Enhanced Flexural Strength and Modules of Elasticity of Lightweight Pumice Aggregate Concrete

Shakir A. Khudair [1, a)]
[1]MSc, Student Building & Construction Department, Technical Engineering College /Mosul, Northern Technical University, Iraq.
[a)] Corresponding author: shakir.alkhufajjy@gmail.com

Mohammed A. Basher [2, b)]
[2]*Lecturer, Building & Construction Department, Technical Engineering College /Mosul, Northern Technical University*
[b)] *mbasher@ntu.edu.iq*

ABSTRACT

Low density and thermal resistance are important characteristics of pumice aggregate concrete. This type of concrete is known to be weak in most of its mechanical properties, the most important of which are bending and modulus of elasticity. It has become necessary to focus on improving the mechanical properties this type of concrete. To increase the flexural strength and modules of elasticity of Lightweight pumice aggregate concrete, steel fiber in various ratios were added to pumice aggregate concrete. Five combinations were chosen to be flexural strength enhanced. The five chosen mixes each received 0.5, 0.75, 1%, of steel fiber. Considered are the mechanical characteristics of produced concrete. Results showed that steel fibers improved flexural strength is more than 50% when added steel fiber 1% by volume compared to lightweight pumice aggregate concrete mix without fibers, and modules of elasticity increased 30% When added 1% steel fiber to mixes compared with mixes without fibers.

Keywords: Pumice aggregate concrete, Lightweight concrete, Steel fiber, flexural strength, modules of elasticity

Introduction

Aggregates can be a combination of light-weight coarse and fine materials or light-weight coarse materials with a suitable natural fine aggregate [1]. Any concrete having a density of under 2,000 kg/m3 after drying in the oven is referred to as "lightweight concrete." [2]. Lightweight aggregate is any aggregate with a dry loose bulk density of less than 1200 kg/m3. Low-density concrete, which has the advantage of making structures lighter and better at insulating heat than traditional concrete. Since the time of the Romans, low-density volcanic rock known as pumice has been used [3]. In order to produce a lightweight matrix, reduced alkali-silica reaction (ASR) expansion, chemical resistance, freeze/thaw resistance, thermal insulation, and freeze/thaw resistance, pumice is regarded as a practical and natural lightweight aggregate. On the other hand, the addition of pumice aggregate had a detrimental effect on the matrix's mechanical strength, workability, shrinkage, and water absorption [4].

Making lightweight concrete from pumice material that can be used to create either load-bearing or non-load-bearing components [5]. A variety of varied ratios of pumice aggregate to cement were used to create the Pumice Aggregate Lightweight Concrete (PALWC) mixture. According to the findings of experimental tests, PALWC with A/C ratios of up to 25:1 has sufficient strength and density to be employed as load-bearing blocks. Pumice aggregates in varying sizes can be combined to create lightweight non-structural concrete without the use of any other ingredients [6]. Liber et al. investigated the effects of pumice lightweight aggregate concrete on the ductility of concrete by adding hybrid steel and polypropylene fibers. It has been established how the mechanical properties, bulk density, and workability of pumice lightweight aggregate concrete are altered by the addition of hybrid steel and polypropylene fibers. Among the characteristics examined were the bulk density and workability of fresh concrete, as well as the compressive strength, flexural tensile strength, splitting tensile strength, and toughness of hardened concrete. Nine different concrete mixtures with varied percentages of steel and polypropylene fibers were tested. The use of steel fibers considerably improved the material's ductility, energy absorption, and flexural strength [7]. Hardened concrete was given a fiber addition that somewhat altered its mechanical characteristics, especially when combined with steel fibers. These results shed light on the potential benefits of different fiber reinforcing techniques for improving the mechanical characteristics of lightweight aggregate concrete containing brittle pumice. These results provide guidance for the creation of lighter, more elastic concrete materials that might be applied in a range of situations, such as the building of tall, earthquake-resistant structures [7]. To discover more about The mechanical properties of fiber-reinforced lightweight pumice concrete The authors Badogiannis et al. A batch of reference lightweight concrete has four different types of fibers added to it: Three steel fibers of various lengths and one polypropylene fiber, both in concentrations of 0.5 and 1.0 percent by volume. Three standard compression and bending test sites were put to the test. Using fibers enhances the mechanical properties of lightweight concrete, according to the experiment's findings. It was found to significantly boost flexural and compressive strength, and it was very helpful in the period following cracking [8]. Ozel et al. examined the permeability and tensile properties of various aggregate and fiber concrete mixes. Basalt, limestone, travertine, and pumice were used as aggregates in two sizes, 5-12 mm and 12-19 mm. Steel and polypropylene fibers were also employed. Pervious concretes underwent tests for compressive strength, rheology, flexibility, splitting tensile, abrasion resistance, porosity, slump, and permeability as part of an experiment program. Because of this, pervious concrete samples had adequate mechanical performance for structural usage. with a splitting tensile strength of 2.2 MPa, a compressive strength of 8.8 MPa, and a flexural strength of 3.0 MPa. Additionally, the fiber-reinforced composites had a very high deflection capacity, which was important to take into account for roads that were constantly subject to tensions brought on by fatigue. 30% porosity and 13.91 mm/s of infiltration rate were the highest findings, respectively. Additionally, strength was best. The polypropylene strands greatly facilitated water passage while the steel fibers increased the material's wear resistance. Polypropylene fiber allowed pervious concrete samples to have an excellent infiltration rate (>10 mm/s) regardless of the type of aggregate used. Travertine, basalt, and limestone were used as aggregate. Additionally, it was discovered that using aggregate with smaller and more uniform sizes enhanced the overall effectiveness of samples of pervious concrete [9].

