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Automated Intelligent real-time system for aggregate classification

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ABSTRACT

Traditionally, mechanical sieving and manual gauging are used to determine the quality of the aggregates. In order to obtain aggregates with better characteristics, it must pass a series of mechanical, chemical and physical tests which are often performed manually, and are slow, highly subjective and laborious. This research focuses on developing an intelligent real-time classification system called NeuralAgg which consists of 3 major subsystems namely the real-time machine vision, the intelligent classification and the database system. The image capturing system can send high quality images of moving aggregates to the image processing subsystem, and then to the intelligent system for shape classification using artificial neural network. Finally, the classification information is stored in the database system for data archive, which can be used for post analysis purposes. These 3 subsystems are integrated to work in real-time mode which takes an average of 1.23 s for a complete classification process. The system developed in this study has an accuracy of approximately 87% and has the potential to significantly reduce the processing and/or classification time and workload.

1. Introduction

Aggregate is one of the major components in the concrete production. Granite and limestone are still the main rocks used in the aggregates production. The characteristics of the aggregates such as the shape, size and surface texture play important role in the production of high strength concrete. The properties such as the nature and the degree of the stratification of rock deposit, the type of crushing plant used and the size reduction ratio greatly influence the shape of aggregate particles and the quality of fresh and hardened concrete (Hudson, 1995; Kwan and Mora, 2001; Rajeswari, 2004). Improvement in the shape has been proven to be a major factor in the reduction of the water to cement ratio needed to produce a concrete mixture (Rao and Prasad, 2002). Similarly, Hudson (1995) has found that this high quality aggregate has the ability to decrease the cost of production and placement of concrete.

Generally, aggregates can be classified into two main classes namely, good and poor aggregates. The forms of good aggregate can be further classified into angular and cubical while those of the poor aggregate can be divided into four types namely elongated, flaky, flaky & elongated and irregular (Rajeswari, 2004; Ramli, 1991) as shown in Fig. 1.

Traditionally, the size and shape analysis of coarse aggregates are done by mechanical sieving and manual gauging as detailed in the British Standard BS812, Section 103.1 (British-Standard-Institution, 1985), BS812, Section 105.1 (British-Standard-Institution, 1989) and BS812, Section 105.2 (British-Standard-Institution, 1990). Generally, in sieving operation, known also as the "gradation analysis", errors can be introduced due to different shapes of particles.

In order to improve the traditional classification method, numerous techniques using imaging systems and analytical procedures to measure aggregates' dimensions are already available; for e.g. the Multiple Ratio Shape Analysis (MRA), VDG-40 Videograder, Computer Particle Analyzer (CPA), Micromeritics OptiSizer (PSDA), Video Imaging System (VIS), Buffalo Wire Works (PSSDA), Camsizer, WipShape, University of Illinois Aggregate Image Analyzer (UIAIA), Aggregate Imaging System (AIMS) and Laser-Based Aggregate Analysis System (LASS).

MRA (Jahn, 2000) is used for categorizing various particle forms found in a coarse aggregate sample. It is based on classifying aggregates according to their dimensional ratios into five different categories instead of one (<2:1, 2:1 to 3:1, 3:1 to 4:1, 4:1 to 5:1, >5:1). The device consists mainly of a digital caliper connected to a data acquisition system and a computer. A particle is placed on a press table, and the press is lowered until it touches the aggregate particle and stops. The device records the gap between the press and the table, which is equal to the particle dimension. The particle is then rotated in another direction and the procedure is repeated to obtain other dimensions. These readings are recorded in a custom-designed spreadsheet that displays the distribution of dimensional ratios in the aggregate sample.

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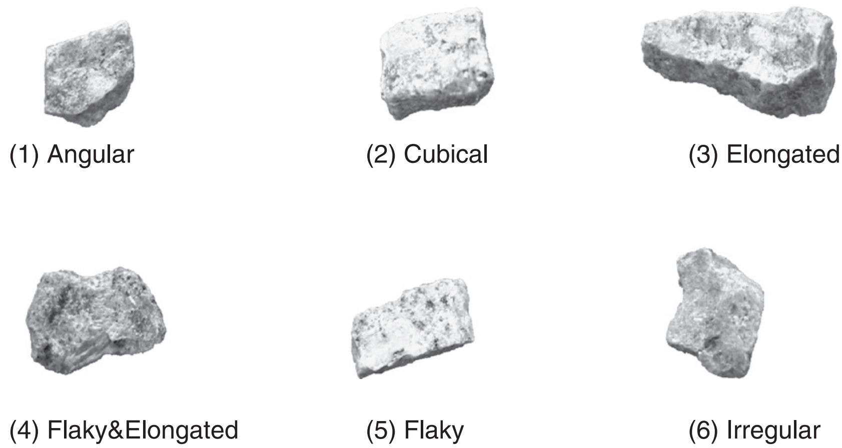

Fig. 1. Six shapes of aggregates.

