

Grinding aid efficiency

Yapichem Kimya Sanayi AŞ has undertaken a study to investigate the influence of polycarboxylate ethers (PCEs) with various amine densities and side chain lengths on cement properties when using grinding aids. The results show that amine-containing polycarboxylate-based grinding aids synthesised by free radical polymerisation can provide good grinding efficiency, optimal mechanical strength and, crucially, increase the fluidity of cement paste during the grinding process.

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Grinding aids are amine (triisopropanol amine), alcohol (diethylene glycol) and ether- (polycarboxylate ether – PCE) based organic materials that are added to the cement mill during the clinker grinding process. They help the physical and mechanical properties of cement and improve grinding efficiency.

In this study, four specifically polymerised PCEs containing amine with different side chain lengths and side chain densities were obtained by free radical polymerisation. The effect of the PCE side chain length and density on the grinding efficiency and mechanical strength was investigated.

Material

The study used an ordinary Portland cement (CEM I 42.5R) with a Blaine surface area of 3620cm²/g. Table 1 shows the composition of the OPC. The specific surface area (SSA) was measured using Blaine air permeability apparatus supplied by Atom Teknik of Turkey (see Figure 1). All particle size ranges were determined by an Alpin AS 200 LS-N air jet sieve (see Figure

2). Density, measured using a pycnometer, was 3.15g/cm³.

The weight ratio of monomers used in the polymerisation process can be seen in Table 2. Qualitative information on the PCE structure is shown in Table 3. Meanwhile, Figure 4 shows the experiment set-up.

Discussion

At the end of each grinding process, the Blaine value of the obtained product and the PCE dosage required to achieve a certain fineness in a laboratory ball mill (see Figure 3) was determined. Following on, the grinding efficiency of the PCEs containing amine exhibiting different side chain length and side chain density was investigated.

The experimental set-up is shown in Figure 4. Yapichem's focus was on a well-balanced ratio of polar to non-polar parts in the PCEs. It was found that the molar ratio of the main chain:side chain is not critical, and that longer side chains are more beneficial if they possess low side chain density (PC-I). This can be attributed to the fact that as the cement particles approach each other, the polymer side

Figure 1: the specific surface area of the OPC used in the study was carried out with Blaine air permeability apparatus



chains provide a repulsive steric force, keeping the particles dispersed. On the other hand, shorter side chains are more beneficial if they possess high side chain density (PC-III). This can be attributed to the fact that the more hydrocarbon parts there are, the smaller the surface energy of covered particles, which improves the grinding effect. Hence, shorter side chains lead to a larger adsorbed amount of PCEs on the clinker due to increasing carboxylate groups and increased intermolecular attraction between the PCEs.

Adding PCE-containing amine increased the compressive strength of two samples and thus improved the quality criterion

Table 1: chemical composition of the Portland cement used in the study

Chemical composition	Share (wt %)
CaO	66.04
SiO ₂	21.47
Al ₂ O ₃	4.76
Fe ₂ O ₃	3.16
MgO	1.17
SO ₃	1.96
Na ₂ O	0.08
K ₂ O	0.53
Other (water, impurities)	0.83



Figure 2: air jet sieve



Figure 3: laboratory ball mill

Table 2: monomer composition of the amine containing PCE samples

Code	PEG monomer (wt %)	Carboxylic monomer (wt %)	Amine content in PCE (wt %)
PC-I	70	30	10
PC-II	70	30	15
PC-III	90	10	15
PC-IV	90	10	10

Table 3: qualitative information on the molecular structures of the PCEs used

Structural parameter	PC-I	PC-II	PC-III	PC-IV
Side chain length	Long	Long	Short	Short
Side chain density	Low	Medium	High	Medium

of the cement. At 0.05 per cent dosage of grinding aids used, the most ground material was obtained with the PC-I grinding aid. As can be seen in Figure 7, the comparison of the percentage increase in compressive strength of all samples shows that the highest increase for two- and seven days belonged to the PC-I (8.8 per cent and 6.9 per cent) and PC-III (3.7 per cent and 5.3 per cent), respectively.

In this study, the highest efficiency is related to the application of PC-I, which caused an 8.15 per cent increase in comminution efficiency and an 8.8 per cent increase in two-day compressive strength. The significantly increased number of 0-32µm particles is one of the main reasons for the enhanced strength.

From the results obtained it was concluded that the high fineness of cement plays a very important role in the development of mechanical properties at an early age.

Conclusions

The aim of this study was to synthesise PCEs containing amines with different side chain lengths and side chain densities and use them as grinding aids in the cement industry. The highest efficiency related to the application of PC-I, which resulted in a 8.15 per cent increase in comminution efficiency. The comparison of increases in compressive strength of all samples shows that the highest increase for two- and seven-day strengths belonged to the PC-I (8.8 per cent and 6.9 per cent) and PC-III (3.7 per cent and 5.3 per cent), respectively.

However, much more work is required in the study of these PCEs. After obtaining the optimal amounts of each of these PCEs on a laboratory scale, future studies will focus on a semi-industrial scale. ■

Figure 4: experiment set-up**Table 4: PSD of cement composite grinding aids**

Grinding aid	PSD (wt %)		Blaine (cm²/g)
	<32µm	<45µm	
Blank	75.45	87.75	3620
PC-I	77.45	89.50	3500
PC-II	77.40	89.05	3490
PC-III	76.90	89.25	3435
PC-IV	76.95	89.90	3480
Commercial product	76.65	88.10	3410

Figure 5: compressive strength test press**Figure 6: concrete test samples****Figure 7: comparison of compressive strength of samples**