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STRENGTH BEHAVIOR OF CONCRETE USING POMEGRANATE PEEL ADMIXTURE

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Abstract: The classical chemical additives to concrete are considered as one of important factors for improving the properties of concrete in structural designs. On another hand, due to the proliferation of wastes resulting from the foodstuff, which is deemed as one of the important reasons for environmental pollution and due to the interest of global studies to reduce the quantities by recycling or using them to produce benefit substance, so this study deals with studying the possibility of utilizing from pomegranate peel residue as an admixture to Ordinary Portland Cement (OPC) and study the effect of these peels on the behavior and the properties of concrete. The chemically treated pomegranate peels was used as additive substance to investigate the behavior, mechanical properties of fresh and solid concrete. The admixture ratio of (pomegranate shell/cement) was ranging between 0-0.7% by weight with mix proportion of (1:2:4) (cement:sand:gravel) by volume and same water to cement ratio (W/C) of 0.45. The experimental tests show that increasing in concrete compressive strength, splitting tensile strength, flexural tensile strength, and modulus of elasticity by 25.94%, 8, 21.05% and 11.10 respectively with increasing the ratio of pomegranate peel additives to certain percentage. Thus, the pomegranate peel deems to be good and non-cost concrete admixture.

Keyword: *Pomegranate peel, admixtures, normal strength Concrete (NSC), and properties of concrete*.

سلوك ومقاومة الخرسانة باستخدام مضافات قشور الرمان

الخلاصة: تعتبر المضافات الكيمياوية التقليدية للخرسانة الطرية عاملا مهما لتحسين خواص الخرسانة المستخدمة في التصاميم الانشائية . ونظرا لانتشار المخلفات الناتجة من المواد الغذائية والتي تعتبر أحد الأسباب المهمة في تلوث البيئة ، وإهتمام الدراسات عالميا للحد من كمياتها ومحاولة إعادة تدويرها أو الإستفادة منها في إنتاج مواد مفيدة. يتناول البحث الحالي دراسة إمكانية الإستفادة من قشور الرّمان المتبقية كمادة مضافة مع الإسمنت البروتلاندي (OPC) ودراسة تأثيرها على سلوك وخواص الخرسانة . تم استخدام مسحوق قشور الرمان المعالج كيميائيا كمادة مضافة لمعرفة السلوك والخواص الميكانيكية للخرسانة الطرية والصلبة والتي أضيفت الى الخرسانة بنسب تتراوح بين (0-0.7%) من وزن السمنت بنسب خلط حجمية ثابتة (4:2:1) (سمنت:رمل:حصو) ونسبة الماء/السمنت (0.45). بينت النتائج التجريبية زيادة في كل من مقاومة الانضغاط، مقاومة الانثناء، الشد، معامل المرونة للخرسانة بنسبة 25.94% و 8 و 21.05% و 11.1% على التوالي بزيادة نسبة قشور الرمان المضافة الى الخرسانة إلى حد معين. وبهذا ممكن إعتبار قشور الرمّان كمادة مضافة جيدة وغير مكلفة لتحسين خواص الخرسانة.

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1. Introduction

Guy Ankerl says “No civilization can exist without concrete” [1]. The rapid activity in the construction of buildings, erection of the installations and facilities, build houses and establishment of multi-residential estates, recreational, scientific, military and other led to increased demand for traditional building materials such as brick, cement, gravel and sand. Owing to the limited mechanical properties of these classical materials, so it has failed in the short plateau in addressing the growing and the renewable requirements demands of modern architectures techniques [2]. These limiting characteristic helm prospectors (especially for low-cost housing) to seek for a variety of new and innovative building admixtures to develop the conventional materials; have better features than its predecessors at the same time be effective and economical, low-cost, environmentally friendly and last longer ones.