Materials

Materials used to produce Pumice Lightweight Concrete (PAC) are cement, fine and coarse aggregate, and pumice are among the materials employed in the experiments. Lightweight concrete mixtures are made with these ingredients. Ordinary Portland Cement was used in this investigation. with chemical composition listed in Table 1. Cement's qualities are all consistent with Iraqi standards. Specifications No. 5/1984. [10]

TABLE 1. Chemical compositions of cement

Oxide	% Weight	Limits of IQS:5/1984

CaO	62.2	---
Fe_2O_3	2.67	---
Al2O3	5.89	---
SiO2	21.31	---
So3	2.56	< 2.80
3 MgO	3.62	< 5.0
Free CaO	1.74	---
Insoluble residue	0.24	< 1.5
Loose Ignition	1.58	≤ 4.0
Lime Saturated Factor	88.19	66 --102
C4AF	8.11	< 2.80
C2S	35.92	< 5.0
C3A	11.08	---
C3S	33.38	< 1.5

This study used locally available normal sand with specific gravity of 2.67 and a maximum aggregate size of 4.75 mm and absorption rate of 2.9%. A Sand sieve analysis has been performed according to ASTM C33 [11]. Natural coarse aggregate with a maximum aggregate size of 19 mm, a specific gravity of 2.7 and absorption of 3.3%. A gravel sieve analysis has been performed according to ASTM C33 [11].
Pumice Aggregate is a type of volcanic rock it has large percent of porous and has a highly vesicular texture. It has a rough texture. pumice was manually crushed to produce the fine and coarse aggregates within the specified tolerances. Pumice has bulk SSD specific gravity 1.28 and 20% absorption. Dry rodded unit weight is 511 kg/m^3 and Dry loose unit weight is 477 kg/m^3 [12].

Methodology

Twenty-six mixes containing pumice in place of coarse and fine aggregate were tested by Khudair and Basher [13]. Five combinations that could be strengthened with steel fiber were generated with acceptable densities and strengths. 35 mm double hock end steel fiber is used. Effect of fiber on the properties of lightweight pumice concrete was investigated. In this investigation, volume steel fibers of 0.5%, 0.75%, and 1% of concrete were employed. The characteristics of steel fiber are displayed in Table 2.

TABLE 2. Properties of fibers

Fibres type	Density (kg/m3)	Length (mm)	Diameter (mm)	Tensile strength (MPa)	Geometry
Steel	8000	35	0.55	1100	Hooked

Concrete mix 1: 1.77: 2.4, with replacement of pumice as coarse aggregate of 90 and 100%, and three mixes, with replacement of pumice as coarse and fine aggregate of 60, 80, and 100%, are five mixes of lightweight pumice concrete used to augment with fibers. The characteristics of a few blends were displayed in Table 3. The materials' quantities and the proportion of fibers added to the concrete mixtures were shown in Table 4.

TABLE 3. Lightweight pumice concrete with steel and polypropylene fibers

Mixes	Coarse Pumice	Fine Pumice	Cement (kg/m^3)	Coarse pumice (kg/m^3	Fine pumice (kg/m^3	Gravel (kg/m^3)	Sand (kg/m^3)	Sp (%)	Dry Density (kg/m^3	Comp. Strength

	(%)	(%)		)	)				)	(MPa)
C1	90	-	425	435.2	0	102	753	1.0	1760	15.22
C2	100	-	425	483.6	0	0	753	1.0	1730	13.78
C3	60	60	425	290.1	216.5	408	301.2	1.0	1715	14.47
C4	80	80	425	386.8	288.7	204	150.6	1.0	1570	14.05
C5	100	100	425	483.6	360.9	0	0	1.0	1356	13.12

TABLE 4. Lightweight pumice concrete with steel and polypropylene fibers.

