https://doi.org/10.33261/jaaru.2022.29.4.003 *Association of Arab Universities Journal of Engineering Sciences (2022)29(4):30–37*

Association of Arab Universities Journal of Engineering Sciences
مجلة اتحاد الجامعات العربية للدراسات والبحوث الهندسية

Effect of Using Grids On the Behaviour of Portland Limestone Cement Self Compacted Concrete.

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Published online: 31 December 2022

Abstract— The civil engineering field currently focus on sustainable development. It is important to develop new sustainable and economic generations of concrete, using eco-friendly materials in the construction industry with a fair amount of costs and minimizing the impact upon the environment by reducing CO_2 emissions from the cement industry as a whole while still obtaining high cement quality and strength. The main objective of this research is to clarify the mechanical behavior and ability to use Portland limestone cement in producing self compacted concrete, due to the beneficious effec of the limestone cement economically and enviromently. The research investigates the effect of using steel and polymer meshs as reinforcement, where the results showed that the steel meshs had the highest results which indicate that the steel mesh was stronger because it had absorbed more impacting energy till it reached failure. Mechanical tests were conducted to detect the benefits of using such meshs on the concrete mixes.

Keywords—Self compacting concrete, sustainable concrete, limestone cement.

1. Introduction

Concrete is a widely utilized material in the construction industry. The qualities of the ingredients used determine the overall properties of the concrete mixture. Many investigations have been conducted on the addition of components to cement and/or the replacement of cement with other materials in order to achieve the desired concrete behavior. Limestone is one of these alternatives. Limestone, which is the focus of this study, can be substituted with Portland cement made from limestone. The use of this type of cement has risen in recent decades as a result of the economic and technical advantages that limestone Portland cement may provide [20]. Flow efficiency of (SCC) is improved by utilization of limestone. Where the cement can be partially replaced with in most masonry cements this because its considered as inert filler [11]. Structures of reinforced concrete, the reinforcement and formworks are being complicated and of extreme dense. Hence, a lot of complications may occur because of the lack of concrete's compaction and inappropriate formworks filling. As a result of this, reduction in durability and performance of concrete may be present. So it has been focused on using alternative type of concrete such as (SCC), which offers better quality of concrete and enhancement in durability [13]. The very first development in (SCC) was in 1986 in Japan. The purpose of its design was to fill the formwork thoroughly and flowing through complex and dense reinforcement areas. Which are considered difficult to access and without need for external compaction during the placement [15]. Filling ability, passing ability, and resistance to segregation are the three primary requirements for (SCC). To meet these requirements, an appropriate mix design method for proportioning (SCC) mixes must be chosen. However, because of the trade-off between fluidity and stability, (SCC) is more difficult to design than conventional concrete. Researchers have widely used various types of mix-proportioning methods to design (SCC) mixes [18]. Based to some studies, a premature increment occurs with limestone additions (5-20%) addition because of the enhancement in particle packing [17]. These days, blended cement is preferred due to its economic and technical advantages. Furthermore, when clinker production is reduced, CO2 emissions are reduced, which reduces pollution [19]. The effect of limestone combined with cement in percentages of 0, 5, 10, 20, and 40% by weight was also investigated [12]. The major purpose of this research was to determine the best percentage of limestone to use in cement mortars and concrete to get the best durability qualities. [16] An investigation of the effect of limestone on blended cement's water demand was carried out. The clay content in limestone powder, however, was found to be the most important component affecting the limestone's influence on water requirements. The use of limestone powder in cement improves the viscosity and physical qualities of the mixture. Limestone powder contains a significant proportion of calcium carbonate. Thus, it serves as a filler ingredient in addition to silica or nanocarbon compounds. Because of the impact of organic components on the overall qualities of concrete, it is not recommended to make concrete with limestone that contains a high organic percentage [10]. [7] Concrete's mechanical properties are significantly improved when polymer grids are used as reinforcement. When compared to plain concrete, it increases the number of blows required to cause failure and delays the first crack. The polymer grids can be easily shaped without sharp bends, making them simple to use. As a result, the polymer grid's tensile capacity can be effectively utilized [6].

