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Development of Green Lightweight Concrete Using Pozzolanic Aggregates: Evaluation of Physical and Mechanical Properties

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□ ABSTRACT □

Concrete is considered one of the most widely used building materials in the world, but it is known to have a significant environmental impact due to the high carbon emissions associated with cement production. This research highlights the possibility of producing lightweight and sustainable concrete by replacing cement with natural pozzolana in the binder mixture in proportions ranging from (10-50%) with a complete change in the aggregate structure according to three groups, including pozzolanic gravel and sand or basaltic gravel. It discusses their effects on the physical and mechanical properties of the resulting concrete.

The study has shown that the pozzolanic aggregate structure with ground pozzolana used in the binder mixture, which reduces the carbon footprint of the concrete by using less cement, improves the physical properties of the concrete represented by workability and absorption capacity due to the low water demand of ground pozzolana. The results of absorption measurements showed that increasing the replacement percentage of cement with natural pozzolana in the binder mixture leads to a decrease in absorption in all mixtures at a replacement percentage of 50%, achieving percentages of (5.4, 11.3, 15.1%) for the first group (natural gravel and silica sand), the second group (pozzolanic gravel and basalt sand), and the third group (gravel and pozzolanic sand) respectively.

As for the mechanical properties represented by the compressive strength at 28 days, we notice a decrease when replacing cement with pozzolana due to the lower efficiency factor of ground pozzolana. However, the value of this resistance did not fall below the minimum limits of the standard specification for cement blocks, allowing the production of lightweight and environmentally friendly cement blocks using natural materials.

Keywords: Sustainable materials, Natural pozzolana, Basalt sand, Workability, Impregnation, Resistance to slight pressure.

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تطوير خرسانة خضراء خفيفة الوزن باستخدام حصويات بوزولانية: تقييم الخصائص الفيزيائية والميكانيكية.

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□ ملخّص □

تعتبر الخرسانة واحدة من أكثر مواد البناء استخداما في العالم ، ولكن من المعروف أن إنتاجها له تأثير بيئي كبير بسبب انبعاثات الكربون العالية المرتبطة بإنتاج الأسمنت. يسلط البحث الضوء على إمكانية إنتاج خرسانة خفيفة الوزن ومستدامة وذلك باستبدال الاسمنت بالبوزولانا الطبيعية في العجينة الرابطة بنسب تتراوح بين(١٠-٥٠٪) مع تغيير كامل للهيكل الحصوي وفق ثلاث مجموعات تتضمن حصى ورمل بوزولانية او بازلتي ويناقش تأثيرها على الخصائص الفيزيائية والميكانيكية للخرسانة الناتجة.

لقد اثبتت الدراسة أن الهيكل الحصوي البوزولاني مع البوزولانا المطحونة المستخدمة في العجينة الرابطة والتي تقلل من البصمة الكربونية للخرسانة الناتجة من خلال استخدام اسمنت اقل فيها، يحسنان الخواص الفيزيائية للخرسانة المتمثلة بقابلية التشغيل والتشرب نظراً لان البوزولانا المطحونة طلبها للماء منخفض. حيث أظهرت نتائج قياس التشرب انه بزيادة نسبة استبدال الاسمنت بالبوزولانا الطبيعية في العجينة الرابطة يؤدي الى انخفاض التشرب في جميع الخلطات عند نسبة استبدال ٥٠٪ حيث حققت نسبة (٥.٤، ١١.٣، ١٥.١) % لكل من المجموعة الأولى(حصى طبيعي ورمل سيليسي) والثانية(حصى بوزولاني ورمل بازلتي) والثالثة(حصى ورمل بوزولاني) على التوالي.

اما بالنسبة للخصائص الميكانيكية المتمثلة بالمقاومة على الضغط البسيط عند عمر ٢٨ يوم نلاحظ انخفاضها عند استبدال الاسمنت بالبوزولانا ويعود السبب في ذلك الى انخفاض معامل الفعالية للبوزولانا المطحونة ولكن قيمة هذه المقاومة لم تتجاوز الحدود الدنيا للمواصفة القياسية الخاصة بالبلوك الإسمنتي، مما سيسمح بتصنيع بلوك اسمنتي خفيف و صديقة للبيئة وباستخدام مواد طبيعية.

الكلمات المفتاحية: مواد مستدامة, بوزولانا الطبيعية, رمل بازلتي, قابلية التشغيل, التشرب, الموصلية الحرارية, مقاومة على الضغط البسيط

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1 Introduction:

Concrete is a versatile and durable building material widely used in various applications, including buildings, bridges, roads and infrastructure. However, concrete production is known to have a significant environmental impact due to the high carbon emissions associated with cement production [24]. Cement, the main component in concrete, is produced by heating limestone and other raw materials to high temperatures [2], which releases large amounts of carbon dioxide into the atmosphere [4]. In recent years, there has been an increasing interest in developing sustainable concrete solutions that reduce the environmental impact of concrete production while maintaining its performance and durability [11].

