Plaster Mould Selection for Ceramic Slip Rotary Moulding System (CSRM)

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ABSTRACT.

The suitability of two types of plaster as mould material for CSRM were investigated. The goal of the study is to select the best type of gypsum plaster to be used as mould material for new alternative of ceramic slip casting named as Ceramic Slip Rotary Moulding (CSRM). The new system required porous and stronger mould as complement to the additional system modification of existing conventional ceramic slip casting. Thus, higher lifespan of mould can be produced and directly reducing plaster waste generation. Two(2) types of plaster (hard and soft) were subjected to several test to determine the properties of the plaster in terms of density, particles size, porosity, water absorption and flexural strength. 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 particle size distribution affects the porosity percentage, water absorption and flexural strength of the mould. The larger the particles size the higher the porosity and water absorption percentage of the mould. Soft plaster has the highest porosity level compared to hard plaster. However, when it is exposed to external heat repeatedly, soft plaster reduced its ability to absorb water from time to time. In contradiction, hard plaster gives higher flexural strength compared to soft plaster. In terms of surface roughness, soft plaster produced the most finely green body compared to hard plaster. This

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result is used as a reference in future research in order to achieve the main goal of producing semi- permanent mould for ceramic slip rotary moulding.

Keywords: *plaster moulding, porosity, water absorption, flexural strength, ceramic slip rotary moulding*

INTRODUCTION

Ceramic Slip Rotary Moulding, CSRM is a new developed system for producing hollow ceramics ware. This system was developed with the integration of polymer rotary moulding and ceramic slip casting. It is known that the rotational process in rotary moulding is able to produce hollow ceramic green body. Currently this system is successful in producing hollow ceramic ware by using porcelain slip[1][2]. The rotational moulding process makes the production of green body faster than the conventional slip casting. However, the use of the conventional Plaster of Paris (POP) as mould material still limits the production of green body as it is known that plaster mould has limited lifespan. It is said that, conventional Plaster of Paris (POP) mould for ceramic slip casting can produce as little as 40 casts before it is totally saturated [3][4]. In addition, the usage of conventional Plaster of Paris (POP) with CSRM system is found to be very unsuitable because addition of external heat radiated from the system tends to accelerate the degradation of the plaster. The mould becomes powdery after several castings and surface of the mould cracks easily as the number of moulding increases [5][6]. Hence a great strength of mould is required for CSRM system.

To achieve the goal of permanent mould, preliminary studies of two types of plaster (hard and soft) are subjected to several tests. The main objective is to determine which of plaster exihibits higher strength as well as an acceptable absorption properties to be used as mould for CSRM system. This type of plaster is widely used in moulding and casting industry [7][8]. Hence, it is very suitable for CSRM mould making. The composition of the solid to water content of the plaster will also be a concern. Current experiment indicates that the consistency of water to plaster for both hard plaster and soft plaster 1:2.33 and 1:1.3 rescpectively are the best composition [9]. Both plasters show no visible air bubbles on the inside and on the surface of the mould upon casting. As for the material of the slip, porcelain slip was suscessfully formulated based on in-situ coagulation moulding process [1][2]. The formation managed to achieve a good final product. Still, the product parting line is a challange since it is a visible on the surface of final product. Thus, the pattern must be designed and fabricated properly to ensure the green product produced have a smooth surface as well as avoided any unnesessary additional cost for finishing. Series of tests were

performed to analyze the porosity percentage, water absorption and strength test for both types of plaster.

Result shows that, hard plaster is the most suitable mould material for CSRM system. However, in longer time, hard plaster will still generate plaster waste because hard plaster is still considered as expandable mould as it will be calcinated.Thus will loose its ability to absorb water.

EXPERIMENTAL ANALYSIS

The steps followed for the preparation of plaster mould is illustrated in Figure 1.

