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Analysis and Optimization of Using Hemihydrates Plaster (β) for Casting Mould in Sanitary Ware Industry

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Abstract

Slip casting is a common method for producing sanitary ware, and it is just possible by plaster moulds. Therefore, in order to reach the best quality of sanitary ware, plaster moulds are playing an important role. Lifetime, water absorption and finished surface of Plaster moulds qualify the quality of final product significantly. Although, some characteristics of plaster mould depends on the plaster directly, others are affected by preparation process of moulds such as mixing time, plaster to water ratio, water temperature and drying process. In this investigation, hemihydrates plaster (β) of different suppliers has been studied by XRD; also particle size distribution of plasters has been analyzed by sieve shaker. Afterward, the best one has been selected, and effects of parameters involved in process of mould making have been studied to make an efficient plaster mould.
Keywords: Plaster mould, Sanitary ware

ANALIZA I OPTYMALIZACJA WYKORZYSTANIA PÓŁHYDRATU (β) GIPSU W FORMACH DO ODLEWANIA W PRZEMYŚLE CERAMICZNYCH WYROBÓW SANITARNYCH

Odlewanie z gęstw stanowi powszechną metodę wytwarzania ceramiki sanitarnej i jest możliwe dzięki formom gipsowym. Zatem, w osiąganiu najlepszej jakości ceramiki sanitarnej ważną rolę odgrywają formy gipsowe. Trwałość, nasiąkliwość i gotowa powierzchnia form gipsowych warunkują znacząco jakość końcowego wyrobu. Chociaż, niektóre charakterystyki formy gipsowej zależą bezpośrednio od gipsu, inne są związane z parametrami procesu przygotowania form takimi jak: czas mieszania, stosunek gipsu do wody, temperatura wody i proces suszenia. W prezentowanej pracy, półhydraty (β) gipsu od różnych dostawców zostały zbadane za pomocą metody XRD; zanalizowano również rozkłady wielkości cząstek gipsów za pomocą wstrząsarki do sit. Następnie, najlepszy gips został wybrany i użyty do zbadania wpływu parametrów procesu przygotowania form w celu wytworzenia wydajnej formy gipsowej.
Słowa kluczowe: forma gipsowa, ceramiczny wyrób sanitarny

1. Introduction

Plaster moulds are a good bed for cake formation due to their high strength and water absorption; on the other hand the quality of final product is affected directly by the quality of plaster mould. Furthermore, the quality of plaster mould can control casting waste and quality of final product in sanitary ware industry [1]. While plaster mould do its important role which is water absorption by their capillary volumes, plaster mould must have proper strength and accurate dimension, they also must have smooth surface by eliminating bubbles and cavities [2]. In this paper to improve quality of plaster mould, first substantial parameters of plaster such as setting time, fluidity of plaster slip and particle analysis has been investigated and then parameters during process of making plaster mould such as mixer speed, mixing time, water temperature and drying has been studied.

2. Experimental

First of all, according to ASTM D422-63 particle size distribution has been analyzed by using sieve shaker, Retsch AS200, series of sieves with mesh numbers 60, 80, 100, 140, 170 and 400, for 5 minutes and amplitude of 1.5 mm for four different plaster suppliers [3]. Water absorption and flexural strength tests have been carried out for all samples. Samples of each particle size were prepared according to ASTM C293-08 with plaster to water ratio of 130 to 100 (distilled water), mixing speed: 750 rpm and mixing time: 1 minute under vacuumed condition, the dimension of samples in flexural strength test is 1.5 x 2.5 x 15 cm [4]. Samples were dried for one day in 40°C and flexural strength test has been carried out by 3 points loading flexural strength apparatus MOR/4-DR of ceramic instrument. Water absorption test has been done regarding to ASTM C373-88(2006) on broken samples of previous test [5].

After selecting the right plaster, to ensure its purity, it has been analyzed by XRD, Siemens D500. XRD results have been shown in Fig. 1, also chemical analysis of considering plaster has been illustrated in Table 1.

The purity percentage of this plaster is about 96 % which is proper for mould making according to ASTM C472-84 [5]. Afterward, parameters affecting quality of moulds during process of mould making has been studied.

Table 1. Chemical analysis of sample C.

