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Effect of Mixing Rate of Plaster with Water on Properties of Gypsum Plaster

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ABSTRACT:
Gypsum plaster is a widely used building material, as it is inexpensive and mechanically strong and to make gypsum model for ceramics manufacture as modelling material. When in contact with water, calcined gypsum rehydrates through dissolution, nucleation and crystallization steps. In this work, the mixing rate of plaster with water was investigated on their effect on the properties of hardened gypsum pieces, focusing on the structure–function relationship. The mixing plaster with water was done at 120, 240, 360 and 600 rounds per minute with a constant water/ plaster ratio of 0.77. The results showed that with increasing mixing rate, the setting time decreased and the mechanical strength of the hardened piece increased. The apparent porosity, water absorption and water diffusion coefficient of the hardened piece decreased with increasing mixing rate. The microstructure of gypsum with the high mixing rate not only seems to be denser, with crystals interlaced, but also shows short crystals, which may improve the mechanical strength of the specimen. The higher mixing rate can lead to the higher rate of the nucleus formation, the smaller crystals and denser structure are formed. This material can have higher strength.

Key words: Gypsum plaster, Mixing rate, Setting time, Strength, Microstructure.

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1- Introduction

Gypsum is a calcium sulfate dehydrate mineral that occurs in several regions around the world with a wide variety of industrial applications. It can be used in its natural or dehydrated form. The hemihydrate (CaSO4.0.5H2O) is obtained by thermal dehydration from calcium sulfate dehydrate (CaSO4.2H2O) in rotary kilns [1-2]. Dehydrated calcium sulfate shows the peculiar facility to lose and recover water due to crystallization. During the calcination process, it loses 3/2 of water due to crystallization, and changes into calcium sulfate hemihydrate (CaSO4.0.5H2O), as shown in reaction (1):

$$CaSO_4.2H_2O \rightarrow CaSO_4.0.5H_2O + 3/2\ H_2O \quad (1)$$

When in contact with water, however, the hemihydrate rehydrates back to the dihydrate form as shown in reaction (2)[3]:

$$CaSO_4.0.5H_2O + 3/2H_2O \rightarrow CaSO_4.2H_2O + heat \quad (2)$$

The hemihydrate in contact with the mixing water forms a saturated solution of Ca2+ and (SO4)2− ions. During the induction period, the first nucleation points occur (forming the first dihydrate crystals). Due to the fact that dehydrate crystals are less soluble than the hemihydrate, they accumulate in the medium until reaching a critical number of crystals, starting the setting time. With continued formation of crystals, the medium becomes saturated of crystals, hardens and acquires mechanical resistance [3-4]. The water/plaster ratio is a parameter of influence on the kinetics of hydration reaction and consequently on the plaster setting time. However, other factors as water temperature, raw material and the procedure used on the plaster production as well as the

energy used in the process of the paste mixing can accelerate the hydration reaction by improving the plaster powder dispersion in the water [1, 5-8]. The present research aimed to observe the effect of the mixing rate of plaster with water on the gypsum properties. The setting times, physical, mechanical properties and microstructure were evaluated.

2- Materials and methods

A gypsum sample produced and provided by Pars Dandan Iran was used in experiments. The gypsum was slowly transferred into a bowl containing water with a water/gypsum ratio of 0.77 in 30 s and then stayed for another 60 s; the mixture was quickly mixed with a mixer at different rates (120, 240, 360 and 600 rpm) for 60 s to form a homogenous paste. The paste was cast into iron molds. In hardened state, after molding, specimens were removed and dried for one days in an oven at 40 °C. Setting time was performed with Vicat apparatus (Figure 1a) [9].

The prismatic 4×4×16 cm specimens were made from 120 and 600 rpm mixing rate. Bending strength of the gypsum prism was tested with three-point loading (Electric cement bending test machine, Controls, Italy). Compressive strength was determined on cubic specimens (5×5×5 cm) (Figure 1b). The tests were performed on a uniaxial testing machine with a load capacity of 30 Kn (Alborz Kosha, Iran). Three specimens were made for each formulation. The two broken prism pieces obtained after the bending strength testing were then used for determination of water absorption.

