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ANALYSIS OF FLEXIBLE PAVEMENT MATERIALS WITH IMAGE ANALYZER

Tariq Umar, Lecturer Civil Engineering, College of Engineering A'Sharqiyah University, Oman
t.umar@asu.edu.om / PhD student at London South Bank University, UK
Sam Chris Wamuziri, Professor and Dean of Engineering, A'Sharqiyah University, Oman
s.wamuziri@asu.edu.om

Abstract

Future demand to study and understand properties of flexible pavement materials to enhance its performance and durability and to increase its life is huge. Keeping these points in mind, this study presents the work to assess the distribution of asphalt in different types of asphalt concrete using image analysis software. A total of 12 cores obtained from different area and having different composition, comprising of 48 slices and 72 images were analysed with a computer image analyser to ascertain distribution of aggregates and asphalt. Finally, study is made of variations between aggregates/ asphalt ratio with unit weight of slice to investigate a relation. There was, however, no valid relation between these values which can tend to a strong conclusion except technique used for the study is easy, time saving and do not need high skill. This matter can be further investigated with computer software which can possibly analyse the images and can extract true area of different colours from images. As the result image analysis technique for different types of asphalt mixes including one with vegetable oil were almost same, therefore in this work it is concluded that there will be less effect on physical properties of asphalt mixtures prepared with some amount of vegetable oil.

Key Words: Asphalt, Asphalt Concrete, Cores, Image Analysis Software, Aggregates Bitumen ratio, Unit Weight, vegetable oil.

1. INTRODUCTION:

Work done so far for the analysis of asphalt material is of course very reliable and understandable. However, all these work for instance ‘’Marshall Stability Test’’ required more technical knowledge, skilled persons to understand and perform such test and conclude from analysis. As all these tests are done manually using machines, chances of mistake occurring is high and the corresponding errors may not be negligible. Furthermore, as all these are done manually, it is time consuming, and sometimes too costly. Asphalt concrete ingredient can be divided into two components, asphalt and aggregates. The first material (asphalt) is playing the role of bonding material and second material (aggregates) is responsible for strength and volume, however asphalt concrete strength cannot increase the strength of aggregates used (Michael et al., 2011). Keeping in view the above, this investigation has the objective of developing a new method for asphalt material analyses having different composition, by introducing the concept of imaging technique. (Lee et al., 1993). Several studies have performed to achieve the application of digital image processing techniques for asphalt concrete mixture (Ki Hoon et al., 2014, Li Zhi et al., 2010, Fereidoon et al., 2015) but these applications are limited either to specific asphalt mixtures or non-destructive approach.

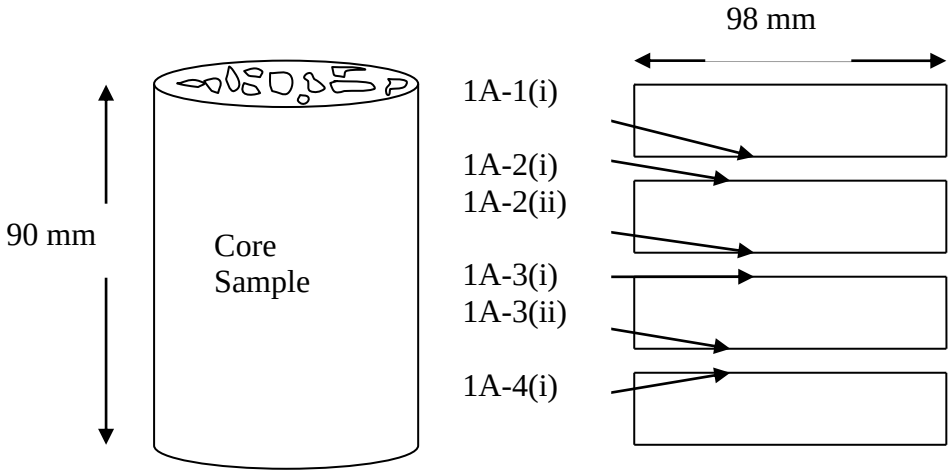
The consequent objectives in this research are to

a) Obtain cores of asphalt material (from six different types of asphalt mixes) (Cope et al., 2007).
b) Prepare a sequence of four slices per core.
c) Determine the density of each slice and its variation across the core.
d) Obtain digital images of each of the surfaces of a slice.
e) Analyse the images for continuity of aggregates and bitumen.

