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Influence of Sustainable Materials and Glass Fibers on Properties of Lightweight Perlite Concrete

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ABSTRACT

The effect of the addition of sustainable materials and alkali-resistant glass fibers on perlite concrete is studied in this paper. The research includes slump, density, flexural strength, split tensile strength, compressive strength, and thermal conductivity tests. This specimen was cast using Portland cement, metakaolin (which replaced 15% of the cement weight as pozzolanic materials), a combination of coarse and fine perlite aggregate, superplasticizer, and local ash (which was employed as a filler and replaced by cement weight in a ratio of 10%). The ratio of cement to perlite (volumetric ratio) was 1:2. The concrete reinforced 1% alkali resistance glass fibers by volume of concrete. The results show that adding sustainable materials to the concrete increased its cylinder compressive strength by a percentage of (57.75%, 41.76%, and 44.82%) for 7,28 and 60 days, respectively and both tensile and flexural strength increased at a ratio of (37.28%, 30.33% and 34.5%), (36.05%, 68.22% and 56.52%) respectively at (7,28 and 60 days). And including alkali-resistant glass fibers increases the compressive, tensile and flexural strength in a ratio of (61.5%, 43.58%, 47.45%), (61.54%, 44.08% and 52.71%) and (113.95%, 124.3% and 97.85%) respectively at (7,28 and 60 days), compared with reference mix. The density increased by adding sustainable materials and fibers but stayed within the limitations of structural lightweight concrete (ASTM C330). The thermal conductivity also increased after adding sustainable materials and glass fibers compared with the reference mix, but it was within the constraints of insulation concrete.

Keywords: Perlite, Lightweight concrete, Glass fibers, Sustainable materials.

1. INTRODUCTION

One method of producing lightweight concrete involves incorporating lightweight aggregates into the concrete mixture, which can partially or fully replace conventional heavyweight aggregates. Selecting and using a suitable Lightweight Aggregate is essential for producing (LWAC) with the desired density and good mechanical properties **(Leong et**

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al., 2020). (LWAC) is categorized by intended use as lightweight structural concrete with a minimum cylinder composite strength of (17 MPa) after (28 days) and a density of (1400-1800kg/m^3), masonry concrete, sometimes called lightweight structural/insulating concrete, with a density of (500-800 kg/m^3) and composite strength of (7-14MPa), and insulating concrete with a density below (800 kg/m^3) **(Neville and Brooks, 2010)**. **(ACI 213, 2014)** defines that structural lightweight aggregate concrete (SLWAC) is constructed entirely of light-weight aggregate or a mix of lightweight and normal-density aggregate with a minimum 28-day composite strength of (17 MPa). The range of its equilibrium density is (1120–1920 kg/m^3).

Perlite, a kind of volcanic glass composed of silica, has the potential to undergo substantial expansion when subjected to high temperatures. The volume of the substance increases by a factor of 4 to 20 when heated over (870 °C) **(Chandra and Berntsson, 2002).**

When perlite is heated quickly, it becomes a cellular material with a low bulk density, the ensuing steam forms foamy formations within the porous rock. This significant water absorption is attributed to this volume expansion and the expanded perlite's porous structure. Furthermore, compared to regular perlite, the density of expanded perlite is comparatively low **(Bagdassarov et al., 2001).**

Incorporating fibers into the concrete mixture is a method to enhance some mechanical properties of concrete. Asbestos and cellulose are natural resources that may be used to produce fiber. The fiber may also be produced using synthetic materials such as glass, steel, carbon, and polymers **(Mehta and Monteiro, 2006; Neville and Brooks, 2010)**. The development of alkali-resistant glass was accomplished in the 1960s, and by 1971, it was being manufactured and sold in the UK. During the 1970s and 1980s, alkali-resistant glass sources were created in various parts of the world. Glass fiber has a significant elastic modulus ranging from (70-80GPa) and an important tensile strength of (2-4GPa) **(Owens, 2009)**.

