Moisture Damage Evaluation of Asphalt Mixtures using Image Analysis

BTP –Report

Submitted by

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DECLARATION

I certify that

(a) The work contained in this report has been done by me under the guidance of my supervisor.
(b) The work has not been submitted to any other Institute for any degree or diploma.
(c) I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the Institute.
(d) Whenever I have used materials (data, theoretical analysis, figures, and text) from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references. Further, I have taken permission from the copyright owners of the sources, whenever necessary.

Date: November 28, 2022 (Banoth Amar Singh)

Place: Kharagpur (19CE33003)

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

CERTIFICATE

This is to certify that the project report entitled "**Moisture damage evaluation of asphalt mixtures using image analysis**" submitted by **Banoth Amar Singh, Roll No. 19CE33003** to Indian Institute of Technology Kharagpur is a record of bonafide project work carried out under my supervision and is worthy of consideration for the award of degree of Bachelor of Technology in Civil Engineering with specialization in Transportation Engineering.

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Abstract

Name of the student: **Banoth Amar Singh** Roll No: **19CE33003**

Degree for which submitted: **Bachelor of Technology**

Department: **Department of Civil Engineering**

Thesis title **Moisture Damage Evaluation of Asphalt Mixtures using Image Analysis**

Thesis supervisor**: Dr. Kranthi Kumar Kuna**

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Stripping is a primary form of moisture-related damage in hot mix asphalt, which mainly results from a loss of bond between the asphalt cement and aggregate. Boiling water test is a common method to estimate stripping of bituminous cover from the aggregate surfaces in loose mixtures, but the accuracy of evaluation depends on skills and experience of technician; therefore, alternatives to subjective visual assessments were sought. Image processing methods are known to be reliable means for quality control in different areas and are able to address the inconsistency issues noted with manual assessment. This project presents a code using python to evaluate the stripping of asphalt coating from aggregate surfaces using the water boiling test.

Acknowledgement

First of all, I would like to thank my project advisor Dr. Kranthi Kumar Kuna for all the help he provided me in this project.

I would also like to thank the mentor assigned to me for this project Mr. Thavamani for guiding me throughout the project in the right direction and solving my doubts and queries whenever I got stuck.

Next, I would like to thank Mr. Naveen as his previous work on this system has motivated us to improve it further and integrate more features into it. His work was really well written and comprehendible, and we have used his already existing system in this project.

Lastly, I would like to thank my friends and my family members for the encouragement and support they have provided me during this whole project. This accomplishment would not have been possible without them. Thank you.

Contents

1.0 Introduction

Flexible pavements are structures designed, built and maintained over a foundation to carry vehicular loads. They are exposed to different weather conditions which results in moisture damage leads to failures such as stripping, raveling and pot holes as shown in figure 1. The durability or integrity related to moisture damage plays an important role in other types of damage or distress, such as rutting and fatigue. Thus, moisture damage in hot mix asphalt (HMA) is one of the major concerns in durability of flexible pavements. The moisture damage can be defined as the progressive functional deterioration of a pavement mixture by loss of the adhesive bond between the asphalt cement and the aggregate surface and/or loss of the cohesive resistance within the asphalt cement principally from the action of water.

Figure 1 Moisture damage

In order to predetermine the moisture susceptibility of specific mixture, different tests such as (1) rolling bottle test, (2) boiling test and (3) static immersion test is carried out in the laboratory. (1) In the rolling bottle test, the glass bottle filled with bitumen coated aggregates and water is allowed to rotate at 60 rpm at 20 ± 5 °C for specified time. After the test, the aggregate will be evaluated for the bitumen coverage. (2) The boiling test involves boiling of bitumen coated aggregates submerged in water for 10 minutes. It is an aggressive and quick test to estimate moisture damage. (3) In the static immersion test, the bitumen coated aggregates immersed in water is conditioned at 40 °C for 24 hours to assess the moisture damage. Though the test procedure adopted in each test is different, the evaluation of moisture damage is being carried out by visual observation which makes the result obtained from these tests are subjective in nature.

Digital Image Processing (DIP) is a technique used to process the digital image with the help of digital computer and various algorithms. Digital image is a two-dimensional array specifically arranged in rows and columns. It consists finite number of elements called pixels and each of the elements have a particular value at a particular location. In other words, the color in each part of the image is represented by a pixel with different pixel value. In DIP, the digital image is subdivided into different groups based on the pixels and analyzed to get the output. So, it is possible to determine the bitumen coverage on the aggregate surface using the image taken after the laboratory test through DIP.