CO_2	SiO_2	Al_2O_3	MgO	H_2O	NaCl	SO_3	CaO
0.5	2.1	0.7	0.3	19.8	0.5	44.6	31.6

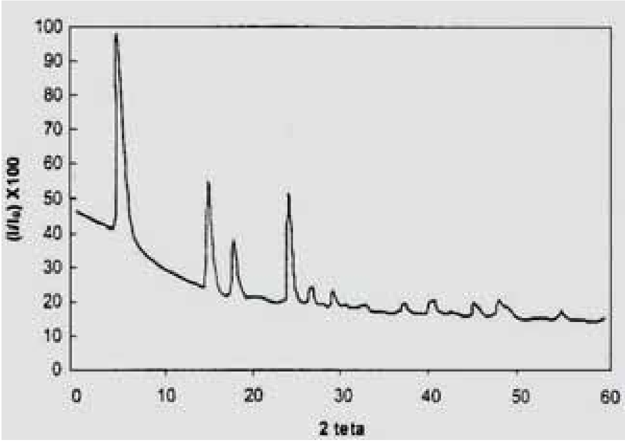


Fig. 1. X-ray diffraction pattern of selected plaster sample.

Mixing time and mixer speed: samples were prepared according to Table 2, all items were fixed just mixer speed has been changed between 100 and 1000 rpm. Setting time of each sample has been measured according to ASTM C150-07 [6]. This test also has been done while the mixing time has been changed between 1 and 4 min.

Plaster to water ratio: samples with different plaster to water ratio (1.1 to 1.6) were subjected to setting time, water absorption and flexural strength tests.

Water temperature: samples were tested with the water temperature of 6 to 70°C.

All tests have been carried out with stilled water to remove the effect of water hardness.

Table 2. All experiments have been done under following conditions.

Temperature [°C]	Mixing time [min]	Mixer speed [rpm]	Soaking time [min]	Plaster/ water
25	1	750	1	1.3

3. Results and discussion

As it is indicated in Fig. 2, particle size distribution is directly related to apparent porosity percentage of plaster mould and its water absorption, where finer particle size distribution, less apparent porosity and water absorption of plaster mould is obtained [7].

Therefore to optimize the quality of plaster mould, it is necessary to analyze the plaster particle size of different suppliers, results have been shown in Fig. 3. Particle size also affects on diameter, number of capillary volumes and flexural strength of plaster moulds, so finding an optimized particle size for making plaster moulds is necessary. Flexural strength of 50 kg/cm^2 and water absorption equals to 35-38 % is proper for using in sanitary ware industry.

As it can be seen in Fig. 3., particle size distribution of sample A, C are close to each other and comparing to two other samples they have finer particles, and as it is anticipated results of flexural strength and water absorption tests in Table 3 justify the mentioned theory.

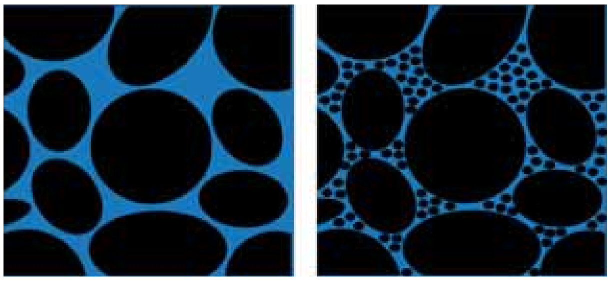


Fig. 2. Effect of particle size distribution on porosity [7].

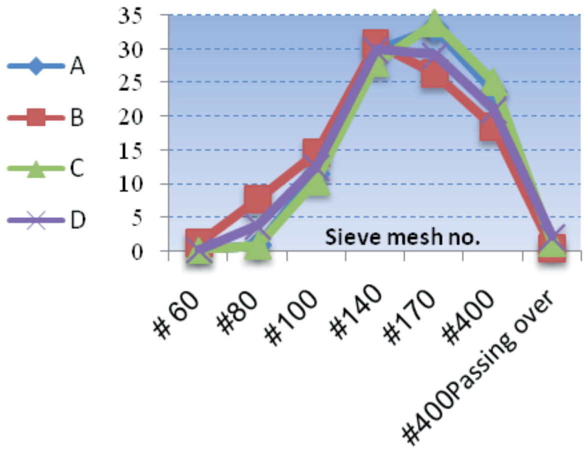


Fig. 3. Particle size distribution of plaster of different suppliers.

