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Analysis of Aggregates By Image Processing Using Matlab

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Abstract: *Aggregates need to pass numerous tests to ensure the performance of concrete structures and pavements. Some of these tests are requiring manual, labour intensive, cost ineffective measurements that do not provide significant statistical validity, and are prone to errors through ignorance, negligence, or even in some cases through deliberate misinterpretation. Durability, workability, shear resistance, tensile strength, stiffness, and fatigue response of concrete and asphalt concrete is heavily depend on the shape of aggregate particles. In recent years, image analysis is widely used to analyze the particle shape characteristics of aggregate. In this research, shape properties of coarse aggregates are compared using image analysis by determining the shape characteristics of aggregate such as elongation, flakiness, sieve analysis with traditional methods. The system provides rapid and accurate determination of aggregate shape properties with minimum interference from the operator. Digital-image processing consists of converting camera pictures into digital form and applying various mathematical procedures to extract relevant information from the picture. In other words, digital image processing and analysis is concerned with the transformation and analysis of picture by a computer. The process starts with the capture of a digital image (usually referred to as imaging) followed by its storage, transmission, processing, and analysis of the image by computer to extract information or features of interest.*

Keywords: *Aggregates, Sieve Analysis, Flakiness Index, Elongation Index, Matlab, Image Processing*

1. INTRODUCTION

Aggregate particles appear in different shape and size in nature. Shape and size are important physical characteristics of aggregates used in engineering.The importance of the shape of aggregate particles is well recognized due to their mechanical behaviour. Durability, workability, shear resistance, tensile strength, stiffness, and fatigue response of concrete and asphalt concrete is heavily depend on the shape of aggregate particles. The majority of aggregates are used in concrete structure, road pavements and railroads. The traditional methods used for size and shape analysis are not very accurate and they are very time consuming. Sieve analysis, flakiness index and elongation index tests used to determine particle size characteristics of granular material including coarse materials for many decades.

1.1 Sieve Analysis

In sieve analysis, the particle size is characterized by a single linear dimension representing the minimum square sieve aperture that which the particle just pass through. Particles passing through sieve can actually have one dimension that is larger than the size of the sieve apertures, it can be seen that an elongated particle that has its length greater than the aperture size can pass through the sieve without any difficulties. Therefore, the sieve aperture size is a measure of the lateral dimensions of the particles only. A relatively flat particle can pass through the sieve aperture, which is square in shape, diagonally. As a result, the breadth of a particle passing through a sieve can also be greater than the sieve size, although it has to be smaller than the diagonal length of the sieve aperture. Determination of grain-size distribution with mechanical method is difficult and it takes long time. Hence, image analysis has been used by several researchers to determine the size distribution, particle shape and surface texture of aggregates.

1.2 Elongation Index

The Elongation Index of aggregate is the percentage by weight of particles whose greater dimension (Length) is greater than one and four fifth times (1.8) their mean dimension. The Elongation test is not applicable to sizes smaller than 6.3mm. The apparatus consists of a standard length gauge of IS sieve sizes 50, 40, 31.5, 25, 20, 16, 12.5, 10 and 6.3mm.

1.3 Flakiness Index

The Flakiness Index of aggregate is the percentage by weight of particles whose least dimension is less than three- fifths (0.6) of their mean dimension. The test is not applicable to sizes smaller than 6.3mm. The apparatus consists of a standard thickness gauge of IS sieve sizes 63, 50, 40, 31.5, 25, 20, 16, 12.5, 10 and

6.3mm and a balance to weight the sample. These measurements are not only slow and laborious, but are also highly subjective. This task is tedious and consequently there is potential for poor implementation and inaccurate results. It is labour intensive and time consuming.

1.4 MATLAB Software

MATLAB is a multi- paradigm numerical computing environment and fourth-generation programming language. MATLAB is a data analysis and visualization tool which has been designed with powerful support for matrices and matrix operations. As well as this, MATLAB has excellent graphics capabilities, and its own powerful programming language. One of the reasons that MATLAB has become such an important tool is through the use of sets of MATLAB programs designed to support a particular task. These sets of programs are called toolboxes, and the particular toolbox of interest to us is the image processing toolbox.