One promising method for producing sustainable concrete is using natural materials such as pozzolana [6], which can be defined as siliceous and aluminum materials that do not individually have binding qualities but when finely ground. In the presence of water, they react chemically with the presence of calcium hydroxide Ca(OH)2 at normal temperatures to form compounds with binding properties. Pozzolana may be found in nature as volcanic ash opaline shales, rock trays (cherts), or artificially prepared such as burnt clay and coal ash. It is provided that the silicates contained in pozzolana are amorphous because the effectiveness of crystalline silicic oxides is low. Pozzolan materials reduce the rate of rapid acquisition of resistance to concrete in the early times and increase it in the late age, reducing the speed of rehydration heat emission.[1]

Previous studies have shown the benefits of using pozzolanic pebbles in concrete production. Pozzolanic substances react with calcium hydroxide in the presence of water to form calcium silicate gel, which improves the microstructure and strength of concrete. Previous research has shown the importance of using natural pozzolana as a substitute for siliceous sand in producing lightweight cement mortar with a resistance to simple pressure ranging from (170-400 kg/cm^2) and lower density (1920 kg/m^3). The results showed that using natural pozzolana offers a set of features, the most important of which is reducing the density of the mortar and then producing a light mortar that can be used in structural elements when its resistance increases over simple pressure.170 kg/cm^2 [16].

Some researchers have studied the effect of replacing Portland Cement with ground pozzolana on the simple pressure resistance of bituminous cubes with dimensions of 15*15*15 cm, where different replacement ratios of 10%, 20%, 30%, and even 50% have been studied. The further increase in replacement led to an increase in compressive strength until the maximum strength was reached when replacing OPC by 30%, and with an increase in this percentage, the resistance on simple compaction decreased, and it was also noticed that the strength of concrete increases with age [19] as in the figure(1):

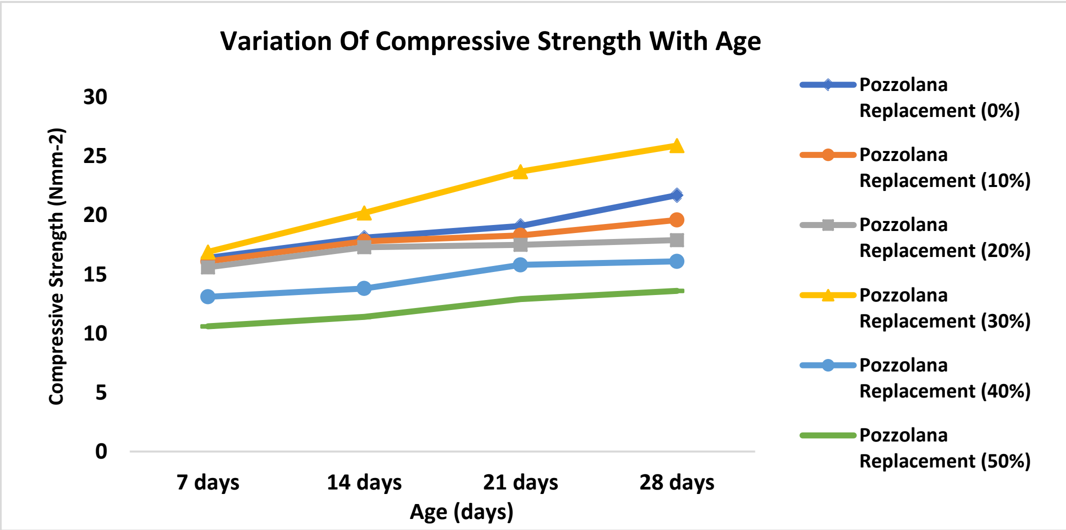

Fig. 1. Change in resistance values on simple pressure with age for different replacement ratios [19].

Pozzolanic aggregates can also reduce the carbon footprint of concrete production by replacing part of the cement in concrete mixtures. The output of pozzolanic materials usually requires less energy and emits fewer greenhouse gases compared to cement production[17, 10], where the use of natural pozzolana reduces the carbon dioxide emissions associated with the production of Portland Cement, replacing Portland Cement by 50% with natural pozzolana means reducing greenhouse gas emissions in cement production by half [13].

Some researchers conducted a study on the potential of using pozzolan from natural source in Algeria as pozzolanic material. This pozzolan is rarely used in concrete due to the absence of a thorough study of its properties. In order to gain more knowledge on the efficiency of pozzolan concrete, six concrete mixtures: one specimen with Portland cement (control) and five mixtures with 10%, 20%, 30%, 40%, and 50% of replacement of cement by pozzolan were tested. Crushed pozzolan was used as lightweight aggregate (LWA) and natural sand was used in all mixes to produce a lightweight aggregate concrete (LWAC) [10].

Fresh concrete mixtures were tested for workability and density. While for the hardened concrete specimens, compressive strength, splitting tensile strength, and flexural strength were determined after 3, 7, 28, 90 and 365 days. A total cementitious materials content of 400 kg/m^3 was maintained invariant in all the concrete mixtures. The concrete mixtures were designed for a constant workability expressed with a measured slump of 5±1 cm.

The results of this study suggest that the use of pozzolan at 20% of the weight of cement produces the highest strength increase of the mixtures that were tested [10].

