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Preparation and Study of the Physical Properties of Lightweight Cement Reinforced with Fillers

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Abstract—*This research included the effect of fillings on the mechanical properties of lightweight white Portland cement, as different percentages of the fillers used in the production of this type of lightweight cement were used. Several engineering and physical tests were conducted on lightweight white Portland cement models in this research, where it was found to produce lightweight cement with a compressive strength ranging between (1.16 - 6.5) N/mm2, and the density was measured and the recorded values ranged between (0.5-1.04) g/cm3, and the weight of the models was recorded and the recorded values ranged between (65-130) gm. The research aims to produce lightweight white Portland cement with good physical and mechanical properties that can be used in the manufacture of building units, with a focus on the economic aspect of producing this type of lightweight cement from available materials and at the lowest possible cost.*

Keywords— *White cement, Cellular light weight cement, Mechanical properties, Fillers, and Foam content.*

I. Introduction

White Portland cement (WPC) has similar bonding characteristics as gray Portland cement. WPC has also higher performance due to use of high quality materials and control process in its production [1]. To lessen the density of the foam concrete and/or make use of waste/recycled materials, a variety of materials were used, including silica fume fly ash, lime chalk, crushed concrete, incinerator bottom ash, recycled glass, foundry sand, quarry finer, expanded polystyrene, oil palm shell, and Lytag fines [2–3]. Both mechanical foaming and chemical expansion have been employed. Chemical foaming involves mixing base-mix materials with a foaming agent (FA), such as aluminum powder, CaH_2, TiH_2, or MgH_2. As a result of the chemical reactions that occur during mixing, foam is created and the concrete's cellular structure is formed. When using mechanical foaming, the concrete mixture is mechanically combined with premanufactured foam that has been made beforehand using a special tool called a foam generator. The foam is made by mixing a specific amount of chemical additive and water. Under typical climatic conditions, the concrete hardens after molding [4-5]. The concept behind the manufacturing of the CLWC is to create porous microstructure by entrapment of air bubbles in the concrete mix. This can be done by adding preformed foam or chemical surfactant which reacts during the mixing to create air bubbles in the mix. Throughout the setting process, the air bubbles maintain their size, shape, and stability. The air bubbles' diameters range from 0.1 to 1 mm. The "skin" of bubbles or voids needs to be resilient enough to endure compaction, transportation, and mixing. These air bubbles give foamed concrete its lightweight property. As there is no coarse aggregate [6]. As suggested by its name, cellular light weight concrete is concrete that weighs less than normal concrete. This offers strength that is nearly identical to regular strength concrete with lower grades. Lightweight concrete is defined as concrete having density (air-dry) below 2000 kg/m³ as compared to normal concrete with a density in the region of 2350 kg/m³ [7]. FC is a subset of cellular concrete, which is a larger class of concrete in which an appropriate aerating agent is used to trap air gaps in the mortar matrix. Because of its lightweight nature, moisture resistance, fire resistance, sound insulation, and good heat insulation qualities, it has been successfully used in oil well cementing projects, as a backfill material in excavation projects, and for energy-absorbing pads in roads, building panels, fire-protection walls, structural fill, foundations, geotechnical applications, and mine fill [8–11]. In Iraq, White Portland cement is generally used in the production of non-structural members, which are built for decorative and aesthetic purposes. In this study, a type of lightweight white Portland cement was produced that can be used as a new energy-conservation and environmental-protection building material and is particularly suitable for the thermal insulation engineering of building external walls. The influences of different mixing amounts of lightweight white Portland cement on the mechanical properties for compressive strength.

II. Experimental Programs, Materials:

White Cement:

The White cement used in this study was SAQR AL-Keetan Co. for Cement Production Company Limited, made according to Iraq Standard No.5 for 2019, IQS 5 CEM I 42.5 R. Its density is 740 kg/m3, and its chemical composition is given in Table (1).

Fillers:

Two types of fillers were used in this research Added to the mixture (white cement with foam). Fiber and perlite stone fillers. The fiber is cut into small pieces cut and then add to the mixture, while the other filler is perlite stone, which is added to the mixture in the form of small balls.

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TABLE 1: Chemical properties of the cement that were used [12].