Metakaolin, a supplementary cementitious material, is produced by precisely regulating the temperature during the calcination process of pure kaolin clay. MK is used in cement-based systems because of its pozzolanic reactivity, which allows silicates, aluminates in supplementary cementitious materials to react with (CH) formed during cement hydration. This reaction forms a secondary (C-S-H) **(Mirza and Soroushian, 2002; Ramezanianpour, 2014)**. **(Ahmed, 2021)** considered employing MK as a pozzolanic additive for mortar and concrete due to the country's high concentration of (kaolinite clay) in its geological constitute and the benefits of adding metakaolin to concrete. Nevertheless, many research studies and scholarly theses have shown that local metakaolin is used to make various types of concrete. **(Fawzi et al., 2013)** examined Metakaolin's impact on the properties of Lightweight Proclinate concrete. Different amounts of MK, ranging from 5% to 20%, were substituted for cement to create the concrete mixes. The results show that all lightweight concrete mixes containing metakaolin (MK) had better mechanical properties when compared to the reference mix without MK. The investigated results indicate that replacing 15% of MK is the most suitable choice. Moreover, it has a high elasticity modulus and high tensile and flexural properties. **(Al-Hdabi et al., 2016)** Studied the enhancement of asphalt concrete mixtures with the addition of pulverized fuel Ash as filler, these components might replace mineral filler in hot asphalt mixes. Numerous experiments, including marshal stability and indirect tensile strength, determine two surface-course mix mechanical qualities. The experimental investigation found that new hot asphalt mixes, or those using PFA mineral filler, are equal to old mixtures and fulfil Iraq's Standard-Commission for Roads and Bridges (SCRB) surface course standards.

This study aims to produce (SLWAC) with good mechanical properties and low thermal conductivity by using (EPA) and some sustainable materials and glass fibers, achieve sustainability by lowering Portland cement production and use waste materials for creating concrete with other constituents.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Cement

Ordinary Portland cement type (CEM I 42.5R) was utilized throughout the experiment. **Table 1** displays the chemical requirements, and **Table 2** displays the physical characteristics. According to test results, the chosen cement conforms with **(IQS No.5, 2019).**

Table 1. Chemical Analysis of Cement.

Oxide Compositions	Weight (%)	Limits of **(IQS No.5, 2019)**
Lime (CaO)	62.33	Not limited
Iron oxide (Fe_2O_3)	3.89	Not limited
Alumina (Al_2O_3)	5.35	Not limited
Silica (SiO_2)	19.91	Not limited
Insoluble residue (IR)	0.55	Max (1.5)
Magnesia (MgO)	2.66	Max (5)
Loss on Ignition (LOI)	2.46	Max (4)
Sulfate (SO_3)	2.41	$SO_3 \leq 2.8$ if $C_3A > 3.5$ $SO_3 \leq 2.5$ if $C_3A \leq 3.5$
*Main Compounds of Cement		
Tri Calcium Silicate (C_3S)	53.98	Not limited
Di calcium Silicate (C_2S)	16.44	Not limited
Tricalcium Aluminate (C_3A)	7.6	Not limited
Tetra-calcium Aluminate – Ferrite (C_4AF)	11.83	Not limited

* The Percentages of main Compounds were Calculated using Bogue equations according to ASTM C150

Table 2. Physical Characteristics of Cement.

Properties	Test Results	Limits of **(IQS No.5, 2019)**
Surface area (Blaine approach) (m^2/ kg)	398.7	≥ 280
Setting time (Vicat's approach) Initial setting (min)	136 min	≥ 45 min
Setting time (Vicat's approach) Final setting time	6.5 hr	≤ 10 hr.
Soundness by Autoclave Approach (%)	0.19	≤ 0.80
Compressive Strength (MPa)		
Compressive strength at 2-day	26	≥20
Compressive strength at 28-day	45	≥ 42.5

2.1.2 Water

The water used for mixing and curing is sourced from Bagdad City's drinking water supply. and confirmed with the Iraqi standards **(IQS 1703, 2018).**

2.1.3 Expanded Perlite Aggregate (EPA)

(EPA) used in this study that fulfilled **(ASTM C330, 2017)** standards by combining fine and coarse aggregate, the EPA has (191kg/m^3) density and absorption of (1.67%) (**ASTM C128, 2015). Tables 3** give the chemical composition of perlite. **Table 4** shows the sieve analysis's results, and **Fig. 1** shows the (EPA) used for this investigation.

Table 3. Chemical composition of the (EPA) Datasheet

Oxide Compositions	Weight (%)
Lime (CaO)	0.24
Iron oxide (Fe_2O_3)	0.54
Alumina (Al_2O_3)	7.5
Silica (SiO_2)	69.6
Insoluble residue (IR)	---
Magnesia (MgO)	0.03
Loss-on-Ignition (LOI)	5.8
Sulfate (SO_3)	0.02

Table 4. EPA Gradation Combined Fine and Coarse Aggregate

Sieve-size (mm)	Cumulative-Passing wt.	Limits of **(ASTM C330, 2017)** (combined fine and coarse aggregate) [0-9.5]mm
12.5	100	100
9.5	100	90-100
4.75	88	65-90
2.36	44.8	35-65
0.3	12	10-25
0.15	5.6	5-15
0.075	0	0-10

Figure 1. Expanded Perlite Aggregate

2.1.4 Metakaolin

The metakaolin (MK) was sourced from Al-Anbar City and was created after a two-hour calcination procedure with temperatures reaching up to 700 °C for the kaolinitic clay. **Table 5** shows metakaolin's chemical requirements, metakaolin has a strength activity index of 7 days (89.67%) and a percentage retained on sieve No. 325 (20.31%) meet **(ASTM C618, 2019)** and **Fig. 2** shows the (MK).