Based on these results, the use of natural pozzolan leads to a low-cost concrete compared to concrete made of artificial lightweight materials such as expanded clay, where the study found that low-cement concrete (LCC) with the addition of natural pozzolan as a fly ash substitute improves mechanical properties and enhances durability. Specifically, concrete with pozzolana provided 50% better protection against steel corrosion than concrete with fly ash [21].

As for the thermal and mechanical properties of concrete containing pozzolanic materials as a partial substitute for natural materials, the results of studies indicated that the use of pozzolana materials improves the thermal and mechanical properties of concrete, making it a viable option, especially in lightweight concrete [7].

2 Purpose and significance of the research:

The research aims to study the replacement of both Portland Cement with ground pozzolana according to different replacement ratios (50%,30% ,10%) and the study their influence on the physical and mechanical properties of concrete and the objectives of the research can be summarized as follows:

1. Study the properties of the resulting lightweight green concrete through impregnation, operability, and resistance to simple pressure and compare these results with conventional concrete

2. To study the nature of the relationship between pozzolanic pebbles and natural pozzolana used as a substitute for Portland Cement, with the study of the effect of replacing natural sand with basalt sand and pozzolanic sand on the properties of the resulting concrete.

The importance of research comes in the production of light concrete (manufactured from natural pozzolana), which is characterized by the following [5, 3]:

- Reducing dead loads in concrete and associated structures by reducing the percentage of reinforcement used, will positively reflect on economic savings.
- Better behavior when earthquakes occur, as seismic loads are proportional to dead loads.
- Providing residential comfort and reducing heating and cooling costs as light concrete can insulate
- Thermal and sound absorption more than in the case of ordinary concrete.
- Reducing the vertical and lateral pressure on the casting molds reduces the cost of mold manufacturing work.
- Reducing the structural damage and risks resulting from the occurrence of fires due to the durability of light concrete in high grades compared to ordinary bitumen.

We add to this the possibility of benefiting from the natural pozzolana, which is a local wealth, as there are hills of it in the southern region and other areas of Syria, where the use of sustainable materials is crucial to reduce the environmental impact of construction and promote a more sustainable future. However the availability and cost of these materials is often a challenge. Therefore, emphasis is placed on materials from local sources, such as pozzolan pebbles, which can be used in building elements and contribute to reducing negative impacts on the environment and reducing construction costs without changing the properties of building elements.

3 Research methods and materials:

The research was based on a theoretical study of the types of light pebbles available in Syria, according to the General Organization for Geology [25]. Some studies and experiments that dealt with the study of light concrete were used to enrich this experimental research, which was conducted in the laboratories of the faculty of civil engineering at Tishreen University using light local materials (pozzolana and natural Basalt) in 2024.

To verify the possibility of producing lightweight and sustainable concrete using pozzolan pebbles and sand with the replacement of cement with ground pozzolana, a series of laboratory experiments were conducted, in which various concrete mixtures were prepared using varying proportions of pozzolan pebbles, basalt sand, conventional cement, and gravel. Then, the mechanical and physical properties of the resulting concrete mixtures were tested, including compressive strength, operability, and impregnability. The performance of concrete mixtures containing different proportions was compared with the performance of conventional concrete mixtures to assess the effectiveness of pozzolana in the production of eco-concrete.

The addition of different types of sand, such as natural sand and basaltic sand, allows for further customization and specificity in certain applications. Each type of sand has its own unique properties, such as grain size, shape, color, and composition, which can affect its performance in various tasks or projects.

For example, natural sand is typically composed of quartz or silica [22] and is commonly used in construction, and concrete production. It is known for its uniformity and versatility, making it a popular choice for a wide range of applications.

On the other hand, basaltic sand is made from basalt rock, which is a dense, fine-grained volcanic rock known for its durability and strength [19]. Basaltic sand is commonly used in pavement construction, road building, and erosion control due to its high frictional properties and resistance to wear and tear.

The research adopted the experimental methodology regarding the study of natural pozzolana pebbles and concrete samples manufactured from pozzolana pebbles and sand, and the analytical and mathematical methods for studying the change of mechanical and physical indicators with the proportions of replacement of Portland Cement with crushed pozzolana and natural pebbles and sand with pebbles, pozzolana sand and Basalt. for this purpose, Concrete samples of all mixtures were subjected to physical and mechanical tests.

3.1 Preparations

A sufficient amount of natural pozzolana was brought from the site of Tel Shihan, located about 70 km southeast of Damascus and 15 km northwest of Sweida governorate, and it is of volcanic origin [8], containing the following principal oxides: ($SiO2$: 44.9%, $Al2O3$: 16.5%, $Fe2O3$: 8.9%, CaO: 9.6%, MgO: 8.4% and alkali oxides: 4.4%). The mineral analysis of natural pozzolana was carried out by XRD Technology to characterize it and use it in manufacturing laboratory samples [9]. Table No. (1) shows the results of measuring the apparent and solid volumetric weights and the percentage of impregnation for natural pebbles and pozzolan pebbles used in the manufacture of concrete cube models:

Table 1. Results of measuring the apparent and solid volumetric weights of the tested pebbles

The sample	Solid volumetric mass kg/l	Virtual volumetric mass kg/l
Pozzolanic Gravel	1.728	0.705
Pozzolanic Sand	2.32	1.257
Basalt Sand	2.374	1.127
Fine Sand	2.55	1.338
Coarse Sand	2.68	1.57
Natural Gravel	2.74	1.439

