The Relationship Between Cement Quality and Separation Cut Size

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Abstract

Cement is prepared by firing a mixture of raw materials, one of which is mainly composed of calcium carbonate and the other of aluminium silicate. The most familiar materials answering to this description are limestone and clay, both of which occur in nature in a great number of varieties. Marls, which are a mixture of clay and shales, are also common raw materials for cement. The production of cement is an energy-intensive process. The typical energy consumption of a modern cement plant is about 90–120 kWh per ton of produced cement.

The service properties of cement such as workability and strength development are affected not only by the chemical and mineralogical composition but also to a great extent by the fineness and particle size distribution of the cement produced; in practice often only the strength development of cement is of primary interest. Yet the effect on workability is just as important. Moreover, the surface area and granulometric parameters may also directly or indirectly affect the frost resistance and other durability-related properties of concrete. There are process engineering options for controlling fineness and particle size distribution of the cement by changing the mode of operation of the mill and the separator.

This paper describes a study of the relationship between cement strength and separation cut size (d_{50}). The separation cut size (d_{50}) of air separator products obtained by different days was ascertained by using particle size analysis. It was found that the cement fineness and separation cut size (d_{50}) are very effective on the strength of cement.

Keywords: cement production, cement quality, separation, cut size, air separator

Introduction

Cement production has undergone a tremendous development over 2000 years. While the usage of cement in concrete has a very long history, the industrial production of cements started in the mid-19th century, first with shaft kilns, which were later on replaced by rotary kilns as standard equipment worldwide. Today's annual global cement production has reached 2.8 billion tones, and is expected to increase about to 4 billion tons per year. Major growth is foreseen in countries such as China and India as well as in regions like the Middle East and Northern Africa (IEA & WBSCD, 2009).

Grinding is a high-cost operation consuming approximately 60% of the total electrical energy expenditure in a typical cement plant and 40% of this energy is for raw material grinding. During the last decade, there have been considerable improvements in comminution efficiency not only due to the development of machines with the ability to enhance energy utilisation, but also due to the optimal design of grinding systems and operating variables that enable more efficient use of existing machines (Deniz, 2003; Deniz, 2004; Deniz, 2012).

Grinding efficiency is essential for all comminution processes as raw material, coal and cement grinding. While the requirements are basically the same in all cases, cement grinding has a special additional focus, which is workability of the final product and its strength development. Both parameters not only depend on the particle size but also to a large degree on the size distribution. Even though technological development drastically increases in cement plant, grinding remains the biggest source of energy consumption in cement production. While total electrical energy consumption for cement production is about 100 kWh/t of cement, roughly two thirds are used for particle size reduction (Tsakalakis and Stamboltzis, 2008; VDZ, 2008; VDZ, 2012).

Ball mills have been used for over 100 years for milling processes in cement production. This mill type has prevailed due to its reliability and the favorable properties of the cement ground with ball mills. Primary ball mills were operated as open-circuit mills, later; separators were added to produce improved cement qualities in a closed circuit. Cement grinding process in the ball mill generates a relatively broad particle size distribution. The selected fresh material feed, the rotational speed of the separator, and the separation air volume flow, can adjust the cement fineness (Schneider et al., 2011).

The particle size distribution of cement and/or its components has an important influence on water demand, the setting behavior, and the strength development of cement in mortar and concrete.

The particle size distribution of the product depends significantly on the mill system used for cement grinding and therefore especially affects the choice of cement mills (Ellerbrock et al., 1990).

Non ground clinker does not have the qualities of cement. Clinker must be ground finely to be able to react with normal water. More finely ground cement has a larger specific surface and the reactive area with water is thus larger. Contact with both fine additives and gravel and sand surfaces is improved, the initial hydration of clinker minerals is made easier, and the distribution of hydration products is accelerated. On the other hand, if cement is too fine, it will get wet and will clot more easily when stored. If it is used in concreting, it displays the tendency to segregate by water erosion, the onset of hardening gets shorter, and the hardening time gets longer. Despite the higher initial firmness of cement that is too fine (less than 20 μm), its final firmness is not higher. The increase of grinding fineness increases the intensity of hydration-heat generation; shrinkage and the consequent tendency to form fine cracks grows. This is reflected by the loss of the mechanical properties of the final products. Thus, over-grinding of clinker results in an increase in energetic demands and consequently in the final price of the cement as well as in other adverse attributes (Sverak et al, 2013).