Table 5. Chemical-Composition of (MK)

Oxide	Test results	**(ASTM C618, 2019)** requirement
Silicon (SiO_2)	52.2	(SiO_2) plus (Al_2O_3) plus (Fe_2O_3) =97.261 Min. (70 %)
Aluminium (AL_2O_3)	44.8	
Iron (Fe_2O_3)	0.261	
Magnesium (MgO)	0.15	------
Sulfate (SO_3)	1.34	Max. (4 %)
Calcium (CaO)	0.192	------
Loss of Ignition	4	Max (10 %)

Figure 2. Image of Metakaolin

2.1.5 Local Ash

Local ash from the thermal electric station of Al-Dora was used as a filler, replacing the weight of cement. The chemical analyses of ash, as shown in **Table 6**, the ash's strength activity index **(ASTM C618, 2019)** at 7 days is (57.55%), and it has a percentage retained on sieve No. 325 of (29.43%).

Table 6. Chemical Composition of Local Ash

Oxide	Test results (%)
Silicon (SiO_2)	12.26
Aluminium (AL_2O_3)	1.752
Iron (Fe_2O_3)	5.146
Magnesium (MgO)	2.979
Sulfate (SO_3)	4.358
Calcium (CaO)	3.611
Sodium (Na_2O)	10.26
Phosphorus (P_2O_5)	4.446
Potassium (K_2O)	28.09
Titanium (TiO_2)	0.2296

2.1.6 Glass Fibers

Alkali-resistant glass chopped strand fiber (GF), as shown in **Fig. 3**, had the following dimensions: (12mm) in length, (0.15mm) in diameter, and 50 aspect ratios. Glass fiber meets the specifications of **(ASTM C1116, 2009; ASTM C1666, 2008)**. **Table 7** provides the details and properties of the fibre from the supplier.

Figure 3. Alkali resistance Glass Fibers (GF)

Table 7. Manufacture characteristics of the GF

Properties	Details
Appearance	Opaque
Length	12mm
Diameter	0.15mm
Specific-Gravity	2.68g/cm^3
Absorption	Nil
Resistance to Chemical	Very High
Elasticity Modulus	72GPa
Tensile- strength	1,700MPa
Softening-point	860°C

2.1.7 Super-plasticizer

BETONAC® 350 is a superplasticizer (SP) that was used; it complies with **(ASTM C494, 2017)**; Type G, with a density of 1.06 ±0.02 gm/ml according to manufacture.

2.2 Mix Proportion of Concrete

The mixtures were created and mixed in accordance**(ACI 211.2, 1998; ACI 213, 2014)**. Following several trials, they were tested to determine the optimum ratio of cement to perlite, and several ratios were used (1:6, 1:5, 1:4, 1:3, 1:2). The optimal volumetric cement: perlite ratio of 1:2 was used. The cement content was (350kg/m^3), (15%) of the cement weight was replaced with metakaolin, and the local ash used as a filler was substituted at a weight of cement with a ratio of (10%). The manufacturer recommended (1000ml) of super-plasticizer for every 100 kg of cement. The amount of glass fibers used in the concrete was (1%) by volume of concrete. The mixed design is shown in **Table 8**.

Table 8. Mix Design of Concrete

Mix	Cement (kg/m^3)	W/C	Mix proportion (cement: perlite) volumetric	MK (%)	Ash (%)	Glass fibers (%)	SP ml/100 kg cement
MT	350	0.45	1:2	---	---	---	---
MR	350	0.4	1:2	15	10	---	1000
MG	350	0.4	1:2	15	10	1	1000

2.3 Preparation of Concrete Specimens and Curing

Proper mixing techniques are crucial to achieve the necessary uniformity and ease of use. Mixing was done using an electric mixer. To avoid adhesion of the mortar to the surfaces, a thin coat of oil was applied to the base and sides of the molds before casting. The molds were filled with layers of concrete, and any air that was trapped within was expelled by subjecting them to pressure on a vibrating table for an appropriate amount of time, as prescribed in the applicable standard **(ASTM C192, 2019)**. The specimens were carefully compacted and levelled using hand troweling to ensure consistent humidity for around 24 hours. **Fig. 4** displays the specimens following the casting and levelling process. After casting, the specimens were kept in polyethylene bags in the laboratory for a day. Following that, they were taken out of the molds and immersed in water for 7, 28, and 60 days before testing. **Fig. 5** shows the curing process of the specimens. Compressive strength is determined by testing cube specimens measuring 100mm on each side and cylinder specimens measuring 100×200mm. For the determination of the density (oven-dry unit weight) of each concrete mix, various specimens were utilized. These included a cylinder measuring 100x200mm, a 50x50x300mm prism for flexural strength testing, and a 100mm cube specifically for thermal conductivity testing. Additionally, a cylinder measuring 100x200mm was employed for the tensile strength test.

