

A Method to Produce a GIS Database of Asphalt Polymer Pavement Distress of National Highway -44

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Abstract

Bitumen, often referred to as asphalt in its solid form, is a complex mixture of organic compounds derived from the distillation of crude oil. Its chemical composition varies depending on its source, processing methods, and intended application. Pavement surface monitoring is an important part to increase the life of pavement and to minimize the cost incur in maintenance of pavement at an early stage. Traditionally pavement monitoring done using manually method. The aim of this study is to detect the distresses at an early stage so that maintenance can be cost effective, time consuming and economical. In this study National Highway -44 is selected which is stretch from New Delhi to Agra about 200 Km. Taj Mahal and Lord Krishna temple in Agra and Mathura respectively is the center point of attraction for tourism and also for Business, therefore traffic increases more in these cities and subsequently on NH-44 because of that pavement distresses are more frequent and need to be maintained effectively. Pavement distresses are captured using camera and at the same time location is also recorded, these images are then plotted on the map using the software, Geo Setter. Geo Setter helps to export the images to Google earth file which can be used to identify the pavement condition. Pavement distress are classified on the basis of their severity, low, medium and high severity pavement condition. Severity parameters from Federal Highway Administration taken as the bench mark to classify distresses on the basis of distress severity. This helps to save the manual labour and provide the efficient and accurate data and safety is also major concern which can be minimized using this method. This file can be shared with maintenance department to plan for future maintenance according to requirement and severity.

Keywords: Mathura, geo setter, pavement distress images, polymerization of bitumen

INTRODUCTION

Bitumen contains oxygenated compounds such as ketones, alcohols, and carboxylic acids. These compounds can influence the adhesion properties of bitumen and its compatibility with other materials. Highway network is considered as an important asset for any country especially for the developing countries [1]. In India, many new expressways and National highways are constructed, and many more are under construction. Development of Expressways, Highways, District roads and other roads make

convenient for the users to travel far distance in a shorter time. With the development of Highways, maintenance problem also emerges [2]. Maintenance of Highways is an important task but at the same time it does not proves to be cheaper [3]. As soon as the construction phase is completed, Highways are open to traffic. In India, mixed traffic like cycle, Motor Bikes, Three Wheeler, Four Wheeler, Buses, Trucks etc. uses the Highways. Major cause of asphalt pavement failure is due to failure of mix design, that is inappropriate selection of bitumen, aggregate or both. Failure of bitumen is due to oxidation of bitumen, caused by oxygen and

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Received Date: April 23, 2024

Accepted Date: July 17, 2024

Published Date: December 12, 2024

Citation: Ravi Kumar, Smita Tung. A Method to Produce a GIS Database of Asphalt Polymer Pavement Distress of National Highway -44. Journal of Polymer & Composites. 2025; 13(Special Issue 1): S99–S108p.

UV radiation [4]. Bitumen molecules have the ability to conduct polymerization events under specific conditions, such as elevated temperatures and extended exposure to UV radiation. During these reactions, smaller molecules join together to create bigger polymeric chains. Excessive polymerization of bitumen i.e. Bitumen (C_nH_{2n}) → Polymerized Bitumen can result in brittleness and diminished flexibility, despite its ability to boost stiffness and strength. Efficient methods for reducing bitumen oxidation involve the application of antioxidants, UV stabilizers, and appropriate pavement design and maintenance techniques. The mechanistic-empirical design technique is frequently employed in pavement design, which integrates theoretical mechanics and empirical data to forecast the performance of pavement under different circumstances. The process of designing pavement involves several essential processes, including traffic study, soil investigation, material selection, layer design, structural analysis, performance prediction, and design iteration. Light motor vehicle (LMV), or non-motorized vehicle does not cause pavement deterioration as much as caused by the heavy commercial vehicles, or heavily loaded vehicles [5–7]. Beside the traffic loads other causes are climatic conditions and the age of flexible pavement. In pavement design, CBR means California Bearing Ratio. This method determines pavement layer thickness and structure based on ground load-bearing capacity by assessing subgrade soil strength. The Indian Roads Congress method is referred to as the IRC approach in pavement design. This method establishes standards and guidelines for the design and construction of flexible and rigid pavements in India, with an emphasis on environmental conditions, material properties, and traffic volume. Many studies have concluded that small capital invested on maintenance improve the service life of pavement [8].