Numerous studies have been conducted to improve the properties of concrete and composite materials, especially in the early nineties. These studies produced a new generation of materials known as Ultra-High Performance Concrete (UHPC) [3]. However, these materials have been expensive so it has been searching for materials added to concrete in order to improve the properties of these materials known concrete additives [4]. The concrete additives are non-traditional three materials known in the concrete mixture which (water, gravel and cement) are added to the concrete mixture before or during mixing to enhance the properties of whether soft or hard concrete [5]. The additives of various kinds are considered the most important elements used in concrete to improve its properties and enhance its efficiency. These additives are not considered (whatever the number) a solution for all types of problems faced by architects or implementers, but gives a special method to improve some of concrete characteristics. Resorting to this method in the absence of other solutions to problems or to minimize the costs required to make the project more economically [6]. Until now not know when the use of additives in concrete began installing, but in general there are three main types of admixtures that are added to a concrete which are: polymeric, mineral and chemical additives [7]. The chemical additives can be divided into several kinds including: set-retarding, air-entrainment, water-reducing, accelerating, shrinkage reducing, super plasticizers, corrosion-Inhibiting, alkali-silica reactivity inhibitors, hydration-control, coloring and other types of additives that lead many other purposes. In contrast, the environment suffers from the accumulation of many types of pollutants significantly and continuously [8].

These pollutants lead to serious damage if left without treated such pollutants are agricultural pollutants. As a result of the large increasing in population, humans need to cultivate larger quantities of crops to provide food for the growing number of inhabitants and this food produce large amounts of waste beginning from cultivation and harvest and ending with its consumption [9]. This agricultural waste has utilized of them in several ways, including the preparation of useful and informative materials or water treatment and contaminated soil or prepare cheap and effective pesticides or used as additives for concrete in order to improve their properties. Pomegranate Peel is considered as one of the largest and most important agricultural pollutants in the world.

In addition, it is deemed as an important source for the production of antioxidants and effective substance in the adsorption of heavy metals due to its moderate surface area totals and functional groups [10]. Thus it has been benefit of crushed and chemically treated pomegranate peel in this research as an admixture for concrete and study their effects on concrete properties such as compressive strength, flexural tensile strength, splitting tensile strength, and modulus of elasticity and comparing the results with normal concrete that hasn't any additive.

2. Material Properties

2.1. *Cement*

Ordinary Portland Cement (OPC), (Type I) Tasluja-Bazian, Sulymania-Iraq was used for all mixes. To avoid any differences between various batches, the whole quantity was brought and stored in a dry place. The chemical composition and physical properties of used cement are shown in Tables (1) and (2) respectively. The results conformed to the [Iraqi specifications No.5/1984].

Table 1. Chemical composition and main compounds of cement used in this study

Oxide composition	Abbreviation	Content %	Limits of Iraqi specification No.5/1984
Lime	CaO	60.60	_
Silica	SiO_2	19.60	_
Alumina	Al_2O_3	5.52	_
Iron Oxide	Fe_2O_3	3.11	_
Sulfate	SO_3	2.27	≤2.8%
Magnesia	Mg O	1.80	≤5.0%
Loss on ignition	L.O.I	1.60	≤4.0%
Insoluble residue	I.R.	1.10	≤1.5%
Lime saturation factor	L.S.F	0.93	0.66-1.02
Main Compounds (Bogue's equations)			
Tricalcium Aluminate	C_3A	9.37	_

Table 2. Physical properties of the cement used in this study*

Physical properties	Test results	Limit of Iraq specification No.5/1984
Specific surface area, (Blaine method),cm^2/gm	2650	≥ 2300
Soundness (LeChatelier Method)	1	≤ 10 mm
Setting time (vicat's apparatus)		
Initial setting ,hrs :min	2:30	≥ 0:45
Final setting ,hrs :min	4:10	≤ 10:0
Compressive strength		
3days, MPa	17	≥ 15
7days, MPa	23.7	≥ 23

* Chemical and physical tests were carried out in the National Center for Construction Laboratories and Researches (NCCLR).

2.2. *Fine Aggregate*

Al-Ekhaider natural sand of 4.75 mm maximum size is used as fine aggregate with rounded-shape particles and smooth texture. The obtained results indicate that the fine aggregate grading and the sulfate content are within the Iraqi limits [Iraqi specification No.45/1984]. Sand grading and physical properties are shown in Tables (3) and (4) respectively.

Table3. Grading of fine aggregate (sand)

Sieve Size(mm)	Cumulative Passing%	Limits of Iraqi Specification No.45/1984 , zone 2
4.75	91	90-100
2.36	76	75-100
1.18	57	55-90
0.600	38	35-59
0.300	11	8-30
0.150	6	0-10

Table4. Physical properties of fine aggregate*

Physical properties	Test results	Limits of Iraqi specification No.45/1984
Specific gravity	2.7	-
Sulfate content	0.1	≤0.5%
Absorption	0.74%	-

*Tests for Chemical properties of fine aggregate were performed by the State Company for Inspection and Engineering Rehabilitation (SIER), Baghdad, Iraq.