To achieve the workability of the cement, sufficient water must be added so that the particles can move against each other. The required amount of water is particularly influenced by the particle size distribution. Consequently, the water demand of cements from more comminution is higher, since cements have narrower the particle size distribution and thus there is a larger gap volume to be filled.

The strength of cements with the same specific surface area increases with narrowing of the particle size distribution. This is caused by an increase of completely hydrated fines as a result of the decreasing average particle size. This position parameter represents the fine particle fraction, which is responsible for the strength behavior of the cement (Schneider et al., 2011).

Several different techniques are available to control the fineness of cement-based materials. These include a series of non-destructive approaches (i.e., sieving (Erdoğdu and Turker, 1998; Paya et al., 2002; Chindaprasirt et al., 2004), air classifying (Paya et al., 2002) or magnetic-extraction (Chindaprasirt et al., 2004) methods as well as destructive approaches (i.e., mechanical grinding (Osbaeck and Johansen, 1989; Paya et al., 1996; Kakali et al, 2000; Kiattikomol et al, 2001; Paya et al., 2002; Jaturapitakkul et al., 2004; Sakai et al., 2009; Sengul and Tasdemir, 2009; Sezer et al., 2010) methods). The cement industry typically uses ball-mill grinding as the preferred method to reduce the size of clinker in cement manufacturing (Paya et al., 1996).

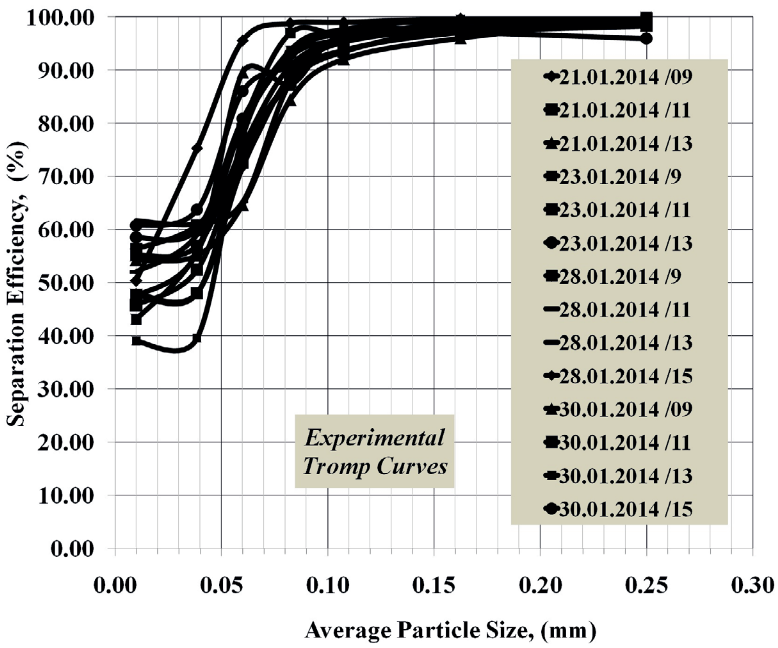

Fig. 1. Observed Tromp curves as experimental determined in air separator

Air separator or dynamic separators are used in a variety of industrial applications such as food, chemical, minerals, building materials and other fields that need to mass-produce fine particles in a limited size range of controlling powder properties including homogeneity and high quality.

The main performance characteristics to be considered in the design of dynamic air separators are the pressure drop and the separation efficiency. The pressures drop across the cyclone air separators a significant characteristic since it is directly related to the operating costs. The pressure drop over a cyclone separator can be calculated when the difference of the static pressure between the inlet and outlet. The confidences in the dynamic separator flow-field predictions can only be obtained by industrial experiment validation. The separator efficiency can also be illustrated by the selectivity curve or the Tromp curve. This curve shows, for each cement grain size what percentage of the separator feed is selected as fines or retained as coarse particles.

