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Mechanical and Structural Properties of a Lightweight Concrete with Different Types of Recycling Coarse Aggregate

Muyasser M. Jomaa'h[1] *

Baraa Thaar Kamil[2]

Omer S. Baghabra[3]

[1] Civil Eng. Department
College of of Engineering
Tikrit University
Tikrit
Iraq

[2] Civil Eng. Department
Kirkuk University
Kirkuk
Iraq

[3] King Fahad University of
Petroleum & Minerals
KSA

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A B S T R A C T

In the light of the world's technological development in the construction field and the continuous need to apply high-efficiency building materials because old methods are no longer used after the advent of the solutions characterized by fast applications and maximum protection in addition to reducing costs and increasing the sustainability of the establishment and its design age.

The lightweights of various installations are an urgent need to decrease the dead loads. Therefore, this study is a local focus on replacing the normal coarse aggregate with lightweight coarse aggregate (claystone (bonza), rubber, thermostone and polystyrene) in various volumetric ratios of (25, 50 and 75) % in addition to a preparation of reference mix. For the purpose of identifying and studying the important specifications the new concrete which contributes to the self-load reduction of the concrete by reducing the total density of the mixture, models of cylinders and standard prisms were prepared, to evaluate the compressive strength and the splitting tensile strength respectively. In addition to that the modulus of rupture and the unit weight, where carried out. The tests results indicated a drop in the mechanical properties of the concrete with increase in the lightweight coarse aggregate, mechanical properties values: compressive strength, rupture modulus, splitting tensile strength and flexural strength were between (10.66-28.99) MPa (1.122-3.372) MPa, (3.606-6.83) MPa and (20.101-25.874)MPa compared with a reference mixes (38.44MPa), (3.969MPa), (10.476MPa) and (26.940)MPa respectively for mixes of (25, 50 and75)% with different light coarse aggregate , also the values of an oven-dry density were between (1665.5-2287.58)kg/m^3 compared with reference mixes (2426.41kg/m^3). The best concrete mix was (M7, M10) of low density (1598.4 kg/m^3) and (1580.4) kg /m^3 and the compression strength within the permissible limits (15.47) MPa.

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الخصائص الميكانيكية والانشائية للخرسانة الخفيفة باستخدام أنواع مختلفة من الركام الخشن الخفيف

الخلاصة

في ظل ما يشهده العالم من تطور تكنولوجي في مجال التشييد والبناء والاحتياج المستمر الى تطبيق استخدام مواد بناء عالية الكفاءة لان استخدام الطرق القديمة لم يعد الامثل بعد ظهور حلول تتميز بالسرعة في التطبيق والحماية القصوى بالإضافة الى تقليل الكلف وزيادة ديمومة ألمنشأت وعمرها التصميمي والوزن الخفيف للمنشآت المختلفة ضروري جدا للتقليل من الاحمال الميتة.لذلك تناول هذا البحث باستبدال الركام الخشن الاعتيادي بالركام الخشن خفيف معاد

* **Email: muyasserjomaah@tu.edu.iq**

التدوير(من مخلفات البناء او الصناعة) كمحاولة لإنتاج خرسانة صديقة للبيئة وتشمل (ركام الصخور الطينية (بونزا) ، وركام الصخور الجيرية أو كتل الثرمستون ، وقطع مطاط إطارات المركبات المستهلكة ، والبولي ستارين (الفلين)) بنسب استبدال حجمية مقدارها (75,50,25)% من الركام الاعتيادي ومقارنتها بالخرسانة المرجعية ، والذي يساهم في تخفيض الحمل الذاتي للخرسانة من خلال تقليل الكثافة الكلية للخلطة. ان دراسة الخصائص الميكانيكية (مقاومة الانضغاط، مقاومة الشد الانشطاري، معايير الكسر، الكثافة) وذلك باستخدام عينات اسطوانية ومواشير قياسية. أشارت نتائج الفحوصات الى انخفاض خواص الخرسانة بزيادة نسبة الركام الخشن الخفيف المستبدل ، حيث سجلت معدلات قيم الخواص الميكانيكية لكل من : مقاومة الانضغاط ومقاومة شد الانشطار غير المباشر ومعاير الكسر للعينات بين (MPa (10.66–28.99 ، MPa (1.122-3.372) , MPa (3.372-1.122)، للخلطات ذات نسب استبدال مختلفة من الركام الخفيف بأنواعه الأربعة، مقارنة بالخلطة المرجعية (MPa (38.44، MPa (3.969) و MPa (10.46) على التوالي ، وكانت معدلات الكثافة ، (kg/m^3 (1665.5-2287.58 مقارنة مع الخلطة المرجعية،(kg/m^3 (2426.41 ، على التوالي لنسب الاستبدال، وكانت افضل خلطة خرسانية هي (M7,M10) حيث حققت اقل كثافة (kg/m^3 (1580.4), kg/m^3 (1598.4 على التوالي ، ومقاومة انضغاط ضمن الحدود المسموح بها (MPa (15.47.