The aim of the research is to investigate the effect of adding reinforcement grids on limestone self-compacting concrete and the advantageous effect on environment by replacing certain amunt of cement by sustainable materials.

2. *Materials:*

The properties of materials and the tests that were carried out in the laboratories of the Civil Engineering Department /University of Baghdad and the laboratories of the Center for Building Research.

2.1 *Cement:*

Karasta limestone Portland cement produced by Lafarg Co., and the second is Tasluja limestone Portland cement produced by Tasluja Factory were used in this study for comparative purpose. Physical, and chemical tests were carried out in the laboratories of the Building Research Center as given in **Table 1 and Table 2**:

Table 1: Chemical properties of Karasta and Tasluja Portland limestone cement IL.

Oxides &phases %	Karasta test results	Tasluja test results	Specification limits ASTM C-595/15
L.O.I	7.44	6.21	Not more than 10
SiO2	18.39	17.81	-
Al2O3	4.63	4.19	-
Fe2O3	4.77	4.91	-
SO3	2.35	2.44	Not more than3
CaO	62.11	62.22	
MgO	1.83	1.95	-
Cl^-	0.01	0.011	
LSF%	1.04	1.02	-
I.R	0.9	0.47	
Main cement compound			
C_3S	64%	57%	-
C_2S	3.5%	10%	-
C_4A	13%	15%	-
C_4AF	6%	5.3%	-

Table 2: physical properties of Karasta and Tasluja limestone Portland cement IL.

Test	Tasluja test results	Karasta test results	Specification limits ASTM C-595/15
Finance (blain) m2/Kg	310.5	365	-
Setting time initial (min) Final (min.)	90 min 125	75 min 190	>45min. < 480 min.
Compressive strength (MPa) 3days curing 7days curing 28 days curing	 14 21 34	 17 25 43.5	 >13 >20 >25

2.2 Sand:

Ekhaider natural sand was used as fine aggregate in this study. The physical and chemical properties of fine aggregate are given in **Table 3**. The sand lies in (zone 2), the tests carried according to the requirement of Iraqi specification (IQS No.45/1984)**,** as given in **Table 4**.

Table 3: Physical and chemical properties of fine aggregate.

Property	Test result	I.Q.S.45: 1984 Limits
specific gravity	2.6	-
Absorption, %	0.72	-
density (kg/m^3)	1580	-
Sulphate content (SO_3)	0.2	0.50% (max)

Table 4: sand analysis according to the requirement of (IQS no.45/1984). **Zone II**

Sieve no.	Passing %	Limits of Iraqi specification no.45/1984
10mm	100	100
4.75mm	93.3	100-90
2.36 mm	77.7	100-75
1.18 mm	66.6	90-55
600 µm	54.4	59-35
300 µm	26.3	30-8
150 µm	3.1	100
Passing from sieve 75	2.6	Max 5

2.3 *Gravel:*

A (14mm) max size crushed gravel was used. Sieve analysis that was conducted according to the requirement of Iraqi specification (IQS No.45/1984) given in **Table 5**.

Table 5: Sieve analysis results.

Sieve No.	% Passing	Iraqi specification **(IQS No.45/1984)** for max size agg. of 14mm
14 mm	100	100
10 mm	99.7	85-100
5mm	23.8	0-25
2.36mm	1.8	0-5
Passing sieve 200%	0.2	3
Sulphate content (SO_3)	00.6	Maximum 1%

2.4 *Lime dust:*

Limestone powder used with cement mixture to improve the viscosity and physical properties of the mixture. Limestone powder has large amount of calcium carbonate (98%) and silica works as filler materials. **Table 6** shows the properties of the lime dust used.

Table 6: properties of lime dust.

