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A-mechanical properties of engineered cementitious composite concrete produced from Portland limestone cement

Sara Salah[1] *, Nada Mahdi Fawzi[2], Ikram Faraoun Ahmed[3]

[1]*Department of Civil Engineering, Baghdad University, Iraq, s.saeed1101@coeng.uobaghdad.edu.iq*

[2]*Department of Civil Engineering, Baghdad University, Iraq, nada.aljalawi@coeng.uobaghdad.edu.iq*

[3]*Department of Civil Engineering, Baghdad University, Iraq, Ikram.faroun@coeng.uobaghdad.edu.iq*

* *Corresponding author, s.saeed1101@coeng.uobaghdad.edu.iq, email*

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Abstract: Conventional concretes are almost unbending, and even a small amount of strain potential leaves them brittle. This lack of bendability is a major source of strain loss, and it has been the main goal behind the development of bendable concrete, often known with engineered ce ment composites, or ECC. This form of concrete has a lot more flexibility than regular concrete. Micromechanical polymer fibers are used to strengthen ECC. In most cases, ECC uses a 2% amount of thin, separated fibers. As a result, bendable concrete deforms but unlike traditional concrete, it does not crack. This study aims to include this kind of concrete, bendable concrete, which can be used to solve concrete problems. Karasta (CK) and Tasluja (CT) Portland Limestone Cements were used .The polypropylene fibers (PP) and polyvinyl alcohol acetate (PVA) were used to make four different mixes. The experiments were performed at 7, 28, 60, and 90 days after water curing. For all tests, mixes including pp fibers and PVA solution performed better than those without fibers.

Keywords: compressive strength, splitting tensile strength, flexural strength, Portland limestone cement, polypropylene fibers, polyvinyl alcohol acetate.

1. Introduction

Ductility is a tensile deformation measurement (strain). Initial attempts by [7] and later by [14] that found according to the study, to produce high tensile ductility of bendable concrete, the using of continuous and aligned fibers can achieve that goal. In flexure as well as tension, bendable concrete is a strain-hardening and even multiple ultra-ductile concrete with multiple-cracking nature. In comparison to 0.01 percent for normal concrete, ECC's tensile strain capacity would be greater than 3-5 percent. Harm resistant and critical small crack width efficiency of ECC have been found attractive by structural designers in recent full-scale structural systems [8]. In manufacturing, different types of cement are used, with ordinary Portland cement being most common and widely used. Supplementing cement clinkers with appropriate environmentally as well as economically friendly materials, such as limestone, is one option to minimise the use of cement clinkers and Carbon emission. Portland-limestone cement (PLC) is a cement that meets the EN 197-1 requirement and contains a specific weight percent of limestone [21].

2. Literature review on some mechanical properties of bendable concrete

Phillip J. Hermes [18] has analyzed the results of ECC concrete on compressive strength during static and dynamic loading to normal concrete. In the ECC and traditional concrete mix models, the cement weights were 580 Kg/m3 and 428 Kg/m3, respectively. Upon 28 days of curing, According to the test results, ECC has a compressive strength of 66.7 MPa. Although conventional concrete had a compressive strength of approximately 56.05 MPa, which represented an increase of 19%. S. Said, H. Razak and I. Othman [19] have investigate the impact of polyvinyl alcohol (PVA) fibers on the compressive strength of ECC concrete. The key parameter investigated in this study was the reinforcing index[Vf(l/d)], and different PVA fiber material (1, 1.5, 2, 2.5, 3%) was used. the results of the research indicated that the compressive strength around seven days tends to reduce as the reinforcing index increases in a nonlinear manner. Compressive strength findings have been minimized about 15percent. Ikram F Al-Mulla and other researcher [11] have made a research on engineered cementitious composite concrete manufactured with Portland limestone cement and compared it to engineered cementitious composite concrete manufactured with ordinary portland cement for flexural strength. The flexural strength of the OPC mixes was only substantially higher than that of mixes formed with Portland limestone cement due to the increased clinker content, which is necessary for strength progression. S.Wang and Li. Victor [22] investigated the flexural behavior of PVA-ECC concrete. The results found that, the most notable flexural strength response was throughout one day and 90 days. The observed flexural strengths were 11 MPa and 16 MPa, respectively. Micromechanics systems have proven to be an efficient approach in PVA-ECC development, primarily by interface as well as matrix tailoring. Engineered cementitious composite mixtures that meet the criteria of self-compacting concrete have been developed by B. Mohammed and other researchers [16]. As PVA fiber is applied to the mix, it enhances some of the characteristics and properties of the concrete. Ten different Polyvinyl Alcohol (PVA) fiber content mixes (0.0 percent, 1.0 percent, 1.5 percent, 2.0 percent, 2.5 percent, 3.0 percent, 3.5 percent, 4.0 percent, 4.5 percent, and 5 percent) were established. The results demonstrate that the splitting tensile strength enhances as the PVA fiber content increases. The mechanical features of manufactured cementitious composites incorporating polypropylene fibers have been studied by S. Abid and others[1] The splitting tensile strength has been explored. The volume fraction dosage of fiber was the most important element of the study, which was variable, whereas the other constituent of the mixture remained constant. Polypropylene fibers come in five different percents: 0, 0.5, 1.0, 1.5, and 2.0. The findings showed that the percentage of fiber has a significant impact on the splitting tensile strength, which increased in accordance with the increase of fiber content.