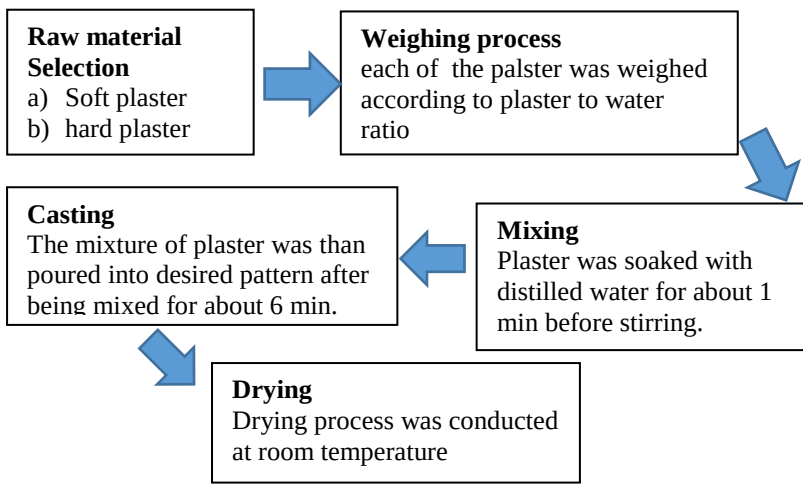


Figure 1: Overall process flow of mould casting

Figure 2: Plaster Powder

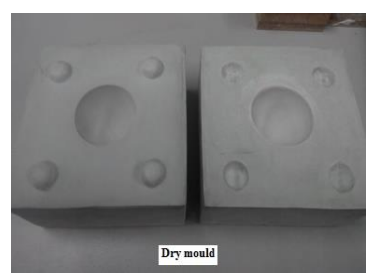


Figure 3: Male and Female Part of dry plaster

The raw materials of both types of plaster were obtained directly from the supplier. Each plaster comes in powder form. Both materials were sampled by using particle analysis test, MASTERSIZER 2000 instrument to determine the particle size distribution for both plasters. Five (5) samples of soft plaster and hard plaster with consistency of 1: 1.3 and 1: 2.33 of water to plaster ratio respectively were prepared to undergo flexural strength test, porosity test and water absorption test. Flexural strength test for both samples have been carried out according to ASTM C293-02[10]. Water absorption test and porosity test have been done on the broken samples of the previous test followed by ASTM C373-88 [11]. To produce a good green body, the smoothness surface of the mould also needs to be considered. Good surface finish plays an important role in determining the best quality surface of green body[7][8]. The lower the roughness size the smoother the surface of green body. Finer surface can eliminate finishing process. If elimination occurs, it can reduce overall production times as well as overall cost of production. The machine that will be used to determine the surface roughness of both types of mould is LEXT OLS4000. It has the capability of measuring surface roughness, surface area textures and surface profile measurements. The machine is filtered as required per ISO. LEXT OLS4000 uses laser to analyze the specimen surface.

Parameters that have been used in preparation of all samples are shown in Table 1. To avoid the effect of water hardness, distilled water was used as solvent[14][15].

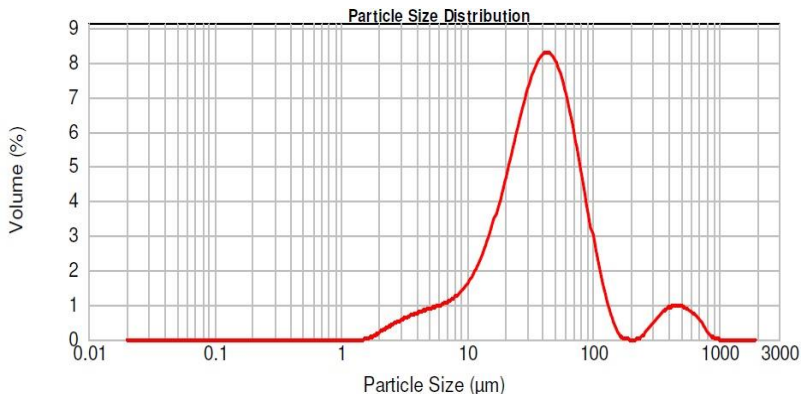
Table 1: Parameter used for sample preparation