Safety and comfort of road users depend upon the condition of the pavement. If condition of pavement getting ignored then there is heavy loss in terms of capital, road users' safety, and pavement life [9,10]. There are both manual and automatic methods that can be used to identify pavement damage. The manual approach entails employing physical labor to examine and categorize different forms of pavement deterioration. However, it is an intricate process that has a greater likelihood of errors. There are several advanced techniques, such as YOLO, R-CNN, U-NET, SSD, and TensorFlow, that use Deep Convolutional Neural Network (DCNN) learning methods to automatically detect pavement distress in real time. These systems have a high level of accuracy. But collection of data and keeping safe manually is a tedious job and also is an inefficient, inaccurate and also subject to safety hazards [11]. Road roughness is the indication of the initial phase of deterioration, if pavement is not cured in the initial phase of deterioration this deterioration gets enlarged and leads to various pavement distresses like longitudinal cracks, transverse cracks, alligator cracking, shoving, rutting, pot holes etc. Manual survey of pavement distress is time consuming and also incur insufficient data [12].

Major cause of pavement deterioration is pavement cracks; therefore it is necessary to identify cracks at an early age so that prevention can done against pavement cracks [11]. Road Surface Monitoring and Mapping (RSMM) is the process of identify the distresses on pavement. Identification of pavement distress at an early stage and application of suitable pavement healing method helps pavement safeguarding the pavement against major deterioration, also helps in reducing the maintenance cost. This also helps in saving the manual work of the employee, only a single person can identify the picture and prepare the Google earth file, which can be submitted to higher authorities for further action [13].

Accelerometer is used for identification of surface condition like, potholes, bumps, etc. at the same time GPS is used to identify the location of surface distress accurately in real time. These devices are connected in 5 vehicles and one device in Test vehicle. At place of potholes and bumps, high energy is needed which resembles the potholes and bumps and it is verified using test vehicle. This energy can be analyzed using application which can be installed in Mobile or Tablets. These energy with respect to particular pot hole or bump is verified using test vehicle and location is recorded with the help of GPS. Using this method surface monitoring can be done easily [14].

Road Surf is an application used to inform the road users of Finland in advance about the condition of road like, friction of surface, road surface temperature variation, snowfall, measurement of

precipitation. This application also used by the authorities of Finland to take prior action for roads, so that services to road users cannot be delayed. Application uses data from the Finnish Meteorological Institute (FMI). In this model data is employed using numerical weather forecast directly or indirectly after some modification. This model helps road users to get prior information about the road that they are going to use [15].

Severity of pavement is important to identify and also to confirm the type of pavement distress, whether pavement is paved or unpaved. On the basis of severity, it is ease to identify that which section of road is to be repaired first, or repairing can be done on the basis of severity as well as it is also important to identify the techniques to be used for particular type of pavement distress. This helps to save time, energy and money with respect to conventional method of pavement monitoring [16].

Road surface condition of Malaysia like potholes, rumble strips, speed bumps and undulated surface can be analyzed using Internet of Things and Machine learning model. Statistical features used for analyzing the road surface condition. This model helps in occupying data at low cost and help local authorities to make final decision on repair and allocation of resources [17].

Automobile industry uses Controller Area Network (CAN) and Ethernet to record the data of vehicle system like braking, engine and transmission. This vehicle system data used to develop algorithm to predict the values about road and vehicle using that road. Road surface condition, road traffic condition, driving style can be easily analyzed using algorithm. Random Forest (RF), Decision tree and Support Vector Machine (SVM) used to develop algorithm to predict the road surface condition (Smooth, even or full of holes), road traffic condition (Low, medium and High), driving style (Normal or Aggressive nature) using data obtained from CAN. Highest accuracy is obtained using Random Forests algorithm [18].