3. Materials and experimental work

3.1 *Materials*

Cement

In this research, basically, two forms of Portland limestone cement were used: Karasta cement (CK) and Tasluja cement (CT), which are both graded 42.5R. Chemical and physical experiments were carried out in the Building Research Center's laboratories in accordance with European Standard EN BS197-1[10].

Table 1: Chemical properties of Karasta (CK) and Tasluja (CT) limestone Portland cement.

Oxides %	Tasluja test results (CT)	Karasta test results (CK)	Specification limits
L.O.I	3.44	2.21	Not more than 5
SiO_2	18.39	17.81	-
Al_2O_3	6.9	6.19	-
Fe_2O_3	1.77	2	-
SO_3	2.35	2.44	Not more than 4%
CaO	62.11	61.5	
MgO	1.83	1.95	
Cl^-	0.01	0.011	Less than 0.1%
I.R	0.9	0.47	Not more than 5%
Cement compounds			
Cement compounds for (CT)cement	Percentage %	Cement compounds for (CK)cement	Percentage %
C_3S	57	C_3S	64
C_2S	10	C_2S	3.5
C_3A	15	C_3A	13
C_4AF	5.3	C_4AF	6

Table 2: physical properties of Karasta (CK) and Tasluja (CT) limestone Portland cement.

Test	Karasta test results (CK)	Tasluja test results (CT)	Specification limits
Finance (Blaine) m^2/kg	4875	5105	2500, min.
Setting time Initial (min)	75 min	90 min	>60, min.
Compressive strength(MPa) 2days curing	25	21	>20
28 days curing	48	43	>42.5

Fine aggregate

The fine aggregate used in this study was Ekhaider natural sand. The sieve analysis indicates that the sand is within zone 2 in the experiments carried out following the specifications of Iraqi requirement No.45/1984 [13] of particles passing standardized sieves, as seen in table 3. Table 4 shows the physical as well as chemical characteristics of fine sand.

Table 3: Sive analysis of fine aggregate.

Sieve No.	Passing %	Specification limites
10mm	100	100
4.75mm	93.3	100-90
2.36mm	77.7	100-75
1.18mm	66.6	90-55
600 µm	54.4	59-35
300 µm	26.3	30-8
150 µm	3.1	10-0

Table 4: Physical and chemical properties of fine aggregate.

Property	Test result	Specification limits
Specific gravity	2.6	-
Absorption, %	0.72	-
Density (kg/m^3)	1580	-
Sulphate content (SO_3)%	0.2	0.50 (max)

Superplasticizer

Superplasticizer is a publicly available aqueous solution of modified polycarboxylates known as (SikaViscocrete-5930). It meets the specifications of ASTM C494 Types G and F [5]. It's frequently used to achieve extreme water removal, better flowability, and maximum cohesion. The SP included in this study had limits ranging from 0.2 to 1.5 percent, 1.3 % was used in this study.