The sand equivalent values for the types of sand used were 85 for fine siliceous sand originating from nabk, 68 for coarse calcareous sand, pozzolan sand 84, and Basalt sand 88. Ordinary portland cement of Type 1 and class 32.5 from the Tartus plant was used for pouring concrete. figure (2) shows the different types of fine and coarse gravel, cement, Basalt and pozzolana used in mixtures:

Fig. 2. Materials used in concrete mixtures.[22]

3.2 Design of concrete mixtures

To prepare laboratory models of green concrete, it was necessary to design the mixture based on the results of the grain gradient of natural and pozzolan Pebbles; the French method of design (Dreux-Goriss) was adopted. Below, we show the stages of designing these mixtures and the final proportions obtained for various mixtures. 12 concrete mixtures divided into three groups were adopted with different replacement ratios for each of the pebbles (natural and pozzolanic) in addition to replacing cement with ground pozzolana in the following weight ratios (10%,30%,50%) concerning replace siliceous sand with pozzolanic and basaltic sand. Figure (3) shows the grainstone gradient curves used in concrete mixtures:

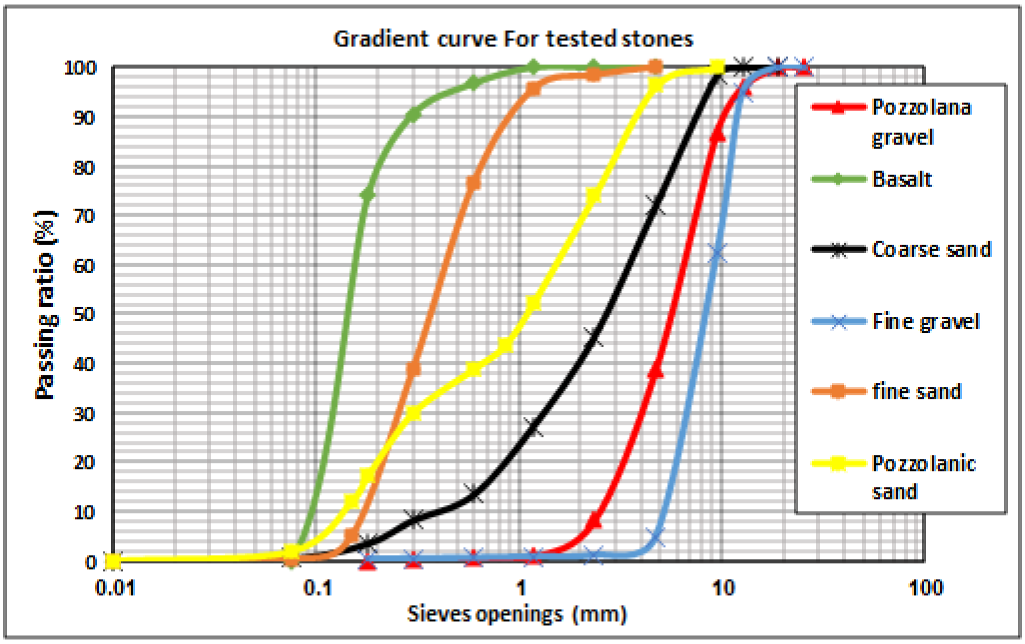

Fig. 3 . Grain gradient curve for the tested pebbles [26]

Below, we show the composition of some of these mixtures:

- The mixture (NC) comprises 100% Portland cement and natural pebbles.
- The mixture ($GCP_{10\%}$) consists of: 90% Portland cement, 10% pozzolana, and natural pebbles.
- The mixture (NCP) consists of: 100% Portland cement, pozzolan gravel, and basalt sand.
- The mixture ($GCP_{P10\%}$) consists of : 90% Portland cement, 10% pozzolana, pozzolan gravel and basalt sand.
- The mixture (NC_{PS}) consists of: 100% Portland cement, pozzolan gravel, and pozzolan sand.
- The mixture ($GCS_{P10\%}$) consists of: 90% Portland cement, 10% pozzolana, pozzolana gravel and pozzolana sand.

It turns out Tables (2 and 3 and 4) of the results of the design of concrete mixtures:

Table 2. Results of designing mixtures for the first group for **1m³**

Mixture components (kg/m³)	**Mixtures of the first group**			
	NC	**$GCP_{10\%}$**	**$GCP_{30\%}$**	**$GCP_{50\%}$**
Normal average stones	1042	1042	1042	1042
Fine sand	366	366	366	366
Lenticular coarse sand	385	385	385	385
Pozzolana	0	35	105	175
Cement	350	315	245	175
water	210	210	210	210

Table 3.Mixture design results for the second group for 1 m³

Mixture components (kg/m^3)	Mixtures of the second group			
	NCP	GCP$_{P10\%}$	GCP$_{P30\%}$	GCP$_{P50\%}$
Lenticular coarse sand	385	385	385	385
Pozzolana	0	35	105	175
Cement	350	315	245	175
Water	210	210	210	210
Pozzolanic gravel	658	658	658	658
Basalt sand	340	340	340	340

Table 4.Mixture design results for the third group for 1 m^3

Mixture components (kg/m^3)	Mixtures of the third group			
	NC$_{PS}$	GCS$_{P10\%}$	GCS$_{P30\%}$	GCS$_{P50\%}$
Pozzolanic sand	666	666	666	666
pozzolana	0	35	105	175
Cement	350	315	245	175
Water	210	210	210	210
Pozzolanic gravel	658	658	658	658

In the mixtures of the first group, pozzolana was used only in the bonding dough, where a decrease in resistance to pressure was observed when performing the substitution process and this was explained by a decrease in the effectiveness of pozzolana.

