Production of Lightweight Geometries Geopolymer Concrete Blocks

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Abstract: In this research two differences geometries of geopolymer lightweight concrete masonry units (GPLWCMUs) were produced. According to the Iraqi Standard No.1077/1987, the GPLWCMUs type I are classified as solid masonry units class A, that are used both in the interior and exterior walls which exposed to calamity effects. As concerned to GPLWCMUs type II, they are classified as hollow masonry units class B, which can be used in the constructions above ground level but not exposed to calamity effects. The density for the two types were 1575, 1350 kg/m³ respectively, whereas water absorption and compressive strength for the two types ranged from 6-7.5%, and 13 MPa and 5 MPa. As a result: the two GPLWCMUs can be classified as lightweight units because they complain the Iraqi Standard No. 1129 for the year 1990.

1. Introduction
The increased focus on energy conservation and environmental rotection has led to the search for alternatives to the usual building materials. Urgent efforts are being made around the world to develop environmentally friendly building materials that require minimal utilization of natural resources and help reduce greenhouse gas emissions [1].

Priya Rachel stated that the compressive strength of fly ash-based concrete based on fly ash achieves good compressive strength and water absorption decreases with increasing concentration and treatment time. The water absorption ratio was found to decrease with increasing NaOH concentration from GP1 to GP4. Water absorption ranged from 2% to 4.33% and 1.33% to 3.42% for treated samples at room temperature and at 60 °C. Water absorption was found in samples treated at a lower temperature than samples treated at room temperature [2].

Revathi, V.and study the use of activated alkali Bottom ash (BA) and slag granular melting furnaces (GGBS) Mix in paving blocks. Initial effort at the bottom of anabolic alkaline Ash, Geopolymer Mortar Industrial Slag Furnace (BA-GGBS-GP) River sand was carried out to determine the appropriate mix of paving block. The test results show that the combination of BA-GGBS geopolymerThe paving blocks achieved remarkable compressive strength under steamTreat as well as in ambient mode in 3 days [3].

Patcharapol Posi and others showed in their results that lightweight polymeric geology Crete with a compressive strength of 28 days from 1.0-16.0 MPa, density of 860-1400 kg / m³ can be manufactured. Lightweight concrete can be used for wall construction and partitions [4].

This paper reports on the use of geopolymer concrete in precast concrete paver blocks and compares the performance with the commercial available OPC paver blocks of the same mix proportions. The mix design with a target strength of 47 MPa was developed to create paver blocks suitable for highways [5].
Ostwal and Chitawadaji [6] stated in their research the features of geopolymer concrete blocks at ambient curing condition. The materials considered were fly ash (Class F), GGBS, Quarry dust and sand. They used Sodium hydroxide and sodium silicate as alkaline activators ratio as 2.5. The experimental program involved casting of geopolymer blocks for testing the compressive strength as shown in Figure 1. The density of geopolymer was 2350 kg/m$^3$ The Alkaline solution to binder ratio was 0.17 to 0.24, masses of alkaline solution and binder in kg/m$^3$ were obtained, the molarity of sodium hydroxide solution was 8M, Compressive strength test showed that the optimum alkaline solution to binder ratio for the preparation of geopolymer concrete blocks was 0.23 with 8MPa for 8M molarity of NaOH at ambient curing. The results show that the substantive of coarse aggregates by quarry dust produced a reduction in compressive strength to reach 4 MPa. Henceforth geopolymer blocks produced can be used as masonry units for non-structural purposes.

![Figure 1. View of GPC block](image)

1.1 Production of geopolymer lightweight concrete masonry units

In this investigation, two type were produced for lightweight concrete construction units (GPLWCMUs), boned and solid. Figure (3) shows the details of concrete blocks and their dimensions. Wooden molds have been prepared for production (GPLWCMUs). The concrete mixture was poured into three equal layers; vibrating the table for 25 sec. The samples were carefully dismantled after 48 hours and then cured in an oven for another 48 hours. At the end of 28 days, the units were ready for experimental testing.