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

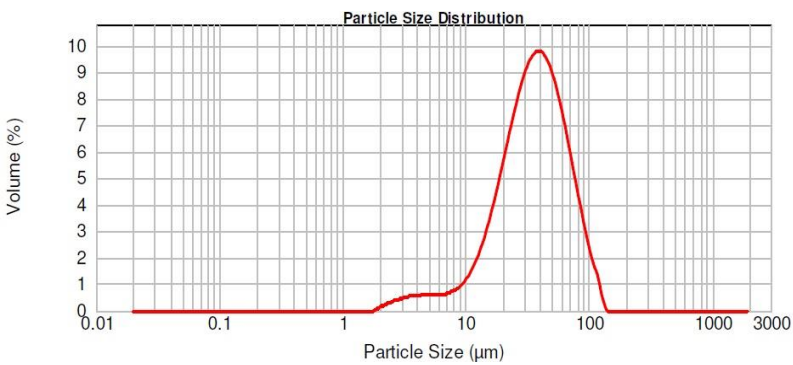
RESULT AND DISCUSSION

Densities for both plasters were tested by using Micromeritics density meter. Only 0.01 g/cm^3 differences between the two plasters where the density of soft plaster is 2.76 g/cm^3, while hard plaster was 2.77 g/cm3. This result shows that both plasters are in hemihydrate gypsum group thus make it suitable for mould selection [16]. The analysis of particle size of plaster powder is essential for the optimization of plaster mould because its known that the particle size distribution of plaster particles is directly related to porosity percentage, water absorption and strength of the mould[14][17]. Result from particle size distribution in Figure 4(a) and Figure 4(b) shows that the particles size of hard plaster is smaller than soft plaster. About 90%

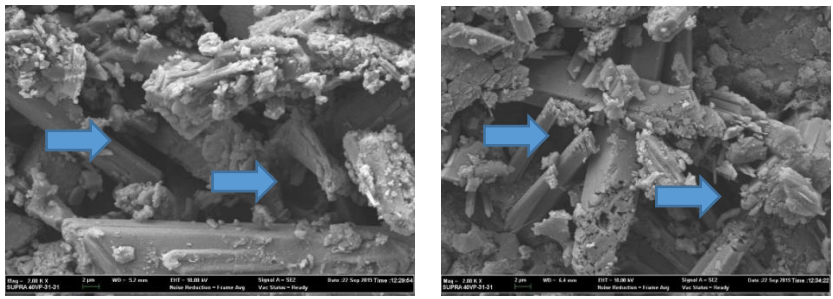
of its particles are in the range of 80µm. As for soft plaster, about 90% from sample test are in the range of 100µm. Figure 4 shows the particles size distribution and SEM micrograph for both plasters. The needle shape crystal structure indicates the calcium sulphate while the dark area of the empty space indicates the pore[6]. Based on the observation of micrograph, both types of plaster have quite similar number of pore. Hence, the ability for both plasters to absorb water is expected to be similar or slightly difference due to the smallest difference number of capillaries shown on the observed SEM result in Figure 4(c) and Figure 4(d).



(a)



(b)



(c) (d)

Figure 4: Particles size distribution of (a) soft plaster (b) hard plaster and SEM Micrograph of Soft plaster mould (c) and hard plaster mould (d) with arrow showing the mould porosity at 2000X magnification

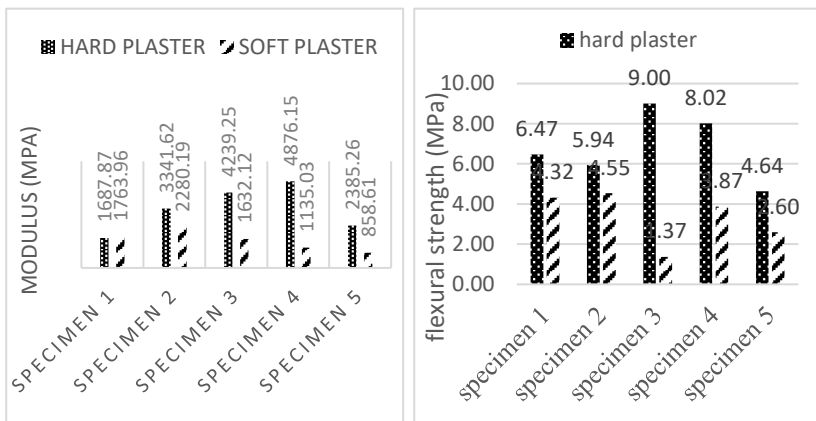


Figure 5: Flexural strength and flexural modulus of 5 specimens for each type of plaster.

