ بنظر الأعتبار تأثير أضافة هذين النوعين من الألياف (ألياف البوليبروبيلين وألياف الحديد) على سلوك الخرسانة الذاتية الرص كتأثيرها مثلا على (مقاومة الأنضغاط , ومقاومة الشد , ومقدار الهطول , وتحسين المطيلية ، بالأضافة ألى نمط وعرض التشقق الذي ممكن أن يظهر في الخرسانة الذاتية الرص) ومقارنة النتائج المستحصلة عمليا مع النتائج المحسوبة تخمينيا طبقا للمدونة الأمريكية المرقمة (ACI ٣١٨ لسنة ٢٠٠٨) , وكل هذا تم دراسته خلال هذا البحث العملي . المتغيرات التي تم دراستها خلال البحث هي نسبة التسليح (ρ%) حيث تم أخذها بنسب تتراوح مابين (٤,٤٩٠٧% - ٦,٠٤٣٤%) وذلك بأستخدام أقطار مختلفة من قضبان حديد التسليح هي (٢٥ ملم , ٢٠ملم , ١٦ملم , ١٢ملم , ٦ ملم , ٤ ملم , شبكة بقطر ٦ ملم) , بالأضافة ألى ذلك أنه تم أستخدام ألياف البوليبروبيلين من نوع (RHEO-FIBER®) بمعدل أضافة مقداره (١كغم / م٣) , وألياف الحديد من نوع (FIBERFORCE®) بنسبة أضافة مقدارها (٠,٥%) كنسبة حجمية من الحجم الكلي للخرسانة الذاتية الرص . كل العتبات ذات المقاطع بشكل حرف (T) تم توزيعها على ثلاث مجاميع , كل مجموعة أستخدم فيها أربع نسب من التسليح بأقطار مختلفة من حديد التسليح , وهذه النسب تم تكرارها على المجاميع الثلاثة مع أستخدام ألياف البوليبروبيلين من نوع(RHEO-FIBERS®) في خلطة الخرسانة الذاتية الرص لعتبات المجموعة الأولى , بينما تم أستخدام ألياف الحديد من النوع (FIBERFORCE®) في خلطة الخرسانة الذاتية الرص لعتبات المجموعة الثانية , أما المجموعة الثالثة فقد تم صبها بدون أستخدام أي نوع من الألياف لكونها المجموعة التي سوف يتم المقارنة معها .

وقد أظهرت النتائج العملية لهذا البحث أنه بأضافة ألياف البوليبروبيلين من النوع أعلاه وبنسبة أضافة مقدارها (١كغم / م٣) مع الخرسانة الذاتية الرص تؤثر بدرجة كبيرة على تحسين السيطرة على التشققات التي يمكن أن تحصل للخرسانة وتعمل على تقليلها , وكذلك تحسين عامل المطيلية بمقدار يتراوح مابين [التغير بالمطيلية ($\Delta\mu_d$) = ٢,٠٣٥٦ ألى ٤,٣٥١٥]، بينما يكون تأثيرها على تقليل مقادير الهطول للعتبات الخرسنية الذاتية الرص قليلا . لكن عندما يتم أستخدام ألياف الحديد من النوع (FIBERFORCE®) وبنسبة أضافة حجمية مقدارها (٠,٥٪ من الحجم الكلي للخرسانة الذاتية الرص) تظهر تأثيرا كبيرا على تقليل مقادير الهطول وزيادة مقدار الحمل الأقصى لفشل العتب الخرساني بمقادير عالية تتراوح مابين (١١,٧٨% ألى ١٨,٤٢%) مع تحسين عامل المطيلية بمقدار يتراوح مابين [التغر بالمطيلية ($\Delta\mu_d$) = ٤,٩٢٣٢ ألى ١٢,١٢٣٨], ولكنها تكون ذات تأثير قليل على تقليل عرض التشققات التي تظهر على العتبات الخرسانية الذاتية الرص ذات المقاطع بشكل حرف (T).