Road surface cracking and disintegration are main pavement distress [19]. Pavement distress causes damage to vehicle, increase in emission and increase in evasive maneuvers. Agencies constantly working on pavement surface distresses, manually it is done by Visual inspection. CNN (Convolutional Neural Network) method of machine learning and video collection methods helps in reducing the cost incurred in manual methods. Model developed using CNN is used to train dataset and also for test data of pavement surface distresses like cracking (longitudinal, block and linear), potholes, patch and pavement surface marking. The accuracy of model of trained data is 83.8% over test data [20].

Intelligent driving needs fast real time, high accuracy performance, which cannot be attain by traditional method. Deep learning model Rectified Linear Units (ReLu) activation unit used for the classification of road surface conditions and this model has better generalization [21].

Smartroadsense is used for automatic detection of road surface characteristics, road sense consists of GPS (Global Positioning System) and triaxial accelerometer contained in mobile device. Smartroadsense gives the up-to-date information of road pavement condition [22].

Internet of things infrastructure, applications and systems prove to be beneficial in serving the smart cities. Crowdsensing is common in smart cities, so traditional method of pavement monitoring is not economical, so new methods of machine learning is common to get effective results of pavement conditions [23].

In this study National Highway -44 (NH-44) and MDR of connecting Mathura city is selected to identify the pavement condition. No research is done on this stretch so our aim is to identify the pavement surface condition of NH-44 for about 201 Km and also MDR of Mathura city. According to Business Standard Mathura emerges as a major domestic tourism hub. Around 10 crore tourist visit Mathura city annually, and one of the way to reach Mathura city using NH-44 and MDR hence traffic

increases in particular stretch, which causes distress to pavement surface like cracking, potholes, ravelling etc. Sometimes these distresses are due to ageing of bitumen and aggregate. Therefore, it is necessary to monitor the pavement condition so that life of pavement can be enhanced and also minimize the cost of maintenance. It also leads to the safety for road users. It is necessary to classify these distresses on the basis of severity as low, medium, high, according to distress identification manual by Federal Highway Administration.

Study Area

Pavement distress images of National Highway-44 (NH-44) are captured. NH-44 stretches from New Delhi to Agra of about 201 Km joining major cities of Uttar Pradesh (Mathura, Agra), Rajasthan (Bharatpur), Haryana (Palwal, Gurugram) and New Delhi. Figure 1 represents the present study area comprising the NH-44 and Major district road of Mathura City. 7th wonders of world Taj Mahal located in Agra and Birth place of Lord Krishna is Mathura, these two cities attract tourism Nationally as well as Internationally. Mathura and Agra cities are located on National Highway-44, because of that tourism are increases yearly specially during weekends.

Mathura and Agra are the attraction point for tourism and also for Business due to this traffic volume increases. Vehicles are more on NH-44 and also on the MDR of two cities then there is probability that distresses begin. In this work identification of pavement distress severity is carried out so that any distress can be repaired at an early stage.

Data Collection

Pavement distress images taken with the help of camera built in GPS, so that location of that distress is also recorded at the same time in the form of latitude, longitude, and elevation. Image is named by default in camera.

