Studying the potentiality of using low cost system based on image analysis technique to survey the gravel's size in asphalt mixes

Eng. Ahmed Nabil
BSc.
Faculty of Engineering in El-Mataria, Helwan University, Cairo, Egypt.
ahmdnabil91@gmail.com

Assoc. Prof. Dr. Eng. Ahmed Serwa
BSc., MSc., PhD., MCP, MCSD, MCT
Faculty of Engineering in El-Mataria, Helwan University, Cairo, Egypt.
ORCID: 0000-0002-5121-5242, **Research ID:** P-9953-2015
Dr.A.Serwa@m-eng.helwan.edu.eg & ahmed_serwa@yahoo.com

Prof. Dr. Eng. Abd Elzaher Mostafa
BSc., MSc., PhD.
Faculty of Engineering in El-Mataria, Helwan University, Cairo, Egypt.
zaher292@gmail.com

ABSTRACT: This study aims to develop the micro-analysis of the bituminous mixtures using 2D scanner and Image Analysis Techniques (IAT). A new methodology and scheme are developed for faster and accurate procedure to compute Gradation of aggregates using (IAT) instead of the conventional methods. 2D scanner is used to analyze the horizontal cross section of HMA slices. This dissertation focuses on introducing a more elaborate method for characterization of the internal structure of aggregates which characterization of internal structure is necessary to understand the behavior of the bituminous mixtures under different conditions. Image Analysis Techniques (IAT) the technological advantages to better understand construction materials and it also provides information that can help to improve the properties of various construction materials. The aggregate internal structure provides the skeleton of the asphalt mixture, which plays an important role in rutting resistance. The Results helped to analyze the internal structure thus improving the ability to understand the behavior of construction materials. Also, the results indicate potential for using this method to evaluate the internal structure of mixtures in field where using this non-destructive, cost effective and a time efficient approach.

KEYWORDS: Surveying; Image analysis; Hot mix asphalt; Gravel size.

1- INTRODUCTION:

Area, perimeter, diameters, and pixel coordinates are the fundamental particle shape properties calculated by most of the image analysis systems. The particle area, perimeter, and diameters are classified as the size measurements, whereas the pixel coordinates fall into the group of position measurements (Kuo and Freeman, 2000). Figure 1 illustrates the geometry of an aggregate cross-section in plane Cartesian coordinates. As shown in the figure, the major axis of the aggregate cross-section connects the two points, which are the farthest apart on the boundary of the aggregate cross-section and corresponds closely to the particle length. The major axis is also commonly termed as the maximum diameter (e.g., Russ, 1999). The minor axis is the longest line that can be drawn from one boundary point to another to be perpendicular to the major axis and corresponds to the particle width (Yue,1995).

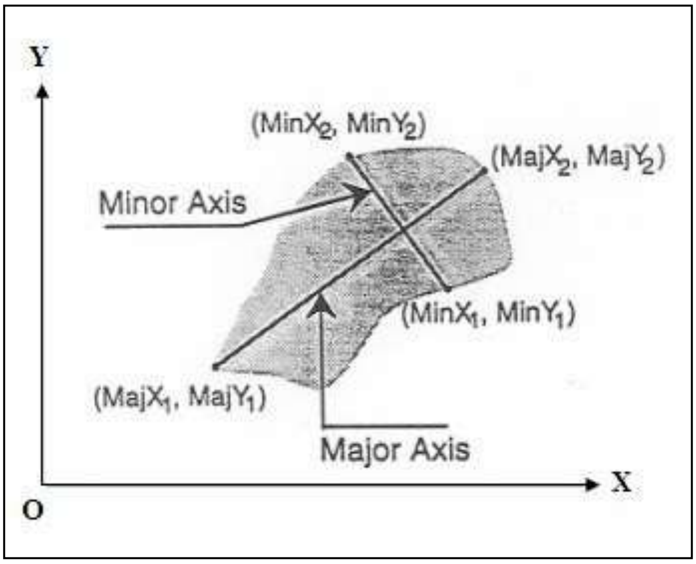

Figure 1: An aggregate cross section in plane Cartesian coordinates (Yue, 1995).

