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Recycle Plaster Waste from Jewelry Casting Process

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Abstract

In this work, the plaster waste from the jewelry casting process has been studied hydration with soaking in water at 20 weeks. The XRD and FTIR confirm the structural phase of the plaster waste is calcium sulphate anhydrite ($CaSO_4$). The plaster waste after soaking in water 20 weeks present, calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$) and plaster waste after calcine at 120 °C present calcium sulphate hemihydrate ($CaSO_4 \cdot 2H_2O$). We can recycle plaster waste from the jewelry casting process by soaking in water at 20 weeks and calcining with rotary dryer 2 h at 120 °C. The plaster waste will have flow and setting time close to standard with water and plaster waste in ratio 50:100. The product can make with plater waste, but it still does not have enough qualities for delicate work.

Keywords: Recycle; Plaster waste; Jewelry casting plaster

Introduction

The hemihydrate is popular to use for many applications. One application is casting of silver and gold in the jewelry industry, some jewelry manufacturers typically prefer to use gypsum as its thermal properties are appropriate for commercial-grade alloys casting and this type of investment has lower prices compared to other types of investments. Traditional gypsum powder consists of a mixture of calcium sulfate hemihydrate ($CaSO_4 \cdot 0.5H_2O$), binder and SiO_2 (α-quartz and α-cristobalite).

Plaster is derived from gypsum or sometimes called calcium sulfate dehydrate ($CaSO_4 \cdot 0.5H_2O$), a naturally sedimentary rock occurring through the evaporation of sea water, trapped in lagoons. Most of the water is driven off when gypsum is heated to 128 °C, resulting in a powdery substance commonly known as Plaster. The molecules incorporate each other into the crystalline lattice of calcium sulfate dehydrate when water is added to the dry plaster. It is worth noting that a great effort is needed in clearing and classifying in order to produce plaster.

In general, plasters occurs three main types: calcium sulphate anhydrite ($CaSO_4$), calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) and calcium sulfate hemihydrate ($CaSO_4 \cdot 0.5H_2O$). The dihydrate is useful material. It was heated at 100 – 130 °C for dehydration some parts of water molecules that are in the form of molecules of hemihydrate [1, 2]. Adding water to hemihydrate powder leads to the occurrence of crystallization of dihydrate according to this equation [3, 4].

$$CaSO_4 \cdot 2H_2O \quad \xrightleftharpoons[+1.5\ H_2O]{-\,1.5\ H_2O,\ 100\ -\ 130^{\circ}C} \quad CaSO_4 \cdot 0.5H_2O$$

when heating dihydrate higher than 350 °C, dihydrate will dehydrate and transform to anhydrite which anhydride is not useful for use [5 – 7]. The jewelry casting process used molding plaster for the current technology requires a wax. It process starts with the wax pattern tree were covered by plaster for casting. The plaster was prepared by mixing the investment powder with water in the ratio of 100:38 of powder per water [8]. The molding was heated up to 850°C for melting and loss wax pattern tree. The internal space was poured the metal into there. The plaster shield was removed by dipping it into the water for crack out. So, the plaster waste incurs high temperatures from the process, therefore it affects anhydrite structure. The jewelry industry has a problem with a lot of useless plaster waste. Waste plaster itself is not dangerous. However, a dangerous gas, known as hydrogen sulfide gas can evolve from it when it is mixed with organic waste and exposed to rain in an anaerobic environment. In this work, we are interested hydration of plaster waste (anhydrite) to dihydrate. From the equation, when dihydrate from recycled plastic waste has been dehydration will transform to hemihydrate [6]. The activator of the ball mill has affected hydration. The center anhydrite was covered with Ca^{2+} and SO_4^{2-} ions and $CaSO_4$ solution affects to further hydration become very difficult. So that activator by ball mill does cover shell crack and the possibility of completion of the hydrations more than in the past. In this work, we are interested in recycling the plaster waste from the jewelry casting process with soaking in water.