2. LITERATURE REVIEW

2.1 Rock Property Measurements Using Image Processing Hakan Lindstrom, Sweden, 2010:

Shape and size of rocks are important physical characteristics of aggregates used in engineering and for interpretation of the genesis of naturally occurring sediment. Several image processing programs are available for measure the size and shape of various types of objects. The accuracy and reproducibility of results of image processing and MATLAB based 3D imaging program has been studied. 3D results are obtained by coupling two images of particles one of their largest and one of the smallest projected areas. In this research, image analysis code has been developed in MATLAB for size and shape determination. The method is named the GID method since Glow-In-the Dark beads are used as the background for the images. The new method for imaging consists of a bed of Glow-In-the- Dark beads on which the particles are placed, several at one time, above which a camera is mounted. The camera is connected directly with a computer so the quality of the image can be evaluated directly. The entire setup is placed in a dark room. An inexpensive portable dark room, consisting of light impenetrable material mounted on a light-weight frame the order of 2 meters high. The light-impenetrable material is lifted in order to expose the beads to the sun light and to place the particles on the bed of beads. When the luminous beads are saturated by the sun light, (this is done by just half a minute during a sunny day) then the light-impenetrable material is lowered down and the beads glow. The researcher snaps a picture and stores that one in the computer. The accuracy of results depends on the focal length used for imaging as well as the positioning of particles in the view field. Two heights (110 cm and 170 cm) are enough accurate to use as a stable distance from camera. In some cases the standard deviation error was less than 5%.

2.2 Clustering of Image Data Using K-Means and Fuzzy K-Means. Md. Khalid Imam Rahmani ectall, India/IJACSA Vol. 5, No. 7, 2014 :

Clustering is a major technique used for grouping of numerical and image data in data mining and image processing applications. Clustering is the unsupervised classification of patterns such as observations, data items, or feature vectors into groups named as clusters. Clustering makes the job of image retrieval easy by finding the images as similar as given in the query image. The images are grouped together in some given number of clusters. Image data are grouped on the basis of some features such as colour, texture, shape etc. contained in the images in the form of pixels. For the purpose of efficiency and better results image data are segmented before applying clustering. The technique used here is K-Means and Fuzzy K-Means which are very time saving and efficient. Applications of clustering is growing nowadays very rapidly because it saves a lot of time and the results obtained from the clustering algorithm is very suitable for the algorithms in the later stages of the applications.

2.3 Image Analysis Techniques on Evaluation of Particle Size Distribution of Gravel. G. H. A. Janaka J. Kumara etcall, Japan, 2012 :

Particle size distribution of granular materials is usually evaluated by sieve analysis test. In this research, an image analysis technique is proposed to evaluate particle size distribution of gravels. On particular conditions, some differences of gradation curves determined by sieve analysis and image analysis were observed. However, it should be noted that in sieve analysis, gradation curves is evaluated using mass of particles. Therefore, to compare gradation curves by the two methods, gradation curve should be evaluated using mass of particles in image analysis. In this paper, the issues affecting gradation curves in image analysis are examined using an image analysis technique. In this arrangement, thickness (i.e., short axis) of particles cannot be measured directly since 2-D images measure only the long and intermediate axes. In this research, particles were arranged without touching or overlapping each other to reduce applying unnecessary image processing techniques. Particles were placed on a transparent sheet during initial Analysis. Images were captured with a Nikon D7000 camera which can measure up to 16 mega pixels.The images analysis was done in ImageJ. ImageJ can read many image formats including TIFF, GIF, JPEG, BMP, DICOM and FITS. JPEG images were used in this research. ImageJ can calculate area and pixel value statistics of user defined selections. Based on the results, several aspects related to image analyzing are discussed in the paper. They include appropriate evaluation of particle grain size in image analysis, minimization of shadow effects appeared in images, effects of number of particles adopted for sieve analysis and image analysis and so on. It was found that grain size in image analysis should be defined appropriately to compare the gradation curves by the two methods. Probably, due to light effects, it was also observed that black colour sheets are better than white colour sheets to place particles. This method can be used as an in situ test method since this method needs only a camera and a computer.

3. MOTIVATION

[1] To introduce cost effective, accurate and less time consuming method for analysis of aggregate.

[2] To eliminate use of costly equipments from laboratory (traditional) methods.

[3] To analyse different samples of aggregate obtained from different quarries just by running single programme.

[4] To use sophisticated method of image processing instead of labours and time consuming traditional methods.

4. METHODOLOGY

4.1 FIELD TEST

4.1.1 Sieve Analysis

Sieve analysis helps to determine the particle size distribution of coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (part 1) - 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

The apparatus used are:

[1] A set of IS sieves of sizes: 20mm, 16mm, 12.5mm, 10mm, 5.6mm, 2.8mm and receiver.

[2] Balance with an accuracy to measure 0.1% of the weight of the test sample.

Procedure to determine particle size distribution of aggregates:

[1] The test sample of 5kg dried to a constant weight at temperature of 110+ 5° C is taken.