Oxides and other requirements	SiO_2	CaO	Al_2O_3	Fe_2O_3	SO_3	MgO	Cl	Na_2O	Specific Gravity
Percentage %	22.2	66. 0	4.3	0.2	3.19	1.12	0.005	0.2	3.08

Foam:

Foam is a chemical substance formed by trapping pockets of gas within a liquid or solid. Well-known examples are sponges and suds. In most foam, the gas volume is large, and the gaseous regions are separated from the liquid or solid regions by a thin film. There are two types of foam, chemical foam and mechanical foam. In this research, mechanical foam was used with the mixture. The foam is prepared in advance using a special device, a foam generator, where water and chemical (foaming agent) are mixed in a certain proportion and the previously manufactured foam (mechanically) is mixed with the concrete mixture. Its self-made white powder is formed by confining gas pockets within a liquid or solid.

Preparation of lightweight white cement:

Prepare lightweight white cement with additives of different concentrations from fillers, the following steps were followed:

We add water to other materials such as white cement, foam stabilizer and filler (perlite stone and fiber) and stir evenly while maintaining the mixture temperature at about 40 ºC. In general, this process takes about (4) minutes. During high-speed stirring, the lightweight white cement mixture forms quickly, resulting in five different cubes. Pour the mixed mixture evenly into a (5 x 5 x 5) cm mold, place it in the mold and wait until it foams; The cubes are shown in figure 2, and table No. (2) Shows the basic materials used (white cement and foam cement) along with the fillings and details of weight and density. The mold is then opened after two hours and kept in the curing box at a constant temperature and humidity until the testing period is over. The key to forming a lightweight white cement structure using chemical foaming is to make the foaming speed match the setting and hardening speed of the mixture.

Figure 1: Lightweight white cement cubes.

TABLE 2: Shows the basic materials used (white cement and foam cement) with the fillers and details of weight and density

Sample Number	Materials	Weight (gm)	Water amount (Ml)	Density (gm/cm^3)	Model size (cm^3)
A	Foam white cement and perlite stone	68.2	1175	0.5	125
B	Foam white cement	65.1	1175	0.52	125
C	Foam white cement and perlite stone and fiber	79.9	1175	0.63	125
D	White cement(Low water content) and perlite stone	130	980	1.04	125
E	White cement(high water content) and perlite stone	90.8	1200	0.72	125

Test Equipment:

A high-speed blender: auto control with a rotating speed of 0∼1200 r/min. A standard tester for consistency and setting time of the cement and Multifunction rock mechanics test (RMT) machine: a series of RMT systems was developed at our institute. The machine has a unique multifunction design and control technology; it can conduct many types of tests such as uniaxial compression, triaxle compression, tension, shear, and fatigue tests. Its maximum load is 1MN, and its maximum confining pressure is 650 BAR. A universal testing machine HUMBOLDT (650 BAR) was used. The compressor modulus was calculated as the ratio of stress to concrete. A photograph showing a mechanical measuring device shown in Figure (2).

Figure 2: A photograph showing a mechanical measuring device.

III. RESULTS AND DISCUSSION.

Figure (3) shows the relationship between the symbol number of lightweight concrete and density. Where we notice from the figure that the maximum density recorded for the models was (1.04 g/cm3) for the sample (D), i.e. White cement (low water content) and perlite stone, and this matter is attributed to the presence of perlite stone in high quantity with low water content of about (980 ml.) that increased the density of the sample as a result of increasing the weight of the sample, which was (130 g), shown in figure (4), and the absence of spaces between the internal structure as a result of high homogeneity between filler and white cement, in contrast to the sample (D) (white cement (high water content of about 1200 ml)), and perlite stone in low quantity) that led to the decrease density recorded was (0.72 g/cm3), as a result of decreasing the weight of the sample, which was (90 g), shown in figure (4), which absorb a high amount of water as a result of the presence of large spaces.