Table 3. Effect of plaster particles on flexural strength and water absorption of moulds.

A	B	C	D	Plaster sample
56	48	60	51	Flexural strength [kg/cm^2]
37.88	38.94	37.33	38.22	Water absorption [%]

Considering Table 3., sample C has better flexural strength and water absorption, therefore this plaster sample has been selected for all tests. Results of experiments during process of mould making has been shown in Fig. 4. As it is depicted in Figs. 4a and 4b setting time and plaster slip fluidity reduce by increasing mixer speed and mixing time, by increasing mixer speed or mixing time gypsum nuclei will be broken into other nucleus which are good sites for nucleation of other gypsum crystals, so the flexural strength of plaster mould which is due to interlocking of gypsum needle like crystals, thus mixing time and speed are two important factors influenced on moulds strength. Setting time, flexural strength and water absorption of plaster moulds have been also affected by plaster to water ratio which has been shown in Figs. 4e and 4f. In fact, by increasing plaster to water ratio nuclei sites will increase, on the other hand; apparent density will reduce by reduction of water amount, and it leads to change in water absorption of plaster moulds. Gypsum inclusions in calcium sulfate hemihydrates are another important factor which can affect moulds quality. This kind of inclusion usually comes from process of producing hemihydrates plaster from gypsum ore. Besides, incomplete cleaning of plaster