Materials and Methods

Waste plaster from the jewelry casting process was used to study in this research. The waste plaster was soaked in water 20 weeks, for the improvement water structure of waste plaster to change $CaSO_4$ (Calcium sulfate anhydrite) to $CaSO_4 \cdot 2H_2O$ (Calcium sulfate hemihydrate). The plaster of final soaked in water was dried in room temperature 7 days, and then the plaster sample was crushed with mortar and pestle. The plaster sample was calcined with rotary dryer 2 h at 120 °C and cool down in a rotary dryer. The plaster sample was tested casting jewelry with brass ring models to improved properties and compere with new plaster. The waste plaster on the jewelry casting process was analyzed the chemical composition, structure, functional groups and morphology properties. The chemical composition was carried X-Ray Fluorescence Spectrometer (XRF, Panalytical, Minipal-4). X-ray diffractometer (XRD, Shimadzu's, XRD-6100) was used to analyze phases and structures. The samples powder was characterized by the diffraction technique with Cu radiation target scanning rate of 5° min^{-1} at 40 kV 30 mA from 10° – 80°. Fourier transform infrared (FTIR, Agilent, Cary 630) to record FTIR transmission and the spectra were collected the frequency of 650 – 4,000 cm^{-1} by the ATR technique. The plaster flow test was measured with a mini cone test at 5 min after plaster mixing water.

Results and Discussion

The plaster samples of plaster waste (PW), plaster waste after soaking in water 20 weeks (PWS) and plaster waste after calcining at 120 °C (PWC) included three main components of Si, S and Ca (Table 1). The calcining at 120 °C condition was selected from TG-DTA curves that it start dehydration curves after 100 °C and maximum at 137 °C show in Fig.1.

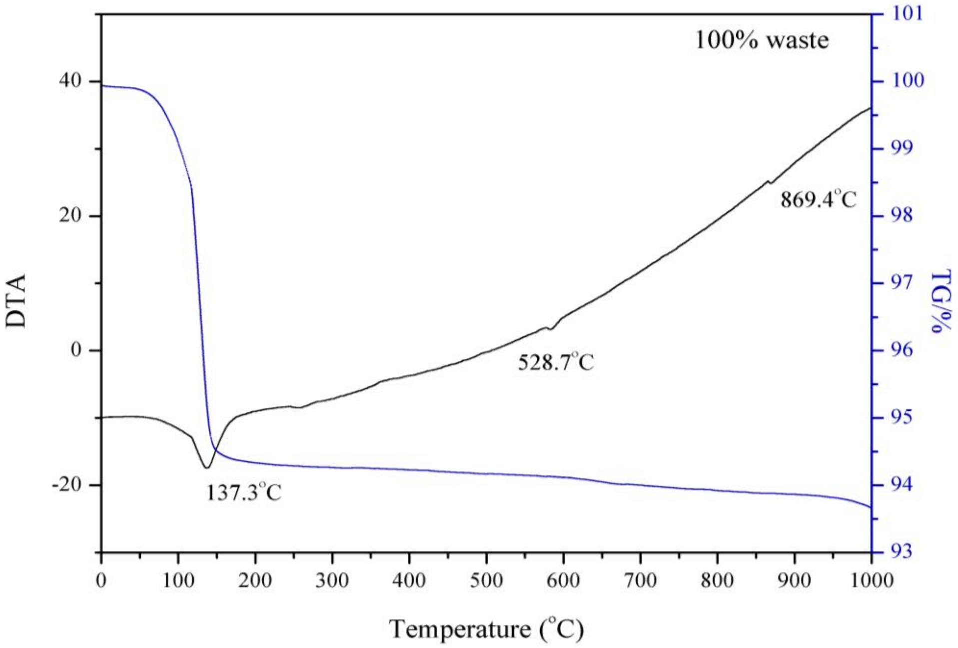

Fig. 1 TG-DTA curves of plaster waste after soaking in water 20 weeks.