الكلمات الدالة: الخصائص الميكانيكية، الركام الخشن، احجار طينية(البونزا)، خرسانة خفيفة، مخلفات المطاط، الثرمستون والفلين.

Introduction

Lightweight concrete is a concrete which has dry density less than (2000) kg/m^3. Lightweight Concrete (LWC) can be produced by replacing a part or all the normal aggregates with lightweight materials. And this is classified into three types according to the manufacturing method, Fig. (1). [1], [2]. The main lightweight concrete types are:

1-No-fines concrete.
2-Aerated concrete.
3-Lightweight aggregate concrete.

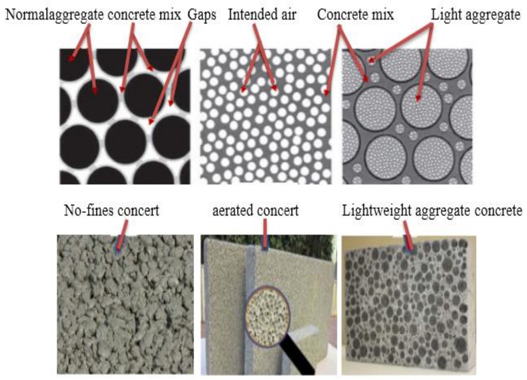


Fig. 1. Types of LWC [1], [2]

The third type of Lightweight aggregate concrete (LWAC) will be studied in this research. The properties of this concrete depends on the properties of the used lightweight aggregate, which in turn depends on its original material and the production method. Generally, the compressive strength and density are considered when the structures concrete is designed, especially when (LWAC) is used, where the difference in density results difference compressive strength of (LWAC). Recently, this concrete is widely used due to its multiple advantages [3]. The experimental program depends on using the lightweight aggregate, and then recycling the lightweight aggregate by adopting the volumetric replacement of the conventional aggregate. Afterward, the mechanical properties will be studied, including compressive strength, splitting, modulus of rupture and density. The best structural properties, energy-saving and production cost will be characterized [3].

Experimental Work:

Materials:

1: Cement

Ordinary Portland cement (type I) is manufactured by Bazian Cement Factory (Sulymania, Iraq) which was used in this project. The chemical analysis and physical test results for the used cement are given in Tables 1 and 2 respectively, [4].

Table 1
Physical Properties of Cement

Physical Properties	Test Results	Limit of Iraqi Specification No. 5\1984
Specific surface area (Blaine method) (m^2/kg)	346 m^2/kg	(230 m^2/kg) lower limit
Setting time (vacate apparatus) Initial setting: Final setting:	3 hrs. 5 min 5 hrs. 20 min	Not less than 45min Not more than 10 hrs.
Compressive strength (MPa) at 3-day at 7-day	22.7 MPa 27.7 MPa	Not less than 15 MPa Not less than 23 MPa

Table 2
Chemical Properties of Cement

Oxides Composition	Content %	Limit of Iraqi Specification No.5\1984
CaO	62.03	-
Al2O3	4.91	-
SiO2	20.83	-
Fe2O3	2.98	-
MgO	2.21	5 % Max
SO3	2.2	2.5 %Max
Loss on Ignition (L.O.I)	1.24	4 %Max
Insoluble material	0.42	1.5 %Max
Lime Saturation Factor (L.S.F)	0.91	(0.66-1.02)
Main Compound		
C3S	50.64	-
C2S	21.7	-
C3A	4.2	< 5 %
C4AF	9.071	-

2: Fine Aggregate

The used sand in the concrete mixtures from Qara Salim / Kirkuk / Iraq. Sieve analysis results and chemical and physical properties of fine aggregate [5], are shown in Tables 3 and 4 respectively.