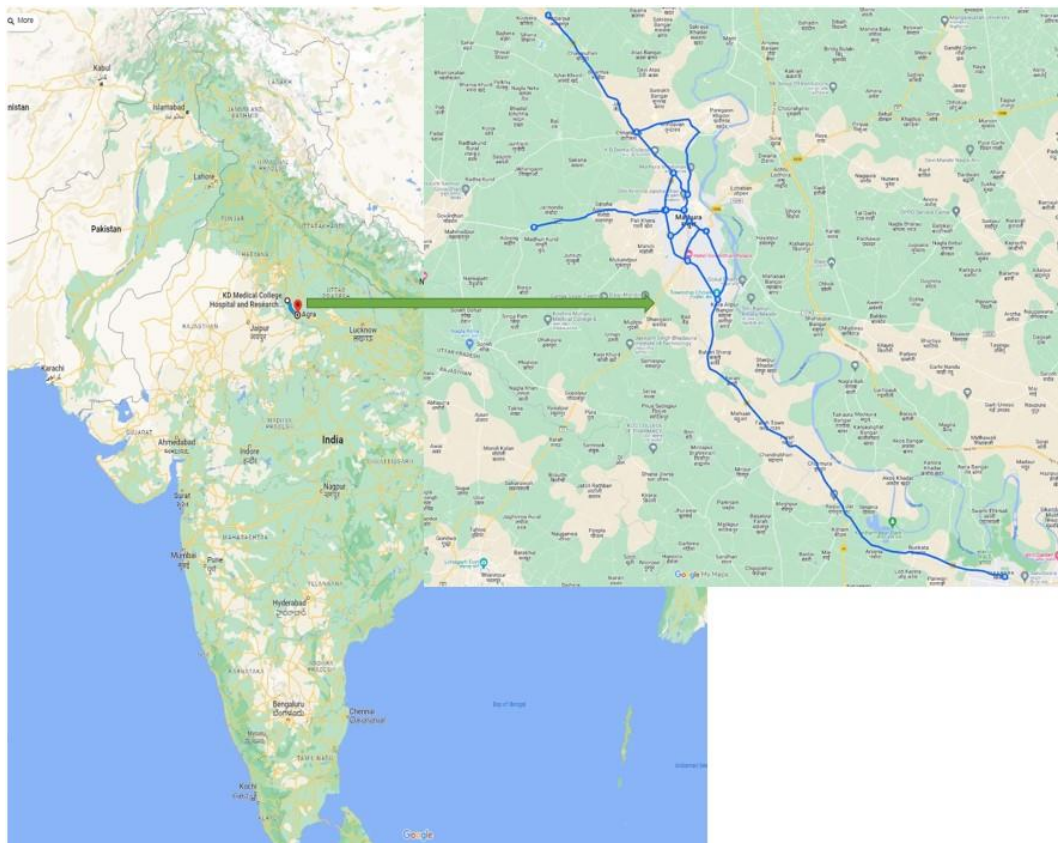


Figure 1. Research area (NH-44, New Delhi to Agra).

Specification of Mobile used for capturing pavement distress images are

- *Camera:* 64MP Main Camera with EIS; 2MP Depth Lens and 2MP Macro Lens;
- *Camera features:* AI scene enhancement, Dual-View Video, HDR, Night Portrait, Panorama Mode, Retouch Filters, 1080p video at 30 fps, SLO-MO: 720p video at 120 fps, TIME-LAPSE: 1080p video at 30 fps, HDR, NIGHT,
- *Operating system:* Oxygen OS based on Android 12
- *Processor:* Qualcomm Snapdragon 695 5G
- *Battery & charging:* 5000 mAh with 33W SuperVOOC

Survey is done with the help of bike and bicycle to identify the distress and capture pavement distress images as shown in Figure 2.(a), (b), (c), (d), (e), (f), (g), (h) of zones marked in the Figure 1. with minor or major severity. Later, this distress is classified as Low, Medium, and High severity and accordingly the authority can act based on priority. Location of pavement distresses noted down and may be somewhat different from the actual location due to many factors, GPS not having proper signals because of the presence of water strips around the location or presence of tree canopies.

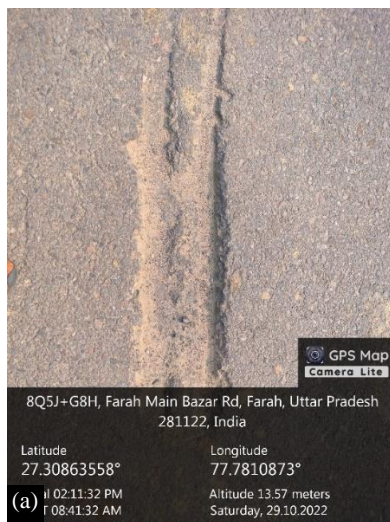


Figure 2. (a) Represents damage pavement.



Figure 2. (b) Represents showing distress.

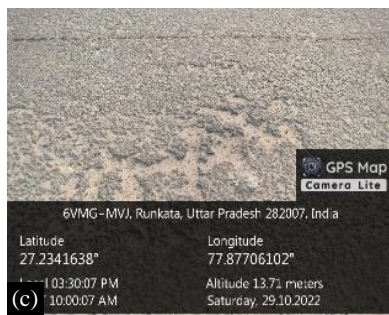


Figure 2. (c). Represents aggregate stripping.