In image analysis, the area of a particle is the total of pixels presents inside the aggregate border as shown in Figure 2. Particle area is often said in terms of correspondent circular diameter. It is the diameter of the untrue circle that has the same area as the particle and defined in the following formula:

$$\text{Equivalent Circular Diameter} = \sqrt{\frac{4\ \text{Area}}{\pi}}$$

Where Area= particle area calculated by the summation of interior pixels.

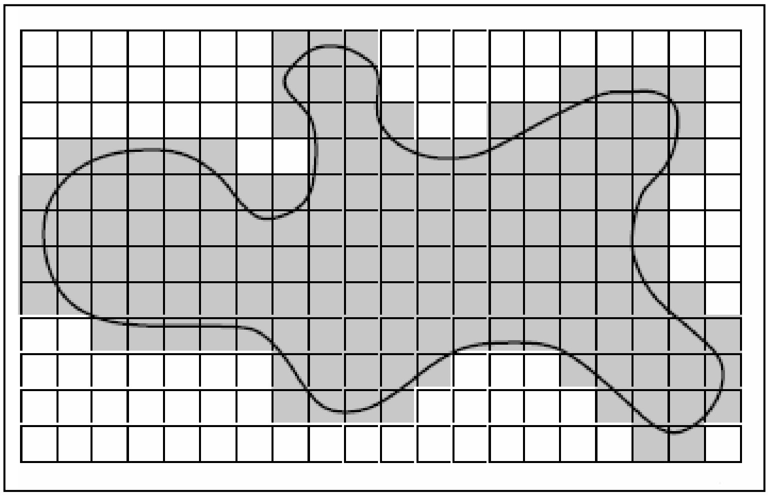

Figure 2: Particle area surveyed through the image analysis (Janoo, 1998).

The perimeter is the summation of all pixels forming the boundary of an aggregate cross-section. Aggregate particle shape might also be assessed in terms of sensual (visually or by touching) observations of the particles. Visually, these types of observations classify particles such as dimension, flat, or elongated. By manually inspecting surface characteristics, particles may also be classified in accordance with their surfaces as smooth or rough.

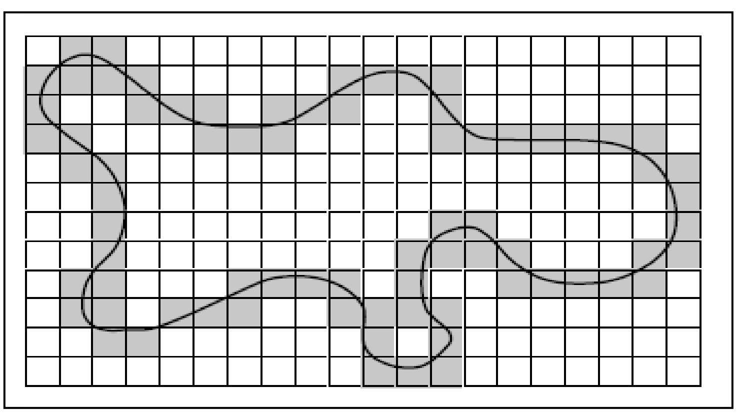

Figure 3: Particle perimeter surveyed through image analysis (Janoo, 1998).

There remain several particle shape parameters defined to describe particle shape and surface characteristics. Some of these parameters are elongation ratio, flatness ratio, shape factor, angularity, form factor, compactness, convexity ratio, fullness ratio, and roughness. However, in the literature, there is an absence of consensus on the definitions of particle shape parameters. For instance, different researchers have used for example using different particle shape parameters to indicate the same shape attribute, e.g., the circularity of aggregate cross-section by form factor and compactness as proposed by Kuo and Freeman (2000) and Yue et al. (1995), respectively. Different definitions and formulations for the same particle shape parameters can be used e.g., several different formulations for elongation ratio as proposed by Kuo et al. (1998) and Barksdale et al. (1991). Different names assigned to the same particle shape parameter, e.g., the same formulation for form factor by Kuo and Freeman, (2000) and for shape factor by Yue et al. (1995).

After the previous introduction the aggregate size can be measured and evaluated using image analysis techniques. The main objective of this research work is to develop a low-cost surveying system to investigate the aggregate size in asphalt mixes.