Types of plaster	Flexural Modulus (MPa)	Flexural strength (MPa)
Hard plaster	3306.03	6.8
Soft plaster	1,533.98	3.3

Table 2: Average modulus and average flexural strength of soft plaster and hard plaster

Based on the result in Table 2, hard plaster has higher flexural strength and flexural modulus compared to soft plaster. The value were calculated based on the average flexural reading of five(5) samples shown in Figure 5. This result is to be expected due to the lower density and bigger particles size of soft plaster compared to hard plaster since the larger the size of the particles the greater the number of apparent porosity thus, weaken the strength of the mould[14][17]. However, the value of flexural strength of soft plaster is lower than acceptable range of conventional plaster mould of slip casting which are in between 5MPa to 10MPa [18]. This probably because the test specimens were not totally dry when the test was conducted or has been exposed to high humidity. In addition, the variation of water to plaster ratio also play an important roles in determining the strength of the plaster mould [19][15][17]. Therefore, it is clear that to manipulate the strength of the mould, both plaster needs the variation of water to plaster ratio as in case of entrainment the product standard in market remain constant while those of the finished product have changed (plaster powder).

Table 3: Average percentage of porosity (P%) and water absorption (A%)

Type of plaster	Average percentage (%)	
	Porosity	Water absorption
Soft plaster	31.30	21.90
Hard plaster	31.27	20.27

Considering result of porosity and water absorption in Table 3, soft plaster has better absorption capability compared to hard plaster. This result justify the theory stated in introduction and the strength result of both plaster. Higher porosity creates greater number of pore water between the crystal structure hence, increase the percentage of water absorption. However, the strength of the mould decreases as the number of pores increase [17][6]. To be noted, all the sample were not exposed to the any heat upon casting. Therefore, to emitate the actual casting process, a set of mould from both plaster were prepared. The casting process were conducted under temperature of 90°C for about 20 minutes. The percentage of water absorption after 10th moulding were recorded to evaluate the performance of the mould in terms of water absorption. The result of the testing were shown in Figure 6. From the two(2) plaster, hard plaster has higher percentage for about 0.3% than soft plaster. This is totally different from the earlier result recored in Table 2 where soft plaster is the highest of two. The different in this two test is because as the moulding process in progress, the heat from the system removes the free water (pore) in the mould. Hence the pore water in the mould were sealed to some degree thus, lower the capillary force of overall suction [21]. Further process of moulding at elevated temperature were predicted to cause the rate up-take by the mould were equal to rate of

evaporation and calcination [14][21]. In addition, the implementation of heat in moulding process will reduced the strength of the mould by even of 70% [17][22]. Finally, the calcinate plaster mould will become powdery or even crack because of thermal shock hence resulting in the generation of plaster waste [14][21][22].

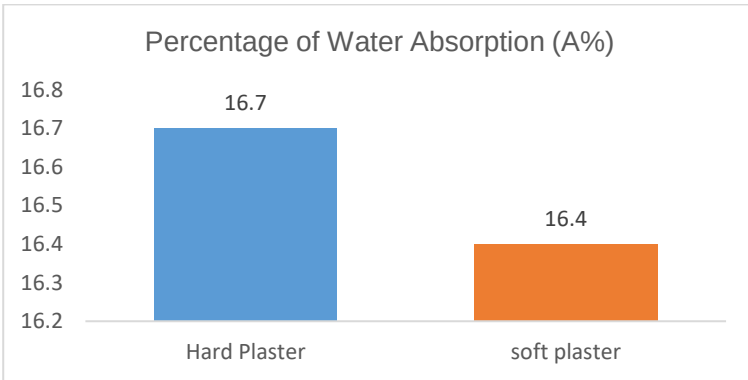


Figure 6: Percentage of water absorption after 10th moulding

As for surface roughness test, the maximum peak value for hard plaster is 4.526 µm which is slightly higher than soft plaster which is 4.0266 µm as shown in Figure 8. As for the minimum peak value, hard plaster is lower than soft plaster. Soft plaster has minimum peak value of 0.148 µm where hard plaster has minimum value of 0.072 µm . This can be proved by physical touch and naked observation, the product of green body of soft plaster was smoother than the hard plaster. Figure 9 shows the image captured by using LEXT on the outher surface of mould cavity. Both image appear similar for hard and soft plaster. Hence for both type of plaster, its surface roughtness can be accepted for mould making as the green body produced by both mould have no other defect other than parting line which is normal in ceramic slip casting of multiple mould piece.

