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Evaluation of Water-to-Plaster Ratio on Products of Nafada Plaster of Paris (POP)

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ABSTRACT

Ceramic mould is one of the most useful products obtained from Plaster of Paris and therefore, it is important to keep to specification the ratio of water-to-plaster in industries as it has direct influence on the product characteristics. This paper presents results of some selected ratio mix: 90:100, 100:100, 110:100, 120:100 and 130:100 subjected to absorption test, compressive strength test, density and shrinkage test to determine a suitable consistency for Nafada POP products. Results obtained showed that the ratio mix of 90:100 and 100:100 gave better properties of the five different samples selected. On the basis of this assessment, industries can obtain standard products from gypsum plaster.

Keywords: Plaster of Paris, Ratio mix, Compressive strength, Density, Absorption

INTRODUCTION

Plaster of Paris (POP) also known as calcium sulphate hemihydrate is a white hygroscopic powder obtained by crushing gypsum into powder and gently heating to drive off its water of crystallization. POP is used for producing ceramic moulds and sculptures of desired shape. It is also used in the field of medicine to create soft bandages to treat bone fractures. In architecture, POP is used specifically for decorative purposes (Asante-Kyei, 2012). To carry out these applications, water to plaster ratio is very important as it has direct influence on the products obtained from POP. Alrawashdeh *et al.*, (2014) studied the influence of water to plaster ratio, gypsum powder size, water temperature, water quality and admixture amount on setting time of POP produced from gypsum deposit of South Jordan. Results obtained showed that setting time was delayed with increasing volume of water, powder size, admixture amount, ageing time and decreased amount of dissolved salts. Nawi *et al.*, (2015) showed the result of a study of change of physical properties of pottery due to addition of different quantities of POP waste to the pottery powder mixture. Rameshwar *et al.*, (2013) researched on the physical properties of gypsum manufactured in India. The study showed the setting time, particle size and consistency of gypsum samples collected from India. Park *et al.*, (2009) described the result of an effort to quantify thermal properties of gypsum board. Results indicated that at elevated temperatures, thermal properties of gypsum revealed significant changes. Madu *et al.*, (2016) developed of Plaster of Paris from gypsum deposit of north eastern Nigeria (Nafada). Result showed that POP can be produced from Nafada gypsum and used in the ceramic industry for making moulds. This paper therefore presents the results of consistency (water-to-plaster ratio) on products of POP from Nafada.

EXPERIMENTAL PROCEDURES

Materials

Digital weighing scale, Manual compressive strength testing machine, Vibrating sieve, stirrer, measuring cylinder, wooden mould (100mm x 40mm x 30mm) and a Vernier Caliper.

Procedures

Variation in the water to plaster ratio has a direct influence on product characteristics. According to Lambi and Adegoke, (2013) the hardness, strength, durability and weight of moulds have been found to be directly related to the mix ratio of water to gypsum plaster used in producing the mould.

Gypsum plaster was investigated using varying percentages of water-to-plaster ratios as shown in Table 1. Its properties which include: compressive strength, density, percentage of absorption and shrinkage were tested.

Table1. *Selected Water-to-Plaster Ratio*

Sample No.	**1**	**2**	**3**	**4**	**5**
Plaster	100g	100g	100g	100g	100g
Water	90ml	100ml	110ml	120ml	130ml
Plaster to water ratio	100:90	100:100	100:110	100:120	100:130

The water-to-plaster ratio (W:P) is known as the consistency of the product (William and Lesley, 2006). For each ratio mix, two samples each was produced by adding 100g of POP to clean water of 90, 100, 110,120, 130 ml respectively. The added plaster was allowed to soak for two minutes to ensure that POP crystals are surrounded by water. Samples were stirred vigorously after soaking to obtain a homogenous lump free consistency. When the mixture became plastic, it was poured into a wooden mould to assume its shape. The samples are shown in plate 1. These rectangular samples were produced by using a wooden mould having a specification of 100mm x 40mm x 30mm.