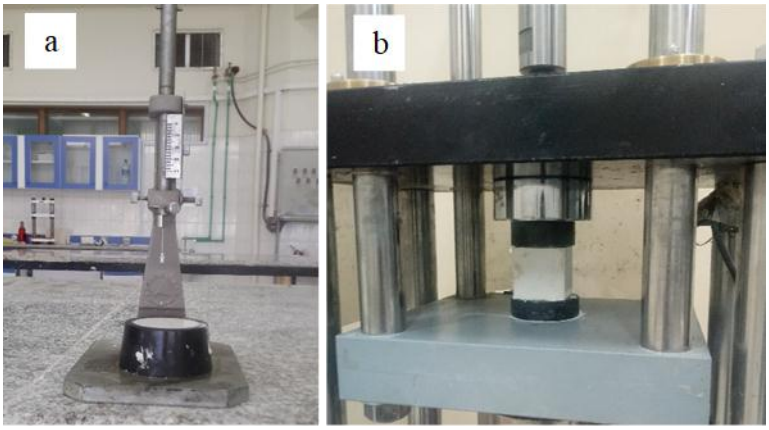

Fig.1.Vicat apparatus (a) and compressive strength test (b).

The above-mentioned broken prism pieces were immersed in a water bath for 24 h at 25 ^{0}C, and then took out to remove the excess water on the specimen surface with a dry cloth. The water absorption (WA) was calculated as follows (3):

$$WA= (M_2-M_1)/M_1 \times 100 \quad (3)$$

Where M1 and M2 are weights of the sample before and after immersing of 24 h, respectively. The apparent porosity (AP) was calculated by an Archimedean method as follows (4):

$$AP=(M_2-M_1)/(M_2-M_3) \times 100 \quad (4)$$

Where M3 is weights of the sample was submerged in water.

The bottom of prismatic 4×4×16 cm specimens was contacted to water and the distance of the water diffusion (x) was measured at different times (t=1, 4, 9 and 16 min) (Figure 2). Water diffusion coefficient (D) was calculated as follows (5):

$$D= x^2/t \ (cm^2/min) \quad (5)$$

Fig.2. Measuring of water diffusion coefficient.

In final, the fragments of specimens broken by strength test were analyzed using field emission scanning electron microscopy (FE-SEM), model 450 FEG, FEI QUANTA.

3- Results

Figure 3 shows the setting time of the plaster as a function of the mixing rate. According to the results, the setting time decreased with increasing mixing rate. The setting time became about half with increasing mixing rate from 120 to 600 rpm.

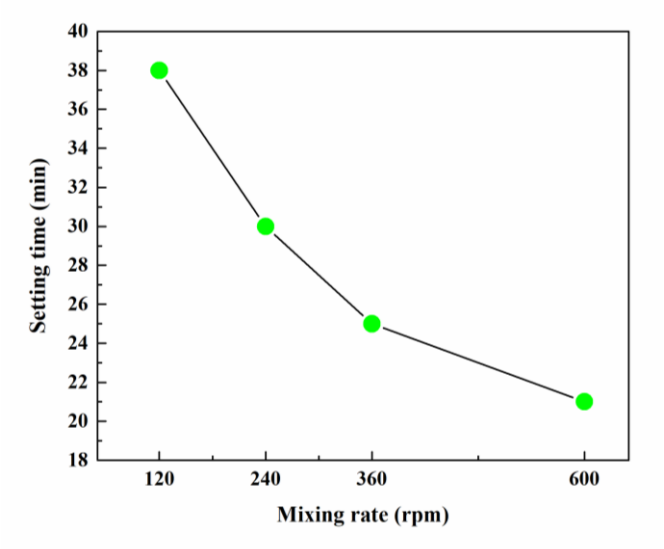

Fig.3. Setting time of the plaster as a function of the mixing rate.

The obtained results attributed to the strength and also water absorption and apparent porosity of 120 and 600 rpm mixing rate are presented in Figure 4 and Figure 5, respectively. With increasing mixing rate, the bending and compressive strength of hardened samples increased while the water absorption and apparent porosity of hardened samples decreased. The higher strength and lower water absorption could have attributed to the decreasing of the apparent porosity [6]. This can also be explained by the microstructure change with increasing mixing rate [3].

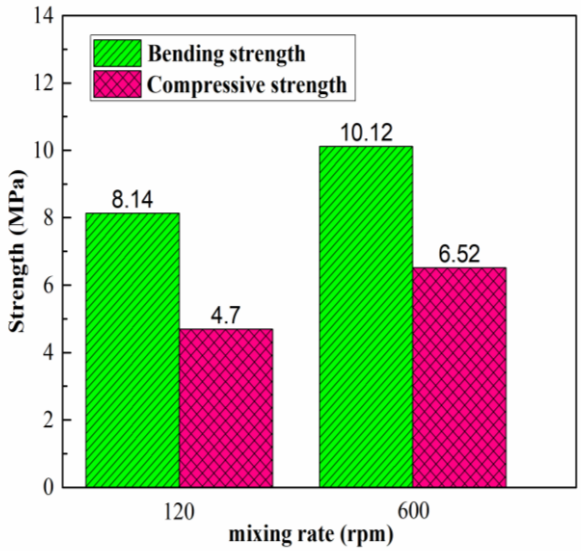

Fig.4. Bending and compressive strength of 120 and 600 rpm mixing rate.

