THE EFFECT OF WATER/ PLASTER RATIO VARIATION ON ABSORPTION PROPERTIES AND FLEXURAL STRENGTH OF GYPSUM PLASTER FOR CERAMIC SLIP ROTARY MOULDING

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ABSTRACT: *The effect of variation on water plaster ratio for two unknown Gypsum plaster were determined and been compared with common Gypsum plaster in terms of its absorptive properties (porosity and water absorption) and flexural strength. Two (2) types of Gypsum plaster (A and B) were subjected to several test to determine the chemical composition, porosity, water absorption and flexural strength property. Five (5) samples of each type of plaster were prepared according to ASTM C293-02 for flexural test and ASTM C373-88 for porosity and water absorption test. Result shows that higher the water plaster ratio resultant in higher porosity percentage and water absorption regardless of plaster type. However, water plaster ratio shows an inversely relationship with flexural strength. Hence it can be concluded that to increase the strength, some porosity must be sacrificed. As for comparison of the two plaster, Plaster A has a superior strength while Plaster B exhibit greater water absorption properties.*

Keywords: *Water Plaster Ratio, Porosity, Flexural Strength, Ceramic Slip Rotary Moulding*

1. INTRODUCTION

The high strength and good water absorption properties make plaster mould important in producing many types of ceramics ware [1]. In order to optimize the usage of plaster mould in ceramic production, the study of the properties and behaviour of the plaster is vital as the quality of the final product is directly related to the quality of plaster mould use [1-2]. Water to plaster ratio is a one of significant factor that determine the quality of plaster mould [2-4]. The selection of the water plaster ratio may vary based on the particular requirement of casting system. In this paper, the relationship of water plaster ratio variables of two types of unknown plaster towards its absorptive properties (water absorption and porosity) and flexural strength are been determine and compared with common mould plaster. The result are expected can be used as benchmark in making plaster mould for a new developed system known as ceramic slip rotary moulding (CSRM).

Ceramic Slip Rotary Moulding, CSRM is a newly developed system for producing hollow ceramics ware. This system was developed with the integration of polymer rotary moulding into ceramic slip casting. Rotary moulding has been used for the manufacture of a wide range of hollow ceramic ware (Figure 1) by using porcelain slip[1-2]. Previously, the process involves heating the precursor polymer powder which is rotated typically across 2 axes. As the powder starts to melt it spreads along the walls of the mould where it forms a skin; after cooling the cast part can be removed. More recently, the technology makes use of slip directly instead of powder [7]. Therefore, the overall production rate cycle time were shorten the as well as potentially reduced the labour requirement due to the simplicity of the process has to offer.

Despite higher initial investment needed for CRSM process implementation, the quest for more suitable mould material which last longer and considerably less wasteful process will provide long term cost reduction. Currently, usage of plaster of paris have a very limited lifespan where it only can be used up to 40 casts only before it is totally saturated [3][4]. In addition, the usage of conventional plaster of paris with CSRM system is fond to be very unsuitable because the addition of external heat radiated from the system tends to accelerate the degradation of plaster of paris. The mould become powdery after several castings. The surface of the mould cracks easily as the number of cast increase. Because of that, this new system required high strength and good absorptive mould material characteristic [5]. Hence, better performance mould in terms of its durability and usability are able to be produced.

Fig (1) Examples of hollow porcelain products produced via CRSM (Adapted from [6])

2. METHODOLOGY

The two types of gypsum plaster (Plaster A and Plaster B) that been used in this study were firstly been subjected to XRD phase analysis for chemical analysed. The result was then been compared with the data base existing in the XRD library to determine the dominant crystalline phase present in both plaster [7]. Afterward, five (5) samples of both plaster A and plaster B are prepared according to water /plaster ratio of 50%, 60%, and 70% before subjected to the flexural testing which was done according to ASTM C293-08 [8]. Subsequently, the residue of the broken sample from the previous test was then subjected to water absorption test according to ASTM C373-88 [9]. All the samples have been done under the condition stated in Table 1.

Table (1) Parameter use for sample preparation.

Water temperature [°C]	Soaking time [min]	Mixing time [min]	Mixer speed rpm
25	1-2	5-7	300-500

To avoid the effect of water hardness, all the sample of both plaster were prepared by mixing the plaster powder with distilled water [4][2]. Technical data between plaster A, plaster B, moulding plaster and casting plaster have been record in Table 2.

Table (2) Comparison of technical data of unknown plaster with common type of plaster moulding and plaster casting.