Although there are many different types of asphalt materials, however this research work focus on 12 asphalt concrete samples of different composition. Methods available so far analysis of asphalt material is quite good, but in this research work it is tried to apply images analysis technique to understand the internal structure of asphalt cores having different composition including mixes with used cooking (vegetable) oil. Asphalt concrete prepared with used cooking (vegetable) become slightly more important as this can be one of the procedures to recycle this oil.

2. Research Method

In this particular case different cores (circular) of the flexible concrete (asphalt materials) have taken and then cut every core in four slices. A total of 12 samples (table 1) have been taken for a random check being prepared by using different material (bonding material and aggregates). Although the composition asphalt materials in Sample ‘’A’’ and sample ‘’B’’ as shown in table 1, are the same but they are obtained from different places.



Height = 90 mm

Diameter = 98 mm

One core is cut and converted into four slice

Figure 1 Description of Cores

One core is divided into four slices (figure 1) to study the composition of materials more critically. Later on, every slice has been shot by a digital camera (figure 2) from top, on a certain height and then analysed through computer using image analysis software. Images of slices were converted into binary images which result the aggregates and asphalt into identical colours. For sake of accuracy five circular region of interest (ROI) were drawn on images with the help of computer software. The computer software can calculate the area of each ROI in unit; however, this does not present the quantitative value of area because the units are irrelevant. The other option which is available in software is that it can give the area of different colours in each ROI, and since the images has two colours (binary image), hence the area under aggregates and asphalt can be obtained. Although as the area determined with this software is not the true area therefore it is unreliable, however as it is calculated by same procedure, it can be used to determine the percentage area occupied by aggregates and asphalt which can help in making any conclusion. As discussed earlier that several asphalt concrete with different composition including different size of aggregates and with cooking oil were selected for this research, hence the result can help in making a conclusion that either there can be any segregation in a core or not. The result can be also related to the reliability of asphalt concrete if a significant amount of cooking oil is used. Even if the result of asphalt concrete with different composition remains same, then the use of cooking in asphalt concrete can be encouraged.

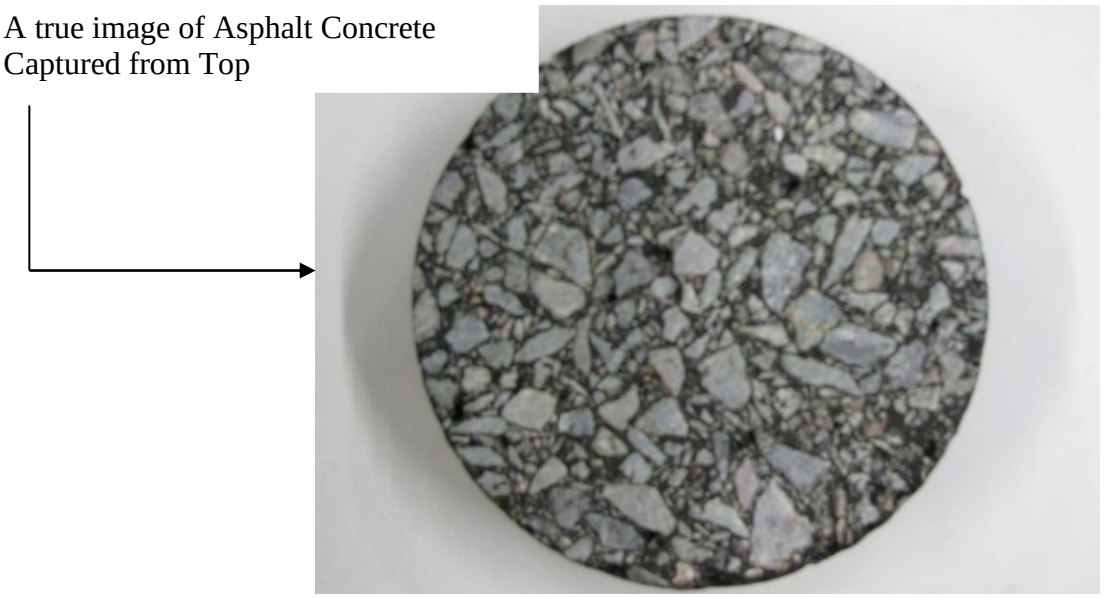


Figure 2. Sample (Slice) Image

S.No.	Material	Core Reference Number	
1	Asphalt Concrete 10 mm Vegetex	1A	1B
2	Asphalt Concrete 10 mm with 40% RAP	2A	2B
3	Asphalt Concrete 10 mm Control	3A	3B
4	Asphalt Concrete 20 mm Vegetex	4A	4B
5	Asphalt Concrete 20 mm with 40% RAP	5A	5B
6	Asphalt Concrete 20 mm Control	6A	6B

Table 1 Core reference number according to material used (Bailey and Zoorob 2012).