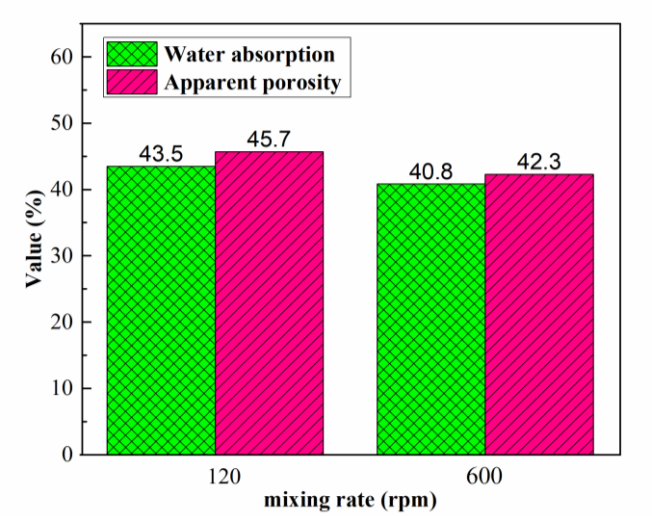

Fig.5. Water absorption and apparent porosity of 120 and 600 rpm mixing rate.

Figure 6 shows the amount of the water diffusion coefficient as a function of diffusion time. According to the results, the water diffusion coefficient of the hardened sample of 600 rpm is lower than the hardened sample of 120 rpm. The average water diffusion coefficient of the hardened sample of 120 and 600 rpm were 4 and 3.03 cm2/min, respectively. The lower apparent porosity of the sample with higher mixing rate could result to lower diffusion coefficient.

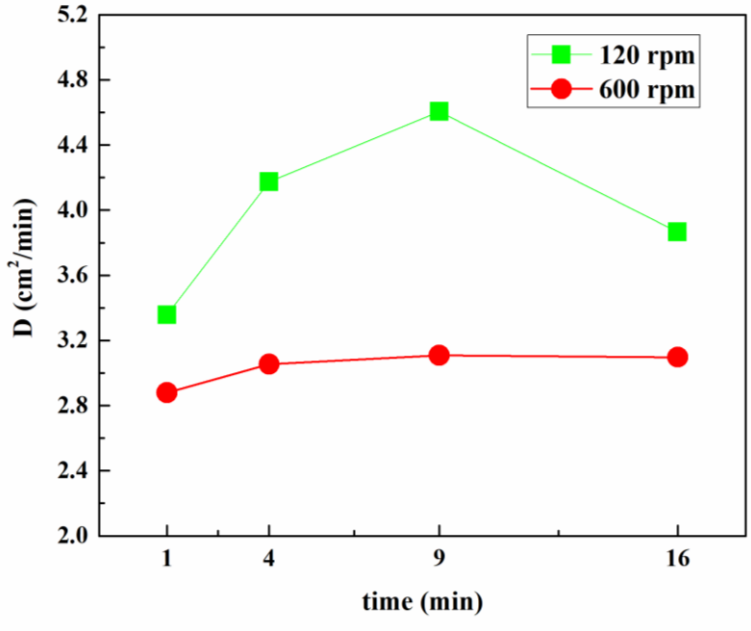

Fig.6. Water diffusion coefficient as a function of diffusion time.

Figure 7 compares the morphology of gypsum with different mixing rates. The higher rate of nucleus formation, the smaller crystals and denser structure are formed. This material will have higher strength [10]. The microstructure of gypsum with higher mixing rate not only seems to be denser, with crystals interlaced, but also shows short crystals. The more uniform microstructure of gypsum with higher mixing rate could lead to the uniform diffusion coefficient through the hard sample (Figure 6).