Oxides	Content
SiO2	0.21
Fe2O3	3.36
Al2O3	0.03
CaO	48.28
MgO	3.97
SO_3	0.08
L.O.I	42.48
CO_3	0.19

2.5 *Water:* Normal tap water was used.

2.6 *Superplasticizer*: "In addition to enhancing workability and cohesion, BETONAC -1030 was employed, which is a high range water reducer, high extended workability superplasticizer that meets ASTM-C494 Type F standards. Increases high early strength due to lower w/c ratio, which means less mixing water is utilized, resulting in a more homogeneous mix". [14]

2.7 *Reinforcement grids:*

Steel and polymer meshs have been used in this study were of square openeings of (1.27 mm.) and diameter of (0.2 mm) as shown in **Figure 1**, where one layer of meshes have been usrd to reinforce cylinders and prizms specimens.

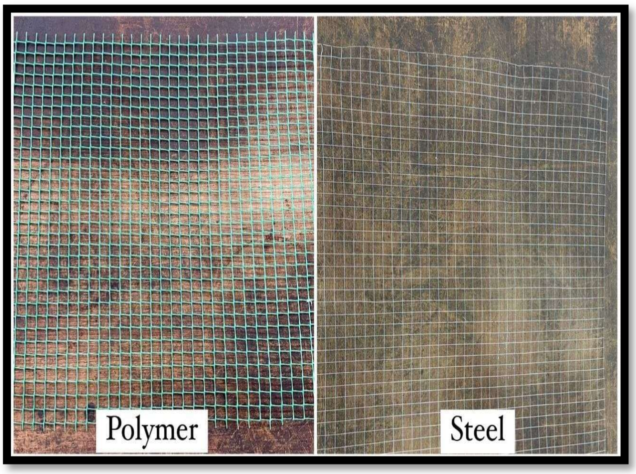

Figure 1: Reinforcement grids.

3. Experimental work:

3.1 *Mix Design:*

The mix design is confirming ACI-211, as given in **Table 7**:

Table 7: Mix design.

Cement	Sand	Gravel	W/C	superplasticizer	Replacement
1	1.71	1.9	0.42	1.4% by weight of cmemnt	20% by weight of cement

3.2 *Fresh concrete tests:*

The Slump flow test, V-funnel test and L-box test has been excuted to assess if the fresh concrete is satisfactory to be self compacting [14], results are given in **Table 8** below:

Table 8: Fresh Concrete Results.

Method	Uint	Karsat L.P.C	Tasluja L.P.C	Typical Range of Values (EFNARC) Specification	
				Min.	Max.
T-50 Slump Flow	mm	4	4.3	2	5
V-Funnel	Sec.	9	10	6	12
L-Box	(H_2/H_1)	0.9	0.86	0.8	1

3.3 *Hardened concrete tests:*

3.3.1 *Compressive Strength Test:*

Concrete's compressive strength is used as a criterion for evaluating its overall quality. An average of three cubic specimens (10x10x10 cm) dimensions for age (28, 56, and 90 days) were tested for two types of limestone portland cement according to BS 1881-116:1983. **Table 9** and **Figure 2** below show average results.

Table 9: compressive test results.

Mix	28 days	56 days	90 days
Karasta L.P.C	51	58	60
Tasluja L.P.C	46	52	55

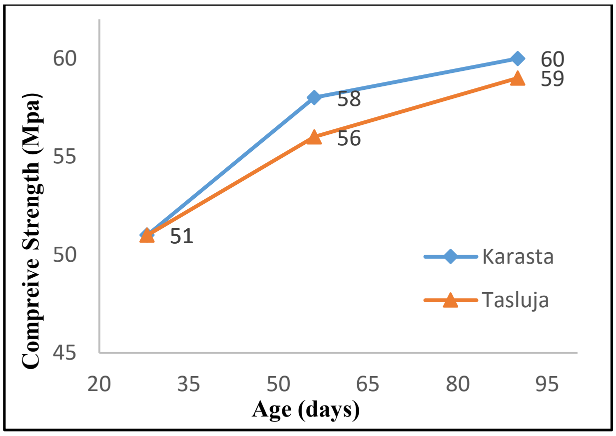

Figure 2: The relationship between compressive strength and curing age for the mixtures.