Property	Type of plaster			
	Moulding plaster	Plaster A	Plaster B	Casting plaster
Water plaster ratio	70-80	50-70	50-70	60-70
Chemical composition	$CaSO_4.1/2H_2O$	$CaSO_4.1/2 H_2O$	$CaSO_4.1/2 H_2O$	$CaSO_4.1/2 H_2O$
Flexural strength (MPa)	2-3	1.3 – 6.8	1.2- 5.2	5-10

3. RESULTS AND DISCUSSION

Phase identification using XRD for both plaster are shown in Figure 2. The comparison made between the results and data base shows that the crystal form of both gypsum plaster powder selected for this research are consist almost exclusively of one phase , which is hemihydrate. Hemihydrate takes place hydration reaction immediately after mixing with water hence make the plaster high in solubility [10].

The complete dissolution of hemihydrate into dehydrate as the plaster were set form series of interlocking of dehydrate crystal matrix (capillaries) giving the plaster the ability to absorb water after it's dry. Thus make the absorption of water in the process of slip casting possible [11].

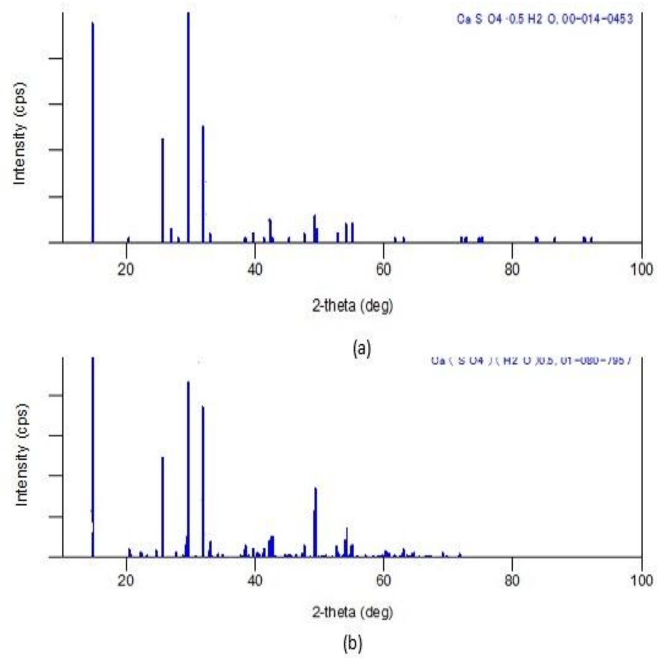

Fig (2) XRD phase identification for (a) plaster A and (b) plaster B.

The complete dissolution of hemihydrate into dehydrate as the plaster were set form series of interlocking of dehydrate crystal matrix (capillaries) giving the plaster the ability to absorb water after it's dry. Thus make the absorption of water in the process of slip casting possible [11]. As mention in the introduction, the variation of water to plaster ratio play an importance role in determining the performance of the mould in terms of water absorption, porosity, and strength. Based on result shown in Figure 3, as the ratio of water/plaster increase, the percentage of water absorption also increase.

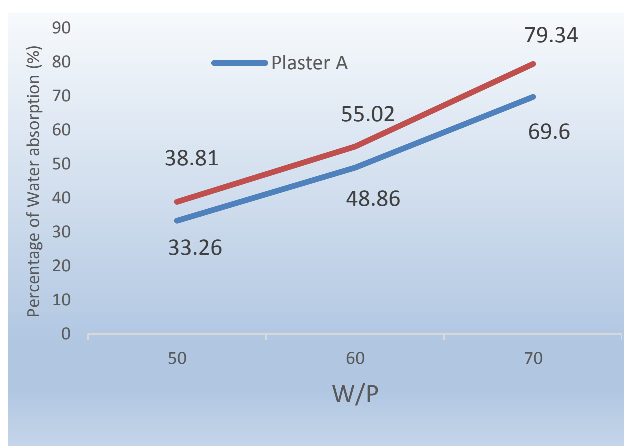

Fig (3) average percentage of water absorption between water/plaster ratios for plaster A and plaster B.

This is true for both types of plaster A and B. However, by comparing the result of the two plaster, plaster B shows higher water absorption percentage then plaster A for each water/plaster ratios, overall by 6.6%. Thus, the data suggest that plaster B is more porous than plaster A.