Silica fume

Silica fume SF (condensate micro-silica) has been used as a mineral admixture (Sika Company Iraq) and it was marketed as "Mega Add MS (D). It has been physically and chemically tested according to ASTM C 1240 standards [2], as shown in Table 5.

Table 5: Physical and chemical requirement of silica fume.

Physical requirement of silica fume			
Accelerated pozzlanic strength activity index at 7 days			Specification limits
112.8			min 105
Chemical requirement of silica fume			
-	SiO_2 %	Loss On Ignition %	Moisture content %
-	92.84	1.59	0.33
Specification limits	85 %, min	6%, max	3%, max

Polypropylene fiber

Polypropylene fibers (pp), are chemical fibers with suitable tensile properties. Fibers in a cementitious composite are used to control cracks, improve tensile strength as well as improving deformation properties. [15].The properties of pp fiber as manufactured are described in the table following table.

Table 6: Manufacturer properties of Polypropylene fibers.

Length (mm)	Diameter (µm)	Density (Kg/m^3)	Tensile strength (MPa)
12	32	910	600-700

Polyvinyl alcohol (PVA)

Polyvinyl alcohol is a liquid-soluble synthetic polymer. It's a dry material that exists in two forms, powder and granulate. It has an excellent bonding strength and better cohesion strength properties.The form used in this study is (BP-20) [12].

3.2 *Experimental work*

Four mixes were prepared:

Table 7: Description of the mixes prepared.

No. of the mix	Description
A1	ECC mix with limestone cement (CK) with pp fibers and PVA.
B1	ECC mix with limestone cement (CT) with pp fibers and PVA.
A2	Reference ECC mix with limestone cement (CK) without pp fibers and PVA.
B2	Reference ECC mix with limestone cement (CT) without pp fibers and PVA.

Based on[20,9] and after several trail mixes were performed in the University of Baghdad laboratories, the suitable mixes were developed and could be used for a variety of building projects while maintaining enough ductility.Within 28 days of curing, the designed compressive strength could be achieved, which was 42 MPa. The percentages of the design mixes are described in table 8.

Table 8: Concrete mixes in (Kg/m^3).

Materials		Mixes			
		ECC	ECC	Ref.	Ref.
Cement	CK	356		356	
	CT		356		356
Sand		320	320	320	320
S.F		285	285	285	285
Water		288	288	288	288
SP		4.6	4.6	4.6	4.6
pp		18	18	0	0
PVA		3.6	3.6	0	0

3.2.1 Compressive strength test

The research was performed on samples after 7, 28, 60, and 90 days of curing, with three samples in each test. ASTM C -39[4] was used to carried out the compressive strength test. Compressive strength was measured by using (100*200 mm) cylinders specimens.

3.2.2 Splitting tensile strength

Splitting tensile strength of concrete is one of the important properties that determine the expansion, as well as the width of cracks in buildings. For 7, 28, 60, and 90 days of curing, ASTM C496 [6] has been used to perform the test. (150*300 mm) cylinders have been used at a range of three specimens within each test.

3.2.3 Flexural strength

Center point loading flexural strength test of three (300*100*25 mm) prisms were tested as according to ASTM C293 [3] at different curing ages (7, 28, 60, and 90 days), and the average number of samples was used for each mix.

4. Results

4.1 *Compressive strength test results*

The results shows that the compressive strength of ECC mixes higher than that of reference mixes, this is due to the inclusion of PVA acetate and pp fibers which plays an important role in improving bonding properties and making the concrete stronger[17]. Also itis clear that there is a difference between the two types of cements and this is due to the difference in their chemical composition and the amount of the clinker.

Table 9: Compressive strength test results.

Mix number	Compressive strength (MPa)			
	7	28	60	90
A1	28.6	44	49	51.92
B1	27	41	46.2	49
A2	21	30	33.5	35.7
B2	18	25	28	30