الكلمات الدالة: *الخرسانة الذاتية الرص؛ العتب ذو المقطع بشكل (T)؛ ألياف الحديد؛ ألياف البوليمر (البوليبروبيلين)؛ الملدنات المتفوقة؛ مسحوق السيليكا الفعال (مادة بوزولانية ذات خواص أسمنتية)؛ مسحوق حجر النورة الكلسي؛ السلوك المرن؛ سلوك التشقق؛ الهطول؛ عامل المطيلية.*

١. General

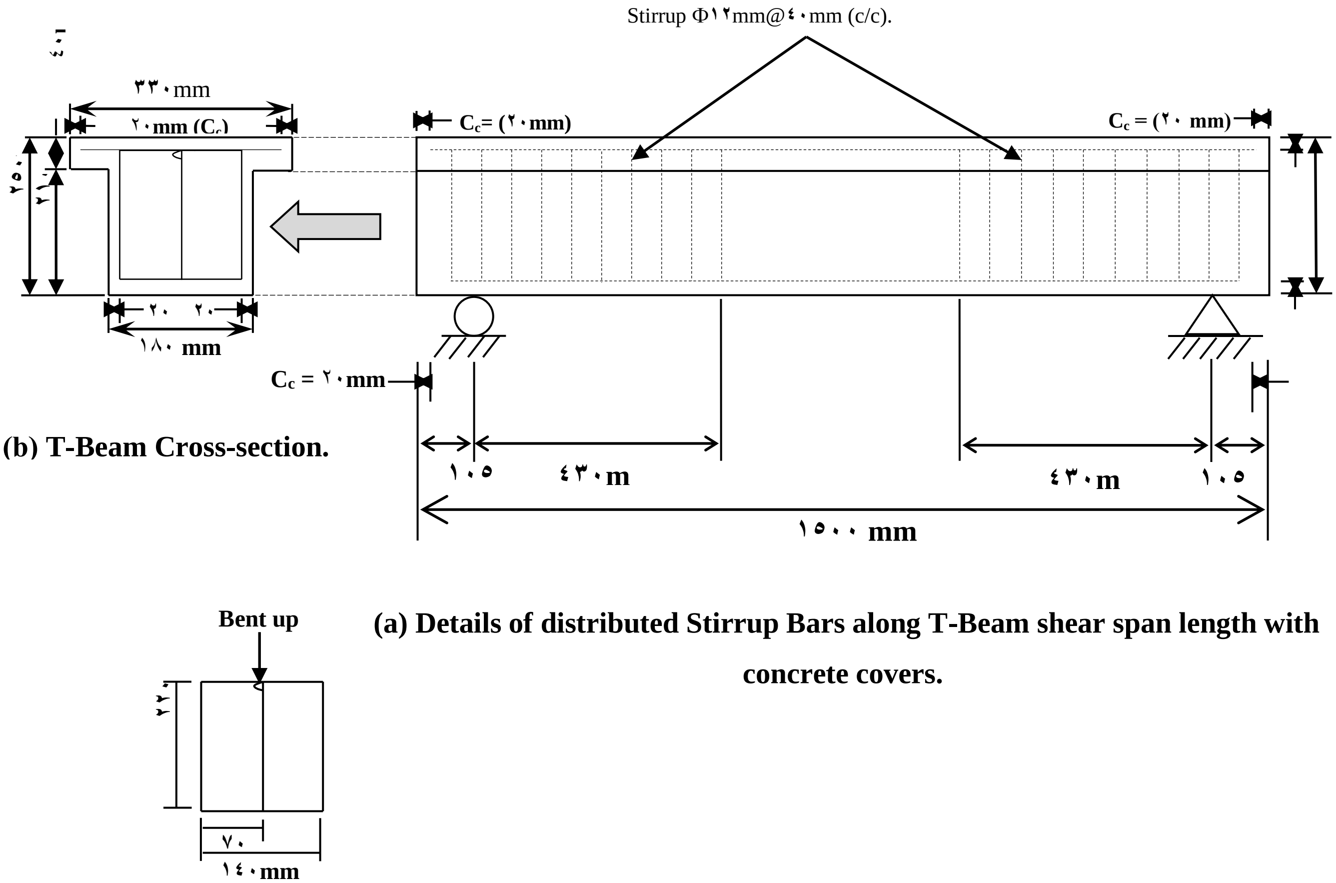
Self-compacting concrete (SCC) represents one of the most significant advances in concrete technology. Inadequate homogeneity of the cast concrete due to poor compaction or segregation may drastically lower the performance of nature concrete at site. (SCC) has been developed to ensure adequate compaction and to facilitate placement of concrete in structures with congested reinforcement and in restricted areas[١].

٢. Scope & Objectives

Experimental work includes a comparison between three groups of twelve T-Beams, each group contains four T-Beams having the same Self-Compacting Concrete mix of the same strength in the same group, but with different reinforcement ratios for the four beams in each group. Polymeric or polypropylene fibers of (١kg/m^{٣}) ratio and steel fiber of (V_f= ٪٠,٥) were used in the first and second groups respectively, while the third group was without reinforcing fibers. Comparison is made between flexural behavior and cracking behavior of the elements in each group.

