Effect of Cement Variation on Properties of CLC Concrete Masonry Brick

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Abstract. One of the methods used to reduce the weight of a construction is by reducing the weight of the walls of the building. In such a case, a wall made of red brick has a volume weight of 1,500–2,000 kg/m^3, and concrete masonry bricks made of CLC have a volume weight of 400–1,800 kg/m^3. So, in comparison, concrete masonry bricks have a volume weight that is ≤ 50% of that of red brick. In the manufacturing of concrete masonry bricks, one variant is CLC (Cellular Lightweight Concrete), produced using a mixture of cement, sand, chemical admixture and water, with the filler material in the form of air generated as microscale soap bubbles (microbubbles), also known as foam agent. In the manufacturing of concrete masonry bricks, the cement as a binder material clearly affects the physical and mechanical properties of the bricks produced. This research is conducted to investigate the effect of the amount or composition of the cement used on the physical and mechanical properties of concrete masonry bricks. The composition is varied among 200, 250, 300, 350 and 400 kg/m^3 of cement usage.

1 Introduction

For the purpose of lightweight construction in soft soil or peatland areas, innovation is required to reduce the self-weight of the construction. One way to reduce this is by reducing the weight of the walls, which are generally made of red brick having a volume weight of 1,500–2,000 kg/m^3 [5], cement brick with a volume weight of 950–1,000 kg/m^3 [6][7] or CLC masonry concrete brick with a lighter volume weight of 400–900 kg/m^3[1]. This CLC masonry concrete brick also has the effect of reducing the reinforcement of a structure, as a result of the lower section dimensions of the structural elements, and it reduces the amount of concrete, avoiding the usage of sand in the plaster, making the building more economical [6][7].

CLC masonry concrete brick can be used as an alternative to red brick, to reduce environmental pollution and global warming. CLC masonry concrete brick is environmentally friendly. The energy consumed in the production of this type of masonry lightweight concrete brick is less than for the production of red brick, and it also neither produces pollution nor creates toxic products or have any impact on the environment [12]. This is because CLC masonry lightweight concrete brick is made of a mixture of cement, sand, water, and chemical admixture, to which is then added a foam that is stable in an

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ordinary concrete mixer. The addition of foam to the CLC mixture creates millions of voids or small cells in the material, which is why it is given the name of CLC masonry concrete brick.

Cement, as one of the basic ingredients of CLC masonry concrete bricks, is a binder that aggregates granules into a solid form. In using cement as a binding agent, the physical and mechanical properties of the CLC masonry concrete brick are determined by the composition of the cement to be used, and determining the optimum composition in terms of cement consumption when manufacturing the lightweight concrete brick will ensure the optimal results. Therefore, research is needed to compare the physical and mechanical properties of the CLC masonry concrete brick that is produced.

2 Material and Dimensions of CLC Masonry Concrete Brick

2.1. Cement

Commercially available cement is used, namely Holcim cement type III (**i.e. ASTM C 150-95a & SNI 15-2049-1994 & BS 12:1989)** with the strength of the initial high Portland Composite Cement (PPC) and a **specific gravity** of 2,950 kg/m^3 [11]. The physical and chemical properties of the PCC cement can be seen in Table 1.

Table 1. Physical and chemical properties of cement [3][11]

A. Compression Strength	
3 day	min 13 MPa
7 day	min 20 MPa
28 day	min 28 MPa
Fineness	280 m^2/kg
B. Time Settings	
Initial	45 mins
Final	375 mins
C. **Chemical properties**	
Silicon Dioxide (SiO_2)	23.04%
Aluminium Oxide (Al_2O_3)	7.40%
Ferric Oxide (Fe_2O_3)	3.36%
Calcium Oxide (CaO)	57.38%
Magnesium Oxide (MgO)	1.91%
Sulphur Trioxide (SO_3)	2.0%
Loss on Ignition (LOI)	3.94%
Free Lime	0.56%
Insoluble Residue	10.96%

2.2 Fine Aggregate

Fine aggregate as one of the components in cement must undergo a series of tests on the properties and characteristics of the material. In this study, the type of fine aggregate used is yellow sand (SNI-03-2834–2002) and the qualification limits determined for the fine aggregate are classified into four groups based on the degree of smoothness of the sand material [13]. This research includes sand zone III with a fines modulus of 3.030 [3].

2.3 Water

The water used is taken from the local water company with a pH 6–7 (**SNI 03-2874-2002** and meeting the requirements of **PBBI 1971 NI-2**).