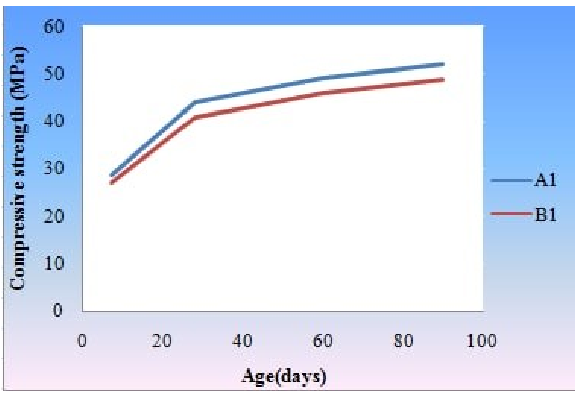
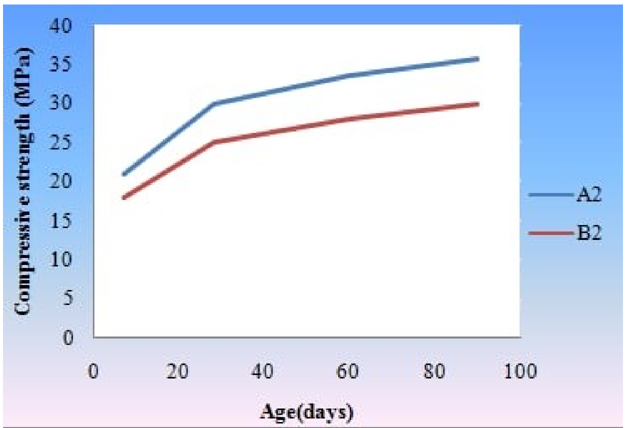


Figure1: Relationship of compressive strength with curing age of ECC concrete mixes.



Figur2: Relationship of compressive strength with curing age of Ref. concrete mixes.

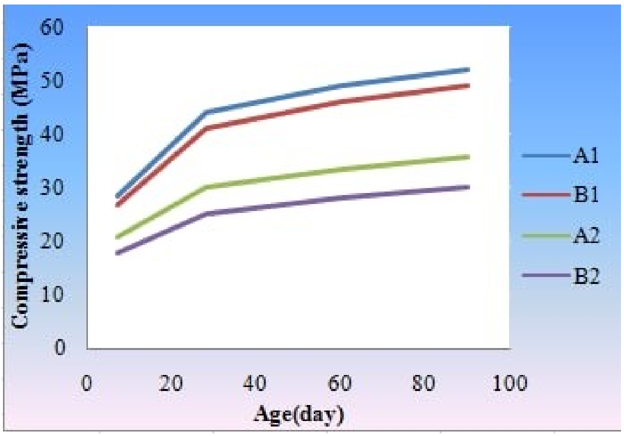


Figure 3: Relationship of compressive strength with curing age for the four mixes.

4.2 *Splitting tensile strength test results*

The results has shown that the splitting tensile strength of ECC mixes is higher than that of Reference mixes and this is attributed to the presence of PVA acetate and pp fibers that making the concrete much stronger[17]. The difference between the two types of cement is mainly attributed to the variations in chemical composition and clinker content.

Table 10: Splitting tensile strength test results.

Mix number	Splitting tensile strength (MPa)			
	7	28	60	90
A1	5.5	8.6	9.2	9.94
B1	5.2	7.9	8.82	9.41
A2	4.21	5.63	6.25	6.9
B2	3.38	4.82	5.2	5.51

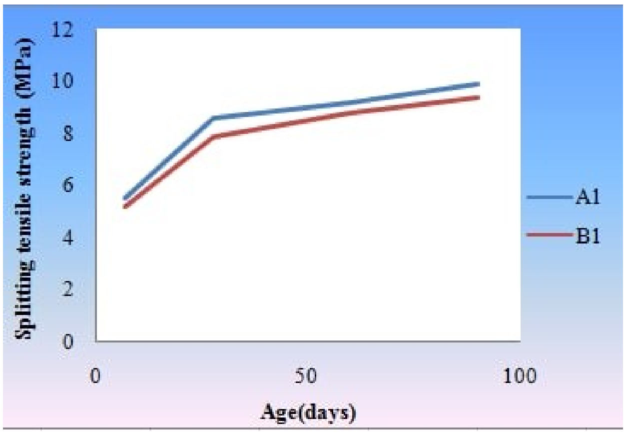


Figure 4: Relationship of splitting tensile strength with curing age of ECC concrete mixes.