٣. Details of Test Beams

The used dimensions of test beams are (١٥٠٠mm) in overall length and (٢٥٠mm) in total depth, the effective width of flange is (٣٣٠mm), the thickness of flange is (٤٠mm), the clear width of web is (١٨٠mm) and the web depth is (٢١٠mm) as illustrated in Figure (١).



(b) T-Beam Cross-section.

(a) Details of distributed Stirrup Bars along T-Beam shear span length with concrete covers.

(c) Details of Shear Reinforcement (Stirrup)

Figure (١): Details of Flexural T-Beam.

The whole beams are made of the same type of concrete, with no cold joints between its web and flange, the type of loading during the test of T-beam samples is of two-point loading as illustrated in Figure (٢). So, the third clear span of loading is (٤٣٠mm) and the distance from the face of beam edge to the center of supports is (١٠٥mm), there is the same distance to the two beam sides. The type of beam supporting is simply supported. Plate (١) shows the T-Beam setup for testing stage with three dial gauges under its web.

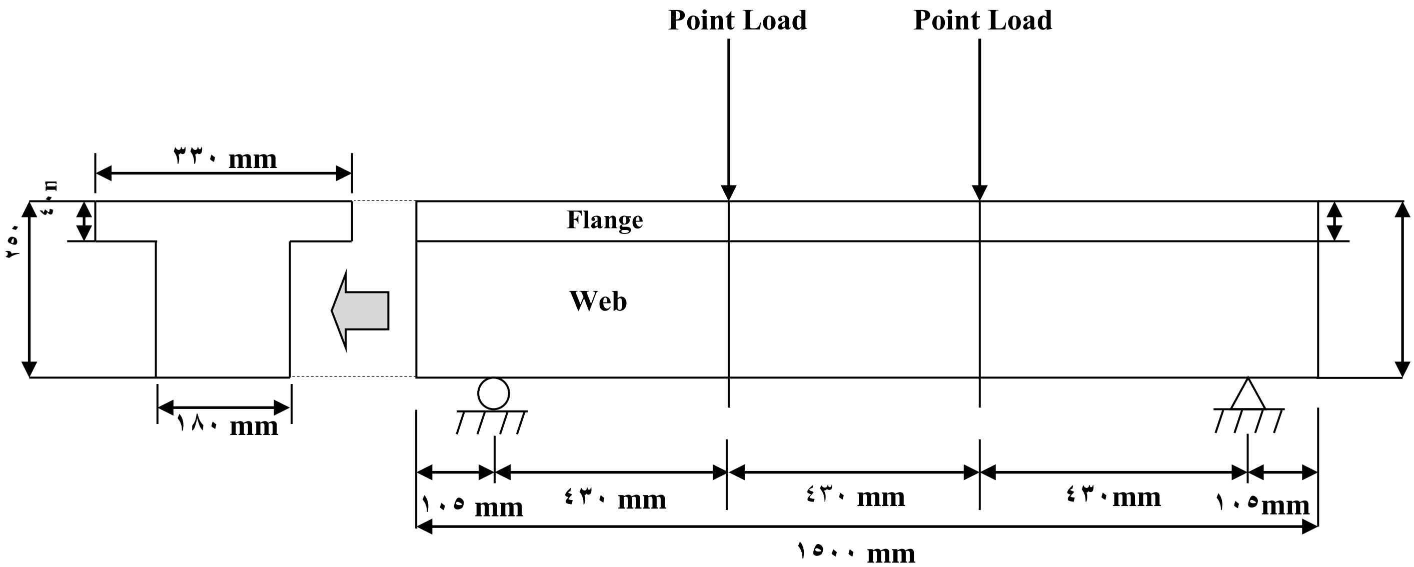


Figure (٢): Application of Two-point Loading upon T-Beam flange.

Plate (١): The T-Beam set up with Three Dial Gauges.

٤. Materials

Materials were selected according to a mix design method taking into account material grading & properties. Satisfactory SCC is achieved by more strength requirements of the ingredients in selecting suitable materials, and good quality control and proportioning.

٤.١. Cement

MASS BAZIAN SULAIMANIA Portland cement type (١) was used. It was tested according to the Iraqi Standard Specifications (IQS) No. ٥/١٩٨٤[٢] for the physical and chemical properties, as shown in Tables (١) and (٢), respectively.