Table 3
Results of the Fine Grading Test

Sieve size		Retained %	Cumulative Passing%	Limit of Passing for IQS No.45\1984 for zone 3
In (SSTM)	Mm			
No.4	4,75	2	98	90 – 100
No.8	2,36	10	90	60 – 95
No. 16	1.18	35	65	30 – 70
No.30	600	68	32	15 – 34
No.50	300	82	18	5 – 20
No.100	150	92	8	0 – 10

Table 4
Chemical and Physical Properties of Fine Aggregates

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01	2.43	-
Absorption %	ASTM C128-01	1.2 %	-
Dry loose unit weight, kg/m3	ASTM C29/C29M/97	1796	-
Sulfate content (as SO3), %	(I.Q.S.) No. 45-1984	0.056	0.5 (max. value)
Material finer than sieve 0.075 mm	(I.Q.S.) No. 45-1984	1.26	5 (max. value)

3: Coarse Aggregate

3-1 Normal Coarse Aggregate

The work nature depends on the maximum size of the crushed coarse aggregate; the maximum size of the available crushed coarse aggregate which was 12.5 mm and are used in the present work. The dust and dirt were removed by washing the aggregate and then was tested depending on the requirements of the (I.Q.S.) [5], the various tests result that conducted on coarse aggregate are given in Tables 5 and 6.

3-2 Claystone Aggregate (Ponza)

The used aggregate in this research is a claystone that called locally (Ponza). A lightweight coarse aggregate is available in light structural unit's and its production plants are in Erbil. Manufactory process uses a fine aggregate after crushing when the production of structural blocks used as partitions in buildings. In this study, it was used a claystone as coarse aggregate without crushing a maximum nominal size (12.5 mm) and with different volume replacement ratios (25, 50, and 75) % of the volume of the normal coarse aggregates in concrete mix. The replace volume used of the lightweight to maintain the aggregate size using a natural mixture. Fig. 2 shows the lightweight coarse aggregate (Ponza) that used in the concrete. Gradation of the lightweight coarse aggregate are shown in Table 7. This conforms the American standard [6], Table 8 shows the chemical and physical properties of the lightweight coarse aggregate (Ponza), as well as Table 9 shows the chemical analysis for the lightweight coarse aggregate.

Fig. 2. Lightweight Claystone Coarse Aggregate (Ponza)

Table 5
Result of the Examination of the Normal Coarse Aggregate

Sieve size	Cumulative Retained %	Passing %	Limit of Passing for IQS No.45/1984
20 mm	0	100	100
14 mm	1.54	98.46	90 – 100
10 mm	38	62	40 – 70
5 mm	98.49	1.51	0 – 15
2.36 mm	99.06	0.94	0 – 5

Table 6
Chemical and Physical Properties of Normal Coarse Aggregates

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01	2.51	-
Absorption (%)	ASTM C128-01	1.1	-
Dry loose unit weight kg/m3	ASTM C29/C29M/97	1500	-
Sulfate content (as SO3) (%)	(I.Q.S.) No. 45-84	0.027	0.1(max.value)

Table 7
Result of the Gradation Test of the Lightweight Coarse Aggregate (Ponza**)**

Sieve size	Cumulative passing %	Limit of ASTM C330-99
12.5-mm	93.6	90-100
9.5-mm	60.3	40-80
4.75-mm	12.7	0-20

3-3 Thermostone Coarse Aggregate

In this research, the lightweight crushed coarse thermostone aggregate were used and the result of the structural waste of a building under construction, after crushing by hand with a hammer as a required gradient. This aggregate is used with a maximum nominal size of 12.5 mm and different volumetric replacement ratios (25, 50, and 75) % of the normal coarse aggregates. This aggregate is submerged in water for one day before usage in a dry saturated condition and not to absorbing the mixing water, thus reducing the strength of the lightweight concrete. Water absorption for this type of aggregates is very high and gradation for this lightweight coarse aggregate as shown in Table 10, it is in accordance with ASTM [6], Tables 11 and 12 show the physical properties and chemical analysis of the lightweight crushed coarse thermostone aggregate. Fig. 3.