Figure 2. (d) Represents alligator cracking.



Figure 2. (e) Represents ravelling.



Figure 2. (f) Represents alligator cracking with low severity pot holes.

All images capture with HD quality of 780 pixels so that images can be zoomed and easy to identify the type of crack and get appropriate method to rectify that crack. Images also labelled with date, time, and location of stresses. Many applications are available on play store to find the latitude and longitude of distress. For the same purpose GPS camera lite application is used as shown in Figure 2.(a), (b), (c), (d), (e), (f), including basic information about distress.

Geotagging

Images captured using HD Mobile Phone, in built with GPS and GPS map camera lite application installed in it, some images having geographical identification metadata, and some images are not having metadata may be some technical error, which is solved by GPS camera lite application. This geographical metadata is added to all images using the software, Geo Setter. Geo Setter software is available free for educational purposes. The metadata of the photo file Exchangeable Image File Format (EXIF) which has standard tags for location information. Location to images is added using the option edit and latitude and longitude data of each image is added, and the location of image can be seen on the right side of the screen using option map. Figure 3 (a) and 3 (b) shows the interface of the geo Setter, and all images are plotted on screen.

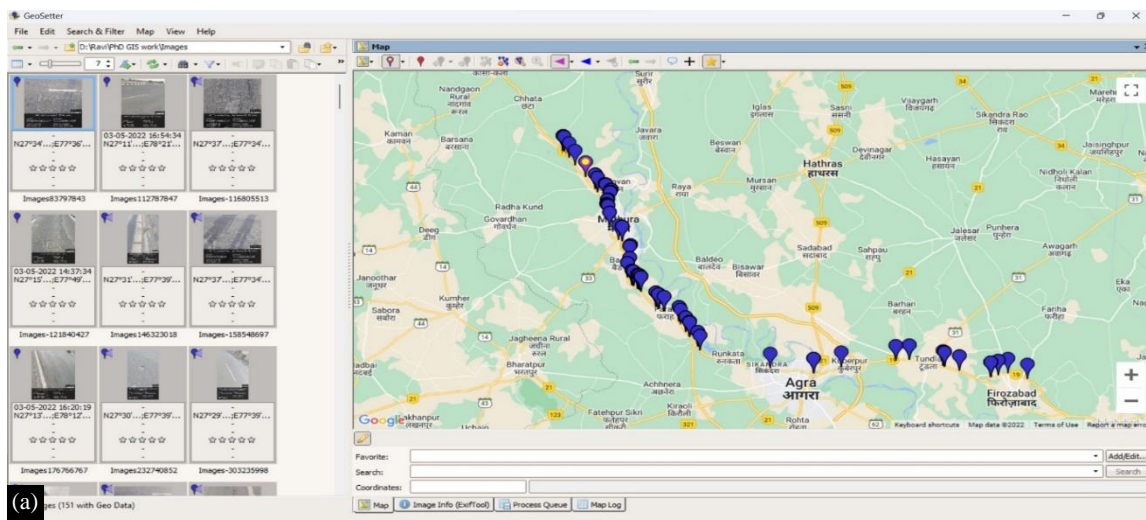


Figure 3. (a) Interface of geo setter after plotting all the images

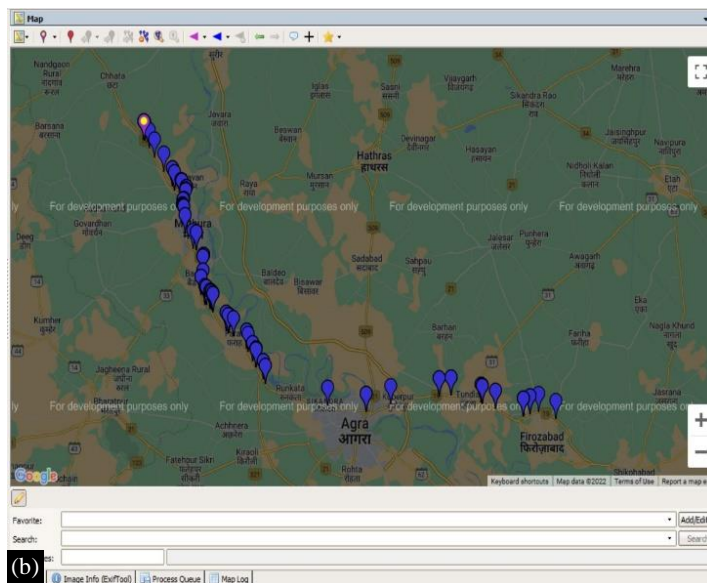


Figure 3. (b) Interface of geo setter with location marked on map.

After mapping all the image on the software, the data can be exported to google earth and that file of google earth can be shared with authorities who are responsible for the maintenance of highways. Google earth file include all the information like image of distress with location. Many options are available on google earth, with the help of these options we can manage our data, like changing the color or icons of marked locations, showing the image names also. As shown in Figure 4. On clicking the location pin, detailed information is visible on screen and the responsible person can analyze the data, and accordingly plan for its solution to pavement distress.