Figure 4. The Specimens after Casting and Levelling

Figure 5. The Curing of the Specimens

2.4 Test Method

2.4.1 Slump Test

A slump test was conducted on recently mixed concrete immediately after the completion of the mixing process. Workability refers to the level of ease with which freshly produced concrete, or mortar may be handled, transported, placed, and compacted, while also preventing any segregation. The research entails using slump cone tests to evaluate the workability following **(ASTM C143, 2012)**.

2.4.2 Density Test

For the density (oven dry unit weight), test cylinders sized 100x200mm are used according to **(ASTM C567, 2014).** The oven dry unit weight is calculated by the following equation Eq. (1) below

$$Om = \frac{(D \times 997)}{(F - G)} \tag{1}$$

where:
D is the cylinder's mass (kg).
G is the apparent mass of the suspended-immersed cylinder (kg).
F is the mass of the SSD cylinder (kg).
Om is the density measured (kg/m^3) .

2.4.3 Compressive Strength Test

The compressive strength of the concrete cylinder (100×200mm) was evaluated using the **(ASTM C39, 2001)**, while the compressive strength of the concrete cube (100×100mm) was determined using the **(BS-EN-12390-3, 2019)**. Three specimens were tested for each mixture. Tests were performed on the samples 7, 28, and 60 days after they were produced. The concrete specimens were subjected to testing until they reached a point of failure. Each concrete cube got a thorough cleaning on all surfaces before going into the compression machines. Eq. (2) determines the compressive strength of each specimen as follows:

$$fc = \frac{P}{Ac} \tag{2}$$

where:
f_c is the Compressive strength (MPa).
P is the load (N).
A_c is the area (mm^2).

2.4.4 Split Tensile Strength Test

The **(ASTM C496, 2011)** was used for calculating the splitting strength of the cylinder, which had dimensions of (100x200mm). The testing process involves compressing a concrete cylinder specimen uniformly along its side until it experiences tensile failure. After examining the cylinders at 7, 28, and 60 days, the mean value of three cylinders was calculated using the method shown in Eq. (3) below:

$$ft = \frac{2P}{\pi l d} \quad (3)$$

where:
ft is the Tensile strength, (MPa).
P is the Max Load, (N).
L is the Length of a cylinder, (mm).
D is the Diameter of the Cylinder, (mm).

2.4.5 Flexural Strength Test

The flexural strength test on concrete prisms with dimensions of (50x50x300mm) was conducted using the center point technique, as specified in **(ASTM C293, 2016)**. Every mix produced an average of three prisms after 7, 28, and 60 days. Eq. (4) was used to get the rupture modulus.

$$F_r = \frac{3PL}{2bd^2} \quad (4)$$

where:
Fr is the Flexural Strength, (MPa).
P is max load. (N).
d is the depth of the prism (mm).
b is the prism width (mm).
L is the length of a prism (mm).
prime

2.4.6 Thermal Conductivity Test

The thermal conductivity (k) of (100mm) cubes was determined using the hot wire method, specifically the method for Using a Platinum Resistance Thermometer, as specified in **(ASTM C1113, 2009)**, after a curing period of 28 days. For this test, the (QTM 500), a device that measures thermal conductivity quickly, was used. The device was accompanied by a probe that consisted of a heated wire and a thermocouple. Three specimens were prepared for each blend. Every sample underwent three tests, and the mean of the results was selected. The experiment was conducted in the Central Laboratory in Baghdad. The Fourier equation is used to get the (k-value). Eq. (5).

$$K = \frac{Qdln(t)}{4\pi dT} \quad (5)$$

where:
K is the Thermal Conductivity (W/m. K).
t is the time (min).
T is the specimen test temperature (°C).
Q is the average power input to the hot wire test (I*V*100/L) during the test (Watts/m).
L is the hot wire length (cm).
V is the average voltage drop across a hot wire (Volt).
I is the average current through the hot wire (V_S/R_S) (Amper).
V_S is the average voltage drop across a standard resistor (Volt).
R_S is the average resistance of a standard resistor (Ohm).

3. RESULTS AND DISCUSSION

3.1 Slump Test Result

The results of slump test experiments conducted on various concrete mixes were 85 mm for (MT) mix, 78 mm for (MR) mix and 71 mm for (MG) mix, as shown in **Fig. 6**.