1.2 Materials

The material utilized to make GPLWAC are; fly ash type F (low-calcium) with SiO$_2$, Al$_2$O$_3$ and Fe$_2$O$_3$ content of 92.25, artificial local coarse lightweight aggregate of Absorption, (%) [7]= 11.5, Specific gravity, [7]of 1.63, and dry rodded unit weight, of 773.31 (kg/m$^3$) [8], alkaline solution, as well as water. The Fly ash utilized was imported from Turkey as by product of coal combustion from ISKENment-Turkey power station during production of electricity. The tests show that the fly ash meets the specification of ASTM C 618 [9]. A high-range water reducing admixture DARACEM 19CFMQ [10] was used. This type of superplasticizer is liquid based sulphonated naphthalene and complies with the ASTM C494-2005 Types F [11].

Na$_2$SiO$_3$ sol plus NaOH sol Figure (2) were used for making the alkali-activated solution, sodium silicate solution, chemical composition and properties were: specific gravity of 1.534 and viscosity of 600,Sodium hydroxide takes the flakes’s shape (NaOH pure by 98 %), manufactured in Iraq. The sol had been made at a previous day so as to cool it, after that it has been blended with Na$_2$SiO$_3$ by a weight ratio of 1: 2.5 before the start of mixing the GPLWAC, after that the mixed was added to the fly ash. Artificial lightweight aggregates produced from bentonite clayey as well as water glass Na$_2$SiO$_3$ [12, 13], were utilized with maximum size of 19mm as coarse aggregate complete substitution in samples done in this research. The properties of artificial lightweight coarse aggregate (ALWCA) that used in this investigation were prepared based on the requirements of ASTM C330-03 [14].
2. Production of GPLWAC

In order to produce the GPLWAC that used in producing the units, ratio of alkali sol, molarity, superplastizaier ratio, fly ash, artificial local coarse lightweight aggregate, natural normal weight fine aggregates (sand) with maximum size of 4.75 mm was used as fine aggregate, its gradation lies in zone (2). Artificial lightweight aggregate produced from bentonite clay and water glass (sodium silicate) [12, 13].

The experimental work start with finding the ideal extent of ALWCA proportion acquired by trialing [15], as there details can been seen in Table 1. ALWCA and fine aggregate were prepared by dampened ALWCA for one day, after that, it was dried for other 24 hours to simulate dried-state. Fly ash added to the ALWCA inside the rotating drum mixing and mixed for three minutes approximately. Sodium silicate and the sodium hydroxide solutions were mixed before minimum twenty four hours to be prepare to mixed it for two min with the mixture. The superplasticizer with the final quantity of the water had been at last blended within two min and included to the mixture.

| Mix designation | FA kg/m³ | Mix proportion FA: S: LWA | A/FA | W/FA | NaOH molarity | Fresh density (kg/m³) | Compressive strength at 7 days (MPa) |
|------------------|----------|---------------------------|------|------|-------------|---------------------|----------------------------------|
| M                | 500      | 1:1.50:1.10               | 0.4  | 0.35 | 16          | 1910                | 27.3                             |

Note 1: Mix proportion by weight, FA= fly ash, S= fine aggregate, LWA= lightweight coarse aggregate, A= activator, W= water.

Note 2: curing temperature = 90 °C for two days, superplasticizer dosage = 1.9% by weight of fly ash, sodium silicate: sodium hydroxide solutions = 2.5 for all mixes.
3. Experimental tests
All the investigational tests for GPLWCMs were made in the National Center for Construction Laboratories and Researches according to Iraq Specification, these test are; water absorption [16], density [17] and compressive strength [16].

3.1 Geopolymer lightweight concrete masonry units
Two geometries of geopolymer lightweight concrete masonry units (GPLWCMUs) were prepared from the selected geopolymer lightweight concrete mix (M), which are shown in Fig. (3). The requirements of concrete masonry units according to Iraqi Standard No. 1077/1987 [16] are illustrated in Table (2).