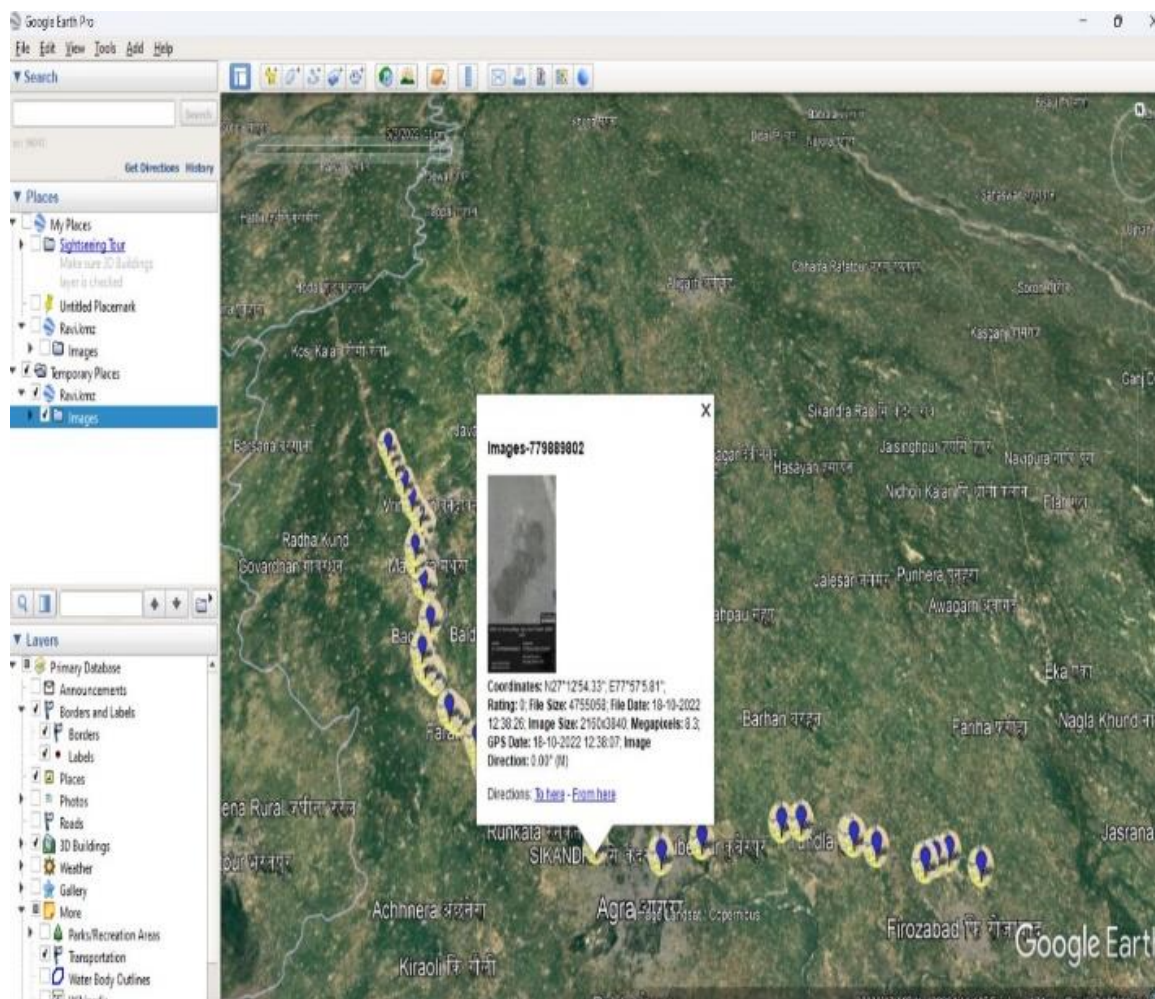


Figure 4. Google earth interface after plotting images.

CONCLUSION

This study presents a cost effective and efficient method for the monitoring of the pavement distress. Data collection does not need highly skilled person, it can be done with the help of a normal skilled person, having knowledge about Gadgets (Mobile and GPS). The entire process of surveying the NH-44 using bike or cycle depending upon the need can be done by single person, same person also able to collect all information like latitude, longitude with the help of GPS device to verify the location of smart phone GPS. Smart phones help to collect latitude, longitude, time, date of images automatically.

This study proves that instead of using the traditional method of pavement monitoring, it can be used efficiently with accuracy. It also helps in the safety of road users whether it is surveyor or the driver or any other person using the same road, because capturing images is too easy using smart mobiles, no need of two or three devices need. For better resolution image is to be captured in daytime under sunlight.

Future work with this method can be done for pavement monitoring and mapping, that can also be possible from the public. Website or application can be developed, which can be used by the public to upload pavement distress images with details, like date, time, location. Later these images can be mapped on using Geo setter software by single person and the google earth file can be shared with the respective maintenance department.

Future of this study can be used in the machine learning to analyse the images and categorised them according to severity, and suitable method can be suggested for the rectification of these distresses based on priority.