Table (١): Physical Properties (Composition) of Cement

Physical Properties	Test Results	Iraqi Specifications No.٥/١٩٨٤
Fineness using Blain air permeability apparatus(m٢/kg)	٣٨١	> ٢٣٠
Initial setting time using Vicat's instruments (hr:min.)	١:٥٥	> ٠٠:٤٥
Final setting time using Vicat's instruments (hr:min.)	٤:٢٥	< ١٠:٠٠
Safety (soundness) using autoclave method (%)	٠,٠١	< ٠,٨
Compressive strength for cement paste cube (٧٠,٧mm) at : (٣days) in (N/mm٢) or (MPa)	٢٥,٨٥	> ١٥
Compressive strength for cement paste cube (٧٠,٧mm) at : (٧days) in (N/mm٢) or (MPa)	٢٨,٠	> ٢٣

٤,٢. Fine Aggregate

Al-Ukhaidher natural sand with fineness modulus of (٢,٦٩) was used it is of rounded particle shape and smooth textures and of a maximum size of (٤,٧٥mm),therefore, requires less mixing water in concrete and for this reason it is preferable in SCC. Grading and sulfate content are shown in Table (٣).Which satisfy the Iraqi Standard Specifications No.٤٥ / ١٩٨٤[٣]– Zone No. (٢).

٤,٣. Coarse Aggregate

Crushed gravel of maximum size of (١٩mm) was used from Al-Niba'ee quarry region. Table (٤) shows the grading and percentage of sulfate content of the aggregate, which confirms to the Iraqi Standard Specification No.٤٥ / ١٩٨٤[٣] – size of grading (٥-٢٠) mm.

Journal of Engineering and Development, Vol. ١٧, No.١, Mar. ٢٠١٣, ISSN ١٨١٣- ٧٨٢٢

Table (٢): Chemical Composition of Cement

Numbering	Compound Name	Compound Chemical Composition	% (weight)	Iraqi Standard Specifications No.٥/١٩٨٤
١	Silica	$SiO_{٢}$	١٩,٨٠	-------
٢	Alumina	$Al_{٢}O_{٣}$	٥,١١	-------
٣	Iron Oxide	$Fe_{٢}O_{٣}$	٣,٢٨	-------
٤	Lime	CaO	٦٤,٥٣	-------
٥	Magnesia	MgO	١,٧٨	< ٥
٦	Sulfate	$SO_{٣}$	٢,٥٥	< ٢,٨
٧	Insoluble Residue	I.R.	١,٠٦	< ١,٥
٨	Loss on ignition	L.O.I	٣,١١	< ٤
٩	Tricalcium aluminates	$C_{٣}A$	٨,٢٩ (From X.Ray diffraction) ٧,٩٩٨٣ (From Bogue equations)	-------
١٠	Lime saturation factor	L.S.F	٠,٩٨	٠,٦٦-١,٠٢
١١		$C_{٤}AF$	٩,٩٧١٢	----------
١٢	Tricalcium silicate	$C_{٣}S$	٦٥,٨٦	----------
١٣	Dicalcium silicate	$C_{٢}S$	٧,١٦٧٥٦	----------

Table (٣): The Grading and Sulfate Content of Fine Aggregate (Sand)

No.	Sieve Size		% Cumulative of passing fine aggregate	Deviation	Iraqi specification No. ٤٥/١٩٨٤ for grading Zone(٢) of % passing of fine aggregate
	In (mm)	In (µm)			
١	١٠	١٠٠٠٠	١٠٠	٠	١٠٠
٢	٤,٧٥	٤٧٥٠	٩٤	٠	٩٠_١٠٠
٣	٢,٣٦	٢٣٦٠	٨٢	٠	٧٥_١٠٠
٤	١,١٨	١١٨٠	٦٩	٠	٥٥_٩٠
٥	٠,٦	٦٠٠	٥٥	٠	٣٥_٥٩
٦	٠,٣	٣٠٠	٢٤	٠	٨_٣٠
٧	٠,١٥	١٥٠	٧	٠	٠_١٠
٨	٠,٠٧٥	٧٥	٤,١	-----	<٥
٩	Pan		٠	-----	------
١٠	Summation of deviations			٠	< ٥
١١	% Sulfates Content = ٠,٠٦٩				< ٠,٥

Table (٤): The Grading and Sulfate Content of Coarse Aggregate (Gravel).