Separation cut size (d_{50}) has been indicated directly from changes of the particle size distribution of cement products in many studies. However, separation cut size between the compressive strength important points of the cement quality has not been investigated. In this study, the relationships between the separation cut size (d_{50}) with compressive strength of cement (as 2, 7 and 28 days) were investigated.

Material and methods

The separation performance of a separator device depends on its structure, operating conditions, separation cut size, feed amount, and cement particle size. The Tromp distribution curve shape relies on the operating conditions of the used device than the feeding material properties. The Tromp curves were plotted using the samples taken at different time periods for the same separator device.

Determination of separation cut size (d_{50}) with Tromp distribution curves

For this study, first, the particle size analyses for the samples obtained from GÖLTAŞ Co. (Isparta/Turkey) air separator unit were performed. The samples (separator feed, over flow and under flow) were taken from the separation device (air separator) at different time intervals. Afterwards, the Tromp distribution curves were plotted for air separator from the sieve size data of the products. Following this study, both observed separation cut size (d_{50}) and corrected separation cut size values were determined because of by-pass product for the air separator, and efficiency curves were drawn (Figure 1).

Material experiments were conducted at the rotor cage rotary speeds of 130 rpm when the air inlet velocity is 56.25 m3/second and the amount of separator feed is approximately 200t/h. Density of cement powder is 3150 kg/m^3. The separation cut size (d_{50}) are not closer from as depending on the time they obtained both observed Tromp curves (Figure 1) and corrected Tromp curves (Figure 2).

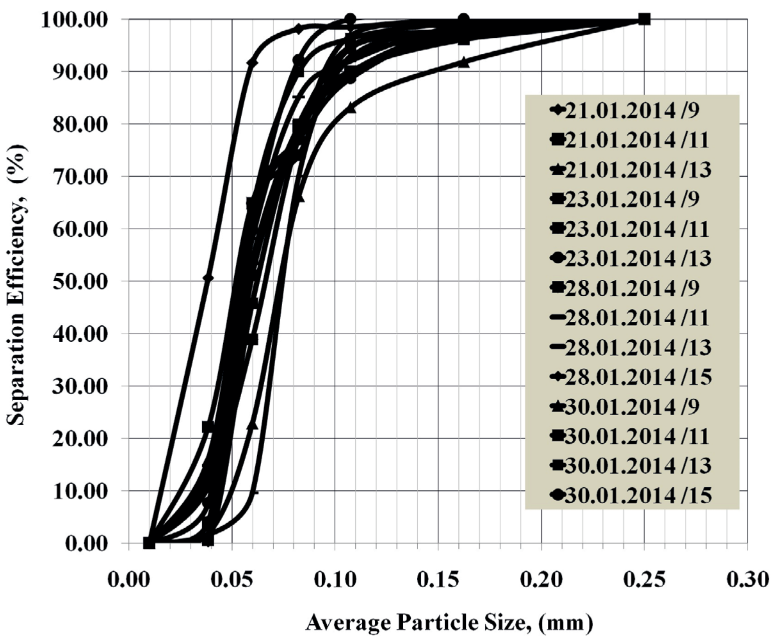

Fig. 2. Corrected Tromp curves derived from observed Tromp curves

Changes of the separation cut size (d_{50}) as depending on the time

In the actual classification process, the separation cut size (d_{50}) is defined as the diameter of a particle whose partial classification efficiency is 50%. As shown in Figure 3, the separation cut size (d_{50}) is obtained by experiments is between 78 µm and 38 µm.

Determination of compressive strength for cement quality

All mortars were prepared in a Toni technique mixer according to ASTM C 305 (1996). After casting, the specimens were prepared for testing. The compressive strength was measured using a Toni-Troll with cylindrical specimens (approximately 40 mm diameter and 150 mm height) in accordance with ASTM C-39 (2003). Each test results were consisted of the average of four samples made experimental. All specimens were sealed until the desired age of testing, which were 2, 7, and 28 days for the cement.