Table 8
Chemical and Physical Properties of the Lightweight Claystone (Ponza) Coarse Aggregate

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C127-88	1.4	-
Absorption %	ASTM C127-88	4.6	-
Dry loose unit weight, kg/m3	ASTM C29/C29M/97	623	-
Sulfate content (as SO3), %	BS 3797-part 2-1981	0.1	1(max. value)

Table 9
Chemical Analysis of Claystone Coarse Aggregate

Oxides	% by Weight
SiO2	66.41
CaO	4.29
MgO	1.94
SO3	0.1
Al2O3	15.85
Fe2O3	2.87
K2O	1.92
Na2O	2.2
L.O.I	4.26
Total	99.84

Table 10
Gradation of Lightweight Crushed Coarse Thermostone

Limit of ASTM C330-99	Cumulative passing %	Sieve size
90-100	95.2	12.5-mm
40-80	71.34	9.5-mm
0-20	17.3	4.75-mm

Table 11
Properties of Crushed Coarse Thermostone Aggregate

Limits of specification	Test Results	Specification	Properties
-	1.25	ASTM C127-88	Specific gravity
-	45	ASTM C127-88	Absorption %
-	450	ASTM C29/C29M/97	Dry loose unit weight, kg/m^3
1(max.value)	0.3	BS 3797-part 2-1981	Sulfate content (as SO_3), %

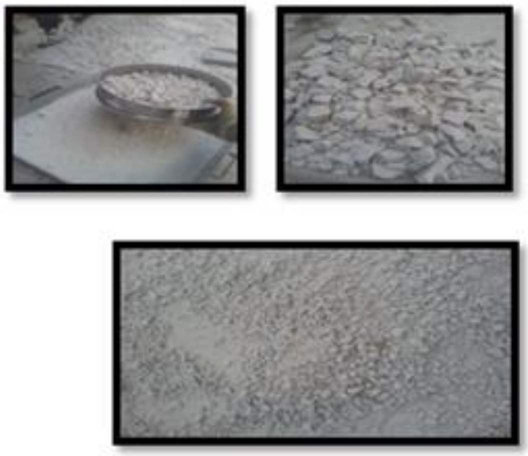


Fig. 3. Stages of Crushing of Thermostone

3-4 Polystyrene

The medium-density of non-compressed cork granules were used in this research, for the purpose of volumetric replacement Fig. 4.

Fig. 4. Polystyrene (or Cork) Used

Table 12
Chemical Analysis of Thermostone Coarse Aggregate

% by Weight	Oxides
46.42	SiO_2
38.44	CaO
3.46	MgO
0.3	SO_3
3.37	Al_2O_3
3.18	Fe_2O_3
4.5	L.O.I
99.67	Total

3-5 Rubber

One of the most modern rubber-based industries is the modern automotive tire industry, where the modern frame is made by mixing hot rubber with auxiliary and other main elements such as sulfur, white zinc, wax, and some laxatives. The car-tires rubber, which is used as normal crushed stone in this research, Fig. 5.

Fig. 5. Rubber from Waste Tires Used

Table 13
Compressive Strength Results of the Different Concrete Mixes

Trail Mix	Cement Content (kg/m³)	W C	Mix Proportion	Av density kg/m³	Compressive strength N/mm²	Slump 25 – 75 mm
1	400	0.38	1 : 1.5 : 3	2408	55.4	18
2	400	0.40	1 : 1.5 : 3	2400	44.6	44
3	400	0.42	1 : 1.5 : 3	2400	43.6	51
4	425	0.38	1 : 1.5 : 3	2400	42	47
5	425	0.40	1 : 1.5 : 3	2367	33.6	65
6	425	0.42	: 1.5 : 3	2400	34.4	60
7	450	0.38	1 : 1.5 : 3	2400	36.1	0
8	450	0.40	1 : 1.5 : 3	2400	42.3	50
9	450	0.42	1 : 1.5 : 3	2403	46.6	54
10	**490**	**0.42**	**1 : 1.31 : 1.79**	**2393**	**47**	**57**