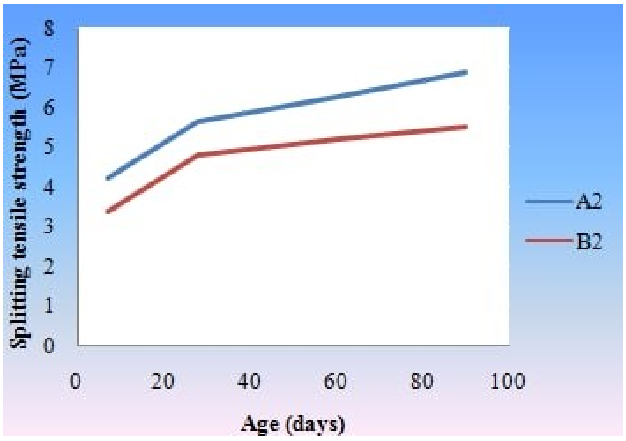


Figure 5: Relationship of splitting tensile strength with curing age of Ref. concrete mixes.

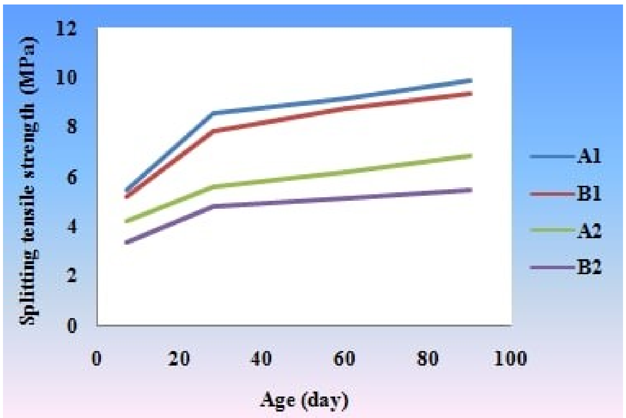


Figure 6: Relationship of splitting tensile strength with curing age for the four mixes.

4.3 *Flexural strength test results*

The test of flexural strength shows that the ECC mixes has higher results than reference mixes and this is because of the presence of PVA acetate which have good cohesion strength and pp fibers which have an acceptable tensile strength that making the concrete more ductile

[17]. Due to differences in chemical components and clinker content, there is a differential between the two types of cement.

Table 11: flexural strength test results.

Mix number	flexural strength (MPa)			
	7	28	60	90
A1	6	11	11.7	12.3
B1	5.2	10.68	11.2	12
A2	2	2.7	3	3.55
B2	1.8	2.4	2.77	2.95

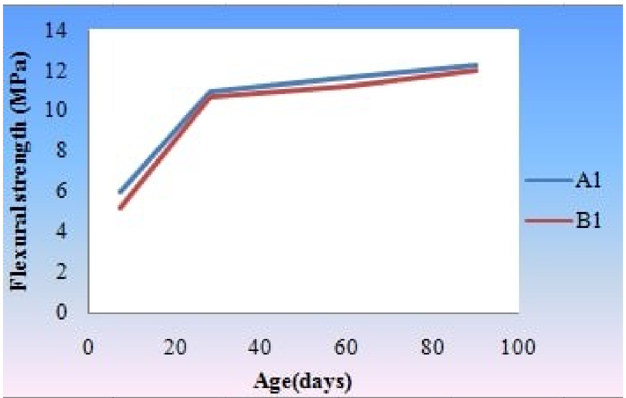


Figure 7: Relationship of flexural strength with curing age of ECC concrete mixes.

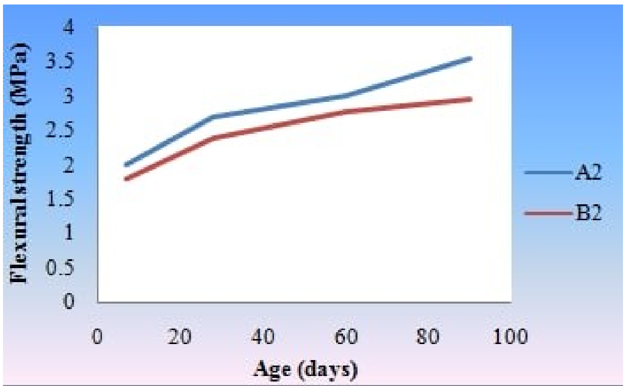


Figure 8: Relationship of flexural strength with curing age of Ref. concrete mixes.