2- METHODOLOGY:

The methodology of this study consists of five phases based on the work plan as the following:

Phase (1): Experimental work which deals with aggregate tests using gradation test for the aggregate according to AASHTO, Code and ASTM. Phase (2): Preparing the asphalt mixture by the Marshall method and preparing the asphalt samples to be ready for cutting. Phase (3): Cut the samples with a saw to cut the samples into two pieces. Phase (4): Preparing samples after they are cut for imaging by 2D scanning device. Phase (5): Using IAT Image Analysis Techniques to analyze images and extract information. The block diagram of the image analysis technique is shown in detail in Figure 4. Phase (6): Using the excel program to make simple calculations to find the gradation of the aggregate. To determine the validation of materials used in the research study using the following tests for HMA materials. The source of the used crushed stones aggregate from Arab Contractors Company located in Kattamia, the tests were performed on aggregates according to American Association of State Highway and Transportation Officials (AASHTO).

The physical properties of coarse aggregate size (1) and size (2) of gradation presented in Table 1.

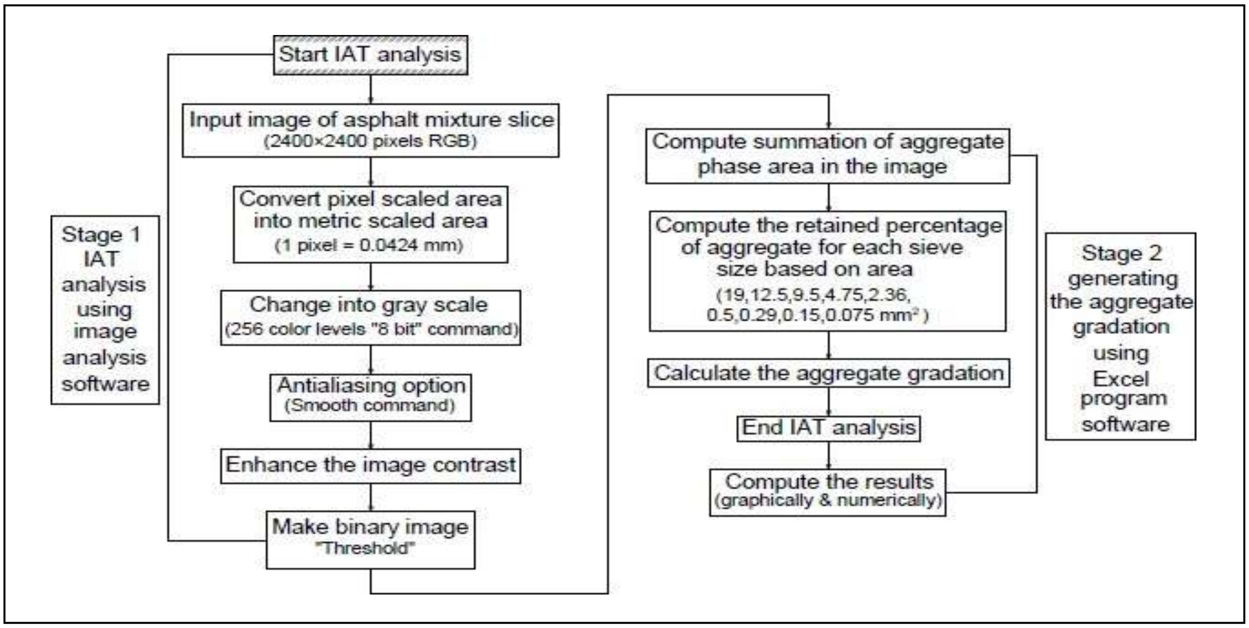

Figure 4: Block diagram of the IAT system.

Table 1: Results of the Physical Properties of Aggregates.

Property	Coarse Aggregate Size (1)	Coarse Aggregate Size (2)	AASHTO Limits
Bulk SG	2.525	2.585	-----
Apparent SG	2.667	2.686	-----
% water abs.	2.11	1.46	5max
Crushing	0.65	0.65	-----

The gradation of the aggregate is the basic test to determine the distribution of the aggregate particles, the test should be determined in accordance with the American Association of State Highway and Transportation Officials (AASHTO) T 27 "Sieve Analysis of Fine and Coarse Aggregate (or the American Society for Testing and Materials (ASTM) C 136 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate). Mechanical shaker machine is used to apply this test as shown in Figure 5.

Figure 5: Mechanical shaker machine.