Therefore, S and Ca are the main components of calcium sulphate anhydrite ($CaSO_4$), calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) and calcium sulfate hemihydrate ($CaSO_4 \cdot 0.5H_2O$). The Si is a component of raw material of investment powder. The silicate plaster molds increase mechanical strength from the poor thermal stability of calcium sulphate molds [8, 9].

Table 1 Chemical compositions of plaster from the jewelry casting process.

Chemical element	Plaster waste (%)
Si	44.083
S	22.752
Ca	29.704
Ti	0.203
Fe	0.355
Sr	0.128
Zr	0.050
Ag	3.725

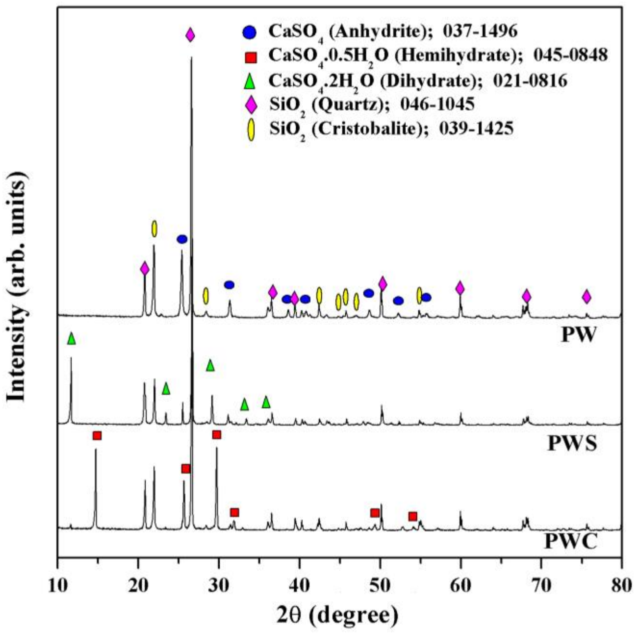

Fig. 2 XRD pattern of plaster waste (PW), plaster waste after soaking in water 20 weeks (PWS) and plaster waste after calcining at 120 °C (PWC).

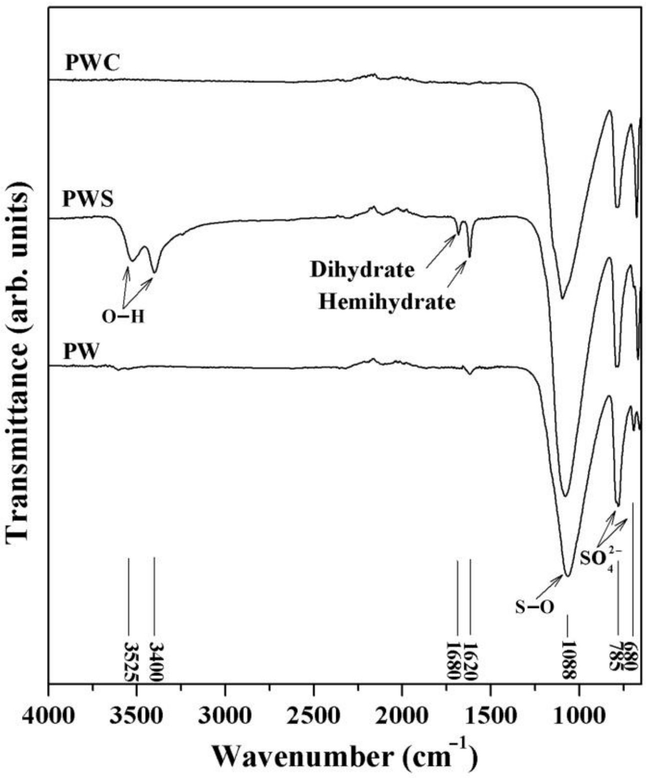

Fig. 3 FTIR spectra of plaster waste (PW), plaster waste after soaking in water 20 weeks (PWS) and plaster waste after calcining at 120 °C (PWC).