The analysis conducted according to TSEN 196-1 (2009) and TSEN196-6 (2010) standards, the effect of the separation cut size (d_{50}) on the quality of the cement are shown in Figure 4. The cement fineness is very effective on the strength and optimal fineness of cement must be specific for maximum strength.

The biggest factors affecting the compressive strength of cement are the heat of hydration. The important factor is the particle size distribution and the d_{50} values (mm) for cement.

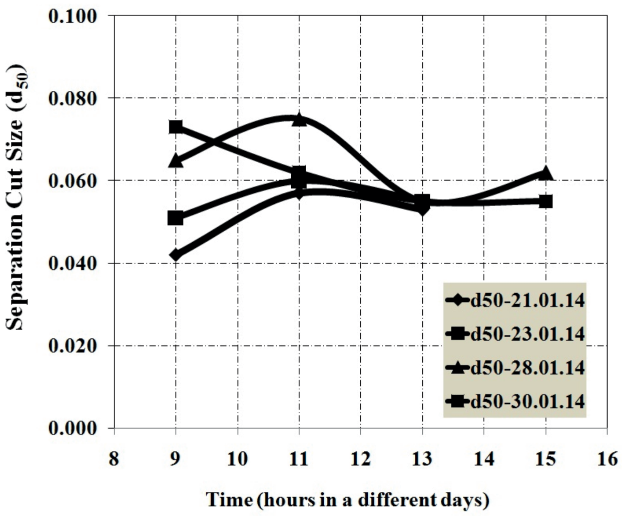

Fig. 3. Relationship the separation cut size (d_{50}) with hours on different days

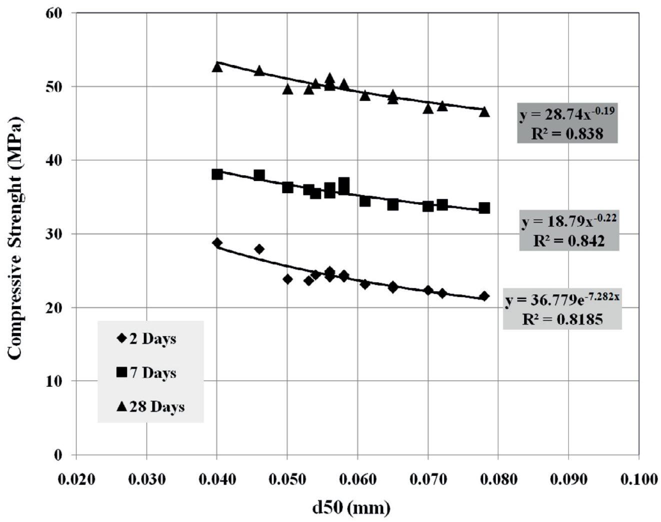

Fig. 4. Relationship compressive strength with the separation cut size (d_{50})

Conclusion

One of the most important factors in determining the quality of the produced cement is the particle size. The most important factors that determine the particle size distribution or the separation cut size (d_{50}) are the grinding circuit. In this study, the relationship was shown that between separation cut sizes of air separator and the compressive strength obtained on different days with high correlation (> 80%). The separation cut size (d_{50}) is between 38 μm and 78 μm. The separation cut size (d_{50}) are expressed, the importance of determining the quality of cement.

It was observed that the separation cut sizes are continuously varies. The reason for this was that the separator feeding sizes were variable. Additionally, the reason for this disorder could be attributed to either the feeder was not arranged according to the particle size of the feeding cement or carelessness of the labourer during those hours.

It could be suggested that the feeding particle size at the closed grinding-separator plant should be note homogenous. Additionally, the variations found in the process are caused by the automatic measurement system not used in the plant. Therefore, if there were established an automatic particle size analysis system in the grinding-separator system than the process would be improved.

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