Mixes	**Coarse Pumice (%)**	**Fine Pumice (%)**	Cement (kg/m^3**)**	Coarse pumice (kg/m^3**)**	Fine pumice (kg/m^3**)**	Gravel (kg/m^3)	Sand (kg/m^3)	**Sp (%)**	**SF (%)**
M1	90	-	425	435.2	0	102	753	1.0	0.5
M2	100	-	425	483.6	0	0	753	1.0	0.5
M3	60	60	425	290.1	216.5	408	301.2	1.0	0.5
M4	80	80	425	386.8	288.7	204	150.6	1.0	0.5
M5	100	100	425	483.6	360.9	0	0	1.0	0.5
M6	90	-	425	435.2	0	102	753	1.0	0.75
M7	100	-	425	483.6	0	0	753	1.0	0.75
M8	60	60	425	290.1	216.5	408	301.2	1.0	0.75
M9	80	80	425	386.8	288.7	204	150.6	1.0	0.75
M10	100	100	425	483.6	360.9	0	0	1.0	0.75
M11	90	-	425	435.2	0	102	753	1.0	1.0
M12	100	-	425	483.6	0	0	753	1.0	1.0
M13	60	60	425	290.1	216.5	408	301.2	1.0	1.0
M14	80	80	425	386.8	288.7	204	150.6	1.0	1.0
M15	100	100	425	483.6	360.9	0	0	1.0	1.0
M16	90	-	425	435.2	0	102	753	1.0	-
M17	100	-	425	483.6	0	0	753	1.0	-
M18	60	60	425	290.1	216.5	408	301.2	1.0	-
M19	80	80	425	386.8	288.7	204	150.6	1.0	-
M20	100	100	425	483.6	360.9	0	0	1.0	-
M21	90	-	425	435.2	0	102	753	1.0	-
M22	100	-	425	483.6	0	0	753	1.0	-
M23	60	60	425	290.1	216.5	408	301.2	1.0	-
M24	80	80	425	386.8	288.7	204	150.6	1.0	-
M25	100	100	425	483.6	360.9	0	0	1.0	-

Results And Discussions

Through in results showed in table 5 clear increasing the modules of rupture with additional steel fiber in mixes, this showed that additional fiber steel 1% by volume improved flexural strength in mixes concrete in group6 more than in mixes contained steel fiber 0.5% and 0.75% in M1, M2, ...M15. The increase in flexural strength is more than 50% when added steel fiber 1% by volume compared to lightweight pumice aggregate concrete mix without fibers

TABLE 5. Showed effecting Fibers on Flexural Strength of Lightweight Pumice Aggregate Concrete mix**.**

Mix Code	Flexural strength. MPa	
	7 Days	28 Days
M1	2.27	2.87
M2	2.18	2.72
M3	2.03	2.55
M4	1.97	2.41
M5	1.89	2.39
M6	2.72	2.93
M7	2.5	2.78
M8	2.1	2.59
M9	2.01	2.5
M10	1.99	2.48
M11	2.83	3.04
M12	2.77	2.91
M13	2.26	2.83
M14	2.22	2.81
M15	2.16	2.8

Through the results of modules of elasticity showed in table 6. fibers have affecting in modules of elasticity for lightweight pumice aggregate concrete. When added 1% steel fiber to mixes increased modules of elasticity 30% compared with mixes without fibers

TABLE 6 Showed Effecting Fibers on the Modules of Elasticity.

Mix	Modules of Elasticity. GPa	Mix	Modules of Elasticity. GPa	Mix	Modules of Elasticity. GPa
M1	11.62	M6	12.17	M11	12.25
M2	10.88	M7	11.44	M12	12.1
M3	10.21	M8	10.26	M13	11.2
M4	10.01	M9	10.09	M14	10.13
M5	8.67	M10	9.41	M15	10.1

Conclusions

Flexural strength of pumice aggregate concrete mixes (M9, M10, M24, M25 and M26) had increased with about 27%, 30% and 40% when steel fiber is 0.5%, 0.75%, and 1% were added, respectively. Modules of Elasticity of pumice aggregate concrete mixes (M9, M10, M24, M25 and M26) had increased with about 8%, 12% and 18% when steel fiber is 0.5%, 0.75%, or 1% were added, respectively.It is apparent from the results that the mixes with high pumice content as a replacement of coarse aggregate or both coarse and fine aggregate were lightweight pumice aggregate concrete and were capable to be used as a loadbearing concrete [16]. The mixes with steel fibers has enhanced the strength of concrete and densities remained as lightweight in concrete mixture while the polypropylene fiber has insignificant effect on the pumice aggregate concrete. The study was carried out to produce lightweight pumice aggregate concrete without using of other additives as fly ash or silica fume. It is obvious from the results that lightweight pumice aggregate concrete with steel fiber has acceptable strength with light in weight than the corresponding normal concrete blocks.

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