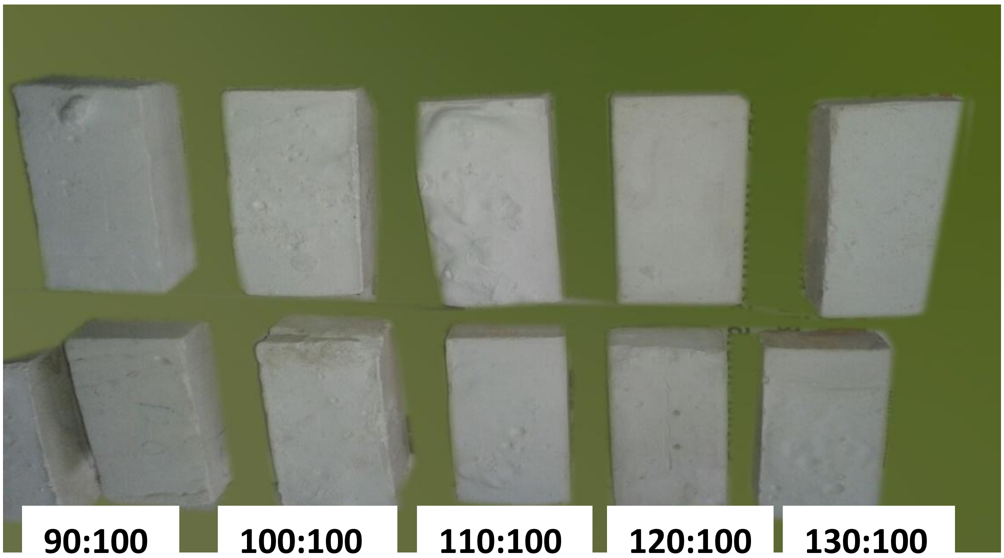

Plate1. *Samples Prepared from Different Ratio Mix*

Samples were allowed to dry after moulding and subjected to the following tests: absorption test, density test, compressive strength test and shrinkage test.

Absorption Test

The samples in plate 1 were weighed using the digital weighing scale and the results were recorded. The samples were again immersed in water for two hours which was enough time for it to get saturated. Finally, the saturated samples were weighed and the results obtained were recorded. The percentage of water absorption is given by equation 1:

$$\%\ of\ WaterAbsorption = \frac{Saturated\ weight - Dry\ weight}{Dry\ weight}\ \text{X}\ 100 \qquad (1)$$

Density Test

Density is defined as the mass per unit volume of a substance (Kashimbila, 2003). That is:

$$\text{Density} = \frac{mass}{volume}\quad (\text{g/cm}^3) \qquad (2)$$

The digital weighing scale was used to measure the mass of the rectangular bar while its volume is given by this formula

Volume = L x B x H (cm^3)

Where L = Length, B = Breath, H = Height

Compressive Strength Test

The machine used for this test was the Manual Compressive Testing Machine which has a capacity of 150 kN and a piston area of $122.71cm^2$. The various ratio mixes were subjected to compression by putting each sample between the upper and the lower jaw and compressed until it was crushed. Readings of force applied to crush the samples were gotten from the indicator after samples crushed into pieces. The twelve samples used for this test were rectangular in shape and the compressive strength is given by equation 3

$$\text{Compressive Strength} = \frac{Applied\ Force}{Cross\ Sectional\ Area} \quad (kN/mm^2) \qquad (3)$$

Where the applied force or the load is measured in kilo Newton and the cross-sectional area of the rectangular sample is given by Length (mm) x Breath (mm). Therefore, the S.I unit for compressive strength of this experiment is measured in kN/mm^2 or MPa.

RESULTS AND DISCUSSION

Figure 1 shows the percentage of absorption for five different samples of ratio mix selected.

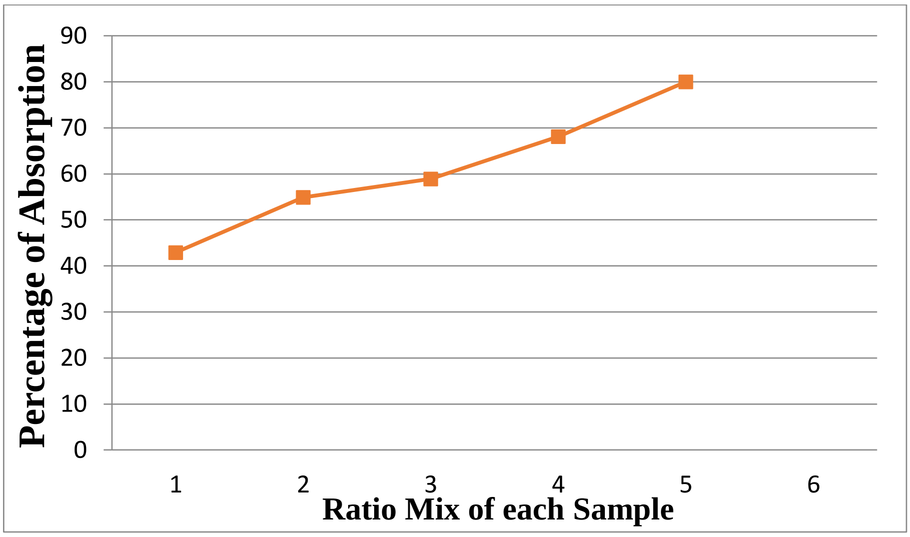

Figure1. *Percentage of Water Absorption for each Ratio Sample*

Figure 1, shows an increasing order of the percentage of absorption for each sample. The reason for this increase in porosity is the addition of excess water on the POP. Thus, POP mixed with excess water give products of high porosity. In general, when the volume of water increase, the voids fraction also increase and the bond between the gypsum particles decreases leading to the lower strength of the sample (Lewry and Willianson, 1994). In addition, when less quantity of water was added to POP, a lower absorption percentage was recorded. Therefore, from this study, it can be ascertained that, the use of the same amount of water and plaster powder ratio is recommendable when processing POP to arrive at an average water absorption level.