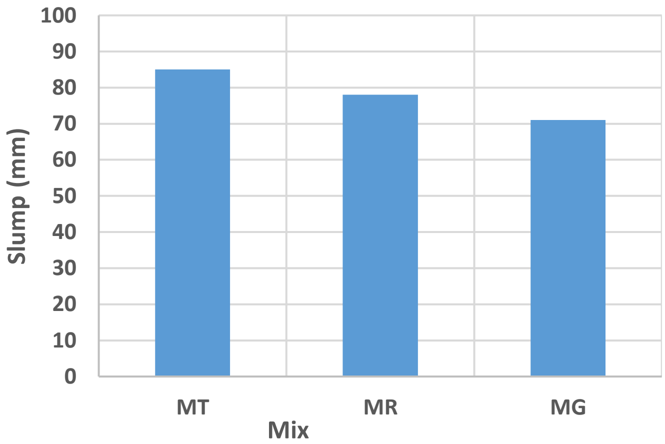

Figure 6. Slump Test Results.

Utilizing perlite in concrete mixes may substantially affect the workability of the result. Enhanced workability of concrete leads to improved compaction and less segregation, yielding a finished product that is more uniform. From a practical point of view, several studies indicate that perlite enhances workability, mostly due to the corresponding rise in air content **(Karakoç and Demirboga, 2010)**. When using (LWC), A slump of no more than 125 mm is necessary to provide a satisfactory floor surface during installation **(ACI 213, 2014).** Use the lowest W/C and a super-plasticizer (SP) to minimize slump. The slump value depends on (W/C) and (SP). **(Mohammad et al., 2023)**.

3.2 Density Test Result

The unit weight of the mixes was 1589.36 kg/m^3 for the (MT) mix, 1614.29 for the (MR) mix and 1641.32 kg/m^3 for the (MG) mix, as seen in **Fig. 7**. The primary advantage of adding perlite is its low density, despite the resulting decrease in mechanical characteristics

(Mladenovič et al., 2004). Weight reduction reduces structural stresses in concrete structures. Construction foundation weights are lowered. Thus, lowering structure weight optimizes component structural properties. A smaller amount of reinforcing steel and lower cross sections are economically beneficial. The lowered weights lead to a cheaper total cost for the building. The reduced unit weight of the concrete results in less pressure on the formwork, which is advantageous in cost savings **(Sengul et al., 2011)**.

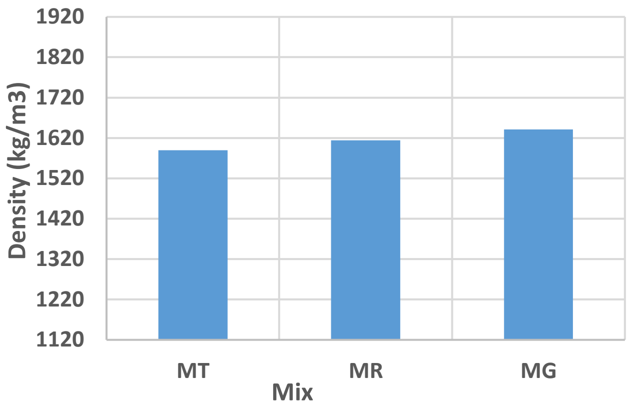

Figure 7. Oven Dry Density Test Results.

3.3 Compressive Strength Result

One of the most important features of hardened concrete is compressive strength, and it has a high correlation with other physical characteristics. **Table 9** and **Fig. 8** provide the results of compressive strength tests conducted on cubes and cylinders of all concrete mixtures at 7,28, and 60 days. Increasing the amount of cement strengthens the material since it has more of an effect on the compressive strength. On the other hand, compressive strength is somewhat decreased by a larger water-to-cement ratio. This indicates that adding extra ingredients to (LWC) mixtures, including pozzolans, may effectively lessen the negative effect of water on compressive strength. Because perlite aggregate is weaker than regular aggregate, increasing the quantity of perlite decreases compressive strength **(Arifuzzaman and Ho-Sung, 2014).** But the compressive strength stays in the SLWAC (17-28MPa) range according to **(ASTM C330, 2017).**

Table 9. Compressive Strength Result

Mix	Compressive Strength (MPa)					
	Cube			Cylinder		
	7days	28days	60days	7days	28days	60days
MT	11.33	16.69	18.14	10.13	15.42	16.69
MR	17.77	25.91	28.64	15.98	21.86	24.17
MG	17.89	26.23	29.11	16.36	22.14	24.61

The inclusion of glass fibers in the (MG) mix showed an increase in compressive strength compared to the (TR) mix, and slightly increased compared with the (MR) mix, adding 1% glass fibers increased the cylinder's compressive strength by 43.58% and 1.28% after 28 days compared with (MT) and (MR), respectively **(Dawood and Hamad, 2013)**. The cylinder strength in comparison to the cubes from the same batch, showed a lower value within the range of (0.84-0.92), which corresponds to the typical size effect factor **(Khonsari and Anvari, 2020).**