Three different bitumen ratios (4-6%) were prepared with an increment of 1%. Marshall Specimens prepared according to AASHTO T 245 were compacted at 75 blows per face using the Marshall compactor which is indicated in Figure 6.

Figure 6: Marshall compactor.

The test standards are applied without any modifications. Figure 7 indicates the prepared samples that will be subjected to the cutting process to obtain the final study samples.

Figure 7: Prepared samples.

Figure 8: Asphalt samples after cutting.

Figure 8 indicates the proposed final cut samples that will be scanned and tested in the research work. Figure 9 shows the scanning process on the scanner in order to obtain the required digital images of the samples.

After scanning the samples, we have pictures of all the samples as shown in the Figure 10 , so this is one of those pictures that were taken for the samples, and therefore we have all the pictures and they are ready to be analyzed by the image analysis program and this we will talk about in the next chapter in detail so that we have results from the laboratory tests We have results from the image analysis and comparison program and know the difference between those results.

Figure 9: Asphalt samples scanning process.

Figure 10: Image of asphalt samples after scanning.

Image processing and quantification of the internal structure features of asphalt mixture were conducted using a 2-D image processing software named „image J‟ (i.e., Image Processing and Analysis System). The functions of the software are divided into two main groups: functions that perform image processing and functions that perform microstructure analysis.

Additional functions used to perform microstructure analysis are explained in this section. Image-J software is a public domain Java image processing program inspired by NIH Image for the Macintosh. This software runs, either as an online applet or as a downloadable application, on any computer with a Java 1.45 or later virtual machine. It can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can measure distances and angles. It can create density histograms and line profile plots. It supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering. It does scale, rotation and flips as shown Figure 11. All analysis and processing functions are available at any magnification factor. The program supports any number of windows (images) simultaneously, limited only by available memory. Spatial calibration is available to provide real world dimensional measurements in units such as millimeters. Density or gray scale calibration is also available (Werner Bailer 2000).

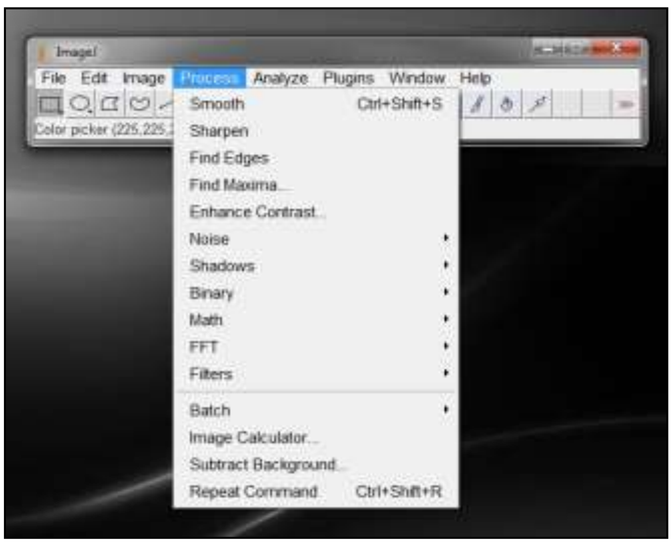

Figure 11: Image-J Software

A calibration is carried out for image-J software according to the standard process mention in its user manual. In brief, some samples are selected from a certain image then it is measured by real ruler or using AutoCAD then measure it using image-j software. A calibration parameter is determined so that we can use these parameters for the rest of samples.

3- RESULTS AND ANALYSIS:

After extracting data samples from the program J image in terms of the area of each particle and transferring it to Excel using the previous equations on the granular gradient, the results were as shown in the following Tables 2, 3, 4, 5, 6.

Table 2: Original mix design and results of IAT analysis for mixture (1).

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100	94.05	78.7	64.91	71.89	68.75	65.76	65.05	64.21	63.75
	Lab	100	98.82	75.71	61.78	50.19	42.93	20.97	11.46	3.56	0.72
	Diff.	0	4.77	-2.99	-3.12	-21.71	-25.82	-44.79	-53.58	-60.65	-63.03
(5%)	Software	98.67	94.51	83.19	65.43	82.21	79.79	77.08	76.32	75.48	75.07
	Lab	100	97.7	79.22	61.57	47.38	39.34	17.92	10.77	4.45	1.42
	Diff.	1.33	3.18	-3.97	-3.86	-34.83	-40.45	-59.17	-65.55	-71.03	-73.65
(6%)	Software	97.26	94.19	82.8	65.41	62.76	60.39	66.18	65.48	64.78	64.41
	Lab	100	97.7	79.22	61.57	47.38	39.34	17.92	10.77	4.45	1.42
	Diff.	2.74	3.51	-3.58	-3.84	-25.38	-30.05	-48.26	-54.72	-60.33	-62.99

Table 3: Original mix design and results of IAT analysis for mixture (2).