2.3. *Coarse Aggregate*

Crushed gravel from AL-Nibaey region was used for NSC. The gravel was washed, and then stored in a saturated dry surface condition before using. The grading and physical properties of the coarse aggregate are shown in Tables (5) and (6). The obtained results indicate that the coarse aggregate grading is within the requirement of the Iraqi standards [Iraqi specification No.45/1984].

Table5. Grading of coarse aggregate

Sieve size	%Passing	
	%Coarse Aggregate	Iraqi specification No. 45/1984
14mm	100	100
10mm	92	85-100
5mm	12	0-25
pan	-	-

Table6. Physical properties of coarse aggregate*

Physical properties	Test results	Limits of Iraqi specification No.45/1984
Specific gravity	2.6	-
Sulfate content	0.08 %	0.1% max
Absorption	0.70%	-

*Tests for Chemical properties of fine aggregate were performed by the State Company for Inspection and Engineering Rehabilitation (SIER), Baghdad, Iraq.

2.4. *Mixing Water*

Ordinary tap water was used for mixing and curing for all the concrete specimens of this work. A constant water/cement ratio added for all samples of 0.45.

2.5. *Admixtures*

The admixture material used in this research is a pomegranate peel which considered an inevitable result of *Punica granatum* fruit. The pomegranate shell used for this work was obtained from local market in Baghdad, Iraq. The sample was allowed to dry under the sun for ten days, then grinding to get powder. The ash of the shell was dried in a muffle furnace for two hours at 1100°C to obtain a finely divided ash, which is then sieved through BS standard sieve size 75μm and its color was black, as shown in the Plate (1), and kept ready for analysis [11-16].

Although the low concentration of harmful substances in Pomegranate peel used in this study, which is almost be negligible, a treatment has been done to decrease it content in fresh mix. The extraction process of harmful substances content in the pomegranate peel, precisely described by previous researchers [10], performed by the Folin-Ciocalteu method. Gallic acid was used as a standard and the total phenolic were expressed as mg/g Gallic Acid Equivalents (GAE). The process has been done in a chemical Laboratory-Environmental Engineering Department by professional expert's skills.

Plate1. Pomegranate powder after burn

3. Experimental Program

The Figure (4), illustrate the details of experimental program. Concrete samples have been casted 16 different concrete mixes in different steel molds; 150mm cubes, 150x300mm cylinders, and 100x100x500mm prisms, as illustrated in Table (8), totally 208 samples. The admixture ratio of (pomegranate shell/cement) ranging from 0-0.7% by weight, with a conventional concrete mix proportion of (1:2:4) (cement:sand:gravel) by volume, and a same water to cement ratio (W/C) of 0.45.