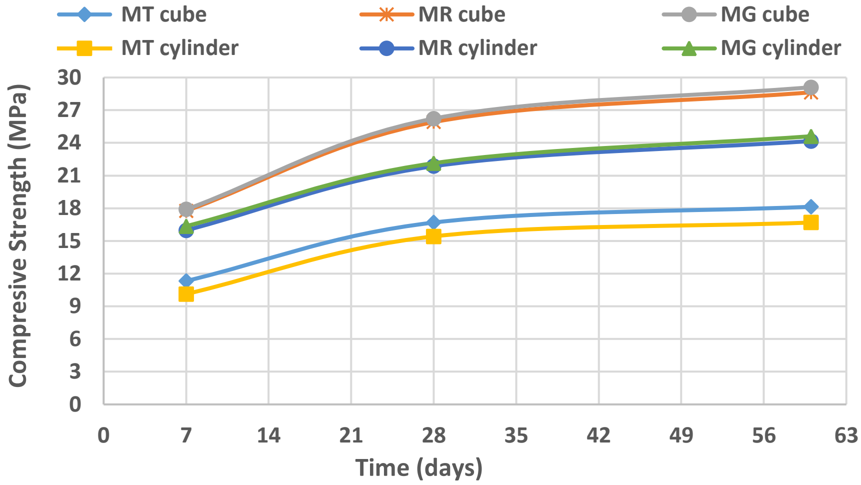

Figure 8. Compressive Strength Test Results.

3.4 Spite Tensile Strength Test Result

Table 10 and **Fig. 9** show the results of the splitting strength tests performed on different concrete mixtures at different durations (7, 28, and 60 days). The addition of 1% glass fiber provides the most advantageous result, exhibiting significant improvements in tensile strength (61.54%, 44.08%, and 52.71%) after 7, 28, and 60 days, respectively, as compared to the (MT) mix. These findings agree with the results reported by **(Rajendran and Lavanya, 2019).** According to **(ASTM C330, 2017)** the (SLWAC) is required to have a minimum strength of (2 MPa). **Fig. 10** illustrates the correlation between tensile and compressive strength.

Table 10. Split Tensile Strength Test Result

Mix	Tensile strength (MPa)		
	7days	28days	60days
MT	1.69	2.11	2.58
MR	2.32	2.75	3.47
MG	2.73	3.04	3.94

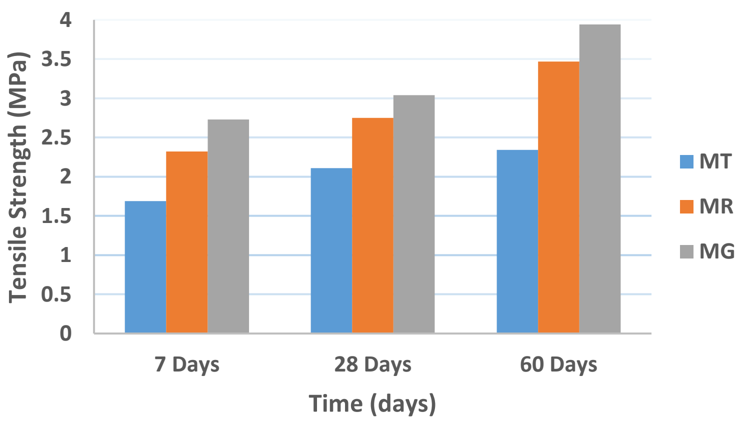

Figure 9. Tensile Strength Results

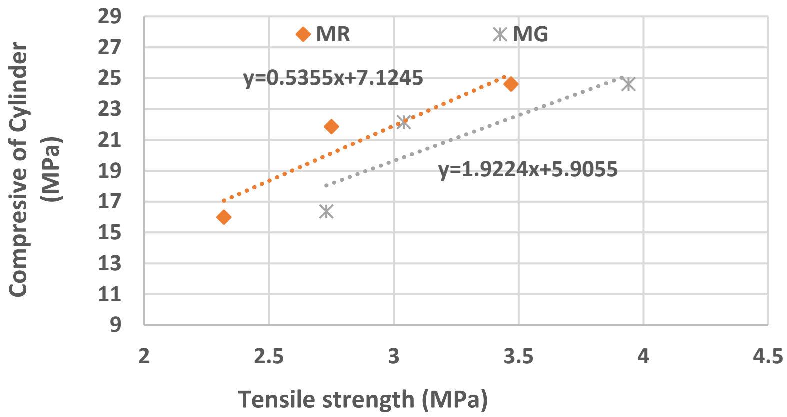

Figure 10. Relationship Between Tensile and Compressive Strength.