REFERENCES

1. Fakhri M, Dezfoulian RS, Golroo A, Makkiabadi B. Developing an approach for measuring the intensity of cracking based on geospatial analysis using GIS and automated data collection system. *Int J Pavement Eng* [Internet]. 2021;22(5):582–96. Available from: <https://doi.org/10.1080/10298436.2019.1628961>
2. Weng X, Huang Y, Wang W. Segment-based pavement crack quantification. *Autom Constr*. 2019;105(November 2018).
3. Leonardi G, Barrile V, Palamara R, Suraci F, Candela G. 3D mapping of pavement distresses using an Unmanned Aerial Vehicle (UAV) system. *Smart Innov Syst Technol*. 2019;101:164–71.
4. Gandhi S, Roji SSS, Motta M, Nalawade RRD, Allah Khan M, Palanisamy S. Analysis of potential incorporation of waste into asphalt pavements. *Mater Today Proc* [Internet]. 2024;(February). Available from: <https://doi.org/10.1016/j.matpr.2024.05.097>
5. Zhang A, Wang KCP, Li B, Yang E, Dai X, Peng Y, et al. Automated Pixel-Level Pavement Crack Detection on 3D Asphalt Surfaces Using a Deep-Learning Network. *Comput Civ Infrastruct Eng*. 2017;32(10):805–19.
6. Abulizi N, Kawamura A, Tomiyama K, Fujita S. Measuring and evaluating of road roughness conditions with a compact road profiler and ArcGIS. *J Traffic Transp Eng (English Ed)* [Internet]. 2016;3(5):398–411. Available from: <http://dx.doi.org/10.1016/j.jtte.2016.09.004>
7. Veeramanickam MR., Mohanapriya M. IOT enabled Futures Smart Campus with effective E-Learning : i-Campus. *Int J Eng Technol*. 2014;2(3):14–20.
8. Nautiyal A, Sharma S. Condition Based Maintenance Planning of low volume rural roads using GIS. *J Clean Prod* [Internet]. 2021;312(May):127649. Available from: <https://doi.org/10.1016/j.jclepro.2021.127649>
9. Kennedy J, Shalaby A, Van Cauwenberghe R. Dynamic segmentation of pavement surface condition data. 2000 Annu Conf Abstr - Can Soc Civ Eng. 2000;273.
10. Moazami D, Behbahani H, Muniandy R. Pavement rehabilitation and maintenance prioritization of urban roads using fuzzy logic. *Expert Syst Appl* [Internet]. 2011;38(10):12869–79. Available from: <http://dx.doi.org/10.1016/j.eswa.2011.04.079>
11. Shao C, Chen Y, Xu F, Wang S. A Kind of Pavement Crack Detection Method Based on Digital Image Processing. *Proc 2019 IEEE 4th Adv Inf Technol Electron Autom Control Conf IAEAC 2019*. 2019;(Iaeac):397–401.
12. Ibrahim A, Zukri NAZM, Ismail BN, Osman MK, Yusof NAM, Idris M, et al. Flexible Pavement Crack's Severity Identification and Classification using Deep Convolution Neural Network. *J Mech Eng*. 2021;18(2):193–201.