Table 14
Classification of Lightweight Concrete by Compressive Strength

Property	Class and Type		
	I	II	III
	Structural	Structural/ Insulating	Insulating
Compressive strength (MPa)	> 15.0	> 3.5	> 0.5

4 -Water Mixing

The normal drinking water (Tap water) is used for Kirkuk city in the preparation of the mixtures of this study. The same water was also used in the curing of the samples. The pH test was conducted and it was found (7.6) according to **(IQS)** [7].

Mixing percentages

A number of experimental concrete mixtures were 6 cubes for each mixture of different (W/C), precipitation ranging from (25-75) mm of slump test. The mixture was then designed using **(ACI) [8]** (1: 1.5: 3), the results that obtained at 28 days period for standard cubes of (150 × 150 × 150 mm) and using loading rate of (0,3 kN/Sec), the concrete mix of (1: 1.31: 1.79) was selected with cement content of (490 kg/m^3). The highest compressive strength of (47 N/mm^2) was obtained; Table 13 represents the experimental mixtures and their own results.

Experimental Program

After the selection of the best mixing trail, concrete mixtures that cast in various proportions volumetric replacement of coarse aggregates with lightweight coarse aggregates (Ponza stone, crushed thermostone, polystyrene, and rubber) with different volume ratios (25%, 50%, and 75%). Then studying the effect of the replacement of normal coarse aggregates by a crushed lightweight coarse aggregate. The mechanical and physical properties of the mixes were investigated. Three cylinders were casted with dimensions of (150×300) mm for each replacement ratio with reference ratio for compressive strength calculation purpose 3 cylinders with (300×150) mm dimensions for calculating the splitting tensile strength, 3 cylinders for the density measurement and 3 prisms with dimensions of (500 ×100 ×100) mm for calculating modules of rapture.

Hardened Concrete Tests

1- Compressive Strength

Cylindrical specimens of the size (150×300) mm were casted in to conduct the compressive strength tests for each mix according to **(ASTM)** [9]. The compressive strength tests were carried out at the end of 7 and 28 days periods of curing, Fig. 6.

Fig. 6. Compressive Strength Test

2-Splitting Tensile Strength Test

The tensile strength of the resultant mix is decided in terms of the splitting tensile strength. A cylindrical specimen of (150 ×300) mm were casted, the test was conducted according to **(ASTM)** [10], The average of three samples were taken as a representative splitting tensile strength of the mix as shown in Fig. 7.

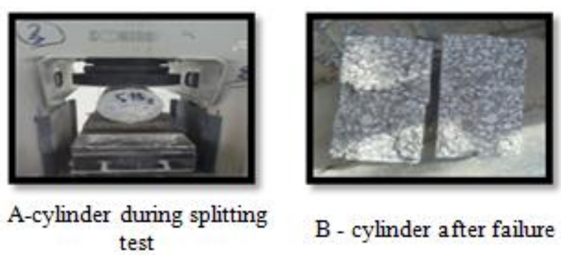


Fig. 7. Splitting Tensile Strength Test

3-Modulus of Rupture Test

Prisms specimens of (100×100×500) mm dimension were casted to determine the flexural strength. The flexural strength tests were carried out at the end of 7 and 28 days periods of curing according to **(ASTM)** [11] The modulus of rapture of any mix has been taken as an average of three prisms strength, Fig. 8.

A-prism during the test B - prism after failure

Fig. 8. Modulus of Rapture Test

4-Density Test

The concrete density is calculated by dividing the specimen weight (in dry saturated condition) up on the specimen volume after the specimen cured with water for 28 days' period. The test was done for a cylindrical concrete models with (150 × 300) mm dimensions and 3 cylinders per mixture.

5-Unit Weight of the Hardened Concrete (Oven Dry Density)

The unit weight of the hardened concrete according to **(ASTM)** [12] was determined, using a cylindrical model with (150 × 300) mm dimensions. After 28 days' period of casting and curing.