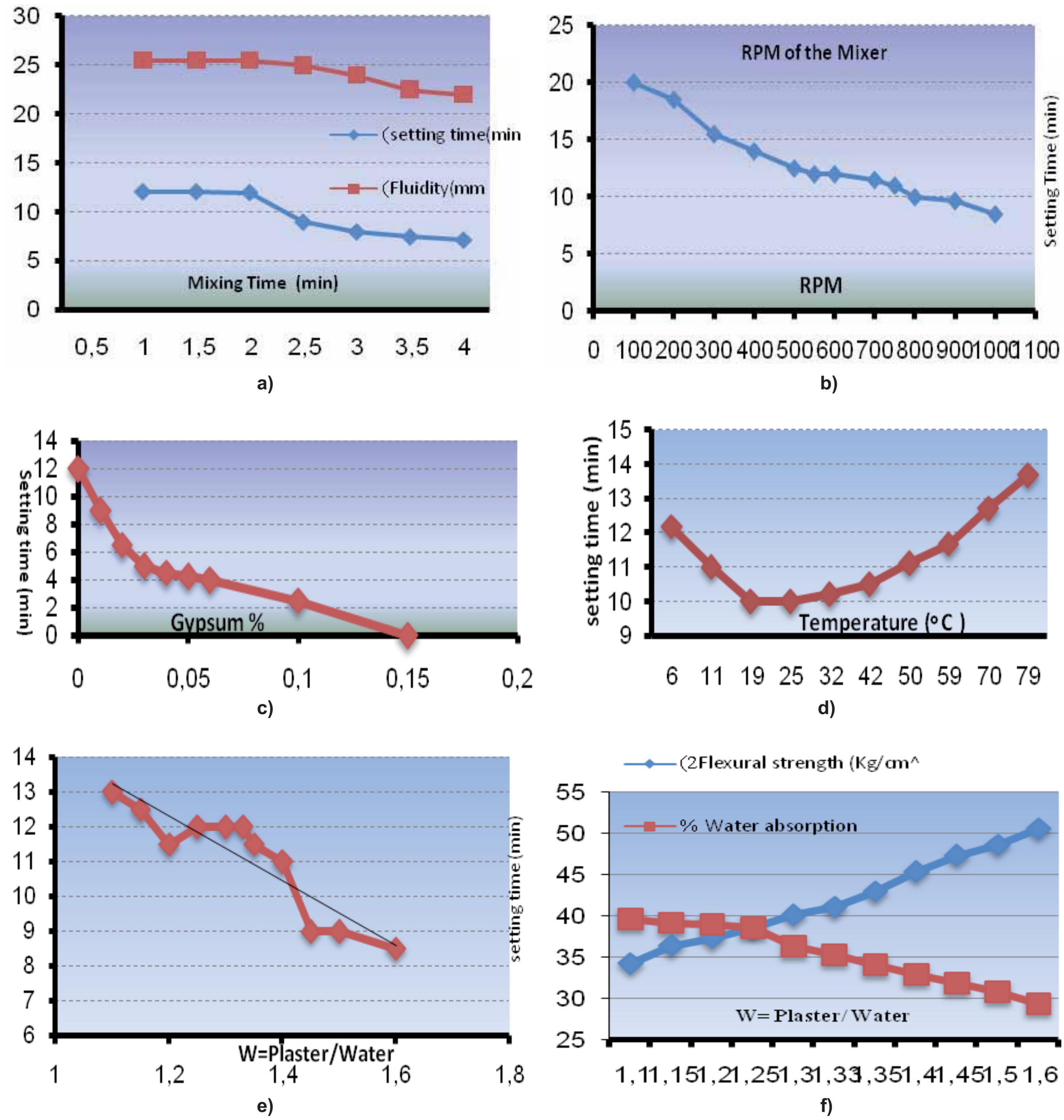


Fig. 4 a) Effect of mixing time on setting time and fluidity; b) Effect of mixer speed on setting time; c) Gypsum effect on setting time; d) Temperature effect on setting time; e) Plaster to water ratio effect on setting time; f) Plaster to water ratio effect on flexural strength and water absorption.

slip tank or mixer in each batch may lead to presence of gypsum plaster in hemihydrates plaster slip, these inclusions are good sites for nucleation of gypsum crystals, so they will reduce setting time and fluidity of plaster slip. As it is indicated in Fig. 4d the presence of 0.03 % gypsum inclusion in hemihydrates plaster, reduce setting time into half of its normal one. Water temperature or ambient temperature can also affect setting time of plaster slip where in low and high temperatures (less than 10°C and above 45°C) setting time will increase (Fig. 4c). The reason for increasing setting time by increasing ambient temperature is due to exothermic reaction of calcium sulfate hemihydrates with water which is reversible, so regarding to Le Chatelier principle the reaction will drive into reverse direction of plaster setting, however, activation energy of reaction decreases by temperature reduction that it leads to increasing setting time again.

$$CaSO_4{\cdot}\tfrac{1}{2}H_2O + \tfrac{3}{2}H_2O \rightarrow CaSO_4{\cdot}2H_2O + Q \qquad (1)$$

Results of effective parameters during mould making have been shown in Fig. 4.

To analyze thermal behavior of plaster by increasing temperature, DTA and TG tests were carried out. Fig. 5. shows DTA and TG diagram of hemihydrates plaster, the most weight reduction has occurred in temperatures from 120°C to 230°C, in this range of temperature hemihydrates plaster turn into anhydrate during an endothermic reaction. The small change in TG diagram at the beginning is due to plaster humidity.

Since the presence of anhydrate and dehydrate as inclusion in hemihydrates plaster is probable, to specify the presence of these inclusion 100 gram of pointed plaster has been placed in an oven in 230° C for 5 hours, regarding to molecular weight of Eq. (1), if the plaster is completely hemihydrates the weight loss will be 6.2 % [8], and if it is more than this amount, there will be gypsum inclusion included, or it may include anhydrate inclusion, if the weight loss is less than 6.2 %.

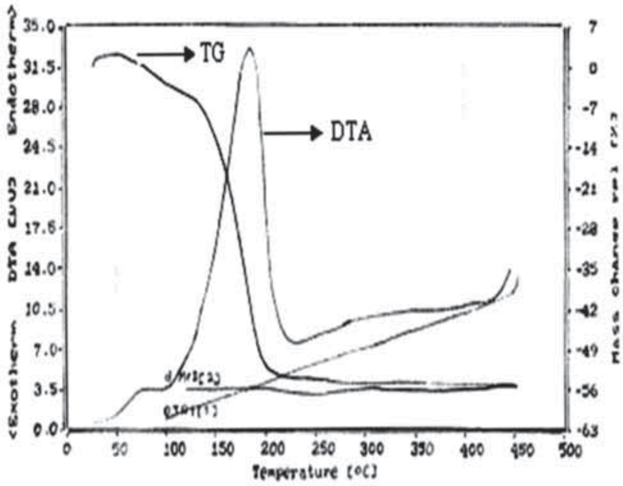


Fig. 5. DTA and TG diagram of selected hemihydrates plaster.