3.5 Flexural Strength Test Result

The test methods examine the responses of materials when exposed to primary beam stresses. The experiment included prisms with dimensions of 50x50x300 mm at the ages of 7, 28, and 60 days. **Table 11** and **Fig. 11** show the results of the flexural test. Utilizing 1% glass fibers has been shown to increase the flexural strength of the MG when compared to MT and MR. Alkali-resistant glass fibers decrease crack widths and promote the formation of multiple cracks. Incorporating glass fibers into lightweight concrete enhances its flexural strength and reduces the detrimental impact of high temperatures **(Mirza and Soroushian, 2002)**. In addition, the use of Metakaolin in (LWC) improves its compressive, tensile, and flexural strengths, as shown by **(Fawzi et al., 2013)**. **Fig. 12** shows the correlation between compressive and flexural strength.

Table 11. Flexural Strength Test Result

Mix	Flexural strength (MPa)		
	7days	**28days**	**60days**
MT	1.72	2.14	2.79
MR	2.34	3.6	4.32
MG	3.68	4.8	5.52

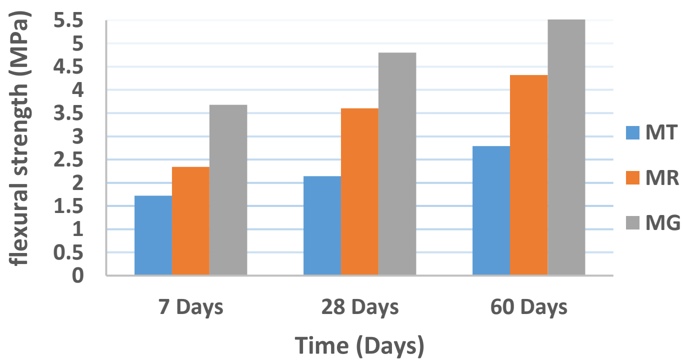

Figure 11. Flexural Strength Results.

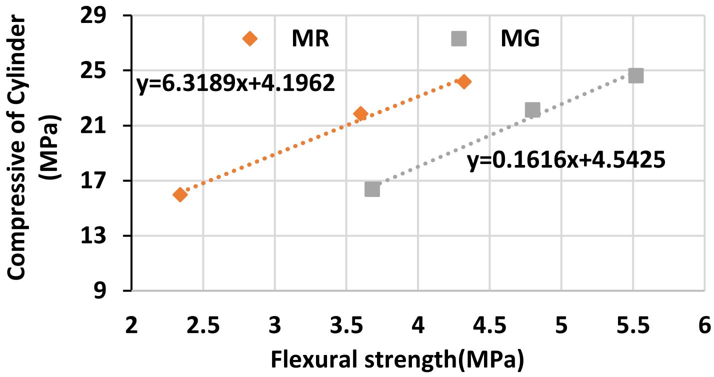

Figure 12. Relationship between Flexural and Compressive Strength.

3.6 Thermal Conductivity Test Result

The perlite thermal conductivity has a direct impact on the reduction of thermal conductivity in EPC. The decrease varies in direct proportion to the increase in the concentration of EP **(Jedidi et al., 2015)**. The thermal conductivity values for the (MT), (MR), and (MG) mixes were determined to be (0.2937W/m.K), (0.3118W/m.K), and (0.3144W/m.K), respectively, as seen in **Fig. 13**. The result is consistent with the range of (0.22-0.43W/m.K) as specified in the **(ASTM C332, 2017)**.

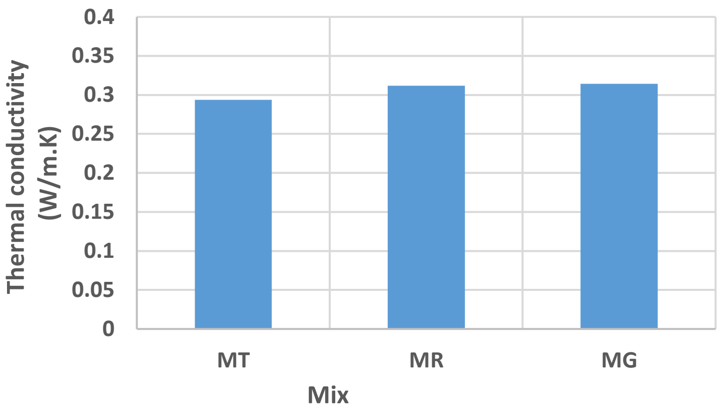

Figure 13. Thermal Conductivity Test Results.