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100	99.01	94.94	87.8	80.19	71.75	66.5	65.62	64.86	64.32
	Lab	100	99.01	94.7	89.29	61.54	43.33	17.84	10.39	4.9	2.52
	Diff.	0	0	-0.24	1.49	-18.65	-28.42	-48.67	-55.22	-59.96	-61.8
(5%)	Software	99.23	97.16	93.54	90.35	85.72	80.44	76.66	75.68	74.57	73.75
	Lab	100	100	95.45	89.23	62.75	43.79	19.47	11.36	4.82	2.41
	Diff.	0.77	2.84	1.91	-1.12	-22.97	-36.65	-57.19	-64.33	-69.75	-71.34
(6%)	Software	100	98.87	93.67	89.23	84.45	78	74.12	73.25	72.31	71.78
	Lab	100	99.06	92.34	87.98	61.3	45.07	19.44	11.54	4.98	2.6
	Diff.	0	0.19	-1.33	-1.25	-23.14	-32.93	-54.67	-61.71	-67.33	-69.18

Table 4: Original mix design and results of IAT analysis for mixture (3).

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	99.08	97.54	90.97	86.66	80.57	75.88	72.56	71.81	70.99	70.54
	Lab	100	100	91.64	82.99	59.16	45.82	20.92	12.85	6.51	3.54
	Diff.	0.92	2.46	0.68	-3.66	-21.41	-30.06	-51.64	-58.96	-64.48	-67
(5%)	Software	100	98.21	92.98	88.04	82.11	76.56	72.69	71.87	71	70.55
	Lab	100	100	94.05	86.96	60.63	45.88	20.51	12.85	6.75	3.8
	Diff.	0	1.79	1.08	-1.08	-21.48	-30.68	-52.18	-59.02	-64.25	-66.75
(6%)	Software	99.95	99.56	93.32	89.16	83.14	76.57	72.21	71.26	70.18	69.59
	Lab	100	100	94.99	87.09	62.48	45.8	20.84	12.83	6.05	3.29
	Diff.	0.05	0.44	1.68	-2.07	-20.66	-30.78	-51.37	-58.43	-64.13	-66.3

Table 5: Original mix design and results of IAT analysis for mixture (4).

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100	97.27	90.81	84.99	79.63	74.15	70.31	69.44	68.43	67.84
	Lab	100	100	92.15	82.27	60.58	45.96	20.11	12.4	5.84	2.81
	Diff.	0	2.73	1.34	-2.72	-19.06	-28.2	-50.2	-57.04	-62.59	-65.03
(5%)	Software	98.88	97.17	89.42	83.93	77.7	71.19	66.71	65.69	64.61	64.03
	Lab	100	98.88	89.31	81.92	60.98	45.05	19.44	11.86	5.46	2.65
	Diff.	1.12	1.7	-0.1	-2	-16.72	-26.15	-47.27	-53.82	-59.15	-61.38
(6%)	Software	100	98.04	91.43	86.76	81.76	76.73	73.08	72.19	71.15	70.55
	Lab	100	100	93.06	83.72	61.81	46.46	20.33	12.59	5.65	3.19
	Diff.	0	1.96	1.63	-3.04	-19.95	-30.27	-52.75	-59.6	-65.49	-67.37

Table 6: Original mix design and results of IAT analysis for mixture (5).