Figure 2 shows XRD spectra of three plaster samples (PW, PWS and PWC), that all samples showed phases of SiO_2 in Quartz (JCPDS file no.37-1496) and Cristobalite (JCPDS file no.39-

1425). The plaster waste showed phases of $CaSO_4$ in anhydrite (JCPDS file no.37-1496) which was improved structure by soaking in water in ratio 1:2 by weight at 20 weeks. After that, anhydrite transforms to dehydrate (JCPDS file no.21-0816). When the plaster was improved by soaking and calcined 2 h at 120 °C that the phase of hemihydrate (JCPDS file no.45-0848) are presented.

Figure 3 shows FTIR spectra of plaster samples. PWS sample presented O–H stretching (3,550 and 3,400 cm^{-1}) and bending vibration (1,680 and 1,620 cm^{-1}) [4]. PWC sample show O–H stretching vibration at 3,600 and 3,550 cm^{-1} and O–H bending vibration show at 1,620 cm^{-1}. For PW sample cannot found characteristic bands of water in FTIR spectra.

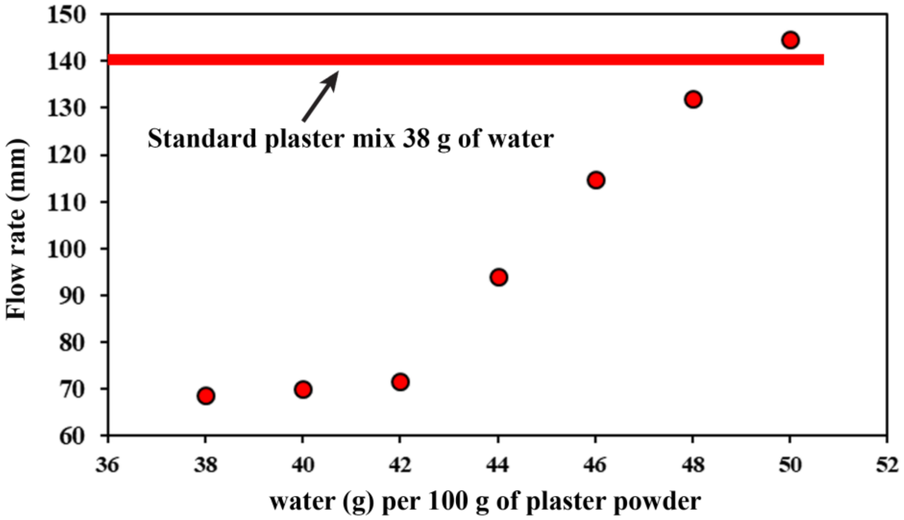

Fig. 4 Plaster flow rate of plaster waste after calcining at 120 °C (PWC).

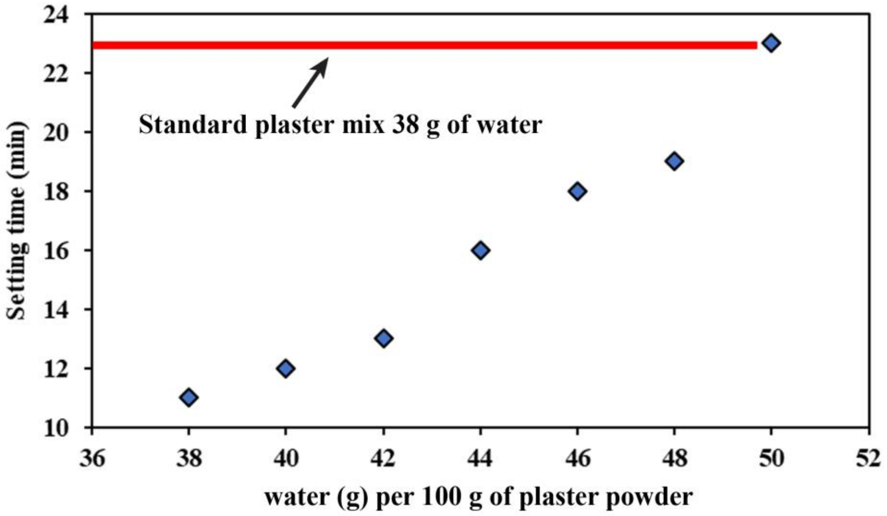

Fig. 5 Setting time of plaster waste after calcining at 120 °C (PWC).