[2] The sieves are arranged in the decreasing order of sizes with sieve of 25mm at top and then 20mm,16mm, 12.5mm, 10mm and so on below it.

[3] The sample is sieved by using those arranged sieves.

[4] On completion of sieving, the material on each sieve is weighed.

[5] Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

Fig 1: *Sieve Setup*

Results

The result should be calculated and reported as:

[1] The cumulative percentage by weight of the total sample.

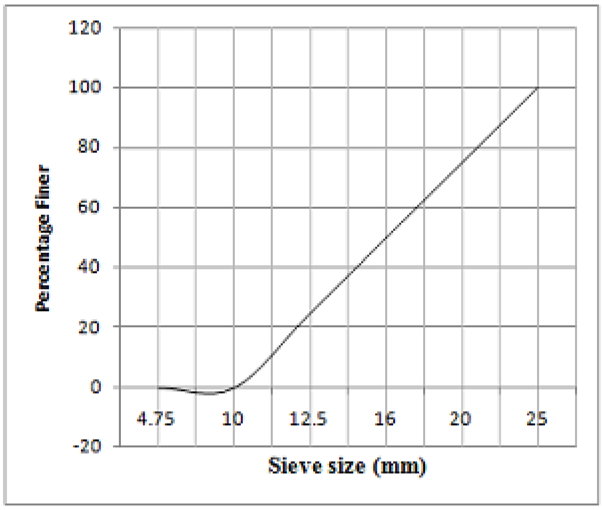
[2] The percentages by weight of the total sample passing through one sieve and retained on the next smaller sieve, to the nearest 0.1%.

[3] The results of the sieve analysis may be recorded graphically on semi- log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

Sample 1

Table 1: *Observation table of sieve analysis (sample1)*

IS sieve size (mm)	Weight Of sieved fraction (Kg)	Percent retained	Cumulative % retained	Percent passing
25	0	0	0	100 (100)
20	3.05 (200)	48.72 (25)	48.72 (25)	51.28 (75)
16	1.79 (200)	28.59 (25)	77.31 (50)	22.69 (50)
12.5	0.925 (200)	14.77 (25)	92.08 (75)	7.92 (25)
10	0.495 (200)	7.91 (25)	99.99 (100)	0.01 (0)
4.75	0	0	-	-
Receiver	0	0	-	-



Graph 1: *Gradation curve of sample 1*

4.1.2 Flakiness Index

The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension is less than three-fifth of their mean dimension. The test is not applicable to sizes smaller than 6.3mm.

The test is conducted by using a metal thickness gauge. A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested. Each fraction is gauged in turns for thickness on the metal gauge. The total amount passing in the gauge is weighed to an accuracy of 0.1 percent of the weight of the samples taken. The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.

Fig 2: *Thickness gauge*

Sample 1

Table 2: *Observation table of flakiness index (sample 1)*

IS sieve size (mm)	Total Weight of aggregate retained(Kg)	Weight of aggregate retained on flakiness gauge(Kg)	Weight of aggregate passing on flakiness gauge(Kg)
25-20	3.05 (200)	2.585 (160)	0.465 (40)
20-16	1.79 (200)	1.495 (158)	0.295 (42)
16-12.5	0.925 (200)	0.76 (155)	0.165 (45)
12.5-10	0.495 (200)	0.405 (149)	0.09 (51)
Total	6.26		1.015 (178)

Percentage of flakiness index = Total weight of aggregate passing on flakiness gauge / Total weight of aggregate *100

= 1.015/ 6.26 *100

= 17.65 %

Mechanical analysis depends on measuring mass of particles; whereas image analysis depends on measuring the number of particles.

Therefore, Percentage of flakiness Index according to number of aggregates,

=178/ 800 *100

= 22.25 %

4.1.3 Elongation Index

The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension. The elongation index is not applicable to sizes smaller than 6.3mm.This test is conducted by using metal length gauge. A sufficient quantity of aggregate is taken to provide a minimum number of 200 pieces of any fraction to be tested. Each fraction shall be gauged individually for length on the metal gauge. The total amount retained by the gauge length shall be weighed to an accuracy of at least 0.1 percentage of the weight of the test samples taken. The elongation index is the total weight of the sample gauged. The presence of elongated particles in excess of 10 to 15% is generally considered undesirable, but no recognized limits are laid down.