Results and Discussion

1- Compressive Strength Test (f'c)

Fig. 9 shows a decrease in the compressive strength with the increase of the light coarse aggregates ratio that compared with the reference ratio. it is logical as areas of the presence of many gaps in the light coarse aggregates. It is possible to give up or neglect a degree of compressive strength in return for a lower weight of concrete, but the decrease should be as low as possible until the compressive strength obtained within the standard field. Thus reducing the self-weight of the origin which is the main objective of the present research.

Also notes through the Fig. 9 low strength at replacement ratio (75%) of the volume of coarse aggregate, this may be happen due to the low percentage of the normal coarse aggregate, so that they bear the bulk load on the model thus increasing the compression strength as it did for other replacement ratios (25%, 50%).There is no uniform classification of LWC according to the compressive strength, but the classification International Federation of Materials testing Laboratories **(RILEM)** [13] is the important classification, covering almost all previous items, Table 14.

2-Splitting Tensile Strength Test (f_t')

Fig. 10 shows the reduction of the indirect tensile strength with the increase of the proportion of the light coarse aggregates. This is due to the light weight of the rough aggregates and the result of the presence of gaps or many porous inside casing a reduction in the specific weight, since rough sand forms a large proportion of the concrete strength this give a certain redaction, in the tensile strength of the concrete, but the concrete is inherently is weak in strength to tensile stresses compared with its strength to compressive stresses. Therefore, reinforcing steel is placed in tensile stresses so as to resist these stresses so this will be neglected because they are little.

The decrease in the tensile strength with the increase of the rough fine aggregates is not particularly significant at the replacement ratios (25, 50%) as in Fig. 10. This is due to the presence of a high percentage of the normal aggregate, which bears the most of the stresses compared with the light aggregates at these replacement ratios, where there is a little difference between the splitting tensile strength of the reference mixture and the splitting tensile strength of the mixtures where the replacement ratios of (25, 50%). The splitting strength for replacing the normal aggregate with 25% of claystone and rubber gave a higher strength than using a thermostone and polystyrene for the same replacement ratio. This means that the internal pores of claystone and rubber are less than for thermostone and polystyrene, therefore it has a higher splitting strength due to few gaps. Non-reinforced concrete tension resistance is less important than compressive strength. Therefore, the structural design is not taken into account because it is very low in contrast to the compressive resistance of the design(f_c'), which represents, therefore, the reinforcement strength (fy) of the reinforcement steel is represented in structural design.

3-Modulus of Rupture Test (f_r)

Flexural strength test shows that the bending resistance of the concrete without rebar where the bending resistance of the concrete is of low value due to the lack of resistance of the concrete to tension as mentioned earlier and is also effected by the quantity of materials that used in the production of concrete. The decrease in the flexure could be seen through Fig. 11 and this is due to the presence of the internal pores in this aggregate. These pores reduce the tolerance of coarse aggregates, which bear the bulk of the aggregate. The concrete resistance to the loads and thus to reduce the bending capacity of the concrete.

The concrete without reinforcing steel and its ordinary materials has a slight resistance for flexure. Therefore, the reduction was slightly lower for the resistance of the flexural between MR1 and other mixtures after the replacement of the usual coarse aggregates with light coarse aggregate and different volume ratios, The bending capacity of the concrete mix, which was replaced by the claystone (M2, M3, M4), which are replaced with the coarse aggregate (25, 50 and 75%), was higher than that of the other concrete mixtures i.e., rubber, thermostone and Polystyrene of percentages (25, 50, 75%), respectively (M5 - M13), this is due to the higher specific weight of the claystone (or Ponza).

The greater flexure capacity of the concrete due to the high bond between the cement paste, the concrete and the rough aggregate, as well as the similarity of the particles of aggregates and the stone and the roughness of their surface, And the cement paste resulted in a higher flexure resistance followed by the substituted mixture with the rubber cutter and then with the thermostone and then the substituted mixture with the cork grains. This is why the cork mixture has less resistant than the rest of the mixtures because of mixing water was reduced to facilitate the integration process.