3.3.2 *Splitting tensile test:*

One of the significant characteristics of concrete is splitting tensile strength. The test was conducted by ASTM C496 with three specimens of (150x300 mm) for each of the reinforced (polymer and steel) which have been bent to clynderical shape to fit in molds as shown in **Firure 3** and non-reinforced mixes**.** The reinforced specimens with (steel and polymer) had better results than the plain specimens, where the reinforcement delayed (obstructed) the failure so the propagation of cracks was also delayed. The steel reinforcement gave better results than the polymer reinforcement overall. There was noticeable increase in the strength with time as the curing (hydration process) continues. The test results are illustrated in **Table 10**, **Figure 4** and **Figure 5**.

Figrure 3: Cyliderical Steel and polymer reinforcement grids.

Table 10: Splitting tensile strength test results

Mix	Type of Reinf.	Dimensions (cm)	splitting tensile strength (MPa)		
			28-days	56-days	90-days
Karasta L.P.C	Plain	15x30	9.45	11	11.4
	Steel	15x30	10.2	11.4	12.4
	polymer	15x30	9.7	11.1	11.8
Tasluja L.P.C	Plain	15x30	9.2	10.5	10.9
	Steel	15x30	9.8	11.2	11.9
	Polymer	15x30	9.67	10.8	11.0

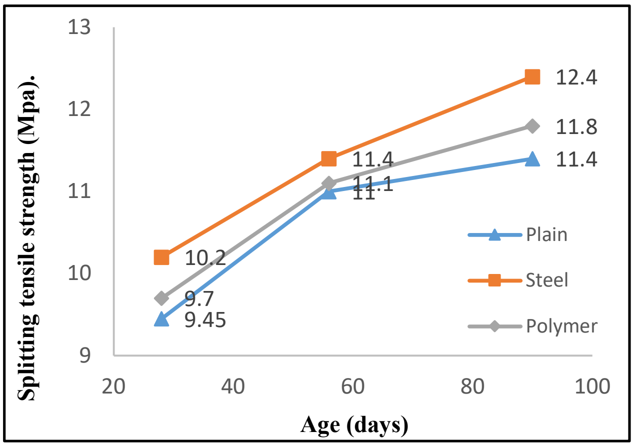

Figure 4: Karasta PLC splitting tensile strength with age.

From **Figure 4** above all results starts to develop tensile strength with age, steel reinforced mix had the highest readings which contributed by (6.77%) increase in tensile strength from the plain mix, then the polymer reinforced mix contributed by (2.35%) increase in tensile strength from the plain mix, and finally the plain mix had very close results to the polymer reinforced mix.

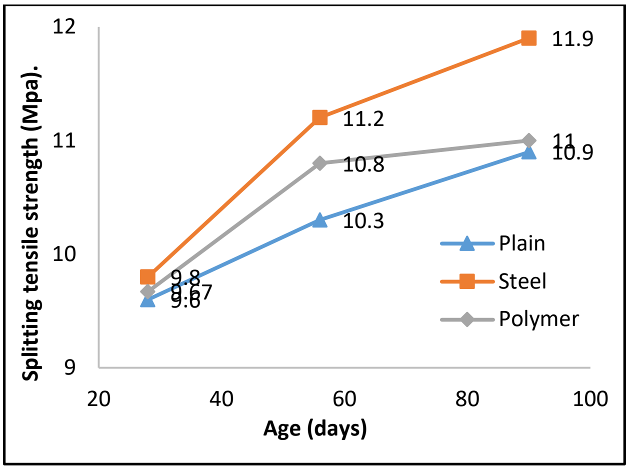

Figure 5: Tasluja PLC splitting tensile strength with age.