No.	Sieve Size		% Cumulative of passing fine aggregate	Deviation	Limit of Iraqi specification No. ٤٥/١٩٨٤ for grading size (٥-٢٠)mm of % passing of coarse aggregate
	In (mm)	In (µm)			
١	٧٥	٧٥٠٠٠			
٢	٣٧,٥	٣٧٥٠٠	١٠٠	٠	١٠٠
٣	٢٠	٢٠٠٠٠	٩٩	٠	٩٥_١٠٠
٤	١٤	١٤٠٠٠			
٥	١٠	١٠٠٠٠	٣٠	٠	٣٠_٦٠
٦	٥	٥٠٠٠	٣	٠	٠_١٠

٧	٢,٣٦	٢٣٦٠			
٨	٠,٠٧٥	٧٥	٠,٠	-----	< ٣,٠
٩	Pan		٠	-----	-------
١٠	Summation of deviations			٠,٠٠	٠
١١	% Sulfates Content = ٠,٠٥				< ٠,١

٤.٤. Limestone Powder

Limestone powder has been used as filler for concrete production for many years. It has been found to increase workability and early strength, as well as to reduce the required compaction energy. The increased strength is found particularly when the powder is finer than the Portland cement particles. The fine limestone powder (locally named as **Al-Gubra**) of Iraqi northern zone with fineness (٤١١ m^{٢}/kg) is used to avoid excessive heat generation, enhance fluidity and cohesiveness, improve segregation resistance and increase the amount of fine powder in the mix (cement and filler). According to **EFNARC[٤],** the fraction less than ٠,١٢٥ mm was of most benefit. Typical properties of lime stone powder (L.S.P) are listed in Table (٥).

Table (٥): The Typical Properties of Limestone Powder (L.S.P)

Physical property	Range
Fineness by using Blain apparatus (m^{٢}/kg)	٤١١
Chemical Composition	**% Content**
$So_{٣}$	١,٦٣
$CaCo_{٣}$	٩٤,٩٠

٤.٥. Mixing Water

Ordinary tap water was used for both mixing and curing.

٤.٦. Superplasticizer

The superplasticizer or High Range Water Reducing Admixture (HRWRA), used in this type of concrete, is one of the high performance concrete superplasticizer based on modified polycarboxylic ether. GLENIUM ٥١[٥]is the superplasticizer which was used, it is free from chlorides and complies with ASTM C٤٩٤ Type A and F.

GLENIUM ٥١ is compatible with all Portland cements that meet recognized international standards. It is differentiated from conventional superplasticizers in that it is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. GLENIUM ٥١ is available in ٢٠٨ liter drums and in bulk tanks upon request. Table (٦) illustrates some important typical properties of GLENIUM ٥١ according to the requirements of BASF Middle East Technical Products Guide. The normal dosage of GLENIUM ٥١ is between ٠,٥ and ١,٦ liters per ١٠٠ kg of cement (cementitious material). Dosages outside this range are permissible subject to trial mixes. The maximum effect is achieved when the GLENIUM ٥١ is added after the addition of ٥٠ to ٧٠ % of the water. GLENIUM ٥١ must not be added to the dry materials, through mixing is essential, and a minimum mixing cycle after the addition of the GLENIUM ٥١, of ٦٠ seconds for forced action mixers is recommended.

Table (٦): Typical Properties of GLENIUM ٥١(٥).

Form	Viscous Liquid
Colour	Light Brown
Relative Density	١,٠٨ – ١,١٥ @ ٢٥°C
pH	٦,٦
Viscosity	١٢٨ +/- ٣٠ cps @ ٢٠°C
Transport	Not classified as dangerous
Labeling	No hazard label required

٤.٧. Reinforcing Steel

All the reinforcing steel bars, used in this study, are deformed and of Ukrainian origin with a nominal diameter (Φ) of (٤،٦،١٢،١٦،٢٠, ٢٥ and B.R.C Φ ٦) mm.

Table (٧): Test Results of Reinforcement Steel Bars

Bars Diameters (mm)	Yield stress (f_y),(MPa)	Ultimate stress (f_t),(MPa)	Estimated Modulus of Elasticity (E_s),(MPa)×١٠٣
٤	٤٤٥	٦٧٠	٢٠٠
٦	٤٦٠	٦٦٢	٢٠٠
B.R.C Φ٦	٥٢٩,٢٥	٩٦٠,٩٥	٢٠٠
١٢	٤٧٦,١٣	٦٨٠.٨٦	٢٠٠
١٦	٤٨٩,٥٧	٧٣٤,٣٦	٢٠٠
٢٠	٥٠٥,١٧	٧٢٧,٤٤	٢٠٠
٢٥	٤٨٦,٣٦	٧١٩,٨١	٢٠٠

٤.٨. Steel Fibers (SF)

FIBERFORCE® is cold drawn wire steel fiber meeting the ASTM A٨٢٠-٩٦ Type ١ requirements as well as C١١١٦ section ٤,١,١ requirements.

٤.٩. Polymer or Polypropylene Fibers (P.F.)(٥)

Table (٨) illustrate the typical properties of polypropylene fibers (RHEOFIBER®) which are used in this experimental study.

