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EFFECT OF GRINDING AIDS ON CEMENT PROPERTIES AND GRINDING PROCESS

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ABSTRACT

The cement industry is one of the most energy-intensive industries, which is why new energy-reducing and reducing CO_2 emissions, additives are being sought. Grinding aid or grinding additives refer to substances that when mixed into the mill contents cause an increase in the rate of size reduction. These terms are very common in cement industries where it increases the throughput of the mill. Grinding aid also affects the cement flowability throughout the circuits. The grinding aid facilitates size reduction so that the mill has to apply less grinding power without hurting any of the properties of the resulting cement. The present research work aimed to investigate the influence of a chemical grinding aid ethylene glycol (EG) on cement properties and mill performance during the grinding of Portland cement beyond 500 ppm reaching up to 1200 ppm. The obtained results show increasing in initial compressive strength and increasing in the productivity of the cement mill.

Keywords: grinding, grinding aid, fineness, surface area, physic-chemical properties.

INTRODUCTION

Chemical additives can be solid or liquid substances that are added to the mill when grinding cement in small amounts to improve efficiency during grinding. Grinding additives act mainly as dispersants, they prevent the ground material from agglomerating, therefore improving the movement of the material along the line, improving the grinding speed coefficient and the efficiency of the separator, and assisting the removal from the air ducts. The main effect is to reduce energy consumption and increase grinding efficiency [1]. However, the mobility of the ground material and the physics-mechanical properties of the cement can also be improved, such as an increase in the initial and final strength indicators. In the grinding process, a range of grinding aids are utilized, including aliphatic amines such as tetraethylenepentamine (TEPA) or triethylenetetramine (TETA), as well as amine alcohols like triethanolamine (TEA), diethanolamine (DEA), or triisopropanolamine (TIPA). Additionally, glycol compounds such as ethylene glycol (EG) and diethylene glycol (DEG) are commonly used [2]. Typically, grinding aid concentrations in cement plants range from 50 to 500 ppm. Furthermore, the chemical composition of the grinding aids changes after the grinding process. It's also worth noting that the composition of grinding aids may not solely consist of pure compounds, but rather more complex raw materials [3 - 7]. The role of triethanolamine (TEA) in cement hydration remains a subject of uncertainty. It is yet to be determined whether it functions as an accelerator or a retarder. When added at 0.02 % to Portland cement, TEA accelerates the setting process, but at 0.25 %, it mildly retards it. At 0.5 %, TEA significantly delays the setting, and at 1 %, it strongly accelerates the process [8 - 12]. Part of the chemical aids as TIPA are used not only in the cement industry but also as chemical admixtures for concrete, the addition of small amounts of TIPA can result in a significant increase in the strength of cement pastes at different ages [13 - 15].

EXPERIMENTAL

During the experimental phase, cement-type CEM I, which consisted of clinker, gypsum, and limestone, was mild in a vertical roller mill. As part of the study, glycol-based grinding aids such as ethylene glycol with specific characteristics including a molecular weight of 62.07 g mol^{-1}, alkali content ≤ 10, density of 1.01 g cm^{-3}, and pH of 10.5 at 25°C, were used. A reference sample was also prepared without any chemical additives. Different quantities of a grinding aid (GA) were introduced during the grinding process (Table 1). The clinker used in the experiment had a low C3A content of less than 5 %. Several physical-mechanical properties of the resultant cement were assessed. Specific surface area was determined using the Blaine air-permeability apparatus and expressed as the total surface area in cm^2 g^{-1}, or m^2 kg^{-1} of cement. The particle size analysis of the feed and ground products was conducted using a Laser Diffraction Particle Sizer Mastersizer 3000 (Malvern Instruments). The setting time was determined by using a needle instead of the plunger. After filling the Vicat ring with consistent cement paste on a glass plate, the Vicat needle was placed on the top surface of the paste and secured with a screw to prevent plunging. The screw was then loosened, and the needle was plunged into different points of the cement paste every 5 min by changing the position of the Vicat ring. The initiation of setting was identified when the needle plunged to a distance of 3 - 5 mm from the glass plate. The initial setting time was the duration from the mixing of cement and water to the initiation of setting. Following the initial setting time, the needle was plunged every 15 min, and the position of the Vicat ring was changed. The final adjustment was made when the needle could be inserted 1 mm beneath the surface of the paste. The compressive strength of mortar was determined by placing prepared mortar in prismatic molds with dimensions of 160×40×40 mm. The molds were cured at a temperature of 20°C in a room with a relative humidity of 90 % for 24 h, followed by curing in tap water at 20°C for 1, 2, and 28 days. After the specified durations, the prismatic specimens were split and broken using Toni Technik 2020 equipment. Each test was repeated three times, and the reported values represent the mean average.

Table 1. Mix proportions of raw materials subjected to grinding.

Mixtures	Clinker, %	Gypsum, %	Limestone, %	GA, ppm
Ref	92	4	4	0
1EG	92	4	4	1000
2EG	92	4	4	1200

RESULTS AND DISCUSSION

For all the collected cement samples, the Blaine surface area, 90 µm and 45 µm residuals, initial and final setting times, and 1 day, 2 days, and 28 day mortar strengths were measured. These values are given in Table 2. The surface area values and residuals are rather consistent across the samples, indicating that the operational and grinding aid changes that were made during the trial did not have a significant effect on the particle size distribution of the finished cement. Although with the addition of EG and with the increase of its content, the specific surface area increases, and the sieve residue decreases Fig. 1 and Fig. 2.