2.0 Literature Review

Amelian et al., (2014) evaluated the moisture susceptibility of asphalt mixes based on image analysis. Boiling water test was performed and the images were captured using digital camera (Samsung GT-I9100) with resolution of 3264 * 2448. The authors used Image pro plus software for removing white sparkles and image toll software for evaluating the amount of bitumen area on aggregate. The authors reported that a close relationship between stripping percentages obtained from boiling water test and stripping percentages of fractured specimens after the indirect tensile test. The author got the results as mixture with no additive, limestone and slag-limestone with stripping of 1.6% and 1.3% which shows appropriate resistance but for quartzite and andsite mixtures with 40.3% and 86.5% which shows excessive potential to moisture damage.

Mei et al., (2014) determined bitumen removal on asphalt pavement using digital imaging processing and spectral analysis. Pictures are captured using a digital camera with a 35 mm focal length and a sensor of 10.7 Megapixels. From each image, Region of Interest (ROI) of aggregates, bitumen and shadow were selected. Author used hyperspectral portable device for spectral measurement and evaluated a correlation among EAI and spectral data, between 390 nm and 900 nm range. Finally, reported the possibility to retrieve asphalt bitumen removal through remote sensed imagery.

Lantieri et al., (2016) evaluated the use of image analysis for the evaluation of rolling bottle tests results. The picture after the rolling bottle test was taken at a distance of 18 cm vertically using 10 Megapixel camera. Further, two light sources with light beam incidence of 45° angle to avoid the shadow of aggregates were used. The authors used ImageJ software to find the extent of bitumen coating on aggregate against visual inspection. The authors reported that around 6.4% to 22.4% difference was observed between visual and software determination. Also, it is reported that, the use of ImageJ software for the aggregates which are black in color will be difficult compared to light color aggregates.

Moghaddam et al., (2019) estimated stripping of asphalt coating using k-means clustering and machine learning–based classification. The authors proposed algorithms to remove noise from pavement images using median filter and morphological operations or Gaussian smoothing when the images were captured under different lighting conditions. The authors mainly used three modules of the open source OpenCV version 3.3.0 library such as image enhancement, k-means clustering, and cluster classification for the image analysis. The author reported that average of 4.91% difference with the manual assessment. However, the authors reported that image analysis have overestimated the bitumen coated area by considering the aggregate shades as bitumen coated.

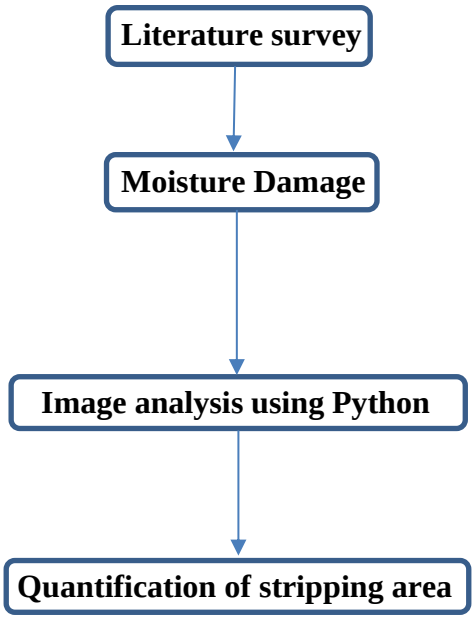
Blom et al., (2019) determined the bitumen stone coverage using digital image processing. The authors used a setup consists of an aluminum frame, a led lighting and a digital camera to capture the image. The moisture damage test was conducted using boiling water test for 10 and 30 minutes. The authors used ImageJ software for evaluating the degree of binder coverage. The authors reported that the background and the light reflection has significant effect on the results obtained. Also, the authors warranted further research on stripping determination using digital image processing.

3.0 Research gap and objectives

Even though different camera setup has been used for capturing the images, the problem of white sparkles remains the same. Also, many researchers used ImageJ software for the image analysis and reported shortcomings associated with it. Thus, there is a need for further research on the quantification of bitumen coating on aggregate surface.

The broad objective of the study is to determine the amount of stripping area through digital image processing approach using python.

4.0 Methodology



a. Moisture damage test

The moisture damage analysis will be done using boiling water test as per ASTM D 3625. The boiling water test is a visual rating of the degree of stripping after boiling the loose HMA mixture for 10 min. Approximately 500 ml of water is placed in a 1000 ml beaker and will be heated to boil along with 250 g of loose HMA mixture at a maximum temperature of 100°C, but not lower than 80°C for 10 min. Once the test is done, the beaker will be removed from the heat source and a paper will be used to skim

off the bitumen on the water surface to prevent recoating. After cooling it to room temperature, the water will be removed, and the mixture will be placed onto a white paper towel to be visually analyzed. The criterion of failure is by visual identification of stripped (uncoated) aggregates. The percentage of asphalt coating remaining from the initial reference condition (before testing) will be visually estimated to quantify the level of degradation due to moisture damage.

b. Image analysis

Image analysis involves processing an image into fundamental components to extract meaningful information. Image analysis can include tasks such as finding shapes, detecting edges, removing noise and counting objects. In this study, Python will be used to develop algorithms using Google colaboratory platform.