As for the second and third groups, pozzolana was used in the bonding paste and as a light gravel, which contributed to improving the operability and reducing the density of concrete.

The reason for studying these parameters together is to reduce the use of Portland cement in concrete, which is reflected positively on the environment by reducing carbon dioxide emissions in addition to reducing the density of concrete to make it lightweight, as the removal of carbon from the concrete structures sector is a priority due to the world climate. Since Portland Cement is responsible for about 7% of anthropogenic emissions worldwide, it is necessary to partially replace it with products with a lower environmental impact. Fly ash has become very much in demand, due to its proven advantages, however, developed countries have announced its end, which prompted us to think about other alternatives [23].

4 Results and discussion

In pouring concrete mixes, we relied on manual mixing, where each component of the dry mix was weighed independently, and then; the molds were poured with dimensions (10*10*10 cm), unscrewed the samples the next day, and put in water for 28 days.

The samples were poured into molds in two layers using the shaking table. Then, leveling the surfaces of the samples in preparation for their subsequent preservation in water as in the figure(4):

Fig. 4a Casting the first group of samples

Fig. 4b Casting of second group samples

Fig. 4c Casting of third group samples

Fig. 4 . Mold casting of samples[26]

The samples were taken out of the water after 28 days and the necessary tests were performed on Figure (5) shows the porous appearance of concrete, the reason for this is due to pozzolan gravel and sand, which belongs to porous sedimentary rocks, in which the size of the porous voids reaches 50% of its total volume and are in the form of channels with openings ranging from 3.0 to 0.8 mm [23]:

Fig. 5 . Removing samples from the water in preparation for testing

The following are the results obtained after conducting physical and mechanical tests.

4.1 Physical properties of concrete

These characteristics included the apparent volumetric weight, impregnation, and landing using a special measuring cone called the Abrams cone to determine the operability of the concrete, its composition, and the percentage of water to be added to the cement. Table (5) shows the values of the measured drop on various mixtures with the volumetric weight of the light concrete and the degree of impregnation.

Table 5. Results of measurement of subsidence on various mixtures with volumetric weight of Light concrete and degree of impregnation

Mixture	Apparent volumetric weight (kg/m^3)	Degree of impregnation %	Concrete slump (cm)
NC	**2277**	**6.09%**	**16**
$GCP_{10\%}$	**2247**	**6.08%**	**15**
$GCP_{30\%}$	**2215**	**5.76%**	**14.5**

Mixture	Apparent volumetric weight (kg/m³)	Degree of impregnation %	Concrete slump (cm)
$GCP_{50\%}$	2207	5.17%	13
NCP	1715	13.55%	8
$GCP_{P10\%}$	1664	13.62%	5
$GCP_{P30\%}$	1419	12.73%	4
$GCP_{P50\%}$	1313	10.19%	2.5
NC_{PS}	1205	16.18%	2
$GCS_{P10\%}$	1178	14.04%	4
$GCS_{P30\%}$	1160	13.67%	6
$GCS_{P50\%}$	1100	13.15%	7

4.1.1 The effect of replacement on the change in concrete density:

Figure (6) shows the impact of changing the ratio of replacing Portland cement with natural pozzolana in the binding dough for the three groups.