The setting times and strengths have interesting variations. The initial and final set times are plotted in Fig. 3. The initial setting time (IST) values decrease with the addition of a grinding aid with an overall reduction of about 20 min. For the final setting times (FST), there

Table 2. Physical-mechanical properties of the cement samples.

Mixtures	Grinding aid, ppm	Blaine SA, cm^2 g^{-1}	Sieve analysis		Initial setting time, min	Final setting time, min	Compressive strength, MPa		
			90 µm	45 µm			1 day	2 days	28 days
Ref	0	3 894	0.5	1.83	195	330	14.7	26.4	61.8
1EG	1 000	3 918	0.2	1.69	190	310	16.7	29.6	62.0
2EG	1 200	3 984	0	1.44	175	270	19.2	30.5	62.7

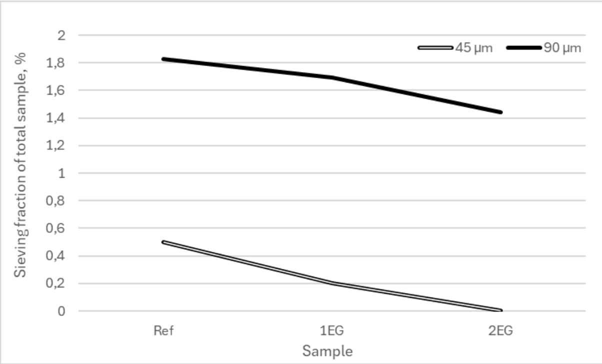

Fig. 1. Sieve residue of cement.

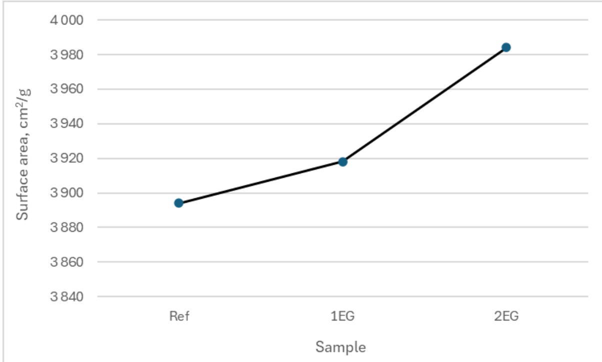

Fig. 2. Specific surface area of cement.

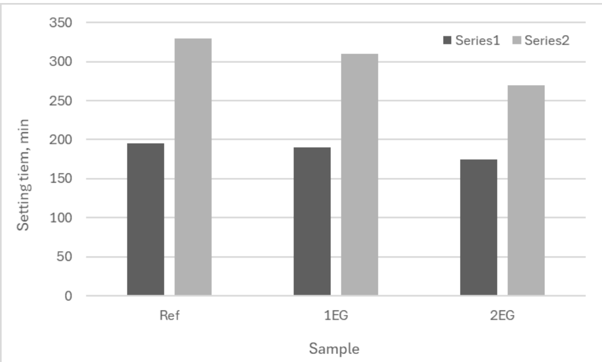

Fig. 3. Initial set time and final set time plotted against the GA dosage level in the vertical roller mill.

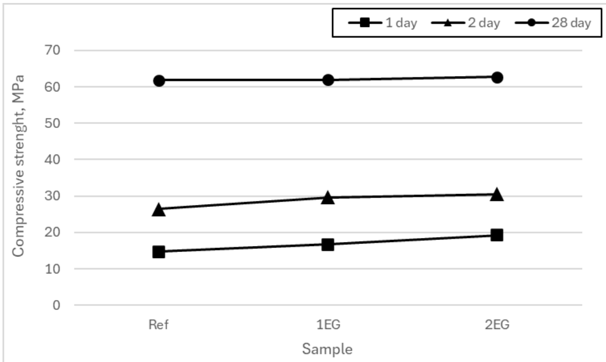

Fig. 4. Mortar strengths at 1 day, 2 days and 28 days.

is again a trend of decreasing FST with increasing EG, with a significant overall reduction of 40 min.

The mortar strength results are presented in Fig. 4. The 1-day strengths increase significantly with increasing GA dosage. In addition, the reference samples have a 1-day strength lower than the trial grinding aid regarding material composition. Overall, the 1-day strengths increased by about 4.5 MPa, which can be attributed primarily to a quality improvement effect of the trial grinding aid and a reduction in cement pre-hydration. The overall variation in 2-day strengths is about 4 MPa for both trial grinding aids giving higher strength than the reference. On 28 days the strengths again show a small increase with increasing the dosage of the GA. In addition, the reference sample without GA again has a noticeably lower strength.

CONCLUSIONS

The addition of the grinding aid to the vertical roller mill led to several notable performance enhancements:

- Early strengths at 1-day and 2-day saw an increase of approximately 4 MPa.
- The 28-day strength showed a gradual improvement with higher GA quantity.
- Initial setting time was reduced by about 20 min with increased GA quantity.
- Final setting time decreased by 20 - 60 min as GA quantity increased.
- A modest increase in the stable production rate of around 5 tons per hour was noted.
- With increased productivity, there was a decrease in the specific consumption of electrical energy.

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