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100	98.4	89.35	82.25	81.29	76.65	73.31	72.25	71.04	70.35
	Lab	100	100	90.31	79.59	58.46	45.74	19.79	12.88	6.56	3.24
	Diff.	0	1.6	0.96	-2.66	-22.82	-30.91	-53.52	-59.37	-64.48	-67.11
(5%)	Software	100	99.17	89.92	81.88	77.48	73.17	69.6	68.57	67.49	66.9
	Lab	100	100	90.73	79.33	58.17	45.8	19.98	12.35	5.6	2.68
	Diff.	0	0.83	0.81	-2.56	-19.31	-27.38	-49.62	-56.22	-61.89	-64.23
(6%)	Software	99.64	97.16	91.54	81.85	80.68	77.21	74.16	73.23	72.2	71.67
	Lab	100	99.33	88.99	78.17	57.71	45.39	20.25	12.53	5.68	3.03
	Diff.	0.36	2.17	-2.54	-3.68	-22.97	-31.82	-53.91	-60.7	-66.53	-68.64

After the comparison was made between the laboratory results and the program results, it was found that the difference in the coarse aggregate is a small difference and the difference in the fine aggregate is high as indicated in a Table 7. This is natural because the coarse aggregate appears clearly in the picture compared to the fine aggregate and therefore a statistical test is made to find out which average difference is significant.

Table 7: Average difference results.

Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
Avg. differences	0.48	2.01	-0.31	-2.34	-22.07	-30.70	-51.68	-58.55	-64.13	-66.38
limitation	-	-	±8	±7	±7	±6	±5	±5	±3	±0.5

The standard statistical test is the P test but since the average difference is the percentage so it can it the values directly without using the tables. One can take 5% or 10% as indication level according to the desired sensitivity. It is clear that we can accept the results of the sieves no. 1, 3/4, 1/2 and 3/8. But we must reject the dependence of the results of the rest of the sieves.

٤- CORRECTION AND VERIFICATION:

The fine aggregate results were corrected. This correction is for the results obtained from the images. A correction factor was found for each sieve by taking a mixture 1, 2, 3 and 4, which is 36 samples to find the correction factor for each sieve. Then it was tested on mixture 5 consisting of 9 samples, and then it was confirmed that the correction factor fulfills its intended purpose. Table 8 shows the correction factors for each sieve separately.

Table ٨. Correction factors for each sieve.

Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
Correction coefficient	1.005	1.02	0.995	0.97	0.73	0.596	0.276	0.168	0.076	0.036

After finding the correction factors for all sieves, they were applied to all samples to be as in the following Tables 9,10,11,12,13.

Table 9: Original mix design and results of IAT analysis for mixture (1) after correction.

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100.59	96.14	78.33	63.05	52.6	40.99	18.2	10.94	4.89	2.34
	Lab	100	98.82	75.71	61.78	50.19	42.93	20.97	11.46	3.56	0.72
	Diff.	-0.59	2.68	-2.62	-1.27	-2.41	1.94	2.77	0.52	-1.33	-1.62
(5%)	Software	99.25	96.61	82.79	63.55	60.15	47.57	21.33	12.84	5.75	2.75
	Lab	100	97.7	79.22	61.57	47.38	39.34	17.92	10.77	4.45	1.42
	Diff.	0.75	1.09	-3.57	-1.98	-12.77	-8.23	-3.41	-2.07	-1.3	-1.33
(6%)	Software	97.83	96.28	82.41	63.53	45.92	36	18.32	11.02	4.94	2.36
	Lab	100	97.7	79.22	61.57	47.38	39.34	17.92	10.77	4.45	1.42
	Diff.	2.17	1.42	-3.19	-1.96	1.46	3.34	-0.4	-0.25	-0.49	-0.94

Table 10: Original mix design and results of IAT analysis for mixture (2) after correction.

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100.59	101.21	94.49	85.28	58.68	42.78	18.41	11.04	4.94	2.36
	Lab	100	99.01	94.7	89.29	61.54	43.33	17.84	10.39	4.9	2.52
	Diff.	-0.59	-2.2	0.21	4.01	2.86	0.55	-0.57	-0.65	-0.04	0.16
(5%)	Software	99.81	99.32	93.09	87.76	62.72	47.96	21.22	12.73	5.68	2.7
	Lab	100	100	95.45	89.23	62.75	43.79	19.47	11.36	4.82	2.41
	Diff.	0.19	0.68	2.36	1.47	0.03	-4.17	-1.75	-1.37	-0.86	-0.29
(6%)	Software	100.59	101.06	93.22	86.67	61.79	46.5	20.51	12.32	5.51	2.63
	Lab	100	99.06	92.34	87.98	61.3	45.07	19.44	11.54	4.98	2.6
	Diff.	-0.59	-2	-0.88	1.31	-0.49	-1.43	-1.07	-0.78	-0.53	-0.03

Table 11: Original mix design and results of IAT analysis for mixture (3) after correction.