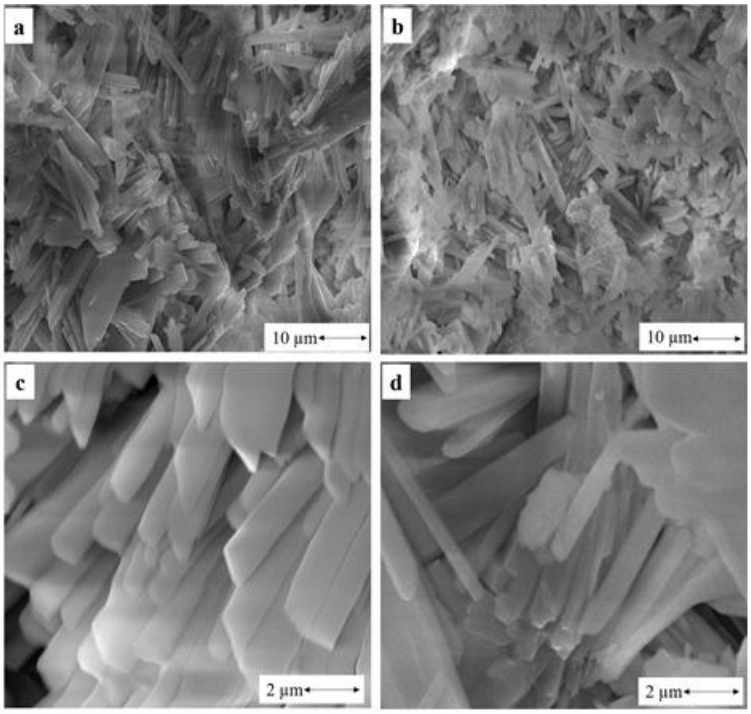

Fig.7. Morphology of gypsum with different mixing rates (a, c) 120 rpm and (b, d) 600 rpm.

The number of nuclei per solution volume unit influences the microstructure growth rate and crystal size. Thus, by increasing or decreasing the number of nuclei per volume unit it is possible to modify the crystalline structure and, consequently, the mechanical properties of the hardened product [1, 3]. The crystal growth conditions directly affect the physical and mechanical properties of the products in the fresh and hardened states. An illustrative diagram of the formation of the nuclei and the crystal growth at different mixing rates is shown in Figure 8. According to the obtained results, the number of nuclei per solution volume unit can been increased with increasing mixing rate and lead to decreasing of the setting time (Figure 3). The final microstructure of sample with the low mixing rate shows long crystals, arranged in parallel, characteristics of a structure that had more time to develop, which may impair the mechanical strength of the specimen (Figure 4) [3].

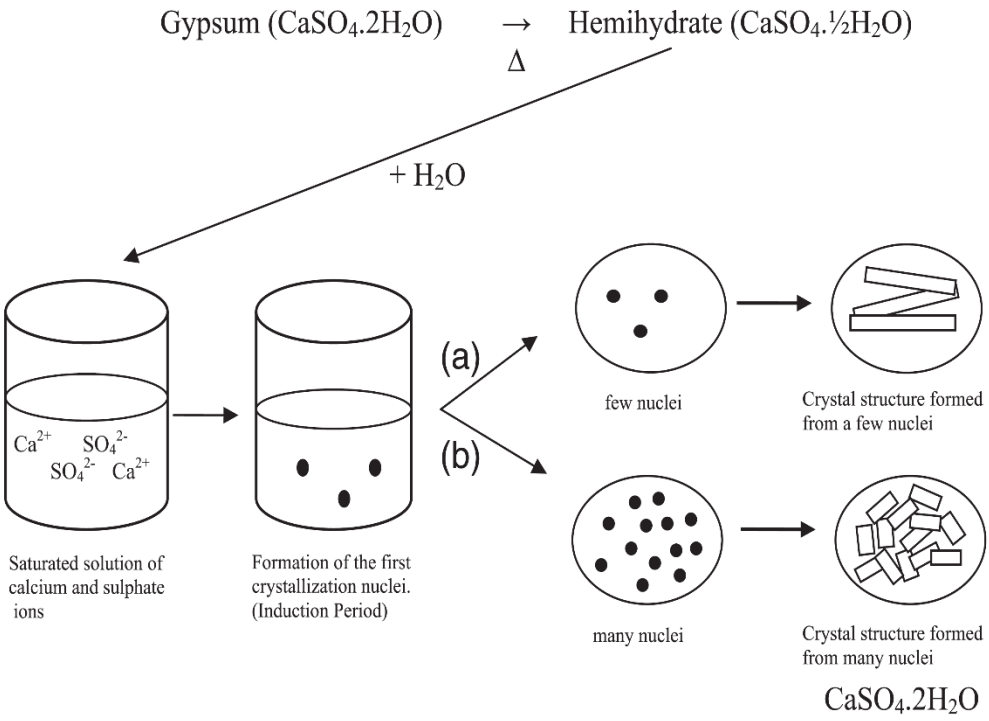

Fig.8. Formation of the nuclei and the crystal growth at low (a) and high (b) mixing rates [3].

4- Conclusion

This research investigated the effect of the mixing rate of plaster with water on the gypsum properties. The results show with increasing mixing rate, the setting time, water absorption and apparent porosity decreased and the strength of hardened samples increased which could attribute to the higher rate of nucleus formation, the smaller crystals and denser structure.

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