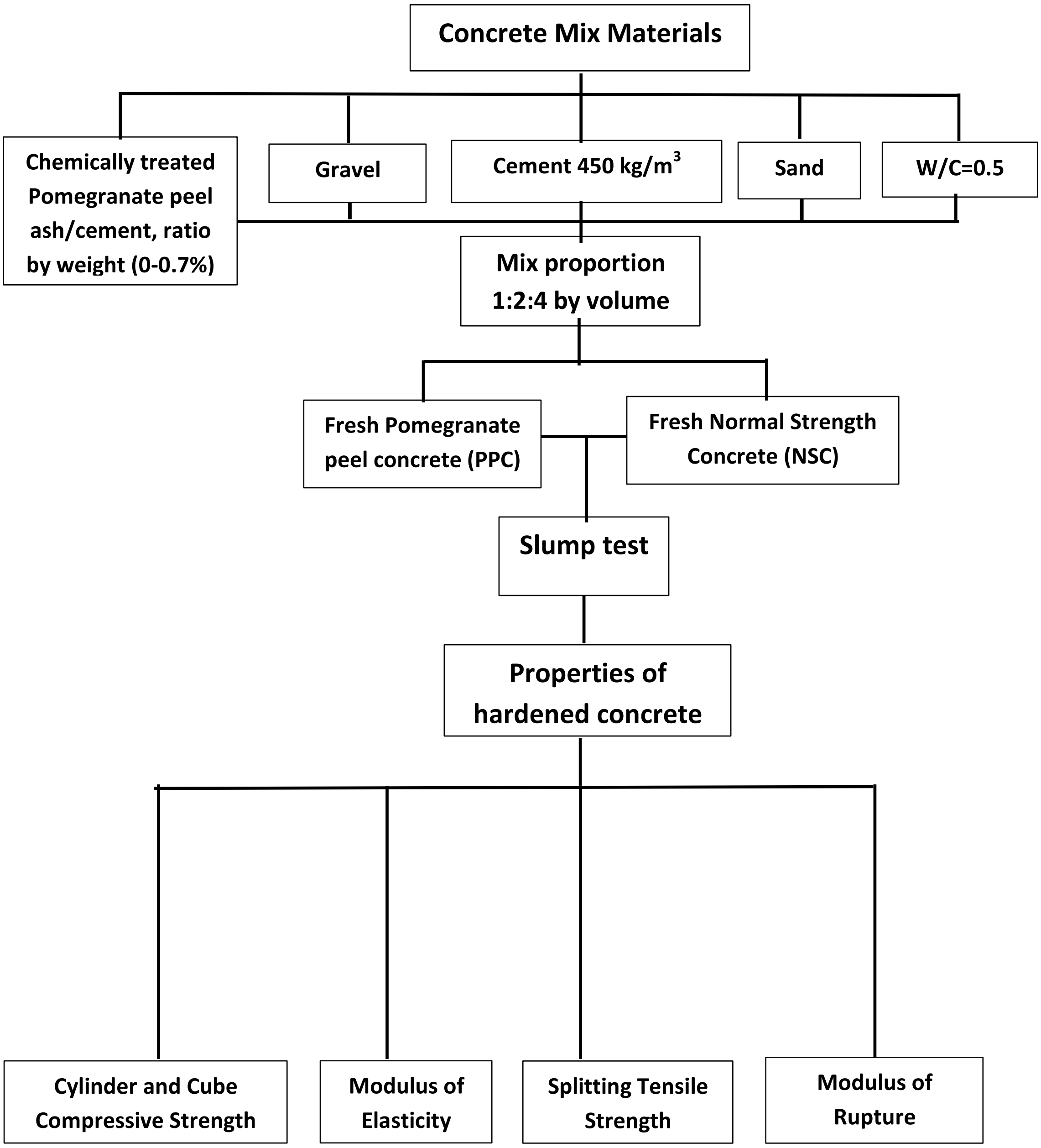

Figure 4. Flow chart of experimental program

Table 8. Concrete samples casted per each mix

Concrete properties	Samples Type	No. of Samples	Total No.s
Cylinder Compressive strength (fc`)	Cylinder 150 × 300 mm	3	48
Cube Compressive strength (fcu)	Cube 150 mm	3	48
Splitting tensile strength (fct)	Cylinder (150 * 300) mm	3	48
Modulus of rupture (fr)	Prism (100* 100 * 500) mm	3	48
Modulus of elasticity (Ec)	Cylinder (150 * 300) mm	1	16
Total Number of tested samples			208

4. Mixing, Casting, and Curing

In this study, mixing was performed by using 0.19 m3 capacity horizontal rotary mixer, as shown in the Plate (2). Before using the mixer, any remaining concrete from previous batch was cleaned off. A damp cloth was used. The steel molds are used in the fabrication of control specimens of cylinders, cubes, and prisms. First of all, the molds are cleaned, assembled and oiled. Pomegranate shell powder was mixed together with cement, aggregate, until a homogeneous mixture was obtained. The measured quantity of water was then sprayed on to the mixture. The mixture was further mixed until a paste of the required workability was obtained. After casting, the specimens are covered with nylon to prevent evaporation of water. After two days, the samples are removed from their molds and cured in water containers at a temperature of about (25^{o}C) until the testing age of (28 days).

Plate2. Rotary concrete mix used in this study

5. Mechanical Properties of Fresh and Hardened Concrete

The hydraulic universal testing machine (MFL system) shown in the Plate (3) with ultimate load capacity 3000 kN has been used to test the; compressive strength, splitting tensile strength, and modulus of elasticity.

Plate 3. Universal testing machine (MFL System) used in this work.