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	99.66	99.71	90.54	84.17	58.95	45.24	20.08	12.08	5.41	2.58
	Lab	100	100	91.64	82.99	59.16	45.82	20.92	12.85	6.51	3.54
	Diff.	0.34	0.29	1.1	-1.18	0.21	0.58	0.84	0.77	1.1	0.96
(5%)	Software	100.59	100.39	92.54	85.51	60.08	45.65	20.12	12.09	5.41	2.58
	Lab	100	100	94.05	86.96	60.63	45.88	20.51	12.85	6.75	3.8
	Diff.	-0.59	-0.39	1.51	1.45	0.55	0.23	0.39	0.76	1.34	1.22
(6%)	Software	100.54	101.77	92.88	86.6	60.83	45.65	19.99	11.99	5.35	2.55
	Lab	100	100	94.99	87.09	62.48	45.8	20.84	12.83	6.05	3.29
	Diff.	-0.54	-1.77	2.11	0.49	1.65	0.15	0.85	0.84	0.7	0.74

Table 12: Original mix design and results of IAT analysis for mixture (4) after correction.

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100.59	99.43	90.38	82.55	58.27	44.21	19.46	11.68	5.21	2.49
	Lab	100	100	92.15	82.27	60.58	45.96	20.11	12.4	5.84	2.81
	Diff.	-0.59	0.57	1.77	-0.28	2.31	1.75	0.65	0.72	0.63	0.32
(5%)	Software	99.46	99.33	88.99	81.52	56.85	42.44	18.46	11.05	4.92	2.35
	Lab	100	98.88	89.31	81.92	60.98	45.05	19.44	11.86	5.46	2.65
	Diff.	0.54	-0.45	0.32	0.4	4.13	2.61	0.98	0.81	0.54	0.3
(6%)	Software	100.59	100.22	90.99	84.27	59.82	45.75	20.23	12.15	5.42	2.58
	Lab	100	100	93.06	83.72	61.81	46.46	20.33	12.59	5.65	3.19
	Diff.	-0.59	-0.22	2.07	-0.55	1.99	0.71	0.1	0.44	0.23	0.61

Table 13: Original mix design and results of IAT analysis for mixture (5) after correction.

	Sieve No.	1 in	3/4 in	1/2 in	3/8 in	No. 4	No.8	No. 30	No. 50	No. 100	No. 200
(4%)	Software	100.59	100.58	88.92	79.89	59.48	45.7	20.29	12.16	5.41	2.58
	Lab	100	100	90.31	79.59	58.46	45.74	19.79	12.88	6.56	3.24
	Diff.	-0.59	-0.58	1.39	-0.3	-1.02	0.04	-0.5	0.72	1.15	0.66
(5%)	Software	100.59	101.37	89.49	79.53	56.69	43.62	19.26	11.54	5.14	2.45
	Lab	100	100	90.73	79.33	58.17	45.8	19.98	12.35	5.6	2.68
	Diff.	-0.59	-1.37	1.24	-0.2	1.48	2.18	0.72	0.81	0.46	0.23
(6%)	Software	100.23	99.32	91.1	79.5	59.03	46.03	20.53	12.32	5.5	2.63
	Lab	100	99.33	88.99	78.17	57.71	45.39	20.25	12.53	5.68	3.03
	Diff.	-0.23	0.01	-2.11	-1.33	-1.32	-0.64	-0.28	0.21	0.18	0.4

٥- CONCLUSION:

This study examines a new methodology and schemes are developed for faster and accurate procedure to compute gradation of aggregates by using Image Analysis Techniques (IAT) instead of the conventional methods. The test results of the experimental works performed, and their analysis, leads to the following conclusions:

- The developed system is 90% - 95% reliable for large (3/8 inch) aggregate size. However, the developed system failed to recognize the smaller assembly less than 3/8 inch but its results could be corrected.
- The developed system is cheaper than the actual standard test because it consists of a scanner and image analysis software.
- The high cost of the standard, classic technique is reasonable and may affect dependency especially in remote wards where there is no laboratory and no equipment available.

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