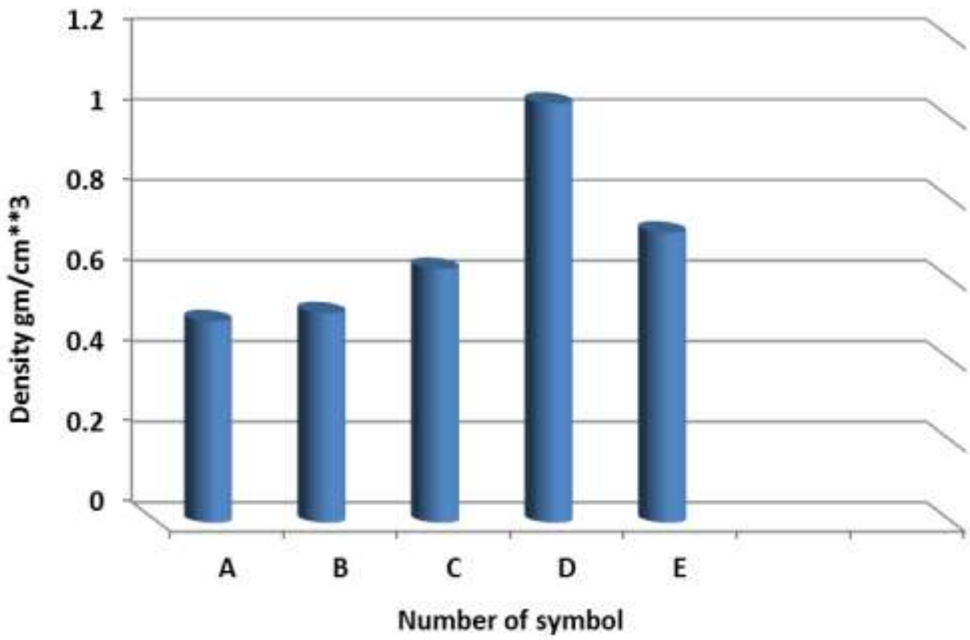

Figure 3: The relationship between the symbol numbers of lightweight white cement with density.

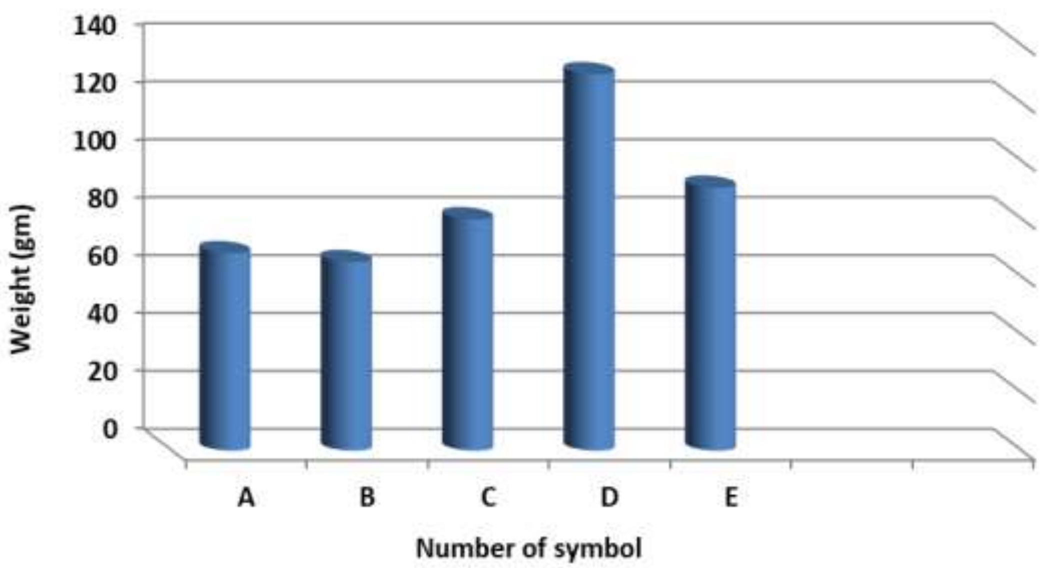

Figure 4: The relationship between the symbol numbers of lightweight white cement with weight.

Figure (5) shows the relationship between the symbol number of the lightweight white cement and the compressive strength. Where we notice from the figure 6 that the behavior of the compressive strength begins at the sample (A), where the ratio of water to cement is (1175 ml), and the compressive strength is (Mpa1.279), then the compressive strength decreases 1.16 Mpa) for sample (B) and foam and water amount remain constant in all samples, and then when adding fillers (fiber) with lightweight cement, the compressive strength increases and is (1.98 Mpa) for the sample (C). Where there is a high homogeneity between the fillings with the white cement and thus filling the spaces between the cement particles and this enhances the strength of the sample bearing the weight and increases the compressive strength. As the internal structure weakens, the compressive strength increases. But for the use of fillers (perlite stone) with the white cement, the compressive strength increases with the decrease in the ratio of the amount of water to cement, as in figure (6), where the ratio of water to cement is (980ml) to the sample (F), where the amount of compressive strength with fillers is (6.5 Mpa), where the perlite stone strengthens the internal structure of the mixture and therefore, the mixture can bear the high pressures and thus, the compressive resistance increases.