5.1. *Concrete Workability*

The slump tests carried out in accordance with [BS 1881-Part 102: 1983] for both pomegranate peel concrete and normal strength concrete. The values of the slump obtained from the slumped test shown in the Figure (5), the slump was increased with decreasing the ratio of the pomegranate peel ash/cement. With a constant water/cement ratio added for all samples, finer pomegranate shell particles demand more amount of water and therefore reduce the slump.

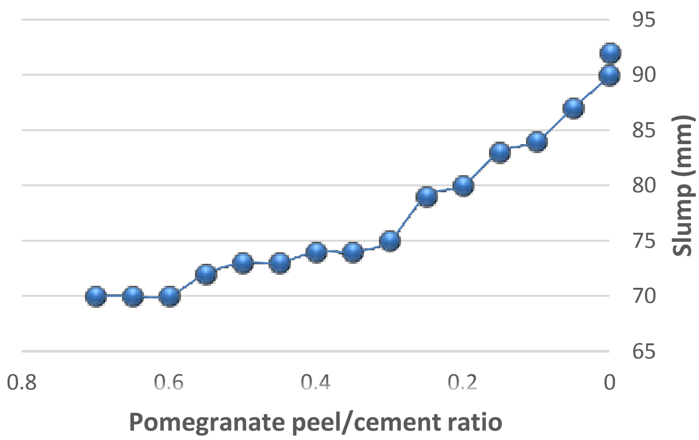

Figure 5. Relation between slump and Pomegranate peel/cement ratio

5.2. *Compressive Strength Test*

The compressive strength of the samples was determined in accordance with the standard procedure of (ASTM- C39/C39M-05) and (BS 1881-Part 116:1983). Three samples of cube and cylinder blocks were crushed at 28 days per each mix, as shown in the Plate (5), and the average value per each ratio of PPC has been compared with the value of NSC, as shown in the Table (9).

Plate 5. Test of compressive strength of concrete

Table 9. Results values of compressive strength of concrete

No.	Pomegranate Peel/Cement Ratio % R	Type of Concrete	Average* Compressive Strength of Cylinder fc' (MPa)	Average* Compressive Strength of Cube fcu (MPa)	$\frac{f_c'}{f_{cu}}$	$\frac{f'_{c(PPC)}}{f'_{c(NSC)}}$ %	Compressive Strength increasing Ratio%
1	0	NSC**	23.82	28.11	0.847	100	----
2	0.001	PPC***	24.83	28.77	0.863	104.24	4.24
3	0.05	PPC	27.54	32.00	0.860	115.61	15.61
4	0.1	PPC	29.25	34.00	0.86	122.79	22.79
5	0.15	PPC	30.00	34.75	0.863	125.94	25.94
6	0.2	PPC	29.85	34.62	0.862	125.31	25.31
7	0.25	PPC	29.02	33.75	0.859	121.83	21.83
8	0.3	PPC	27.45	32.00	0.857	115.24	15.24
9	0.35	PPC	25.61	29.61	0.865	107.51	7.51
10	0.4	PPC	23.15	26.77	0.864	97.19	-2.81
11	0.45	PPC	20.25	23.45	0.863	85.01	-14.99
12	0.5	PPC	17.00	19.68	0.863	71.37	-28.63
13	0.55	PPC	13.55	15.70	0.863	56.88	-43.12
14	0.6	PPC	10.00	11.50	0.869	41.98	-58.01
15	0.65	PPC	6.22	7.21	0.862	26.11	-73.89
16	0.7	PPC	2.35	2.72	0.863	9.86	-90.13

*each value represents the average of 3 specimens tested values

**Normal Strength Concrete.

*** Pomegranate Peel Concrete

The maximum values of average compressive strength of cylinder and the average compressive strength of cube, gained when the pomegranate peel/cement ratio is 15%, which considered as a perfect value of the pomegranate peel/cement ratio as an admixture. These average values decreasing accordingly with the increasing or decreasing the ratio of pomegranate peel/cement.