The first geometry of geopolymer lightweight concrete masonry units is classified as solid according to Iraqi Standard No.1077/1987 that the hollow volume is less than 25% of the total volume of concrete masonry units. While the second geometry is classified as hollow masonry units, (their hollow volume is greater than 25% of their total volume). Experimental test for GPLWCMUs were carried out including; water absorption, density, and compressive strength. The results were compared with the requirements of the Iraqi Standard No.1077/1987[16].

| Unit type | Class | Compressive strength (MPa) | Maximum water absorption (%) |
|-----------|-------|----------------------------|-----------------------------|
|           |       | Average of three units | Individual units |
| Solid     | *A    | 13            | 11           | 10 |
|           | *B    | 9             | 7            | 15 |
| Hollow    | A     | 7             | 6            | 15 |
|           | B     | 5             | 4.5          | 20 |

*A: Used in the construction of interior and exterior walls which are exposed or not exposed to moisture, weather effects, under or above ground level [16].

*B: Used in the constructions above ground level in the interior and exterior walls none exposed to moisture and weather effects[16].
3.2 Water absorption
The water absorption results of GPLW concrete masonry units are shown in Table (3). It can be seen that the value of water absorption is low compared with the Iraqi Standard, and that made it usable in different construction uses.

3.3 Density
According to the Iraqi standard for concrete building units, the density is the mass of these units divided by their total size. Iraqi Standard No. 112/1990[17] classifies concrete building units into three groups according to their density. These groups are, normal weight units whose dry oven density is not less than 2000 kg / m³, moderate weight units, containing dry oven density in the range of 1680 to 2000 kg / m³, lightweight units, with oven drying density more From 1680 kg / m³. Table (3) shows the density of units prepared in this investigation. The results indicate that the geopolymer concrete building units prepared in this investigation can be classified as lightweight units in accordance with Iraqi Standard No. 1129/1990[17].

3.4 Compressive strength
The compressive strength results of GPLWCMUs units are shown in Table (3). According to the Iraqi Standard No.1077/1987[16], the first geometry of masonry units prepared in this investigation is classified as class A, which is used in the construction of interior and exterior walls exposed to moisture and weather effects. While the second geometry of masonry units, is classified as class B which is used in the construction above ground level in the interior and exterior walls not exposed to moisture and weather effects.

Figure 4. GPLWCMUs geometries
Table 3. Properties of masonry units

| Type of units | Absorption (%) | Density (kg/m³) | Compressive strength (MPa) * | Classification according to Iraqi Standard No.1077/1987 and No.1129/1990 |
|---------------|----------------|-----------------|-----------------------------|--------------------------------------------------------------------------------|
| GPCMUI        | 6              | 1575            | 13                          | Class A, Solid, Lightweight                                                   |
| GPCMUII       | 7.5            | 1350            | 5                           | Class B, Hollow, Lightweight                                                  |

* Based on net loaded area of the unit.

4. Properties of geopolymer lightweight concrete products
1. Two geometries of geopolymer lightweight concrete masonry units (GPLWCMUs) from reference geopolymer lightweight concrete mix were produced. The GPLWCMUs type I are classified as solid masonry units class A according to the Iraqi Standard No.1077/1987, which is used in the construction of interior and exterior walls exposed to moisture and weather effects, while GPLWCMUs type II are classified as hollow masonry units according to Iraq Standard No.1077/1987, is classified as class B according to Iraq Standard No.1077/1987, which is used in the constructions above ground level in the interior and exterior walls not exposed to moisture and weather effects.
2. The two geometries of geopolymer lightweight concrete masonry units can be classified as lightweight units according to Iraqi Standard No. 1129 /1990, with density 1575, 1350 kg/m³, water absorption 6, 7.5%, and compressive strength 13 MPa and 5 MPa respectively.

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