5.0 Work Done

For the development of algorithms, a trial water boiling test was conducted and the images were captured using mobile camera as shown below. Later the images were processed using OpenCV, numpy, and matplotlib library functions available for Python coding. Also, the trial coding is given below.

Step:1 Masking the background

#Changing green background to white back ground
Initially picture is with green background then background is masked with black pixels then after changed black pixels to white pixels.

```
from google.colab import drive
drive.mount('/content/drive')
```

```
import numpy as np
import cv2
from google.colab.patches import cv2_imshow

img = cv2.imread('/content/drive/MyDrive/amar_test.jpg')
lab = cv2.cvtColor(img, cv2.COLOR_BGR2LAB)
a_channel = lab[:,:,1]
th=cv2.threshold(a_channel,127,255,cv2.THRESH_BINARY+cv2.THRESH_OTSU)[1]
masked = cv2.bitwise_and(img, img, mask = th)    # contains dark background
m1 = masked.copy()
m1[th==0]=(255,255,255)

cv2_imshow(m1)
cv2.imwrite('my_img2.jpg', m1)
```

Output of step:1

Step:2 Image Segmentation

Now the picture is with white background and all other remained the same Through image segmentation whole picture is converted into three segment colors.

```
import matplotlib.pyplot as plt
import numpy as np
import cv2
sample_image = cv2.imread('/content/my_img2.jpeg')
```

```
img = cv2.cvtColor(sample_image,cv2.COLOR_BGR2RGB)

twoDimage = img.reshape((-1,3))
twoDimage = np.float32(twoDimage)
criteria = (cv2.TERM_CRITERIA_EPS + cv2.TERM_CRITERIA_MAX_ITER, 10, 1.0)
K = 3
attempts=10
ret,label,center=cv2.kmeans(twoDimage,K,None,criteria,attempts,cv2.KMEANS_PP_CENTERS)
center = np.uint8(center)
res = center[label.flatten()]
result_image = res.reshape((img.shape))

plt.axis('off')
plt.imshow(result_image)
cv2.imwrite('my_img4.jpg',result_image)
```

Output of step:2

Step 3: Pixels calculation

Step 2 output image contains three different colors. White refers to background and black refers to bitumen and gray refers to aggregate. Calculating the number of pixels covered by each color.

```
import cv2
import numpy as np
from matplotlib import pyplot as plt
```

```
in_path ='/content/my_img3.jpg'
CImage = cv2.imread(in_path)
DImage = cv2.imread(in_path)
##Image = cv2.cvtColor(CImage, cv2.COLOR_BGR2GRAY)



Image2=np.array(CImage,copy=True)
Image3=np.array(CImage,copy=True)
print('threshold values at coordinate [948][2127] in image:',Image2[948][2127])
white_px=np.asarray([255,255,255])
black_px=np.asarray([0,0,0])
(row,col,_) = CImage.shape
print('total number of rows and columns:',row,col)

white=0 #white
black=0 #Black
total=0 #total pixels in image
gray=0 #gray
for r in range(0,row):
  for c in range(0,col):
    total=total+1
    px = CImage[r][c]
    if(px[0]==255 and px[1]==255 and px[2]==255):
      white=white+1
    elif(px[0]<30 and px[1]<27 and px[2]<41):
      black=black+1
    else:
      gray=gray+1
print('Number of total pixels in image:',total)
print('Number of black pixels in image:',black)
print('Number of white pixels in image:',white)
print('Number of gray pixels in image:',gray)
```

Output of Step:3

threshold values at coordinate [948][2127] in image: [22 25 39]

total number of rows and columns: 2001 2383

Number of total pixels in image: 4768383

Number of black pixels in image: 649785

Number of white pixels in image: 3621243

Number of gray pixels in image: 497355

Calculation

Total area of bitumen coated to aggregate before test is:

Number of black pixels + Number of grey pixels = 649785 +497355 = 1147140

Percentage of coated area is: (649785/1147140)*100 = 56.64%

Percentage of Stripping area is: (497355/1147140)*100 = 43.36%

After performing the boiling water test due to moisture damage on asphalt mixture the amount of stripped area is 43.36%.

6.0 Observations and Future Work

From the trial it can be observed that white sparkles are observed on the bitumen surface in the image. Later these white sparkles were considered as background when the images are converted to white background which reduces the accuracy of the results.

In the future study, the above-mentioned shortcomings will be addressed with the help of modified imaging process and improved algorithms. Later, these algorithms will be used to determine the stripping area of interest materials and will be validated with other set of data.

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