2.4 Foaming Agent

Foamed concrete is produced by either a pre-foaming method or a mixed foaming method. The pre-foaming method involves the separate production of a base mix cement slurry (cement paste or mortar) and a stable preformed aqueous addition (foam agent with water), and this foam is then thoroughly blended into the base mix. In mixed foaming, the surface active agent is mixed with the base mixture ingredients and, during the process of mixing, the foam is produced, resulting in a cellular structure in the concrete as shown in Fig. 1. The preformed foam can be either wet or dry. Wet foam is produced by spraying a solution of foaming agent over a fine mesh, has a 2–5 mm bubble size, and is relatively less stable. Dry foam is produced by forcing the foaming agent solution through a series of high-density restrictions and forcing compressed air simultaneously into the mixing chamber. Dry foam is extremely stable and has a size smaller than 1 mm. Table 2 shows the properties of foamed concrete [1].

Table 2. Typical properties of foamed concrete [1]

Dry density (kg/m^3)	Compression strength (MPa)	Modulus of elasticity (E-value) (GPa)	Thermal conductivity (3% moisture) (W/mK)	Drying shrinkage (%)
400	0.5-1.0	0.8-1.0	0.10	0.30-0.35
600	1.0-1.5	1.0-1.5	0.11	0.22-0.25
800	1.5-2.0	2.0-2.5	0.17-0.23	0.20-0.22
1000	2.5-3.0	2.5-3.0	0.23-0.30	0.15-0.18
1200	4.5-5.5	3.5-4.0	0.38-0.42	0.09-0.11
1400	6.0-8.0	5.0-6.0	0.50-0.55	0.07-0.09
1600	7.5-10	10.0-12.0	0.62-0.66	0.06-0.07

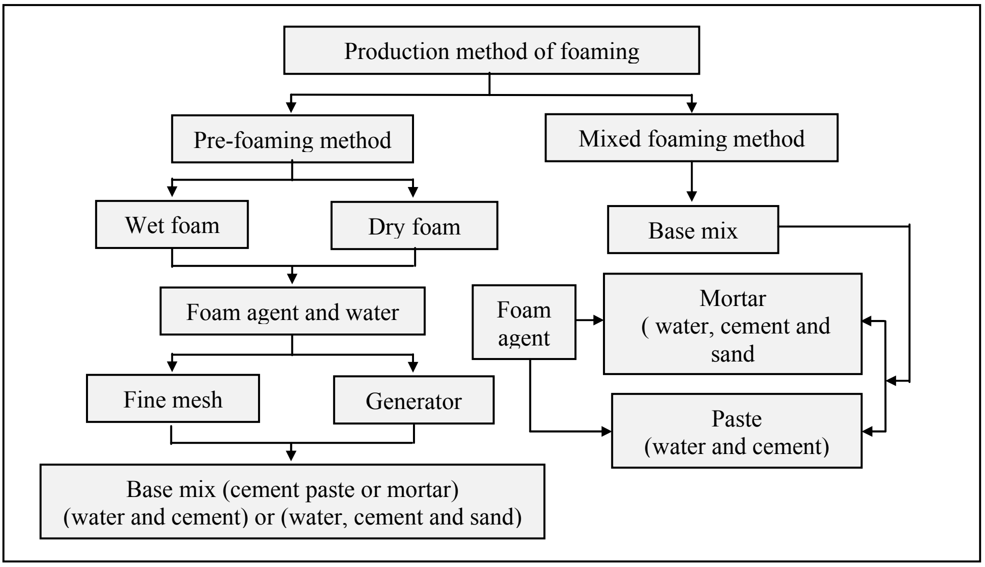

Figure 1. Classification process of production method for foamed concrete

The container holding the foaming agent must be kept airtight and under temperatures not exceeding 25°C. Once diluted in 80 parts of potable water, the emulsion must be used as soon as possible. The weight of the foam solution used is a minimum of 80 g/l, the containment solution used is as close as possible to 10 litres in volume, to check the weight (density) of the foam. Under no circumstances must the foaming agent should not contact with any oil or fat, chemical or other material that might harm its function (oil has an influence on the surface tension of water) [6] [10]. The foaming agent used is a brand under the trademark ADT.

2.5 Chemical Admixture

The chemical admixture is usually used in small amounts in the concrete mix. Its use is intended to improve certain properties of the mixture. The materials used are a high-range water-reducing admixture, wherein the material can reduce the water demand of the cement by up to a maximum of 15%. The product Sikament LN from Sika Company is a type of chemical additive used as a water reducer and to speed up the hardening of mortar that requires an immediate settling time or an accelerator. Sikament LN is an admixture classified as ASTM C494-92 type F [2]. With Sikament LN, the composition uses a dose rate of 0.40% of the total cement requirement of 300 kg, so the quantity needed for this experiment is as much as 1.2 kg.