Table (٨): Typical Properties of RHEOFIBER®(٥)

Specific gravity	٠,٩١ g/cm٣
Alkali content	Nil
Sulphate content	Nil
Area entrainment	Area content of concrete will not be significantly increased
Chloride content	Nil
Constituents	Polymerized polypropylene
Fiber diameter	١٨ micron
Fiber length	١٢ mm
Surface area	٢٣٠ m٢/kg min.
Young's modulus	٣٥٠٠-٣٩٠٠ MPa
Tensile strength	Min ٣٥٠ MPa
Melting point	١٦٠°C

٤.١٠. Pozzolanic Additives (micro-silica)(٥)

Table (٩): Typical Properties of MEYCO® MS٦١٠ (٥)

Form	**Powder**
Colour	Grey
Bulk density	٥٥٠-٧٠٠ kg/m٣
Chloride content	< ٠,١٪

٥. Results of Fresh SCC Tests

According to the fresh tests of the four self-compacting concrete mixes, the results are shown in Table (١٠).

٦. General Behavior of Tested T-Beams

Test results that describe behavior of tested T-Beams are shown in Tables (١١-١٣) as hereafter.

Table(١٠): The Fresh Tests Results of SCC.

Mix	Slump Flow (mm)	$T_{٥٠٠mm}$ (sec)	V-Funnel		L-Box		
			Tv (sec)	$Tv_{٥}$ (sec)	Blocking Ratio	$T_{٢٠}$ (sec)	$T_{٤٠}$ (sec)
SCC١	٦٨٠	٣,٠٠	١٠	١٢	٠,٨	٢	٢,٥
SCC٢	٧٨٠	٢,٥	٧	٨	١,٠	١,٠	٢,٠
SCC٣	٧٢٥	٣,٠٠	١١,٥	١٣,٥	٠,٩٥٣	١,٥	٣,٢٥
SCC٤	٧٦٠	٣,٥٠	٩,٠٠	١٠,٥٠	٠,٩٤	٠,٩	٢,٠
permissible limits according to EFNARC[٤]	(٦٥٠-٨٠٠)	(٢-٥)	(٦-١٢)	(٦-١٥)	(٠,٨-١,٠)	------	------

SCC: Self – Compacting Concrete.

Table (١١): the experimental and calculated first crack loads of tested T-Beams.

Beam No.	Pcr , (kN) (Exp.)	Pcr , (kN) (ACI ٣١٨)	Pcr (Exp.) / Pcr (ACI ٣١٨-٠٨)	Pu , (kN) (Exp.)	Pcr (Exp.) / Pu (Exp.) (%)
B١-G١	٦٢	٦٠,٧٥٧	١,٠٢٠٥	٥٩٥	١٠,٤٢٠
B٢-G١	٦٣,٥	٦٢,٧٧٢	١,٠١١٦	٥٩٠	١٠,٧٦٣
B٣-G١	٥٤	٥٢,١٤٨	١,٠٣٥٥	٧٤٥	٧,٢٤٨
B٤-G١	٦١	٦٠,٠٤٨	١,٠١٥٩	٥١٢	١١,٩١٤
B١-G٢	٦٥	٦٣,٤١١	١,٠٢٥١	٦٦٥	٩,٧٧٤
B٢-G٢	٦٥,٥	٦٤,٩٨٢	١,٠٠٨٠	٦٥٥	١٠
B٣-G٢	٥٧	٥٤,١٠٣	١,٠٥٣٦	٦٤٧	٨,٨١٠
B٤-G٢	٥١	٤٨,٩٦٩	١,٠٤١٥	٥٩٨	٨,٥٢٨

B١-G٣	٦٠	٥٨,٩٩٧	١,٠١٧٠	٥٩٢	١٠,١٣٥
B٢-G٣	٥٨,٥	٥٧,٦٤٢	١,٠١٤٩	٥٨٦	٩,٩٨٣
B٣-G٣	٧١	٦٩,٠٨٥	١,٠٢٧٧	٦٧٨	١٠,٤٧٢
B٤-G٣	٦٦	٦٤,١٤٠	١,٠٢٩٠	٥٠٥	١٣,٠٦٩