The software used for the image analysis is analySIS®.

3. LABORATORY ANALYSIS, OBSERVATION AND DISCUSSIONS

As mentioned in table 1, that Samples A (1A, 2A, 3A, 4A, 5A, and 6A) has six cores, and every core is cut into four slices. Thus, every slice has two faces except the top slice and bottom slice. In other words, every slice has two images except top slice and bottom slice those are having only one. Every image is awarded a number which represent the core and slice number (figure 1). For instance, image No. 1A-1(i) represents the bottom face of extreme top slice of sample 1A. Every image is divided into five Region of interest (ROI's).

The results of every ROI are given on a measurement sheet. Hence the same procedure is repeated for B samples. Figure 3 shows a true image and binary images with location of five ROI's, while table 2 shows measurements sheets. Calculation sheet show (table 2) the results of different ROI's and the ratio aggregates and asphalt. The area of each ROI, the area occupied by aggregates and asphalt in an ROI is calculated by computer software, the remaining calculation such as % area occupied by asphalt and aggregates in table 2 are obtained by mathematical computation to determine aggregates/ asphalt ratio.

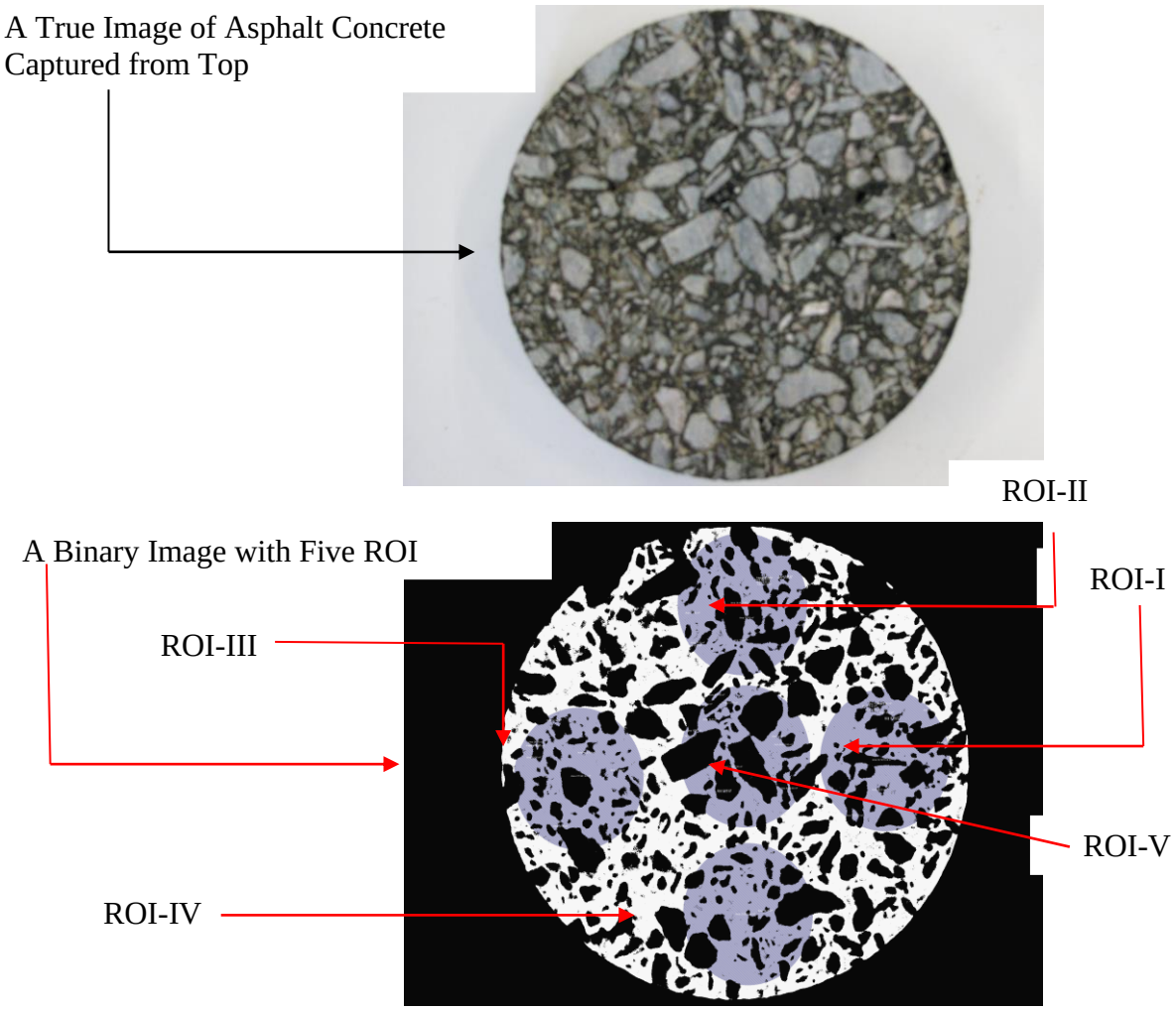


Figure 3 Sample 1A (i) with Analysed Image

ROI No.	Area of ROI (unit)	Area of Asphalt (unit)	Area of Aggregates (unit)	% of area occupied by asphalt	% of area occupied by aggregates	Aggregates/ Asphalt Ratio
I	418901	194830.85	224070.14	46.51	53.49	1.15
II	418901	245852.99	173048.00	58.69	41.31	0.70
III	418901	278778.61	140122.38	66.55	33.45	0.50
IV	418901	276684.11	142216.89	66.05	33.95	0.51
V	418901	251256.8	167644.18	59.98	40.02	0.66