A polynomial equation (1) has been predicted to find the pomegranate peel concrete compressive strength for cylinder at 28 days, which approximately match the experimental values gained by test, as shown in the Figure (6).

$$f'c(\frac{N}{mm^2}) = -246.23R^6 + 582.11R^5 - 566.56R^4 + 388.82R^3 - 280.32R^2 + 69.668R + 24.747 \quad (1)$$

Where:
R is Pomegranate Peel/Cement ratio %

5.3. *Splitting Tensile Strength (f_{ct})*

The indirect tensile strength (splitting tensile strength) shown in the Plate (6), are carried out on NSC and PPC samples in accordance with (ASTM C496/C 496-04) using the same machine used for compressive strength determination. The splitting tensile strength values were calculated experimentally and theoretically respectively as shown in Table (10), by the following expressions:

$$(f_{ct})_M = \frac{2P}{\pi dL} (\text{ASTM C496-04}) \quad (2)$$

$$(f_{ct})_P = 0.56\sqrt{fc'} \; (\text{ACI 318M-11}) \quad (3)$$

where:
$(f_{ct})_M$: Measured splitting tensile strength (MPa)
$(f_{ct})_P$: Predicted splitting tensile strength (MPa)
(f_c') : Compressive Strength of Cylinder at 28 days (MPa)
P : Maximum applied load (failure load) (N)
L : Length of the cylinder (300 mm)
D : Diameter of the cylinder (150 mm)

Plate 6. Splitting tensile test of concrete

Table (10), Measured and predicted splitting tensile strength

No.	Pomegranate Peel/Concrete Ratio %	Average measured splitting tensile strength (fct) (MPa)	Average predicted splitting tensile strength (fct) (MPa)*	(fct) Measured / (fct) Predicted	Increasing Ratio%
1	0	2.85	2.73	1.04	4
2	0.001	2.93	2.79	1.05	5
3	0.05	3.13	2.94	1.06	6
4	0.1	3.25	3.03	1.07	7
5	0.15	3.30	3.07	1.07	7
6	0.2	3.29	3.06	1.08	8
7	0.25	3.23	3.02	1.07	7
8	0.3	3.12	2.93	1.06	6
9	0.35	2.99	2.83	1.06	6
10	0.4	2.80	2.69	1.04	4
11	0.45	2.57	2.52	1.02	2
12	0.5	2.31	2.31	1.00	0
13	0.55	2.00	2.06	0.97	-3
14	0.6	1.65	1.77	0.93	-7
15	0.65	1.22	1.40	0.87	-13
16	0.7	0.66	0.86	0.77	-23

*equation (3)

The Maximum values of the average; measured and predicting splitting tensile strength, gained at the pomegranate peel/concrete ratio between 15% and closer to 20%. These average values accordingly relate with the compressive strength of concrete.

A polynomial equation (4), has been predicted to find the pomegranate peel concrete splitting tensile strength for cylinder at 28 days, which approximately match the experimental values gained by test, as shown in the Figure (7).

$$f_{ct} = -119.54R^6 + 228.77R^5 - 178.25R^4 + 75.391R^3 - 27.556R^2 + 5.4192R + 2.9233 \quad (4)$$

Where:

R is Pomegranate Peel/Cement ratio %

5.4. *Modulus of Rupture (fr)*

Modulus of rupture tested by flexural testing machine shown in the Plate (7) by conducted The average of three simply supported prisms 100x100x500mm of NSC and PPC according to (ASTM C78-75) taken at age of 28 days for each mix type under two points loading.

Plate7. Modulus of rupture test

The flexural tensile strength values shown in the table (11) were calculated experimentally by equation (6) and theoretically by equation (7):

$$fr = \frac{3}{2} \text{ x } \frac{P(L - l_i)}{bh^2} \tag{5}$$

Since $l_i = \frac{L}{3}$; Then

$$fr = \frac{Pl_i}{bh^2} \text{(exp.) ..... (ACI 318M-11)} \tag{6}$$

where:-

fr: modulus of rupture (MPa).

P : failure load (N).

L : span length (mm).

b : width of specimen (mm).

h : depth of specimen (mm).

l_i : The distance between two points load (mm)

$f_r = 0.62\sqrt{fc'}$ (predicted) ...(ACI 318M-05) ......(7)

Table 11. Measured and predicted flexural tensile strength

No.	Pomegranate Peel/Concrete Ratio %	Measured flexural tensile strength (fr) (MPa)	Predicted flexural tensile strength (fr) (MPa)
1	0	2.90	3.03
2	0.001	2.90	3.09
3	0.05	2.94	3.25
4	0.1	3.14	3.35
5	<u>0.15</u>	<u>3.15</u>	<u>3.40</u>
6	<u>0.2</u>	<u>3.15</u>	<u>3.39</u>
7	0.25	3.09	3.34
8	0.3	2.92	3.25
9	0.35	2.90	3.14
10	0.4	2.87	2.98
11	0.45	2.84	2.79
12	0.5	2.61	2.56
13	0.55	2.32	2.28
14	0.6	1.60	1.96
15	0.65	1.24	1.55
16	0.7	0.75	0.95

The Maximum values of the; measured and predicting flexural tensile strength, gained at the pomegranate peel/concrete ratio between 15% and 20%. These values accordingly relate with the compressive strength of concrete.