4. CONCLUSIONS

Based on the findings obtained through this research, many significant conclusions may be derived from the section that came before:

- The value of slump of the (MR) mix and mix containing glass fibers (MG) is decreased compared with the (MT) mix in the percentage of (8.24% and 16.47%) respectively, due to reduce the w/c ratio and addition of sustainable materials and fibers.
- The density also increased due to the use of sustainable materials and the incorporation of fibers for (MR) and (MG) mix compared with (MT) mix with ratios of (1.57% and 3.27%), and this oven dry density was in the range of (SLWAC).
- The addition of pozzolanic materials (metakaolin) and reducing the w/c ratio by adding a super-plasticizer to the (MT) mix increased compressive strength. This increase in strength achieved the limitation of structural lightweight concrete where the (MR) mix

has increased cylinder compressive strength (57.75 %, 41.76%, and 44.82%) at (7,28 and 60 days) respectively, also adding glass fiber in (MG) mix increase the compressive strength (61.5%,43.58%, and 47.45%) at (7,28 and 60 days) respectively.

- The cylinder strength, in comparison to the cubes from the same mix, showed a lower value ranging from 0.84 to 0.92.
- Adding sustainable material in the (MR) mix increased the split and flexural strength in ratios of (37.28%, 30.33% and 34.5%), (36.05%, 68.22% and 56.52%) respectively, at (7,28 and 60 days), compared with the (MT). Also, adding glass fibers to mix (MG) increased the tensile and flexural strength at rates of (61.54%, 44.08% and 52.71%), (113.95%, 124.3% and 97.85%) respectively at (7,28 and 60 days), compared with the (MT).
- Adding sustainable materials to concrete in the (MR) mix and glass fibers in the (MG) mix increased the thermal conductivity by (6.16%) and (7.05%) compared with the (MT) mix, respectively. However, the thermal conductivity was limited by the lightweight aggregate for insulation concrete between (0.22-0.43 W/m.K).

NOMENCLATURE

Symbol	Description	Symbol	Description
LWAC	Lightweight aggregate concrete	SLWAC	Structural lightweight aggregate concrete
MK	Metakaolin	SP	Superplasticizer
LWC	Lightweight concrete	GF	Glass fiber

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Credit Authorship Contribution Statement

Ahmed Jasim Qasim: Writing – review & editing, Writing – original draft,
Nada Mahdi Fawzi: Review & editing, Validation, Methodology and Supervising

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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تأثير المواد المستدامة والألياف الزجاجية على خواص خرسانة البيرلايت خفيفة الوزن

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الخلاصة

تمت دراسة تأثير إضافة المواد المستدامة والألياف الزجاجية المقاومة للقلويات على الخرسانة البيرلايت خفيفة الوزن في هذا البحث. يتضمن البحث فحوصات الهطول والكثافة ومقاومة الانضغاط ومقاومة الشد الانشطاري، ومقاومة الانثناء والتوصيل الحراري. المواد المستخدمة لصب العينة هي السمنت البورتلاندي الاعتيادي، الميتاكاولين الذي استبدل من وزن السمنت كمواد بوزولانية بنسبة 15%، الرماد المحلي المستخدم كمادة مالئة والذي تم استبداله بوزن الأسمنت بنسبة 10%، ركام البيرلايت مركب الخشن والناعم، والملدن الفائق، وكانت نسبة الأسمنت إلى البيرلايت 1:2 (نسبة حجمية). الخرسانة مسلحة بألياف زجاجية مقاومة للقلويات بنسبة 1% من حجم الخرسانة. أظهرت النتائج أن إضافة مواد مستدامة للخرسانة أدى إلى زيادة مقاومة انضغاط للأسطوانة بنسبة (57.75%، 41.76%، 44.82%) لمدة 7، 28، 60 يوما على التوالي وأيضا زادت مقاومة الشد والانثناء بنسبة (37.28%، 30.33%، 34.5%)، (36.05%، 68.22%، 56.52%) على التوالي عند (7،28، 60 يوماً). إضافة الألياف الزجاجية المقاومة للقلويات يزيد من مقاومة الانضغاط والشد والانثناء بنسبة (61.5%، 43.58%، 47.45%)، (61.54%، 44.08%، 52.71%) و (113.95%، 124.3%، 97.85%) %) على التوالي عند (7،28، 60 يومًا) مقارنة بالخلطة المرجعي. وقد زادت الكثافة بإضافة مواد وألياف مستدامة، ولكنها ظلت ضمن حدود الخرسانة الانشائية خفيفة الوزن (ASTM C330). كما زادت الموصلية الحرارية بعد إضافة المواد المستدامة والألياف الزجاجية مقارنة بالخلطة المرجعية إلا أنها كانت ضمن حدود الخرسانة العازلة.

الكلمات المفتاحية: بيرلايت، خرسانة خفيفة الوزن، الياف الزجاج، مواد مستدامة.