VDG-40 Videograder (Browne et al., 2001) consists mainly of a device to feed the aggregates that fall in front of a backlight and a camera to capture images. The system uses a line-scan charge-coupled device (CCD) camera to capture the image and evaluate every particle in the sample as it falls in front of the backlight. A mathematical procedure based on assuming elliptical particles is used to calculate each particle's third dimension from the two-dimensional (2D) projection images captured. All analyses and data reporting are performed in a custom software package. This system is used in the laboratory to obtain automated aggregate gradation measurements and also particle flatness and elongation.

The third system called the CPA (Tyler, 2001) is similar to the VDG-40 Videograder. The CPA uses a line-scan CCD camera to capture the image and evaluate every particle in the sample as it falls in front of the backlight. However, it can be used in the laboratory as well as on-line (continuous scanning of a product stream). The current analysis of this system focuses on the gradation and form by assuming an idealized shape for aggregate particles to obtain the third dimension from images of the 2D projection. The CPA delivers information about particle count, particle size distribution, flat and elongation and sphericity. All analyses and data reporting are performed in a specifically-tailored software package.

The PSDA was initially developed for online applications (Browne et al., 2001). The system also uses a line-scan CCD camera to capture the image and evaluate particles in a sample as it falls in front of the backlight. Similar to the image analysis system discussed earlier, an idealized shape of particles is used to provide information about the gradation and shape. All analyses and data reporting are performed in a custom-made software package.

Another system that uses a line-scan CCD camera to perform similar tasks is the VIS (Browne et al., 2001). Similar to the VDG-40 Videograder system, the VIS assumes an idealized shape of a particle to provide information on the gradation and form. All analyses and data reporting are performed in a custom-made software package.

Browne et al. (2001) also described another system called the PSSDA. Again, this system performs similar tasks of capturing the image and evaluating particles as they fall in front of the backlight. The system developed for a laboratory environment, provides information about the particles' gradation and shape. Roundness is used to describe the form and angularity of the aggregate. There are two systems available for measuring the characteristics of coarse and fine aggregates. One system is used for the analysis of coarse aggregates (PSSDA-Large) and another for fine aggregates (PSSDA-Small).

The Camsizer system consists of two optically matched digital cameras, which are used to capture images of fine and coarse aggregates at different resolutions. Individual particle exits the hopper and falls between the light source and the camera. Particles are detected as projected surfaces and are digitized in the computer. This commercially available system automatically produces particle size distribution and provides some aspects of the particles' shape characteristics. The Camsizer measures the aggregate through their sphericity, symmetry and ratio of the length to breadth. Angularity in the Camsizer is described based on convexity.

The ninth system called the WipShape was developed for coarse aggregate analysis (Maerz et al., 1996; Maerz and Lusher, 2001; Maerz and Zhou, 2001). In the first version of the system, the aggregate particles are fed from a hopper into a mini-conveyor system. In a more recent version, the aggregate particles are placed in front of two orthogonal oriented synchronized cameras, which capture images of each particle from two views. These images are used to determine the three dimensions of particles. The system provides information on the aggregate's shape and gradation. The WipShape provides a measure of aggregate form by providing information on the dimensional ratio from particle images. This particular system also uses the minimum average curve radius method to quantify aggregates' angularity. The system is small-sized, which makes it only usable in field laboratories.

The UIAIA system uses three cameras to capture projections of coarse particles as they move on a conveyor belt (Rao et al., 2002). These projections are used to reconstruct three-dimensional representations of particles. The shape is determined from the measured dimensions directly without the need to assume the idealized shape of particles. The system provides information on the gradation, form, angularity and texture. The form of aggregate particles is measured by calculating the flat and elongated ratio. The UIAIA measures angularity using the outline slope method, while the aggregate's surface texture is measured using the erosion–dilation method.

The AIMS system operates based on two modules (Fletcher et al., 2002; Masad, 2005). The first module is for the analysis of fine aggregates, where black and white images are captured using a video camera and a microscope. The second module is devoted to the analysis of coarse aggregate, where gray images as well as black and white images are captured. The fine aggregates are analyzed for form and angularity, while the coarse aggregates are analyzed for form, angularity and texture. The coarse aggregate form is determined based on a three-dimensional analysis of particles (using sphericity). The video microscope is used to determine the depth of particles, while the images of 2-D projections provide the other two dimensions. Angularity is determined by analyzing the black and white images, while texture is determined by analyzing the gray images. Two methods are used to quantify the angularity of coarse and fine aggregates. These methods are gradient angularity and radius angularity. The texture of coarse aggregate is quantified by the wavelet method.