Fig 3: *Length gauge*

Sample 1

Table 3: *Observation table of Elongation Index (Sample 1)*

IS sieve size (mm)	Total Weight of aggregate retained(Kg)	Weight of aggregate retained on elongation gauge(Kg)	Weight of aggregate passing on elongation gauge(Kg)
25-20	3.05 (200)	0.195 (11)	2.855 (189)
20-16	1.79 (200)	0.515 (27)	1.28 (173)
16-12.5	0.925 (200)	0.420 (70)	0.51 (130)
12.5-10	0.495 (200)	0.235 (76)	0.265 (124)
Total	6.26	1.365 (184)	4.91 (616)

Percentage of elongation index = Total weight of aggregate retained on elongation gauge / Total weight of aggregate *100

= 1.365 / 6.26 *100

= **21.81 %**

Mechanical analysis depends on measuring mass of particles; whereas image analysis depends on measuring the number of particles.

Therefore, Percentage of elongation Index according to number of aggregates,

= 184 / 800 *100

= 23.00 %

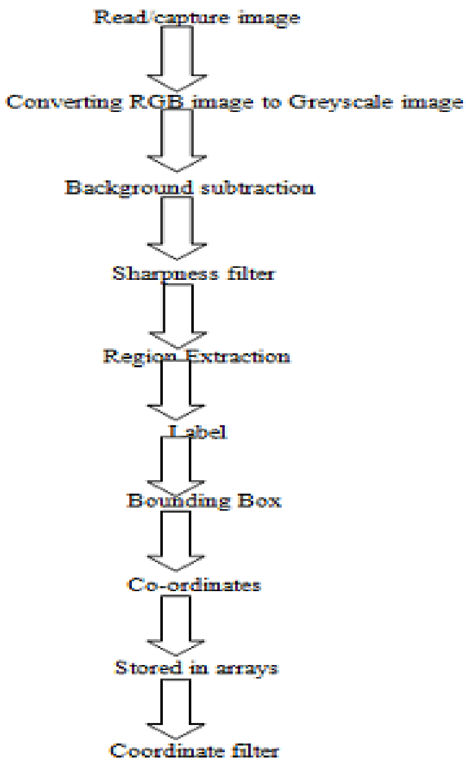
4.2 IMAGE PROCESSING OF AGGREGATES

4.2.1 Image Acquisition

The photographs of aggregate samples were taken in a dark room from a fixed height. The camera was fixed at a height of 70cm. Particles were arranged without touching or overlapping each other to reduce errors. It was also examined whether there is any effect of colour of particle placed sheets due to light effects. However, it was found that black colour sheets give better results compared to white colour sheets; probably black colour sheets have less effect from lights than white colour sheets.

In this arrangement, thickness (i.e., short axis) of particles cannot be measured directly since 2-D images measure only the long and intermediate axes. But to determine Flakiness and Elongation indices of aggregate sample it is necessary to know all three dimensions of aggregate. For this purpose along with 2D, 3D photographs were also taken.

4.2.2 Aggregate Image Processing



Flowchart 1: *Various steps of processing*

4.2.3 Algorithm

[1] Read/capture image

The image is first acquired from an existing image can be loaded from the memory. We shall consider that the acquired image is in RGB format which is a true colour format for an image. In MATLAB, the captured or imported RGB image each pixel is represented by an element of a matrix whose size corresponds to the size of the image.

Fig 4: *Aggregate image*

[2] Background subtraction

Background subtraction, also known as Foreground Detection, is a technique in the fields of image processing and computer vision where in an image's foreground is extracted for further processing (object recognition etc.). After the stage of image pre processing (which may include image de-noising, post processing like morphology etc.) object localisation is required which may make use of this technique. Background subtraction provides important cues for numerous applications in computer vision, for example surveillance tracking or human poses estimation. However, background subtraction is generally based on a static background hypothesis which is often not applicable in real environments. With indoor scenes, reflections or animated images on screens lead to background changes.

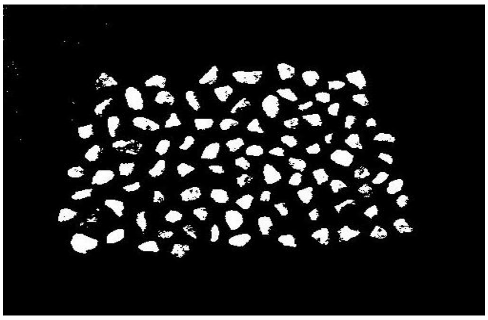


Fig 5: *Background Subtraction*

[3] Sharpness filter

Image sharpening is a powerful tool for emphasizing texture and drawing viewer focus. It's also required of any digital photo at some point whether it's been applied or not. Digital camera sensors and lenses always blur an image to some degree, for example, and this requires correction. However, not all sharpening techniques are created equal. When performed too aggressively, unsightly sharpening artefacts may appear. On the other hand, when done correctly, sharpening can often improve apparent image quality even more so than upgrading to a high-end camera lens.