Average Value of Aggregates / Asphalt Ratio = (1.15+0.70+0.50+0.51+0.66)/5 = 0.70						**0.70**

Table 2 Calculation Sheet of the Image 1A-1(i)

As noted before every core have four slices and six images, the above procedure as mentioned in table No. 2 of calculating aggregates / asphalt ratio is repeated for every slice to get an average value of this ratio at the end of every core. Hence these values (aggregates / asphalt ration for every image of core A) are appended in table 3 below.

Image reference	Aggregates / Asphalt Ratio
1A-1(i)	0.70
1A-2(i)	1.01
1A-2(ii)	0.70
1A-3(i)	0.72
1A-3(ii)	0.84
1A-4(i)	0.90
Average Value of Aggregates / Asphalt ratio for Core 1A	**= Submission of above / 6 = 0.82**

Table 3 Average Aggregates / Asphalt Ratio for Core 1A

These values of aggregates / asphalt ratio for all remaining cores i.e., 2A, 3A, 4A, 5A, and 6A were determined and entered into table 4. The whole procedure of analysis was repeated for sample B cores (1B, 2B, 3B, 4B, 5B, and 6B) which gives the average aggregates / asphalt ratio as entered in table 4. It is noted from table 4 that all these values of aggregates / asphalt ratio do not represent any constant variation which can be defined as a significant relation to come over a conclusion except that aggregates / asphalt ratio of cores 1A, 2A, 3A, 1B, 2B, and 3B where aggregates size is 10 mm remained in range of 0.78 to 0.99; while at other hand the same values for cores 4A, 5A, 6A, 4B, 5B, and 6B where aggregates size is 20 mm remained in range of 0.96 to 1.15. Although size of aggregates can be considered for these variation of aggregates / asphalt ratio but at the same time the role of other ingredient in asphalt especially vegetex oil (cooking oil) which were used in core 1A, 1B, 4A, and 4B cannot be avoided.