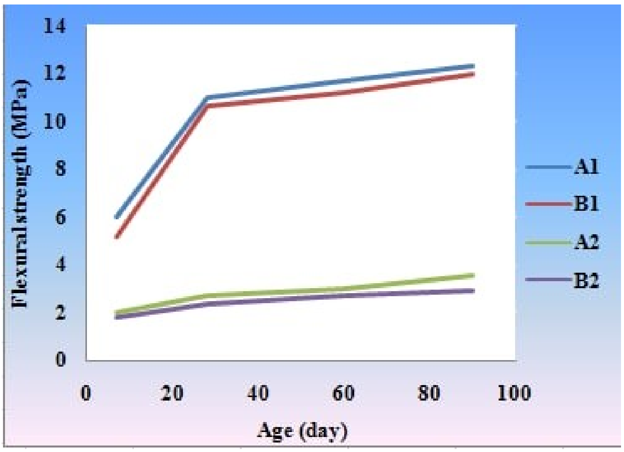


Figure 9: Relationship of flexural strength with curing age for the four mixes.

5. Conclusion

From the analysis of the study results described in this work, it is clear that the compressive strength, splitting tensile strength, and flexural strength of bendable concrete were higher than that of reference mixes, due to the presence of PVA acetate which increasing bonding strength and pp fibers that act as a bridge between matrix, fiber, and matrix/fiber interface and making the concrete stronger as well as more durable. According to the previous explanation, the microstructure and bonding strength of the concrete were improved.

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الخواص الميكانيكية للخرسانة القابلة للأنثناء المصنعه من السمنت البورتلاندي الكلسي

ساره صلاح سعيد [1*]، ندى مهدي فوزي [2]، اكرام فرعون احمد [3]

[1] قسم الهندسة المدنية ،كلية الهندسة،جامعة بغداد، العراق، s.saeed1101@coeng.uobaghdad.edu.iq

[2] قسم الهندسة المدنية، كلية الهندسة،جامعة بغداد، العراق،*nada.aljalawi@coeng.uobaghdad.edu.iq*

[3] قسم الهندسة المدنية ،كلية الهندسة،جامعة بغداد، العراق، *Ikram.faroun@coeng.uobaghdad.edu.iq*

الباحث الممثل: سارة صلاح سعيد s.saeed1101@coeng.uobaghdad.edu.iq

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الخلاصة – الخرسانة التقليدية تكاد تكون غير قابلة للأنحناء وان كمية صغيرة من الجهد تجعلها هشة. يعد هذا النقص في قابلية الانحناء مصدرا رئيسيا لفقدان الانفعال, وقد كان القوة الدافعة وراء تطوير الخرسانة القابلة للانحناء والتي تعرف غالبا بخرسانة المركبات الاسمنتية. يتمتع هذا النوع من الخرسانة بمرونه اكبر بكثير من الخرسانة الاعتيادية. تستخدم الألياف البوليمرية الدقيقة لتقوية هذه الخرسانة. في معظم الحالات تستخدم خرسانة المركبات الاسمنتية كمية 2% من الالياف الرقيقة المنفصلة. نتيجة لذلك تتشوه الخرسانة القابلة للانحناء ولا تتصدع عند مقارنة بالخرسانة الاعتيادية.تهدف هذه الدراسة الى تضمين هذا النوع من الخرسانه القابلة للانحناء والتي يمكن استخدامها لحل المشكلات الملموسة.تم استخدام نوعين من السمنت الكلسي البورتلاندي, احدهما اسمنت كرسته والاخر طاسلوجه. ايضا تم استعمال الياف البولي بروبيلين ومحلول بولي فينيل الكحول لعمل اربعة خلطات مختلفة. تم اجراء الفحوص بعمر انضاج 7,28,60,90 يوم. بالنسبة لجميع الفحوص, لقد كان اداء الخلطات الحاوية على الياف البولي بروبيلين ومحلول بولي فينيل الكحول افضل من تلك التي لا تحتوي عليهما.

الكلمات الرئيسية – مقاومة الانضغاط, مقاومة الشد, مقاومة الانثناء, السمنت الكلسي البولرتلاندي.