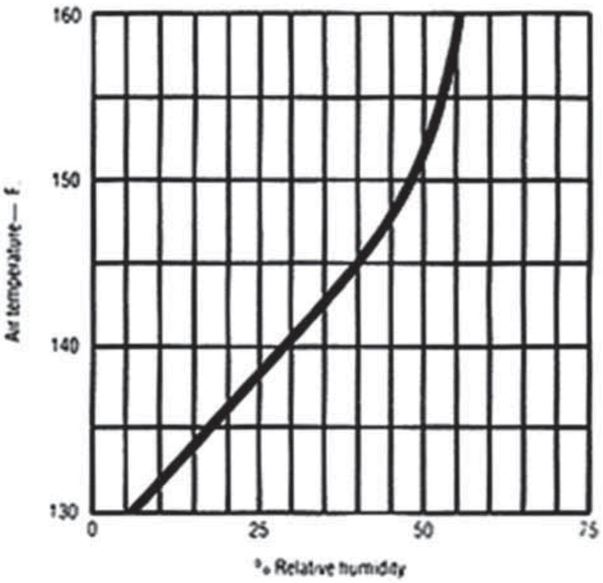
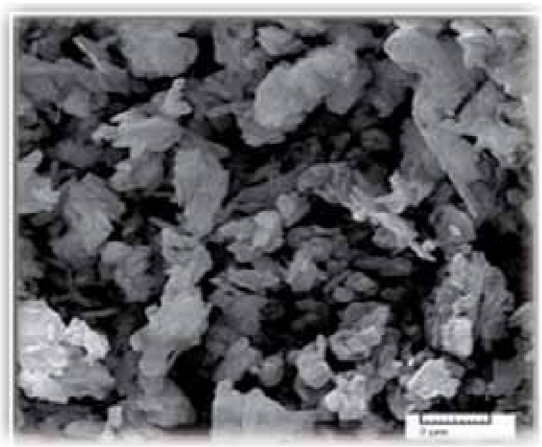


Fig. 6. Minimum relative humidity at temperature to prevent calcination of gypsum casts.

Since strength of a dry plaster mould is more than wet one for several times, drying of plaster mould has a special importance [9], however it would be impossible to do slip casting in wet mould, moreover unsuitable drying cycle leads to calcinations of moulds that they become powdery also cracks will be more likely to happen due to thermal shock, therefore designing an efficient drying cycle for plaster mould dryers is so important. Considering to Fig. 6. temperature and humidity cycle design of plaster mould dryers has to be done in a way that the contact point of temperature and humidity lines places under the border line [9]. The SEM - micrograph of calcined plaster mould and suitable dried plaster mould showed that the microstructure of calcined plaster mould would be flake like however suitable dried plaster mould forms clusters of needles with porosity in between (Fig. 7).

4. Conclusions

Spontaneous properties of plaster such as particle size, flexural strength and water absorption have tangible effect on casting mould quality.



a)

b)

Fig. 7. SEM micrographs of: a) dried plaster mould, b) calcined plaster mould.

Quality of casting mould will be altered by changing production process parameters such as mixer speed, time of mixing, plaster purity, plaster to water ratio and water temperature.

Although the above parameters can affect the final quality of casting mould, drying of these moulds must be controlled under suitable temperature and humidity cycle to avoid any calcinations and flexural strength reduction.

References

[1] Kelley K.K., Soutard J.C., Anderson C.T.: U.S. Bureau of Mines, Technical paper No.,625, (1994).
[2] Holdridge D.A.: Trans. Brit. Ceram. Soc., 64, (1965), 212-231.
[3] ASTM D422 – 63, Standard Test Method for Particle Size Analysis of Soils, (2007).
[4] ASTM C293 – 08, Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading), (2008).
[5] ASTM C373 – 88, Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products, (2006).
[6] ASTM C150 – 07, Standard Specification for Portland Cement.
[7] Lewry A.J., Williamson J.: J. Mater. Sci., 29, (1994), 5279-5284.
[8] Hoffman R., Pan W.-P.: Thermochimica Acta, 192, 135-146.
[9] Marchant D.D., McAlpin J.L., Stangle T.: Ceram. Ind., (1994), 64.

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