Test 4-Density

The density of all concrete mixtures, except for the reference mix, with the ratio of light fine aggregates are increased. This is due to the presence of many gaps or pores in the light coarse aggregates. The reason of decreasing is that the coarse aggregates constitute the largest proportion of the percentage of the materials that forming the concrete. The impact on the concrete is great and the low weight of the coarse aggregate greatly reduces the weight of the concrete significantly. Fig. (12) shows the concrete density in the mixtures (bonza and rubber) when is higher than the concrete density in the mixtures of (thermostone and polystyrene). The mixtures (M2, M3, M4, M5, M6 and M7) They have a higher weight than the specific weight of the crushed thermostone aggregate, and the light coarse mixture (M8, M9, M10, M11, M12 and M13) except the reference mixture.

Oven Dry Density) (5- Unit Weight of Hardened Concrete

The weight or the dry density unit was reduced due to the increase of the light coarse aggregates percentage. Previous notes are also observed through low dry density in the oven mixtures (M8-M13), larger than dry density drop for mixtures (M2-M7). This is because of the difference in the specific weight between the light coarse aggregates, as the specific weight of the lightweight claystone aggregate greater than the specific weight of rubber, thermostone and Polystyrene those found in other mixtures except for the reference mixture. The gradient of the coarse aggregate also has a great effect on the density value. Higher gradient, means higher density. The concrete mortar is suitable to avoid insulation and homogeneity of the concrete materials during mixing. Density has been decreased but it didn't reach a low level.

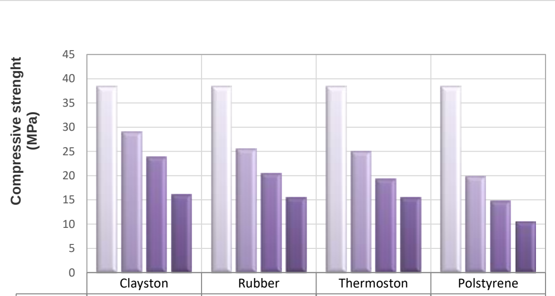
It is noted that the mixtures (M2, M5, M8 and M11), which represent the replacement ratio (25%) of the normal coarse aggregates were densely close to the concentration of the reference mixture compared with the other mixtures. The coarse aggregate in general represents a large proportion of the weight of the total concrete so did not affect these mixtures density so much.

RILEM [13] classification is the most comprehensive of all types of researchers, this classification states that the highest dry density for light concrete is (2000) kg/m^3. Light concrete is also classified according to its density. Light concrete with density (1600-2000 kg / m^3) is a lightweight construction concrete, light concrete with a density of less than (1600 kg / m^3) and equal or greater than (1450) kg/m^3 is a lightweight insulating concrete, and concrete of less than (1450 kg / m^3) is a light insulating concrete [14], [15].

It is noticed that the concrete in the mixtures (M1, M2, M5 and M8) is not a light concrete but is a normal concrete. Concrete in mixtures (M3, M4, M6, M9, and M11) is a lightweight construction concrete, and concrete in mixtures (M10, M12 and M7) is a lightweight building concrete, and concrete in the mixture (M13) is a light insulating concrete.