13. Fendi KG, Adam SM, Kokkas N, Smith M. An Approach to Produce a GIS Database for Road Surface Monitoring. *APCBEE Procedia* [Internet]. 2014;9:235–40. Available from: <http://dx.doi.org/10.1016/j.apcbee.2014.01.042>
14. Astarita V, Caruso MV, Danieli G, Festa DC, Giofrè VP, Iuele T, et al. A Mobile Application for Road Surface Quality Control: UNIQUALroad. *Procedia - Soc Behav Sci*. 2012;54:1135–44.
15. Kangas M, Heikinheimo M, Hippo M. RoadSurf: A modelling system for predicting road weather and road surface conditions. *Meteorol Appl*. 2015;22(3):544–53.
16. Shtayat A, Moridpour S, Best B, Shroff A, Raol D. A review of monitoring systems of pavement condition in paved and unpaved roads. *J Traffic Transp Eng (English Ed)* [Internet]. 2020;7(5):629–38. Available from: <https://doi.org/10.1016/j.jtte.2020.03.004>

17. Ng JR, Wong JS, Goh VT, Yap WJ, Yap TTV, Ng H. Identification of road surface conditions using IoT sensors and machine learning. *Lect Notes Electr Eng*. 2019;481:259–68.
18. Al-refai G, Elmoaqet H, Ryalat M. In-Vehicle Data for Predicting Road Conditions and Driving Style Using Machine Learning. *Appl Sci*. 2022;12(18).
19. Bahoria BV, Ranjith A, Laxmaiah G, Solomon Raj S, Ranjan Padhi M, Palanisamy S. Verification of the mechanical behavior of concrete with partial replacement of the fiber resulting from tire retreading. *Mater Today Proc* [Internet]. 2024;(April). Available from: <https://doi.org/10.1016/j.matpr.2024.04.067>
20. Zhang C, Nateghinia E, Miranda-Moreno LF, Sun L. Pavement distress detection using convolutional neural network (CNN): A case study in Montreal, Canada. *Int J Transp Sci Technol* [Internet]. 2022;11(2):298–309. Available from: <https://doi.org/10.1016/j.ijtst.2021.04.008>
21. Cheng L, Zhang X, Shen J. Road surface condition classification using deep learning. *J Vis Commun Image Represent* [Internet]. 2019;64:102638. Available from: <https://doi.org/10.1016/j.jvcir.2019.102638>
22. Abbondati F, Biancardo SA, Veropalumbo R, Dell'Acqua G. Surface monitoring of road pavements using mobile crowdsensing technology. *Meas J Int Meas Confed* [Internet]. 2021;171(August 2020):108763. Available from: <https://doi.org/10.1016/j.measurement.2020.108763>
23. El-Wakeel AS, Li J, Noureldin A, Hassanein HS, Zorba N. Towards a Practical Crowdsensing System for Road Surface Conditions Monitoring. *IEEE Internet Things J*. 2018;5(6):4672–85.