From the **Figure 5** above the results starts to develop tensile strength with curing age, and also the use of reinforcement grids contributed to the development of tensile strength, where the steel grids reinforced mix had highest values where increased strength by (6.6%) from the plain mix and the polymer reinforced mix had the middle value were increased strength by (3%) from the plain mix.

3.3.3 Flexural strength test results:

Flexural strength is one of the fundamental properties in which the concrete is assessed to withstand deforming (bending) forces, and its affected by the compressive strength where its increased by the increase of compressive strength. In this research a simple beam specimen of (10x10x40) cm dimensions was tested according to BS 12390-5:2000. there are two groups of specimens, the first is specimens without reinforcement (plain), and the second group is with reinforcement (steel and polymer) which have been cut to stripes according to the molds dimensions as shown in **Figure 6** and placed at (2 cm) from the bottom of the specimens.

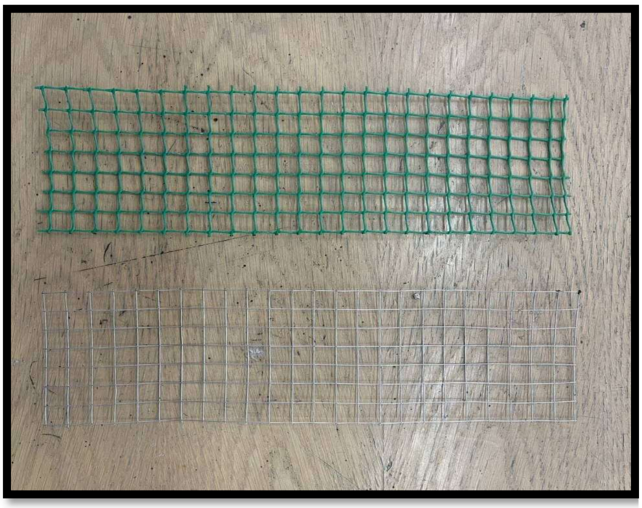

Figure 6: Prizm steel and polymer reinforcement grids.

In the first group its noticed that the (Karasta) mix had the highest flexural strength, followed by (Tasluja) which had the lowest of the results. This is related to the compressive strength where also the (Karasta) mix has the highest chemical components of cement (C_3S and C_3A).

The second group is specimens with reinforcement (steel and polymer). It's found from results that the use of reinforcement has an overall advantageous result, where the flexural strength has increased. The steel reinforcement had higher results than the polymer, where the steel exhibited more resistance which led to better results in general. As the curing age increases a general substantial increase in flexural strength is also observed. As seen in results in **Table 11, Figure 7** and **Figure 8.**

Table 11: Flexural strength test results.

Mix	Type of Reinf.	Dimensions (cm)	Flexural strength (MPa)		
			28-days	56-days	90-days
Karasta L.P.C	Plain	10x10x40	5	5.4	5.8
	Steel	10x10x40	5.5	5.9	6.3
	polymer	10x10x40	5.3	5.7	6.1
Tasluja L.P.C	Plain	10x10x40	4.4	5	5.6
	Steel	10x10x40	4.9	5.4	5.9
	Polymer	10x10x40	4.6	5.1	5.7

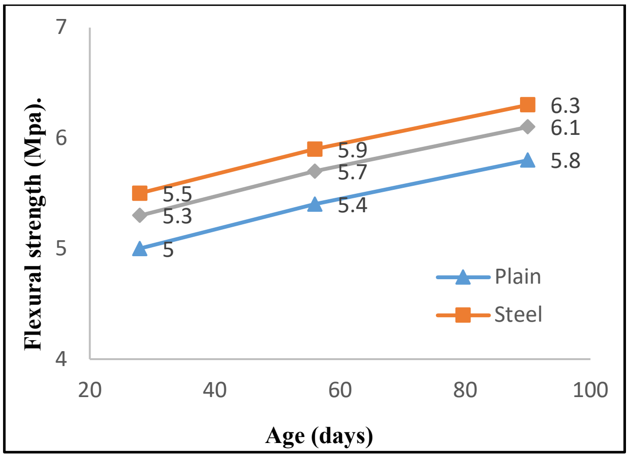

Figure 7: The relationship between flexural strength and curing age for the (Karasta) mix.