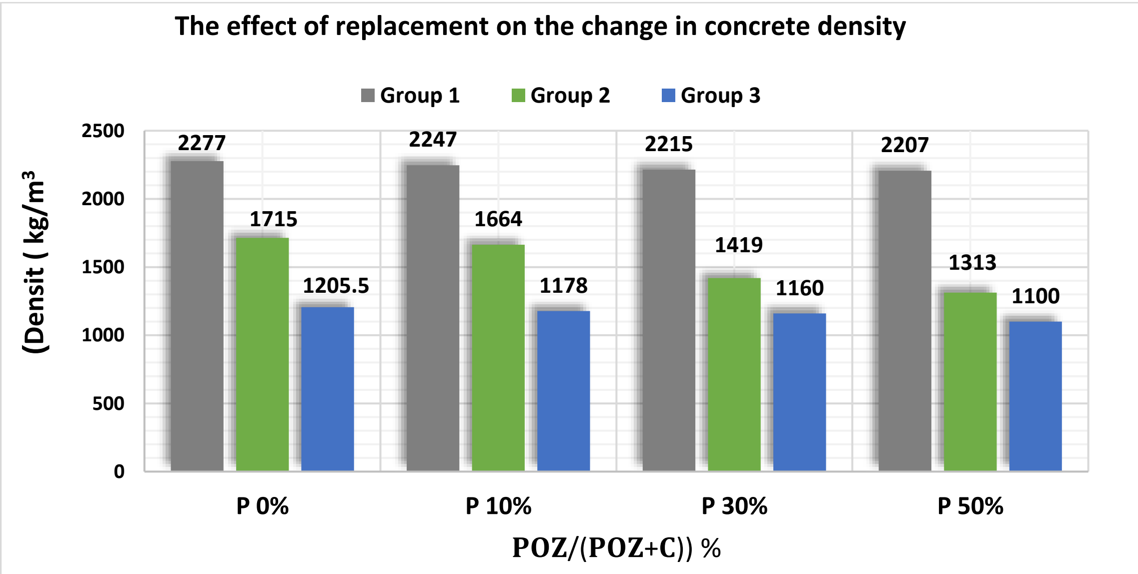

Fig. 6 . Change in replacement ratio on concrete density.

Increasing the percentage of cement replacement with pozzolana in the binding paste leads to a decrease in the volumetric weight of the concrete, as it achieved the lowest weight at a replacement rate of 50% for all mixtures. We also note that the mixtures containing gravel and pozzolanic sand (mixtures of the third group) achieved the lowest volumetric weight, and the reason for this is the low density of pozzolana compared to natural gravel, This is consistent with a study conducted to determine the mechanical properties of lightweight concrete, where the results showed that concrete samples containing crushed pumice aggregate (coarse and fine) had a lower density than the reference concrete sample containing gravel aggregate because of the high gravity [24].

4.1.2 The effect of substitution on the change of concrete texture represented by the slump test:

The figure(7) shows the severe impact of the consistency of concrete when replacing its natural pebbles with pozzolan pebbles and siliceous sand with basalt sand, with the stabilization of the ratio of water to cement W/C=0.6, as the samples came out of the plastic texture slide slump>4cm to the rigid texture slide slump<4cm at a replacement ratio of 30% of cement with pozzolana for mixtures of the second group, due to the gluttony of Basalt to water, we also note the reduced operability of mixtures when using sand pozzolana as a substitute for natural sand with pozzolana pebbles without replacing cement with pozzolana as in the mix (NCPS) but with an increase in the replacement rate, we notice an improvement in operability where The samples came out of the rigid texture segment to plastic at a replacement rate of 10%, as in the mixture (GCSP10%), i.e. replacing cement with pozzolana improves the operability when changing the gravel structure from natural pebbles to pebbles and pozzolana sand. This may attributed because the crushed pozzolana does not enter into the rehydration reaction directly, as in cement, but needs a medium, namely live lime, so its water demand is less.

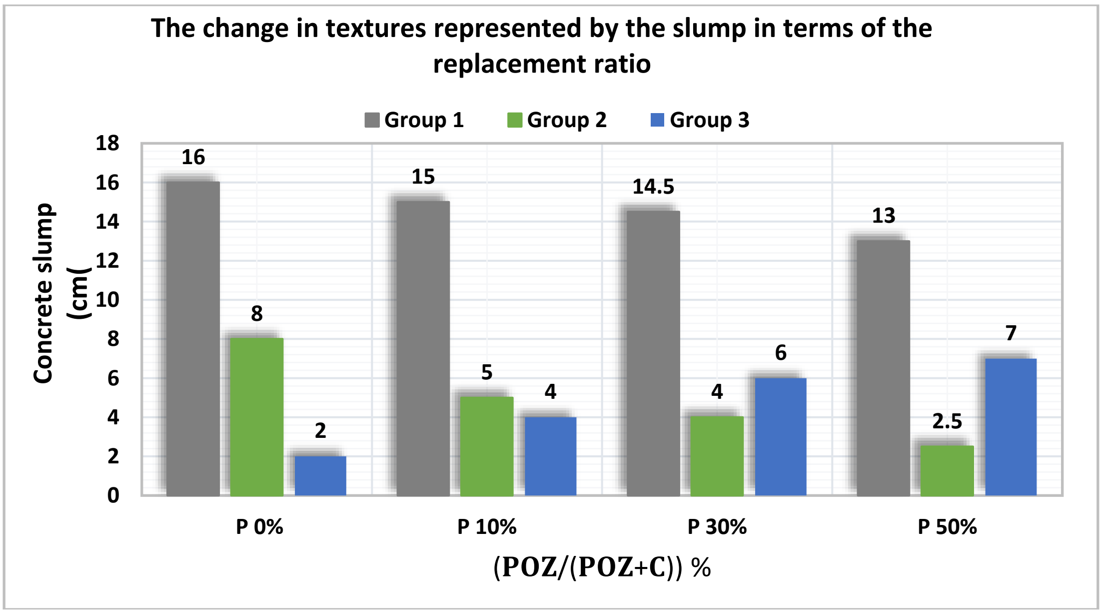

Fig. 7 . The change in textures represented by the slump in terms of the replacement ratio

4.1.3 The effect of substitution ratios on the maximum water absorbs

Figure (8) shows the relationship between the maximum water saturation and the proportions of cement substitution with pozzolana for the three concrete mixtures:

