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Measuring characteristics of aggregate material from vertical shaft impact crushers

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Abstract

Natural gravel has traditionally been the main choice of material for Swedish concrete manufacturers. However, due to the fact that natural gravel also acts as a fresh water filter, the deposits are limited. The obvious question is how to compare machine made and natural gravel in terms of particle shape, rheology and other material characteristics. This paper will present some methods and results that demonstrate performance of different machine made rock materials. Particle shape characteristics were assessed from flow measurements in a standard cone. The vertical shaft impact crusher (VSI) produces gravel that is a good alternative to natural gravel. The quality of the material and the particle shape seem to meet concrete producers' demands.

Keywords: Flakiness; Shape; Angularity; VSI; Cone crusher; Abrasive

1. Introduction

Natural gravel is a limited resource. The use of natural gravel in Sweden has been regulated by the government, who imposed a tax on quarrying. The reason for this regulation is that the gravel deposits are limited and, as the fresh water that most Swedish people drink every day is filtered through natural gravel, it is necessary to restrict its use.

Natural gravel is frequently used in concrete production partly because of its grading characteristics but also due to the fact that it has a very low amount of flaky particles. According to Kaplan (1959), in order to control the characteristics of concrete, knowledge of the flakiness and surface texture of the aggregate is important. The importance of these factors increases in line with the demand on concrete strength. Changes in angularity have greater effect on workability of concrete than changes in flakiness (Kaplan, 1958; Järvenpää, 2001). Kaplan's research focused on coarse aggregate. According to Mass (1983), an upper limit on flakiness in coarse aggregate is appropriate when it is used in concrete. The flakiness and angularity correlates with the void quantity in the aggregate (Metso Minerals, 2005). The flow time and void content of fine aggregate can be measured by means of a flow cone test (NZS 3111:1986). Le Pennec et al. (1995) showed that the mass flow is independent of sample size.

The shape of the fine particles in gravel is of great interest to concrete producers. If the particles are classified as flaky, it indicates that there will be problems in the production of concrete.

However, flaky particles are not the only problems associated with concrete production. It is likely that parameters such as size, roughness, sphericity, angularity and so forth are factors that determine the suitability of the crushed aggregate for concrete production.

It is difficult to quantify parameters such as roughness and sphericity. It is possible to perform observations, but not easy to obtain accurate measurements (Smith and Collins, 2001).

The determination of shape in smaller fraction sizes is often difficult and cost intensive. The most common

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Nomenclature

C	constant in Eq. (2) (–)	g	acceleration due to gravity (m/s^2)
k	constant in Eq. (2) (–)	M_1	mass test proportion of flaky particles (kg)
D	outlet diameter (m)	M_2	total test proportion (kg)
ρ_b	bulk density (kg/m^3)	FI	flakiness index in Eq. (1) (%)
d	particle diameter (m)	$\dot{m}$	mass flow in Eq. (2) (kg/s)

method for determining particle shape involves microscope observations and the use of computer software. While this is considered efficient, it is both time consuming and expensive.

Fig. 1 shows the influence of different crushing methods on flakiness. The way in which different crushing techniques influence particle shape in coarser aggregates is well known (Kojovic, 1995). It is, however, unclear how the particle shape of finer aggregates differs as a result of different crushing techniques.

A major advantage of the cone crusher is its ability to limit the amount of waste material produced. The disadvantage is poor shape in most fraction sizes. Previous work carried out by the authors (Bengtsson and Evertsson, 2006) revealed that the main process parameters that influence shape are average feed size and CSS setting. Fig. 2 presents the size and shape of the output of a cone crusher.

The performance of a VSI differs considerably from that of a cone crusher. The advantage of the VSI is the possibility of producing cubical particles, while the disadvantage is that the cubical particles result in a large amount of fines. In Fig. 3 product curves from a VSI is shown.

The VSI requires a certain velocity to shape the particle and higher velocity leads to an increased amount of fines. It was proposed that when nature creates gravel, the shaping mechanism leads to an increase in fine material although the large particle remains almost the same, which is also the case with the VSI.

The purpose of this work is to present a simple and cost efficient method for indirect measurement of particle shape of fine aggregates.

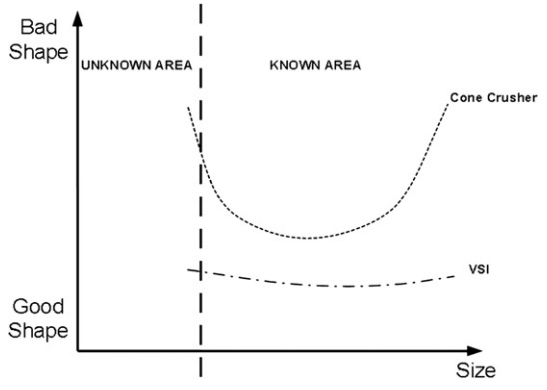

Fig. 1. Known area of shape characteristics.

This paper also aims to show the benefits of employing a VSI to produce crushed fine aggregate with cubical shape.

2. Experimental

In this experiment two types of crushers were used. One cone crusher of type Hydrocone with a medium chamber and VSI crusher with rock box and no cascade flow. Both crushers operated in open circuit and the feed to the cone crusher had the size 32–64 mm. The VSI was fed with an 11–16 mm and a 11–22 mm fraction.

The material used in the study is tonalite that was crushed in either a cone crusher or a VSI. The VSI crushing is performed with three different rotor velocities. Natural gravel from the west of Sweden was used as a reference. A laboratory VSI located at Sandvik Rock Processing Research laboratory in Svedala was used in these tests.

The purpose with the tests was to show how different crushers affects the shape of fine aggregate and to see if the product can be used to replace natural gravel. Natural gravel was used as a reference in order to compare the shape of the crushed aggregate.

3. Methods for measuring shape

There are numerous methods for determining particle shape. European standards such as the EN 933-3 (flakiness index) and EN 933-4 (shape index) are often used to determine aggregate shape. There are some disadvantages of these methods. The most common problems are that they are time consuming and result in poor working conditions for the test personnel due to monotonous work and at times heavy lifting. Other problems are that the methods are only valid for a certain fraction size. Most of the time the shape has to be determined based on fraction sizes of between 5 and 32 mm, for which these methods are well suited. These methods cannot be used for determining the shape of smaller fractions in the 0.1–1 mm range. In this chapter alternative methods for determining particle shape will be presented, some of which are well known, while one is new.

3.1. Flakiness index

The flakiness index comprises *two screening* sessions. A sample is divided into fractions d_i/D_i with the aid of screens with square holes. Each fraction d_i/D_i is screened through a