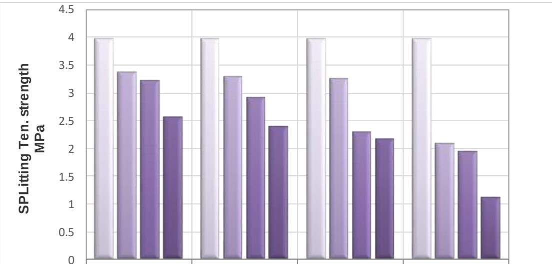
Conclusions

1. Using light coarse aggregate as a partial replacement for normal coarse aggregate this could reduce the concrete weight due to the low concrete density due to increasing the replacement ratios.
2. Applying light coarse aggregate reduces the compressive strength, splitting tensile strength, flexural strength and bending resistance of concrete for age of 7 and 28 days due to its weak strength and weak structure.
3. Increase the absorption ratio when the percentage of light coarse aggregates increase in concrete mixtures.
4. The possibility of using industrial waste from industrial cork and construction waste from the rubble of the thermostone and parts of rubber tires that consumed after recycling in useful areas. It is found that polystyrene are the most available, lowest cost and best heat insulation.
5. Replacing the normal coarse aggregates with clay stones (25, 50 and 75) %, compressive strength was obtained between (16.12-28.99) MPa, tensile strength between (2.56-3.37) MPa, flexural strength between (4.84-6.83) MPa, density between (1835.8-2287.5) kg\m^3, oven dry density (1715.5-2177.58) kg\m^3.
6. Replacing normal coarse aggregates with Rubber (25, 50 and 75) %, the obtained compressive strength is between (15.47-25.47) MPa, tensile strength between (2.39-3.30) MPa, Flexural Strength between (4.22-6.67) MPa, density between (1774.4-2164.8) kg\m^3, oven dry density (1598.4-2044.8) kg\m^3.
7. Replacing the normal coarse aggregates with Thermostone (25, 50 and 75) %, the obtained compressive strength is between (15.47-25.01) MPa, tensile Strength between (2.15-3.26) MPa, flexural strength between (3.98-6.47) MPa, density between (1755.8-2146.8) kg\m^3, oven dry density (1580.4-2026.8) Kg\m^3.
8. Replacing the normal coarse aggregates with polystyrene (25, 50 and 75) %, the obtained compressive strength is between (10.66-19.84) MPa and tensile strength between (1.12-2.09) MPa, flexural strength between (3.6-5.75) MPa, density between (1665.5-2023.8) kg/m^3, oven dry density (1440.5-1913.8) kg\m^3.
9. The best concrete mix was (M7, M10) of less density (1598.4 kg/m^3) and (1580.4) kg / m^3 and compression strength within the permissible limits (15.47) MPa.



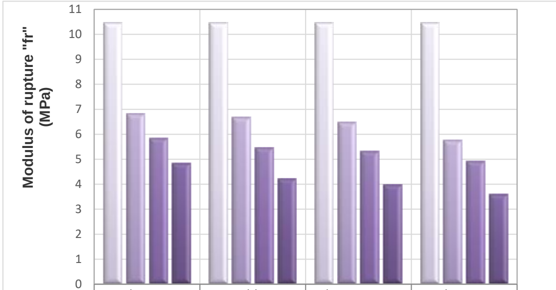
	Clayston	Rubber	Thermoston	Polstyrene
Refrence	38.44	38.44	38.44	38.44
25%	28.99	25.47	25.01	19.84
50%	23.85	20.46	19.33	14.71
75%	16.12	15.47	15.47	10.66

Fig. (9): Compressive Strength Test Results for All Mixes



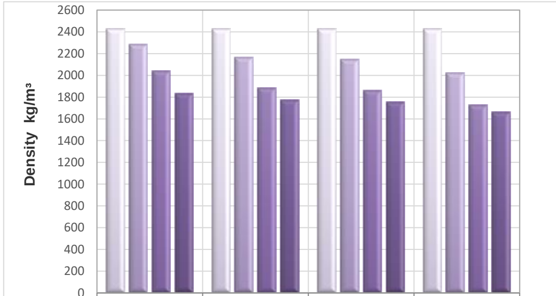
	clay ston	Rubber	Thermoston	Polystyrene
Refrence	3.969	3.969	4	3.969
25%	3.37	3.3	3.26	2.097
50%	3.21	2.91	2.29	1.95
75%	2.564	2.39	2.158	1.122

Fig. (10): Results of the Splitting Tensile Strength Test for All Concrete Mixtures



	Clayston	Rubber	Thermostone	Polystyrene
Refrense	10.467	10.467	10.467	10.467
25%	6.83	6.677	6.476	5.753
50%	5.84	5.461	5.33	4.93
75%	4.84	4.229	3.989	3.606

Fig. (11): Modulus of Rupture for Different Mixes



	Rubber	clayston	Thermoston	polystyrene
Refrence	2426.41	2426.41	2426.41	2426.41
25%	2287.58	2164.8	2146.8	2023.8
50%	2043.3	1887.13	1860.15	1730.2
75%	1835.5	1774.4	1755.8	1665.5

Fig. (12): Shows the Densities of All Mixtures

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