٦.١. Ductility (μ_d)

Ductility is usually defined as the energy absorbed by the material until a complete failure occurs[٨]. In the present work, the experimental ductility factors are calculated according to the deflection at ultimate load divided by the deflection at yielding [٩] which can be found from the load value in (the load-deflection curve) when this curve is transformed from elastic state to plastic state, the deflection value which in this load value must be taken such as (B١,B٢,B٣ and B٤ of G١), the yield deflections values (δ_y = ٢,١٥mm @ ٣٠٠kN,δ_y = ١,٦٥mm @ ٢٢٥kN,δ_y = ١,٨٣mm @ ٢١٠kN and δ_y = ٠,٨٥٥mm @ ١٠٠kN), also the yield deflections values for (B١, B٢, B٣ and B٤ of G٢) are (δ_y = ١,٢٠mm @ ٢١٠kN, δ_y = ٠,٩٨mm @ ١٥٠kN,δ_y = ٠,٨٣mm @ ١٠٠kN and δ_y = ٠,٤٢mm @ ٧٠kN) and the yield deflections values for (B١, B٢, B٣ and B٤ of G٠) are (δ_y= ٦,٩٠mm @ ٥٠٠kN, δ_y = ٤,٣٥mm @ ٤٢٥kN, δ_y = ٣,٩٧mm @ ٤٣٥,٧١kN and δ_y = ١,٥mm @ ١٥٠kN) respectively. As shown in Table (١٢).

Table (١٢): the experimental deflection ductility factors of tested T-Beams.

Group No.	Beam No.	Deflection (mm)		Ductility Factor ($\mu_d = \delta u / \delta y$)
		δy	δu	
G١	B١	٢,١٥	٧,٠٥	٣,٢٧٩١
	B٢	١,٦٥	٧,٣٣	٤,٤٣٩٤
	B٣	١,٨٣	١٠,٢٢	٥,٥٨٤٧
	B٤	٠,٨٥٥	٧,٩١	٩,٢٥١٥
G٢	B١	١,٢٠	٧,٤٠	٦,١٦٦٧
	B٢	٠,٩٨	٨,٣٠	٨,٤٦٩٤
	B٣	٠,٨٣	٧,٦٢	٩.١٨٠٧
	B٤	٠,٤٢	٧,١٥	١٧,٠٢٣٨
G٠	B١	٦,٩٠	٨,٥٨	١,٢٤٣٥
	B٢	٤,٣٥	٧,٤٠	١,٧٠١٢

	B٣	٣,٩٧	٩,٢٠	٢,٣١٧٤
	B٤	١,٥	٧,٣٥	٤,٩

Table (١٣): Mid-span Deflections at First Crack and Service Loads of all beams Experimentally and According to (ACI ٣١٨ – ٠٨) Code [٦].

Group No.	Beam No.	At first crack load			At service load		
		Experimental		ACI ٣١٨	Experimental		ACI ٣١٨
		P_{cr} (kN)	δ_{cr} (mm)	δ_{cr} (mm)	$P_{sr} = (P_u /$ ١,٦),(kN)	δ_{sr} (mm)	δ_{sr} (mm)
G١	B١	٦٢	٠,٣١٨	٠,٢٨٥	٣٧١,٨٨	٢,٩١٩	٢,٨٢٠
	B٢	٦٣,٥	٠,٣٧٢	٠,٢٨٦	٣٦٨,٧٥	٣,٧٦٨	٢,٦١٥
	B٣	٥٤	٠,٣٩٠	٠,٢٩١	٤٦٥,٦٣	٥,٣٥٦	٢,٨٨١
	B٤	٦١	٠,٤٦٩	٠,٢٨٠	٣٢٠	٣,٤٠٠	٢,٤٩٨
G٢	B١	٦٥	٠,٢٧٥	٠,٢٢٥	٤١٥,٦٣	٣,٩١٣	٢,٨٧١
	B٢	٦٥,٥	٠,٣٦٩	٠,٢٢٤	٤٠٩,٣٨	٣,٦٩٤	٢,٥٩٣
	B٣	٥٧	٠,٤٩٦	٠,٢٨٢	٤٠٤,٣٨	٣,٩٤٤	٢,٨٥٢
	B٤	٥١	٠,٣٠٥	٠,٢٧٢	٣٧٣,٧٥	٣,٧٨٥	٣,١١٧
G٠	B١	٦٠	٠,٤٥٠	٠,٣٤٧	٣٧٠	٤,٢٢٠	٣,١٧٠

	B٢	٥٨,٥	٠,٥١٠	٠,٣٤٥	٣٦٦,٢٥	٣,٥٩٤	٣,٢٤١
	B٣	٧١	٠,٧٢٥	٠,٢٤٩	٤٢٣,٧٥	٣,٨٤٩	٢,٤١٨
	B٤	٦٦	٠,٧٢٦	٠,٢٤٥	٣١٥,٦٣	٣,٥٥٦	٢,١٠٨

٧. Conclusions

According to the test results,the following conclusions were obtained:

١. Adding polypropylene fibers of the type of (RHEO-FIBERS®)(٥) in the rate of (١kg / m٣) to the self-compacting concrete mix results in high improvement in the cracks patterns (a decrease in the crackwidths, heights and the numbers of developed cracks.