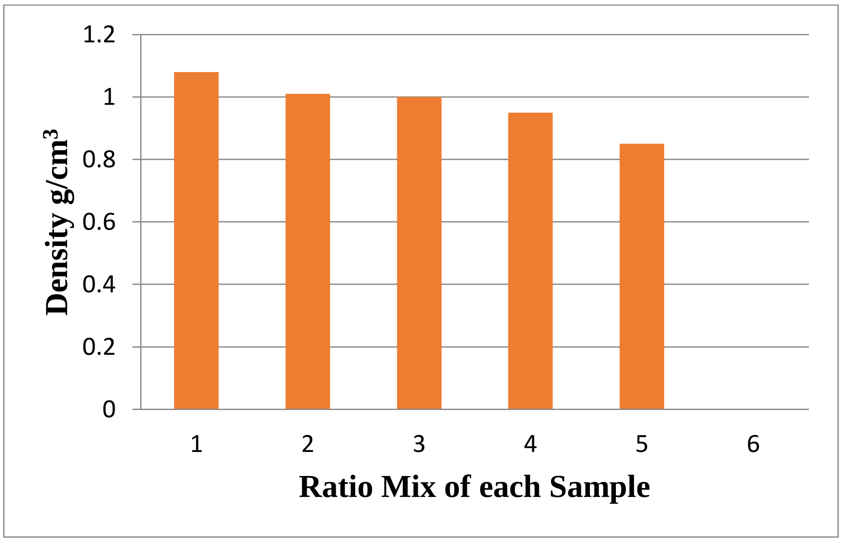

Figure2. *Density versus Ratio Mix of Sample*

Figure 2 shows the density of the selected samples. The five different samples showed slight decrease in the density of each mixture as volume to water increased. Sample 1, 2, 3, 4 and 5 showed a density of 1.08g/cm^3, 1.01g/cm^3, 1.00g/cm^3, 0.95g/cm^{3}and 0.88g/cm^3 respectively. Samples 1, 2 and 3 have better densities with an average of 1.03g/cm^3 while samples 4 and 5 have lower densities with average of 0.92g/cm^3. All these densities have their respective volumes, depending on the quantity of water used in mixing each sample. Density result therefore shows that the lower the volume of water the higher the density and the higher the volume of water used for the sample the lower the density.

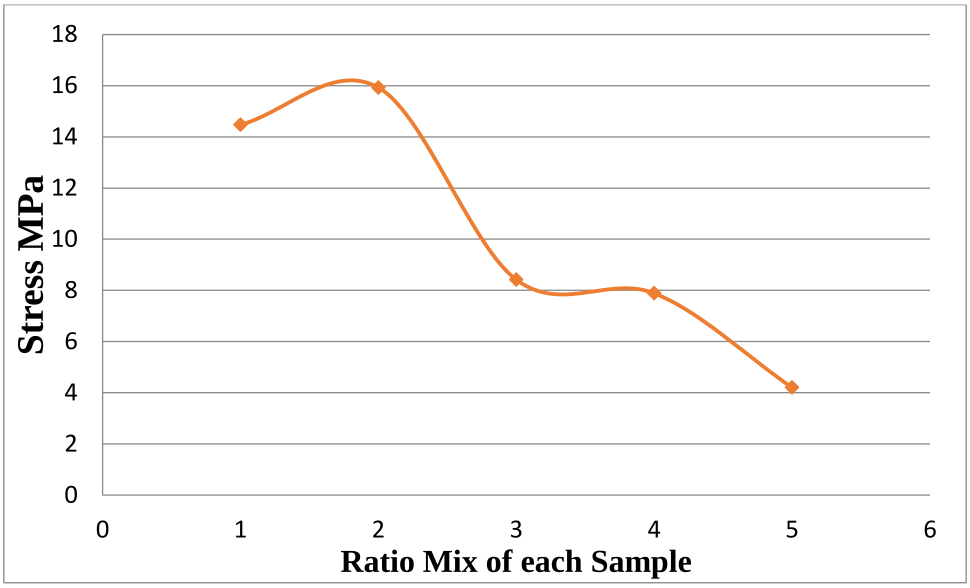

Figure3. *Compressive Strength Variation with Ratio Mix*

From figure 3, Sample 1, which has a ratio of 90:100, has a compressive strength of 14.47 N/mm^2. Sample 2, with ratio 100:100 has a compressive strength of 15.92 N/mm^2. It shows that when 100g of POP was added to water of 100ml and below, there is an increase in strength. But as water quantity of 110ml in sample 3 to 130ml in sample 5 were added respectively, it was observed that the compressive strength decreased down the graph with the values 8.4, 7.8, 4.2 N/mm^2 respectively. The POP strength therefore decreases with greater increase in the volume of water added. Generally, when the volume of water increases, bond between gypsum particles decreases leading to a lower strength of the sample (Lewry and Willianson, 1994).

CONCLUSION

The consistency of products from gypsum plaster shows that POP mixed with excess water produces products of high percentage absorption. The void fraction on samples increases when volume of water increases and lowers the strength of the products of plaster. Density result revealed that the lower the volume of water, the higher the density of the products. Therefore, the ratio of 90:100 and 100:100 from the samples gave good percentage of absorption, density and high compressive strength which could be used by industries to obtain POP products with excellent properties.

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