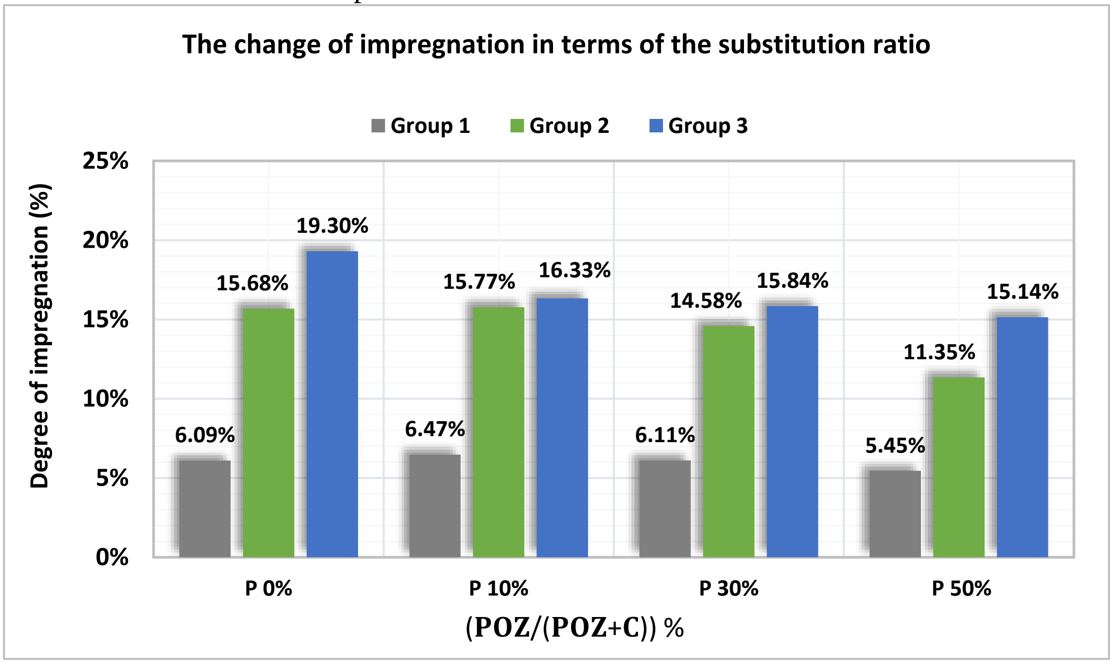

Fig. 8 . The change of impregnation in terms of the substitution ratio

Samples record an increase in their absorbing when replacing natural pebbles with pozzolan pebbles by 7.46% for samples manufactured from pozzolan pebbles and Basalt sand and by 10% for samples manufactured from pozzolan pebbles and sand due to the gluttony of pozzolan Pebbles for water, which contain vacuum pores in their composition[23], and therefore the engineer will need when using these pebbles to take care of the issue of exposure to water by tact without neglecting the good mix design, which is supposed to achieve the greatest compactness and less porosity, which will result in a limited absorbs, however, we note that Increasing the replacement rate of cement leads to a decrease in impregnation, where the lowest percentage of impregnation was achieved at a replacement rate of 50% for all mixtures, where the degree of impregnation decreased by (15.2%, 24.8%, 18.7%) for each of the first, second and third group of mixtures, respectively.

4.2Mechanical properties of concrete:

4.2.1 The change of resistance on a simple pressure in terms of replacement ratios

To determine the compressive strength of concrete samples at the age of (28 days), we applied a force to its surface, where the resistance to the simple pressure of the samples is calculated by calculating the pressure force that leads to the failur of the sample and calculating the surface exposed to that force The table (6) shows the results of the simple compressive strength of concrete samples:

Table 6. Results of measuring compressive strength compression of concrete mixtures

The mixture	$\left(\frac{POZ}{POZ + C}\right)\%$	compressive strength **kg/ cm²**
NC	0	330
$GCP_{10\%}$	10	244
$GCP_{30\%}$	30	180
$GCP_{50\%}$	50	162
NCP	0	143
$GCP_{P10\%}$	10	132.5
$GCP_{P30\%}$	30	112.5
$GCP_{P50\%}$	50	77.5
NC_{PS}	0	41
$GCS_{P10\%}$	10	44
$GCS_{P30\%}$	30	59
$GCS_{P50\%}$	50	76.5

We represented the relationship between the cubic resistance of the cast samples (10*10*10 cm) at simple pressure and the replacement ratios as follows, as shown in the figure(9):