S.No.	Material	Detail of Observation			
		Core Reference Number	Average Value of Aggregates and Asphalt Ratio	Core Reference Number	Average Value of Aggregates and Asphalt Ratio
1	Asphalt Concrete 10 mm Vegetex	1A	**0.82**	1B	**0.78**
2	Asphalt Concrete 10 mm with 40% RAP	2A	**0.96**	2B	**0.99**
3	Asphalt Concrete 10 mm Control	3A	**0.81**	3B	**0.93**
4	Asphalt Concrete 20 mm Vegetex	4A	**1.08**	4B	**1.11**
5	Asphalt Concrete 20 mm with 40% RAP	5A	**0.96**	5B	**1.12**
6	Asphalt Concrete 20 mm Control	6A	**1.02**	6B	**1.15**

Table 4 Average Value of Aggregates and Asphalt Ratio for different Cores

To overcome upon a solid conclusion from these analyses it was decided to compute unit weight of every slice and later compares these values (unit weight) to the average aggregates / asphalt ratio. The unit weight of each slice of cores A (1A, 2A, 3A, 4A, 5A, and 6A) and cores B (1B, 2B, 3B, 4B, 5B, and 6B) are presented in table 5 and table 6. Weight of slice is computed with a digital scale; volume is computed from cross-sectional area of core and thickness of slice.

Samples A						
Slice No.	**1A**	**2A**	**3A**	**4A**	**5A**	**6A**
1	2.15	2.27	2.32	2.44	2.33	2.42
2	2.58	2.48	2.42	2.61	2.41	2.56
3	2.4	2.36	2.41	2.47	2.47	2.43
4	2.44	2.23	2.3	2.39	2.22	2.25

Table 5 Unit Weight (grams/mm3) of Every Slice in Sample A

Samples B						
Slice No.	**1B**	**2B**	**3B**	**4B**	**5B**	**6B**
1	2.29	2.23	2.3	2.49	2.31	2.27
2	2.41	2.36	2.43	2.66	2.47	2.49
3	2.45	2.35	2.5	2.61	2.44	2.51
4	2.28	2.05	2.35	2.35	2.25	2.31

Table 6 Unit Weight (grams/mm3) of Every Slice in Sample B

Graphical presentation of average value of aggregates / asphalt ratio for both sample A and B are presented in figure 4. As the trend/ regression value R both in figure 4 is very small (less than 0.9), therefore it does not show any significant relation between average aggregates and asphalt ratio with unit weight of slice. However, as figure 4 does not show any significant relation between aggregates / asphalt values with slice unit weight, the possibilities of segregation by using different types of asphalt concrete especially the cooking oil was not indicated with these analyses; this somehow increases reliability of using cooking oil in asphalt concrete.

Aggregates / asphalt ratios were further compared with depth of cores and result are presented in figure 5. Although there is no significant indication, and this may be because of different cores were cut approximately equal in size. Thickness of cutting saw could be another factor which somehow can affect these results. As described before that software used in these analysis coverts a digital image in to binary image (two colours) this also force to avoid empty area in slices occupied by voids or air content which can significantly change the results. Physical such as weight, shape and angularity of aggregates can be further factors which will possibly influence these results.

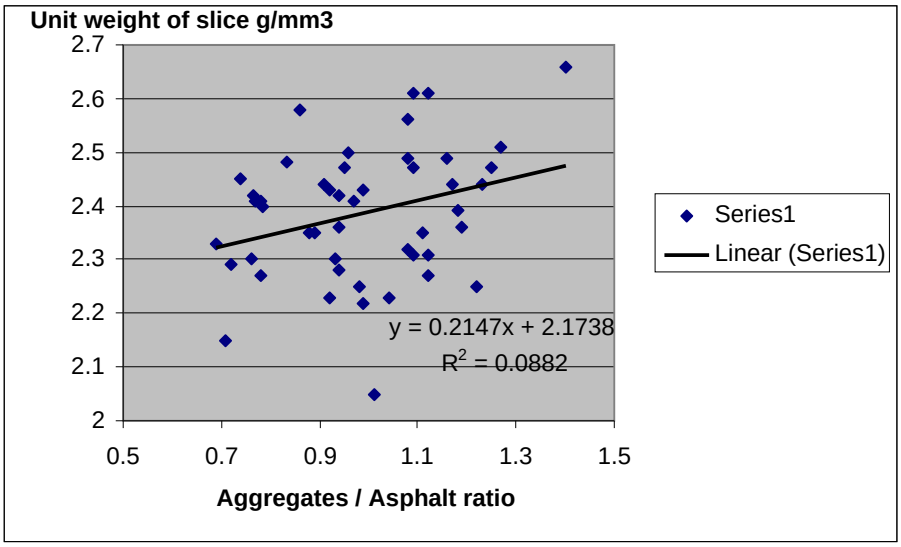


Figure 4 Graphical Presentation of Aggregates, Asphalt ratio with Unit Weight for Samples A & B