From **Figure 7** above all the mixes have developed strength over time. Where the steel reinforced mix increased flexural strength by (9.3%) from the plain mix and polymer reinforced mix contributed by (5.57%) from the plain mix, where the plain mix was the lowest in values.

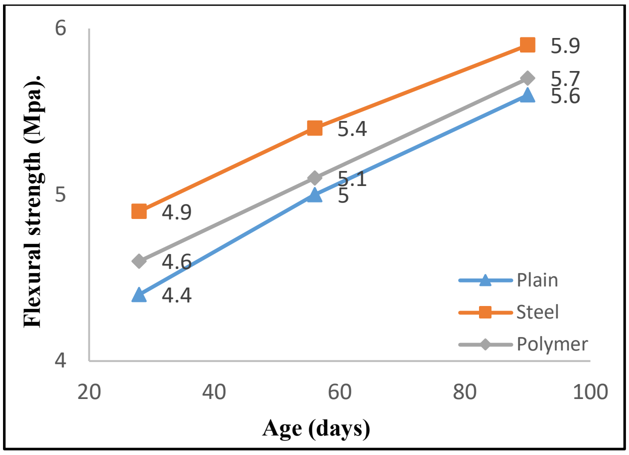

Figure 8: The relationship between flexural strength and curing age for the (Tasluja) mix.

From the **Figure 8** above all the results were very close in values with an overall increment especially in latter ages where most of the hydration products are achieved. The steel reinforced mix increased flexural strength by (8.23%) from the plain mix and polymer reinforced mix increased by (2.77%) from the plain mix.

4. Conclusions:

- Self-compacting concrete manufactured with locally available reinforcement grids might be widely employed instead of traditional concrete at complex construction sites at cheaper costs, contributing to our country's long-term sustainable development.
- Using lime dust and limestone cement to make this sort of environmentally friendly self-compacting concrete is beneficial to the environment since it reduces CO2 emitted in the atmosphere by reducing the amount of cement generated and utilized.
- The results have shown that the steel grids reinforcement had a higher contribution in developing the overall behavior than the polymer grids reinforcement.

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تاثير استخدام المشبكات على اداء خرسانة السمنت الكلسي ذاتية الرص

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نشر في : 31 كانون الاول 2022 .

الخلاصة – ينصب التركيز الحالي في مجال الهندسة المدنية على التنمية المستدامة. من المهم تطوير أجيال جديدة مستدامة واقتصادية من الخرسانة ، باستخدام مواد صديقة للبيئة في صناعة البناء مع قدر معقول من التكاليف وتقليل التأثير على البيئة عن طريق تقليل انبعاثات ثاني أكسيد الكربون من صناعة الأسمنت ككل مع الاستمرار في الحصول على نسبة عالية جودة الأسمنت وقوته. الهدف الرئيسي من هذا البحث هو توضيح الخواص الميكانيكية والقدرة على استخدام نوعين من السمنت الكلسي البورتلاندي في الخرسانة ذاتية الرص ، بسبب الفوائد الاقتصادية والبيئية للسمنت الكلسي البورتلاندي. تم التحري هذا البحث عن تأثير استخدام مشبكات الفولاذ والبوليمر كتسليح، حيث أظهرت النتائج أن المشبكات الفولاذية كانت لها نتائج عالية مما يشير إلى أن المشبكات الفولاذية كانت أقوى لأنها امتصت المزيد من الطاقة المؤثرة حتى وصلت إلى الفشل. تم اجراء الفحوصات الميكانيكية لتحديد فوائد استخدام هكذا انواع من المشبكات في الخلطات الخرسانية.

الكلمات الرئيسية – خرسانة ذاتية الرص، خرسانة مستدامة، سمنت كلسي، مشبكات فولاذية مشبكات بوليمرية.