A polynomial equation (8), has been predicted to find the pomegranate peel concrete flexural tensile strength for cylinder at 28 days, which is not exactly match the experimental values gained by test, as shown in the Figure (8).

$$fr = 1436.1R^6 - 2811.6R^5 + 1999.8R^4 - 629.54R^3 + 77.551R^2 - 1.0733R + 2.8961 \quad (8)$$

Where:- R is Pomegranate Peel/Cement ratio %

5.5. *Modulus of Elasticity (Ec)*

Measurements of static modulus of elasticity (E_c) of 150x300 mm NSC and MRPC cylinders were tested at age 28 days under uniaxial compression to get the compressive stress-strain diagrams accordance with (ASTM C469-87). The stress strain relationship of concrete in compression was obtained from the data recorded using a compressor meter as shown in Plate (8). Modulus of elasticity values were calculated experimentally by equation (9) and theoretically by equations (10), as shown in Table (12):

$$E_c = \frac{S2 - S1}{\epsilon_2 - 0.00005} \times 10^{-3} \qquad \text{(ACI 318M-11)} \qquad (9)$$

where:
E_c = Static modulus of elasticity of concrete, GPa
S2 = Stress corresponding to 40% of ultimate load, MPa
S1 = Stress corresponding to a longitudinal strain (0.00005), MPa
ϵ_2 = Longitudinal strain produced by stress S2

$$E_c = 4700\sqrt{fc'} \text{(ACI 318M-11) for NSC}, \quad f_c' \leq 42 \text{ MPa} \qquad (10)$$

Plate8. Modulus of elasticity test of concrete specimens

Table (12), Measured and predicted static modulus of elasticity

No.	Pomegranate Peel/Concrete Ratio %	Measured Static Modulus of Elasticity (GPa)	Predicted Modulus of Elasticity (GPa)
1	0	20.90	22.94
2	0.001	21.23	23.42
3	0.05	21.53	24.66
4	0.1	22.86	25.42
5	0.15	23.65	25.74
6	0.2	23.55	25.68
7	0.25	23.34	25.32
8	0.3	23.01	24.62
9	0.35	22.82	23.78
10	0.4	21.23	22.61
11	0.45	19.87	21.15
12	0.5	17.76	19.38
13	0.55	15.54	17.30
14	0.6	13.21	14.86
15	0.65	11.23	11.72
16	0.7	8.24	7.20

The Maximum values of the; measured and predicting modulus of elesticity, gained at the pomegranate peel/concrete ratio 15%. These values accordingly relate with the compressive strength of concrete.

6. Conclusions

1. Performance the compressive strength of the concrete using the natural materials of pomegranate peel. This study considered a green method to keep the environmental land clean from organic materials, and decrease the aggravate of chemicals admixtures added to the concrete, in addition to support the sustainable engineering.
2. Adding 0.15% of (pomegranate shell/cement) to the normal strength fresh concrete mix proportion (1:2:4) and W/C ratio 0.45, will increase the compressive strength value by 25.94%. Since, each 100 g of pomegranate shell contains 162.1 mg of calcium [24]; it contributes additional formation of calcium gel that contributes to the strength development of the concrete because the C-S-H gel was produced. This gel filled the void between cement matrixes and causes the densification effect.
3. The maximum compressive strength of concrete presented with the ratio of 0.15% of the Pomegranate Peel/Cement added to the concrete. Increasing this ratio will decrease the compressive strength values, since the higher amount of (Pomegranate Peel/Cement) prevent binder (cement) to complete the chemical reaction.
4. With a constant water/cement ratio added for all samples, finer pomegranate shell particles demand more amount of water and therefore reduce the slump.

7. Acknowledgments

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