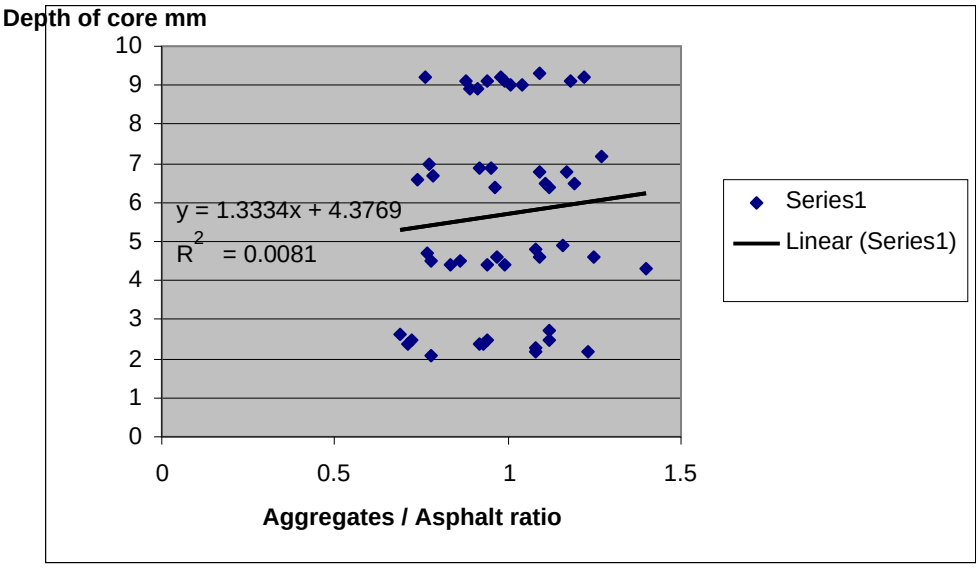


Figure 5 Graphical Presentation of Aggregates, Asphalt ratio with Depth of core for Samples A & B

4. CONCLUSION

The software analysis® which was used in this research can only find out the area occupied by aggregates and asphalt, while a better research can be done if a software can calculate voids occupied by air. In fact, as the aim of this research work was to apply a new method for analysis of different types of asphalt materials and as the research was mainly based on the image analysis software, if a new software would be develop which can do more than just calculating the area, then better results can be obtained especially if the software can calculate true area of images. Furthermore, it is noted from results of analysis that there is no evidence of consistent segregation when aggregates / asphalt ratio of different asphalt concrete was compared with unit weight of slice and depth of core. This somehow increases the reliability of using vegetable which will possibly help in recycling.

5. REFERECNES

Cope M, Allen B and Zoorob S.E, 2007. A study of the effect of bitumen / vegetable oil blends on asphalt mixture performance. Fourth International Conference Bituminous Mixtures & Pavements, Thessaloniki, Greece, vol. 1 pp. 261-270

Fereidoon Moghadas Nejad, Farah Zare Motekhases, Hamzeh Zakeri, and Ahmad Mehrabi, 2015. An Image Processing Approach to Asphalt Concrete Feature Extraction. Journal of Industrial and Intelligent Information 3(1):54-60

Helen K Bailey, Salah E Zoorob (2012), The use of vegetable oil in Asphalt Mixtures, in the Laboratory and Field. 5th Eurasphalt & Eurobitume Congress, 13-15th June 2012, Istanbul, A5EE-162

Lee, Hosin Chou, Eddie Y J, Digital Image Processing: Techniques and Applications in Civil Engineering. American Society of Civil Engineers 1993: 301

Ki Hoon Moon, Augusto Cannone Falchetto, and Jin Hoon Jeong 2014. Microstructural analysis of asphalt mixtures using digital image processing techniques. *Canadian Journal of Civil Engineering*, 2014, 41(1): 74-86

LI ZHi, WU Wen-liang and WU Wen-liang, 2010. Fractal Characteristics Analysis of Asphalt Mixtures with Digital Image processing. Published in E-Product E-Service and E-Entertainment (ICEEE), DOI 10.1109/ICEEE.2010.5660337

Michael S. Mamlouk and John P. Zaniewski, third edition-2011. Materials for Civil and Construction Engineers. Pearson Education, Inc., pp. 196