٢. Increasing the steel reinforcing ratio (ρ%) improves the ductility by increasing the ultimate load as the ultimate deflection increased.Yielding deflection reduced due to high reinforcement. The ductility factor increased by (٠,٢٢٦٥ – ٠,٤٥٧٧), but when the polypropylene fibers are added in a combination with steel bar ratio (ρ%) they results in good improvement in beam ductility by (٠,٥٨٤٦ – ٤,٠٥١٤).Ductility of beams also increases when the steel fibers of type of (FIBERFORCE® steel fibers)(٧) are added in the range of (٤,٩٢٣٢ – ١٢,١٢٣٨).

٣. Adding the polypropylene fiber to the self-compacting concrete mix, has a minor effect on the tensile strength (flexural strength) of concrete (by the range of ٪٤,٥٣), however, these fibers in combination with the self-compacting concrete makes the concrete mix more cohesive, because the self-compacting concrete is with less voids and hence gaining high cohesion.

٤. Adding steel fibers of type (FIBERFORCE®)(٧) at a volume range of (V_f = ٪٠,٥ from total concrete volume) to the self-compacting concrete mix has major effect in improving the flexural strength of the self-compacting concrete by the range of increasing of approximately (٪٦,٦٢). This value is larger than the effect of adding polypropylene fibers to the same mix in the same compressive strength ($f'c$).

٥. All tested T-Beams of the three groups showed cracking load,between (٧,٢٤٨٪ - ١٣,٠٦٩٪) of the ultimate loads and the first cracks were found to occur in the constant moment region.

٦. Adding steel fibers to SCC promotes slight gain in the ultimate load capacity and lowers midspan deflection. Therefore, itwill lower deformations in the reinforcement bars in comparison with the T-Beams produced with only SCC or PFRSCC.

٧. Increasing the reinforcement ratios (%ρ) in combination with the steel fibers results in high effect on the reduction of deflections and increasing the ultimate loads by (١١,٧٨٪ - ١٨,٤٢٪) of self-compacting concrete T-Beams, but when it is increased in combination with the polypropylene fibers, the increase in the ultimate loads was found to be in the range (٠,٥١٪ - ٩,٨٨٪).

References

[١] Carolin, A., "***Improvement of load-bearing capacity exiting bridges literature review***", Technical Report, Luleä University of Technology, Sweden, ١٩٩٩.

[٢] I.Q.S. No.٥:١٩٨٤, Iraqi Standard for Portland Cement. * المواصفة العراقية / رقم ٥ , "**السمنت البورتلاندي الأعتيادي**" , الجهاز المركزي للتقييس والسيطرة النوعية , بغداد , ١٩٨٤ .

[٣] Iraqi Standard Specification (IQS) No.٤٥, ١٩٨٤, "***Natural Sources of Aggregate Used in Building and Concrete***". Baghdad. * المواصفات العراقية / رقم ٤٥ , "ركام المصادر الطبيعية المستعمل في الخرسانة والبناء " , الجهاز المركزي للتقييس والسيطرة النوعية , بغداد , ١٩٨٤ .

[٤] EFNARC: Eurpean Federation Dedicated to Specialist Construction Chemicals and Concrete Systems ***"Specifications and Guidelines for Self-Compacting Concrete***", EFNARC, Association House,٩٩ West Street, Farnham, Surrey GU٩ ٧EN, U.K., Feb.٢٠٠٢, ٣٢pp.

[٥] Product Guide & Technical Data Sheets of the chemical company of BASF®for admixture and construction systems, ٢٠١٠, p٨٦٠.

[٦] ACI Committee ٣١٨,"***Biulding Code Requirements for Structural Concrete***".(ACI٣١٨M-٠٨) and Commentary (ACI ٣١٨R-٠٨), ACI Manual of Concrete Practice, American Concrete Institute, Farmington Hills, U.S.A.

[٧] Data sheet of FIBERFORCE Steel Fibers, "***SPI company for Composite Systems***".

[٨]Hussain M., Alfarabi S., Basunbul A., Baluch M.H., Al-SulaimaniG.J.,***"Flexural Behavior of Precracked Reinforced Concrete Beams Strengthened Externally by Steel Plates***" ACI Structural Journal, Vol.٩٢, Issue.١،١٩٩٥.

[٩] Mohammed Abdur Rashid and AhsanulKabir, "***Behavior of Reinforced Concrete Deep Beam Under Uniform Loading***",Journal of Civil Engineering, The institution of Engineers, Bangladesh, Vol.CE ٢٤,No.٢،١٩٩٦.