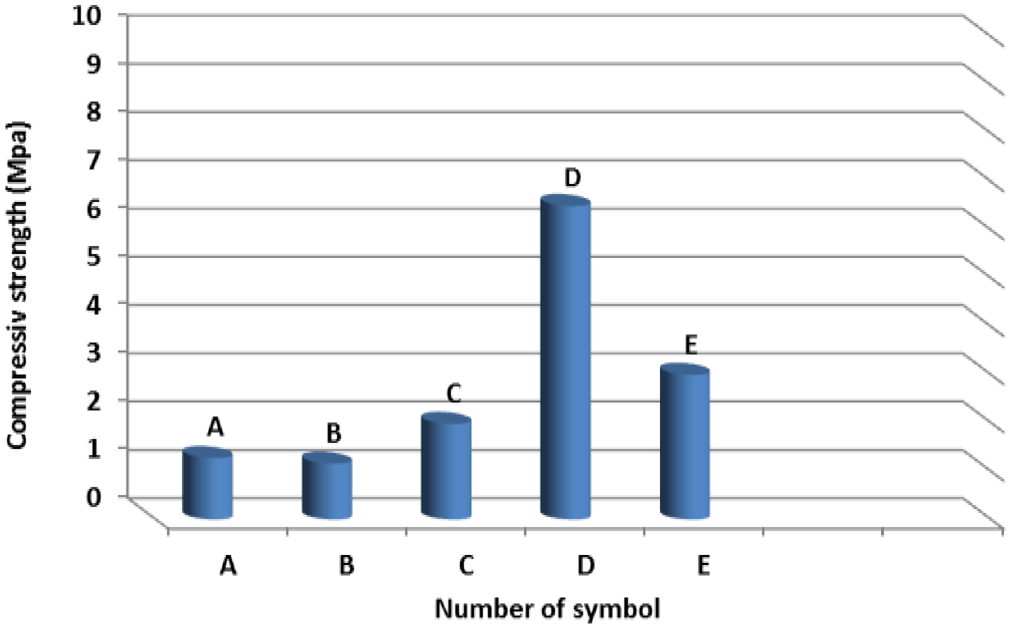

Figure 5: The relationship between the symbol numbers of lightweight white cement with compressive strength.

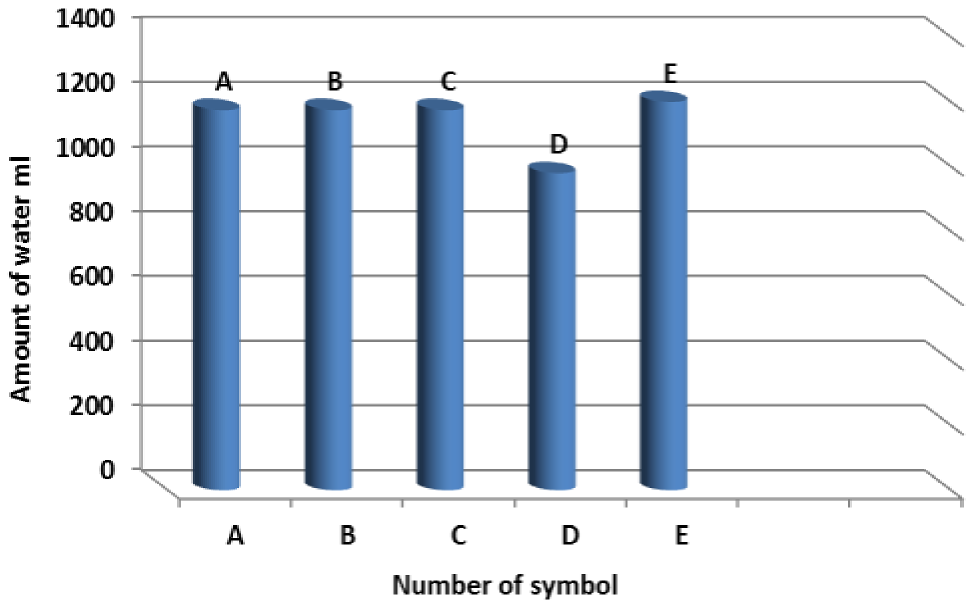

Figure 6: The relationship between the symbol number of lightweight white cement with water amount.

IV. Conclusion:

The amount of foam is getting more attention nowadays because its use usually improves the properties of lightweight white cement and reduces adverse environmental effects. The properties of foam lightweight white cement vary depending on the type and composition of the mixture. Several engineering and physical tests were conducted on lightweight white Portland cement models in this research, where it was found to produce lightweight cement with a compressive strength ranging between (1.16 - 6.5) N/mm^2, and the density was measured and the recorded values ranged between (0.5-1.04) g/cm^3, and the weight of the models was recorded and the recorded values ranged between (65-130) gm. The research aims to produce lightweight white Portland cement with good physical and mechanical properties that can be used in the manufacture of building units, with a focus on the economic aspect of producing this type of lightweight cement from available materials and at the lowest possible cost.

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