2.6 Dimensions of the test objects

The nominal dimensions of the CLC brick of the United States standard are as follows: length: 600 mm, height: 200 mm, width: 75 mm. And the dimensions for modulus of elasticity testing diameter 150 mm and height 300 mm [5][6].

3 Experimental

This stage of the study involves the design of the mixture that will be used in the creation of samples of CLC masonry lightweight concrete brick. This variation plan is created as a guide to the composition of the mixture that will be investigated in this research and is presented in Table 3.

Table 3. Composition of the basic materials of samples [3][8]

No	Ingredients	Number /m^3					Units
		V1	V2	V3	V4	V5	
1	Cement	200	250	300	350	400	kg
2	Sand	500					kg
3	Foam agent and water	64.8					litres
4	Water	150					kg
5	Sikament LN	1.2					kg

4 Results and Discussion

From the research that has been done, the findings obtained based on the test results, i.e. according to ASTM and ACI standards, can be seen in Table 4.

Table 4. Comparison of the results for different amounts of cement in the making of CLC masonry concrete brick

No	Parameters	Cement 200 kg/m³	Cement 250 kg/m³	Cement 300 kg/m³	Cement 350 kg/m³	Cement 400 kg/m³
1	Success rate of CLC brick making (%)	33	100	100	100	100
2	Slump flow (mm)	280	280	275	275	280
3	Drying shrinkage (%)	31.13	0	0	0	0
4	Porosity (%)	0	23.93	27.64	42.30	25.38
5	Sound resistance (db)	0	49.38	34.94	31.10	50.57
6	Thermal conductivity (W/mK)	0	0.55	0.57	0.47	0.55
7	Permeability (cm/second)	0	2.77 x 10^{-5}	1.62 x 10^{-5}	2.60 x 10^{-5}	2.96 x 10^{-5}
8	Modulus of elasticity (MPa)	0	51.00	45.74	98.64	75.23
9.	Dry volume weight at the age of 28 days (kg/m³)	0	851	895	749	842
10.	Compressive strength (MPa)	0	0.82	1.28	0.56	0.68
11.	Absorption (%)	0	16.02	29.11	37.85	28.69

5 Conclusion

The different compositions studied included the use of 200 kg/m³, 250 kg/m³, 300 kg/m³, 350 kg/m³ and 400 kg/m³ of cement. From the research conducted, it was found that the cement composition affects the physical and mechanical properties of concrete masonry bricks, including the success rate of CLC brick making, volume weight, compressive strength and others.

The research results show that the CLC masonry concrete brick variants that qualified as brick CLC included only the cement proportions of 250 kg/m³, 300 kg/m³, 350 kg/m³ and 400 kg/m³, while the cement sample with 200 kg/m³ cannot be recommended for use as a successful mixture for producing CLC masonry bricks because of the drying shrinkage seen at the age of just 1 day.

The use of different cement compositions of 200 kg/m³, 250 kg/m³, 300 kg/m³, 350 kg/m³ and 400 kg/m³ has an influence on the physical and mechanical properties of the CLC masonry concrete bricks produced, as can be seen in Table 4. The results of the research show that the average volume weight is 749–895 kg/m³. The lightest variant is the sample using 350 kg/m³ of cement. The average compressive strength after 28 days is 0.56–1.28 MPa, where the highest compressive strength is found in the sample using 300 kg/m³ of cement. The average modulus of elasticity after 28 days is in the range 45.74–98.64 MPa, and the highest value of the modulus of elasticity was when using 350 kg/m³ of cement.

If we compare the results from Table 4 with previous studies shown in Table 2, then we can see that the results obtained for the average volume weight (749 to 895 kg/m³), compressive strength (0.56 to 1.28 MPa), thermal conductivity (0.47 to 0.57 W/mK) and drying shrinkage (0%). The compressive strength and volume weight are similar, while the results for the thermal conductivity, modulus of elasticity, and drying shrinkage are different.

Therefore, increase in the use of cement in the manufacturing of CLC masonry concrete brick is found not to produce an increase in compressive strength and also resulted in a more severe volume weight of the CLC masonry concrete brick. From this review of the mechanical and physical properties obtained using varying amounts of cement, the best (optimum) result is achieved with the use of 350 kg of cement.

We give thanks to the Faculty of Engineering Tanjungpura University Pontianak West Kalimantan for support and funding, and to all parties involved in this research.

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