Fig. 6 Jewelry product casting by Standard plaster (left) and PWC plaster (right).

The PWC was studied to be reused to the jewelry casting process. The PWC powder sample was studied plaster flow rate and setting time. The powder sample was mixed with water at a different ratio at 38 – 50 g :100 g of powder sample shown in Fig. 4 and Fig. 5. The plaster flow rate and the setting time presented to increase with increasing of water. When the PWC was compared with standard plaster that it mixes water at 38:100. Found that, same condition at 38:100 presented poor value of flow rate and fast time for setting a time that it is not suitable for use in the jewelry casting process. When the PWC was mixed with water at ratio 50:100 that presented flow rate and setting time suitable for use in the jewelry casting process. The PWC was used to jewelry casting process with a ratio of 50:100. Fig. 6 shown jewelry product casting by Standard plaster and PWC plaster. Found that, the sample was casting with PWC plaster the can made jewelry, In the future, it is possible to develop PWC plaster to increase quality to be suitable and reduce the cost of use in the industry.

Conclusion

The recycle plaster waste from the jewelry casting process was carried out by soaking in water at 20 weeks and calcining with rotary dryer 2 h at 120 °C. The plaster waste will have flow rate and setting time close to standard with water and plaster waste in ratio 50:100. The product can be made with plater waste. It is possible to develop PWC plaster to increase quality to meet certain requirement and to reduce the cost of use in the industry

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References

[1] N.B. Singh, B. Middendorf, Calcium sulphate hemihydrate hydration leading to gypsum crystallization, Prog. Cryst. Growth Charact. Mater. 53 (2007) 57 – 77.

[2] A. Jerome, M. Sylvain, T. Solene, M. Eric, S. Layla, In-situ X-ray tomographic monitoring of gypsum plaster setting, Cem. Concr. Res.82 (2016) 107 – 116.

[3] P. Zongyou, L. Yi, Y. Guangyong, N. Xiao, C. MoChuan, X. Huazi, M. Xigeng, L. Jianli, H. Chunfeng, H. Qing, Preparation of calcium sulfate dihydrate and calcium sulfate hemihydrate with controllable crystal morphology by using ethanol additive, Ceram. Int. 39 (2013) 5495 – 5502.

[4] Q.L. Yu, H.J.H. Brouwers, A.C.J. de Korte, Gypsum hydration: a theoretical and experimental study, Conference: 17th Internationale Baustofftagung, Weimar, Germany 23 – 26 September 2009, 1.

[5] P. K. Mandal, T.K. Mandal, Anion water in gypsum ($CaSO_4.2H_2O$) and hemihydrate ($CaSO_4.1/2H_2O$), Cem. Concr. Res. 32 (2002) 313 – 316.

[6] T. Sievert, A. Wolter, N.B. Singh, Hydration of anhydrite of gypsum ($CaSO_4$.II) in a ball mill, Cem. Concr. Res. 35 (2005) 623 – 630.

[7] R.H. Geraldo, S.M.M. Pinheiro, J.S. Silva, H.M.C. Andrade, J. Dweck, J.P. Gonalves, G. Camarini, Gypsum plaster waste recycling: A potential environmental and industrial solution, J. Clean. Prod. 164 (2017) 288 – 300.

[8] T. Phetrattanarangsi, C. Puncreobutr, A. Khamkongkaeo, C. Thongchai, B. Sakkomolsri, S. Kuimalee, P. Kidkhunthod, N. Chanlek, B. Lohwongwatana, The behavior of gypsum-bonded investment in the gold jewelry casting process, Thermochimica. Acta. 657 (2017) 144 – 150.

[9] P. Sbornicchia, G. Montesperelli, G.M. Ingo, G. Gusmano, Advances in jewellery microcasting, Thermochimica. Acta. 419 (2004) 195 – 204.