[4] Region

Region growing is the procedure that groups pixels or sub regions into larger regions based on predefined criteria for growth. When a prior information is not available the procedure is to compute at every pixel the same set of properties that ultimately will be use to assign pixels to regions during the growing process. If the results of these computations show clusters of values, the pixels whose properties place them near the centroid of these clusters can be used as set.

[5] Finding bounding box of the object

The bounding box of an object is an imaginary rectangle that completely encloses the given object and its sides are always parallel to the axes. Fig.10 illustrates the concept of a bounding box. It is worth noting that due to the various angles of inclination of an object, the dimensions of the bounding box change accordingly however, to make the shape recognition independent of the rotation of the object, the dimensions of the bounding box must be constant. This is because the area of the bounding box is an important parameter which we will be using to classify the shape of the object. This is precisely the reason why we rotate the object in the opposite direction by the angle of orientation as mentioned in the previous step. Therefore we ensure that irrespective of the orientation of the object, we can construct a bounding box of constant dimensions. This method works well with squares, circles as well as rectangles. However, triangles require a different type of treatment as will be shown shortly.

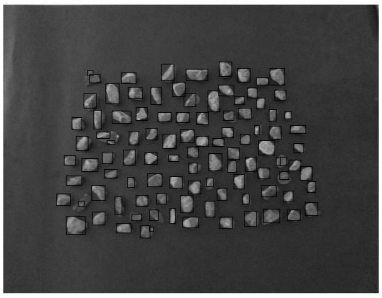


Fig 6: *Bounding box of given object*

[6] Coordinate

The appropriate size of bounding boxes for aggregates of various sizes we tried to determine coordinates of standard sized aggregates obtained from sieve analysis, flakiness apparatus and elongation apparatus. For this we captured photographs of white paper pieces which were cut according to standard sizes from fixed height i.e. 70cm.

[7] Stored in array

An array operation involving one or more images is carried out on a pixel by pixel basis. The array is fundamental form that MATLAB uses to store and manipulate data. An array is list of no. arranged in rows or column. The simplest array (one dimensional) is a row or column of numbers. A more complex array (two dimensional) is a collection of numbers arranged in rows and columns. Use of array is to store information and data, as in a table.

5. CONCLUSION

Sieve Analysis, flakiness index and elongation index of coarse aggregates were evaluated using the image analysis. 2-D images of particles were used in the image analysis. As particles were in irregular shapes, rectangular shape was used to represent them. Finally, the following conclusions were made,

[1] All the particles used for sieve analysis tests should be considered to obtain accurate gradation curves since taking a small sample from a large sample of particles does not necessary represent the original sample appropriately.

[2] It was found that black colour sheets are better than white colour sheets to place particles. That's to say, shadow effects on black colour sheets should be less than that of white colour sheets.

[3] It was also found that gradation curves determined in image analysis is always at right side of the gradation curve determined by sieve analysis i.e., larger grain size when minor axis of ellipse is used as the grain size.

[4] It was found that operator tends to get a sample with coarser particles from the main sample of a large number of particles if enough attention is not given.

[5] It was further found that grain size in image analysis should be defined appropriately to compare the gradation curves by the two methods since particles pass through diagonal of a sieve in sieve analysis.

[6] Volume of particles can easily be determined from the results of image analysis (using 2-D images) and shape characteristics measured manually for the same materials. Since this method gave same gradation curves as that by sieve analysis test, the image analysis technique used can be considered as simple and less time consuming process than sieve analysis test. This method can also be applied as an in-situ method since the method needs only a computer and a camera.

6. FUTURE SCOPE

[1] The image analysis is considered to be a significant technological advancement towards grain-size distribution of soils with images obtained from digital cameras from taken photos.

[2] It should also be pointed out that further studies on the determination of index properties of soils by using image analysis are needed to make more reasonable judgments for utilization of image analysis in geotechnical engineering.

[3] The area factors measurements error can be improved and the error should be decreased by revising program and method of calculation.

[4] The calculation of volume of rock is a good aim which is possible to operate.

[5] It is important to emphasize that scientific work is describing the output parameters from a 8 mega pixel camera. However, any other camera of different specifications is to be calibrated before starting any experiment.

[6] Nowadays image processing is going to be useful in numerous engineering projects and it is possible to use this method to represent the shape of rocks.

[7] Image analysis is a tool that hand over good evidences, pointing out that this is a good rock for just that kind of usage purpose, and another rock type/shape is of no good quality.

[8] Image analysis can also be used to conduct various tests used in concrete technology such as crushing test, impact test, abrasion test etc.

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