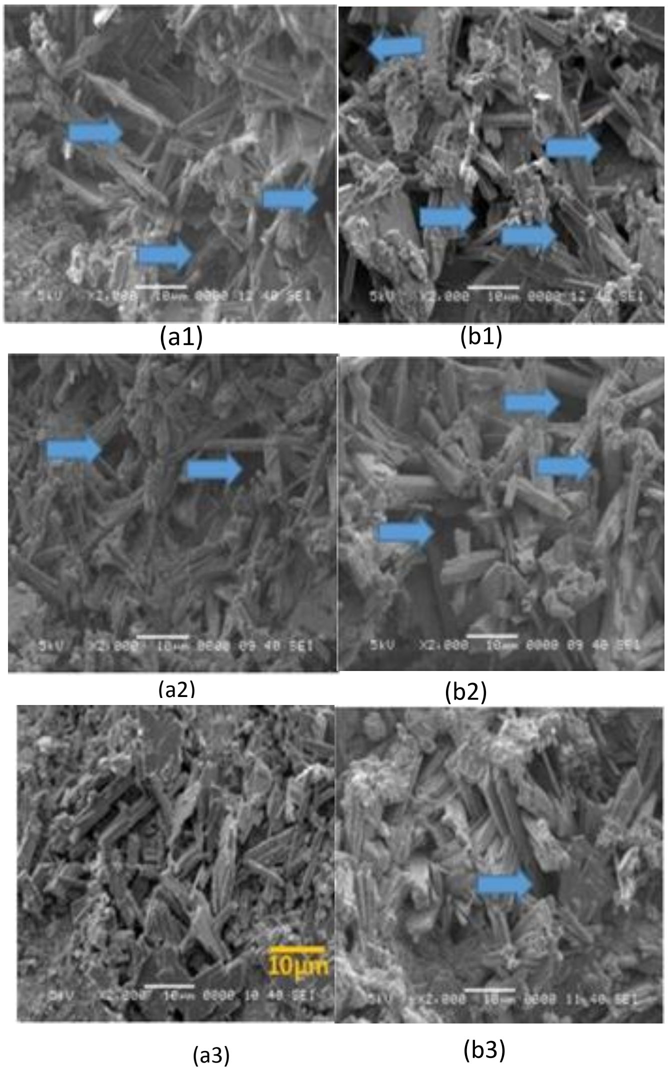

Fig (4) SEM micrograph of the plaster with (a1 &b1) 70% (a2 & b2) 60% and (a3 & b3) 50% of water/plaster with arrow showing the porosity of (a) plaster A and (b) plaster B at 2000X magnification.

To support these result, SEM morphology image of each water/plaster ratio of both plaster were capture and studied. Figure 4 shows the SEM image of different water/plaster ratio for both plaster A and plaster B. Based on the image, the structure of calcium sulphate crystals are in the cluster of needle structures whereas the dark sport in between the structure is the empty space or pore. From the figure, it can be observes that as water/plaster ratio increase the dark sport are also increase. Hence it can be deduce that water/plaster ratio has linear relationship with percentage of water absorption and porosity. Contradiction to the result in Figure 2, there is an inverse relationship between flexural strength and water/plaster ratio as shown in Figure 5.

Types of plaster	Average Flexural strength (Mpa)		
	Water to plaster ratio		
	70	60	50
Plaster A	1.3	3.8	6.8
Plaster B	1.2	3.4	5.2

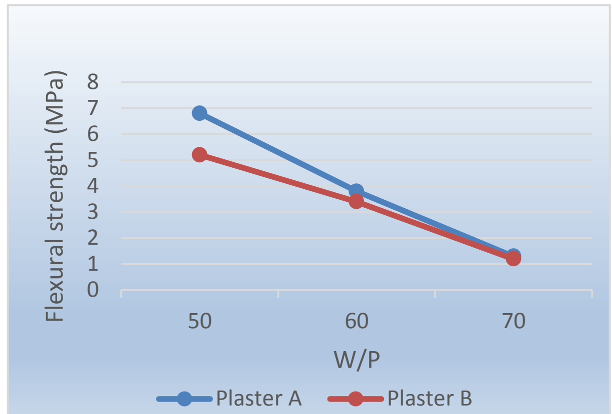

Fig (5) Relationship between flexural strength and water/plaster ratio for Plaster A and Plaster B (a) and its measured data (b)

As the ratio of water/plaster increase, flexural strength will decrease. These result exhibit a similar pattern behaviour done by previous researchers. This is due because of as the amount of water increase the void fraction between the crystalline structures of plaster also increase. Thus, weaken the bonding of the dehydrate crystal structure of the plaster [3],[12]. Hence affected the strength of the mould. Referring to Figure 4 and, plaster A shown higher strength properties compared with plaster B.

4. CONCLUSIONS

The result collected from both plaster clearly said that the variation in water plaster ratio will affect the absorption and porosity properties and flexural strength of the plaster mould. The higher the water plaster ratio, the higher the absorption and porosity of the mould which is vice versa with flexural strength. To increase the strength of the mould, some porosity must be sacrificed. However, the selection of the water to plaster ratio of the mould to be used in CRSM must be based on the particular requirement of the set plaster and its application.

5. REFERENCES

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