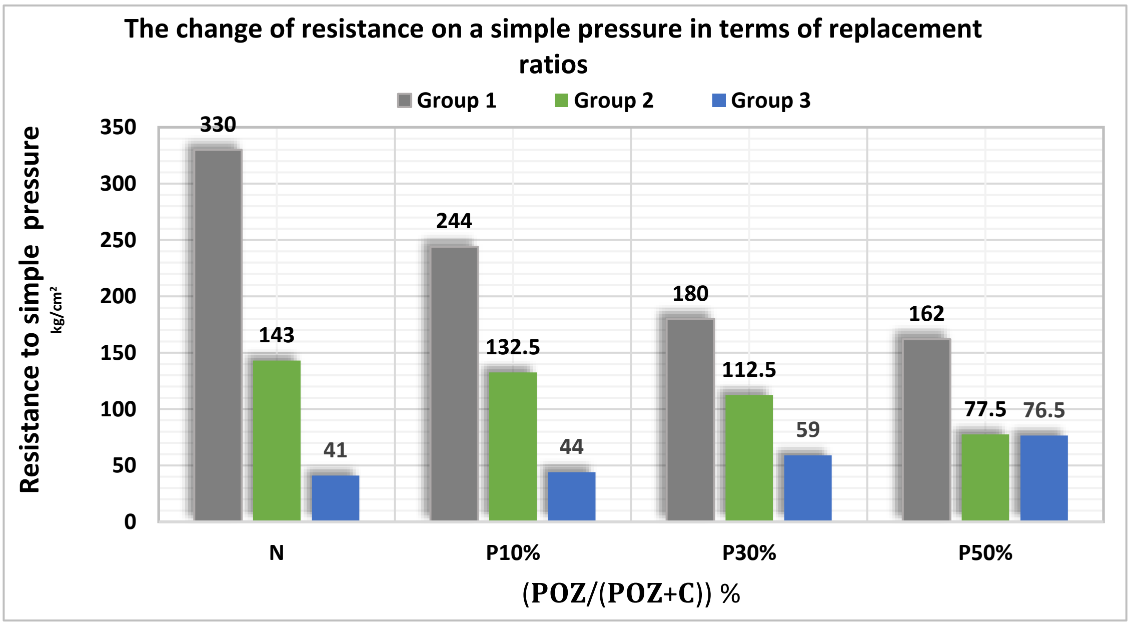

Fig. 9 . The relationship between the simple pressure resistance of concrete and the replacement ratios

The coefficient of effectiveness of ground pozzolana is lower than cement. As a result, the resistance to simple pressure decreases when replacing cement with pozzolana, as in the mixtures of the first group(Natural pebbles) and the second(pozzolana pebbles with basalt sand), except for the third group containing pozzolana pebbles and sand, where with the replacement of 50% of cement with pozzolana, the resistance to simple pressure increases by more at 46.4%, and the reason for this is pozzolana sand, as the particle size and distribution also on the compressive strength of concrete, the appropriate size and distribution of pozzolan sand particles helps facilitate the wetting process and increases the overall strength of concrete, unlike sand The Basalt used in the samples of the second group.

The particle size of pozzolan Pebbles is important because the microparticles have a larger surface area and can react more effectively with calcium hydroxide. Mixing different pozzolan materials can also adjust the properties of concrete, such as permeability and resistance to chemical attack, as well as the use of basalt sand as a substitute for siliceous fine sand in light concrete to reduce the environmental impact of concrete production, as we note that the size of basalt sand particles affected the strength of concrete, as smaller particles lead to higher compressive strength, but increase the cohesion of the mixture and reduce porosity, which negatively affects the physical properties of thermal conductivity.

The results of the current study are consistent with the results of the studies [7, 10, 14, 21], which confirmed the contribution of red pozzolan aggregate to reducing the density of concrete, while all mechanical properties also decreased. The reason for this is the vacuum structure of the pozzolanic aggregate and its low density compared to the coarse aggregate of limestone.

5 Conclusions and recommendations

In light of these results obtained by us of the effect of replacing Portland Cement with ground pozzolana and natural pebbles with pozzolanic and Basalt pebbles on the physical (workability and impregnability) and mechanical (resistance to minor pressure) properties of the produced concrete to reduce the environmental footprint the following points can be recorded as conclusions of this research:

- With an increase in the percentage of replacement of cement with pozzolana, the workability of concrete improves, and this may attributed because the crushed pozzolana does not enter into the rehydration reaction directly as in cement but needs a medium, namely live lime, and therefore its water demand is less.
- Resistances on simple pressure decrease with increasing proportions of cement replacement with ground pozzolana in mixtures.
- The replacement of natural gravel with pozzolana in the gravel structure leads to a decrease in the volumetric weight of concrete, as it achieved the lowest weight in mixtures containing pozzolanic gravel and sand with a 50% replacement of cement with pozzolana .
- Pozzolanic pebbles give acceptable values of resistance to minor pressure when used in concrete, which offers a wide scope for thinking about using them in civil facilities as an insulating and environmentally friendly concrete with low costs due to the removal of a large section of the paste cement bonded to the ground pozzolana.
- The resistance values to simple compression of cubic samples exceed the minimum limits of the standard specification for cement blocks [23], which will allow the manufacture of cement blocks using pozzolana gravel, with the possibility of replacing cement with ground pozzolana by up to 50%.
- According to the ACI318-19, lightweight concrete is defined as concrete having an equilibrium density from 1440 to 2160 kg/m^3 [3, 5] Accordingly, lightweight concrete can be produced when natural gravel is replaced by pozzolanic gravel, as the density decreased from 2277 kg/m^3 to 1205 kg/m^3.
- From an economic perspective, replacing half of the cement in concrete with natural pozzolanic materials can have many financial implications. Since the cost of this material is low and is represented only by processing and transportation costs, the total cost savings on cement can be significant. Cement usually makes up a significant percentage of the cost of concrete, so using a cheaper alternative material can reduce the total cost of producing one meter of concrete by half.

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