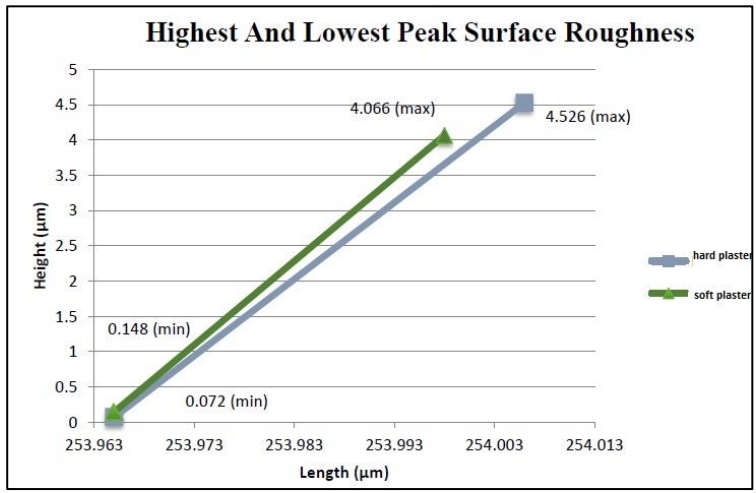
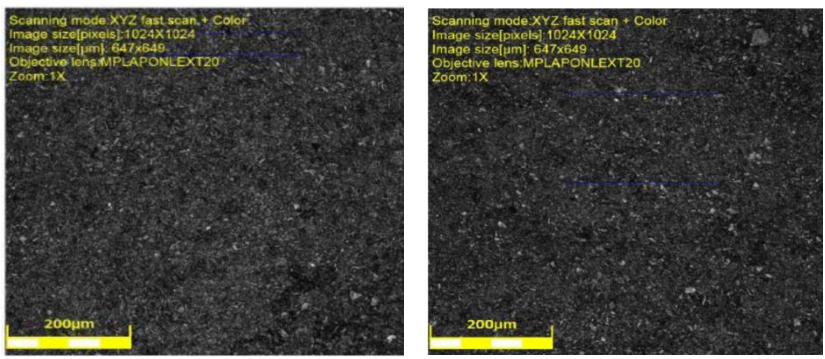


Figure 8: Comparison of surface roughness in terms of its height and length across the surface on point 1 and point 2



(a) (b)

Figure 9: Scanning image of soft plaster (a) and hard palster (b) surface under LEXT machine

CONCLUSION AND SUMMARY

The casting mould quality is directly related to the properties of plaster. The particles size of the plaster play an importance role on the ability of the plaster to absorb water and have a tangible effect on the strength of the

mould. In terms of porosity and percentage of water absorption, soft plaster are better than hard plaster. However, the strength of the soft plaster is clearly lower than the hard plaster. In addition, upon heating with higher temperature, soft plaster tends to loose its water absorption capability and become calcinated. Hence reducing the strength of the mould. Since the CSRM system used the addition of heat in the moulding process, a greater strength of mould is required to avoid any strength reduction cause by repeated heating during the slip moulding process. Hence the mould can last longer and plaster waste generation can be reduced. Based on the overall testing result, hard plaster is the most suitable material as CSRM mould. However, hard plaster is still considered as expendable mould. It must be replaced once reached the limit of moulding.

To achieve a total green technology, further research must be done to replace the use of gypsum plaster as mould for CSRM due to heat involved in the system. The mould must be higher in strength and have considerable ability to absorb water in the ceramic slip. Porous resin is said to be *promising* material in *replacing* gypsum plaster as a semi permanent mould for the CSRM system. It is porous and have higher strength. However it is not capillary by nature compared to gypsum plaster as capillary action of resin mould would required additional force to drive out the water from the ceramic slip.

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