PAPER NAME

Pavement Shoulder Drop-off Measurement.pdf

WORD COUNT	CHARACTER COUNT
2856 Words	**19608 Characters**
PAGE COUNT	FILE SIZE
27 Pages	**2.1MB**
SUBMISSION DATE	REPORT DATE
Jun 6, 2023 1:23 AM GMT+6	**Jun 6, 2023 1:23 AM GMT+6**

9% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 8% Internet database
- Crossref database
- 3% Submitted Works database
- 2% Publications database
- Crossref Posted Content database

Excluded from Similarity Report

- Bibliographic material
- Cited material
- Manually excluded text blocks
- Quoted material
- Small Matches (Less then 8 words)

Unbound Pavement Shoulder Drop-off Measurement for Flexible and Rigid Pavement in Dhaka Roads

This thesis has been submitted for the partial fulfillment of the degree of Bachelor of Science in Civil Engineering in the graduate college of Islamic University of Technology (IUT, OIC) in 2023.

Prepared by:

Nazmuz Sadat, 180051248

Rafid Bin Zaman, 180051249

Supervised by:

Dr. Nazmus Sakib

Assistant Professor

Department of Civil and Environmental Engineering

Islamic University of Technology (IUT, OIC)

Board Bazar, Gazipur-1704,

Dhaka, Bangladesh.

Department of Civil and Environmental Engineering

Islamic University of Technology (IUT, OIC)

Board Bazar, Gazipur-1704,

Dhaka, Bangladesh.

June 2023

CERTIFICATE OF RESEARCH

This is to certify that this thesis work has been done by our group of two members and neither this thesis nor any part of thereof has been submitted elsewhere for the award of any degree or diploma.

Dr. Nazmus Sakib	Nazmuz Sadat **Nazmuz Sadat**
(Countersigned by the Supervisor)	
	Rafid **Rafid Bin Zaman**
	(Signature of the Candidates)

Acknowledgment

Our heartiest gratitude to everyone who contributed to the completion of this research endeavor in any way possible.

We are grateful to the Creator for blessing us with knowledge as well as wisdom and furthermore, providing us with the necessary strength to complete our studies.

We would like to acknowledge Dr. Nazmus Sakib for his continuous support and patience during the entirety of the training process and for guiding us on how to carry out this study. We are indebted to him for his constant support, teachings, and motivation.

Abstract

Pavement edge drop-off plays a major role in road safety. A significant shoulder drop-off may result in a loss of vehicle control. Despite current specifications, the road agencies of Bangladesh do not have a specific edge drop-off criterion. In addition, there is no reliable way to measure shoulder drop-offs.

Several roadways have unbound type shoulders, resulting in increased drop-off issues. Rigid pavements, which are fewer in number than flexible pavements in Bangladesh, also show similar issues due to a lack of shoulder compaction.

In this study, several sites constructed by different road authorities were evaluated, and shoulder drop-off was measured using an indigenously made profilometer. Upon analysis of the result, it was found that the profilometer is capable of measuring shoulder drop-off accurately and can give a clear idea about the profile of the drop-off.

This information can be used to plan effective road maintenance and prevent accidents due to shoulder drop-offs. Regular use of the profilometer can help ensure the safety and integrity of roadways in the long term.

Table of Contents

List of Tables

No table of figures entries found.

List of Figures

Chapter 1 Introduction

1.1 Shoulder Drop-off

The shoulders adjacent to the pavement's surface are one of the most crucial and essential parts of the overall structure of the pavement as shoulders offer lateral support for the pavement. Shoulders are often used as a recovery area when a car wheel comes off the pavement, a location for cars to stop in an emergency, and extra width to allow large agricultural equipment. (Jensen et al., 2015)

Shoulder drop-off is the vertical elevation difference between the pavement's surface and the adjacent shoulder surface. Various drop-off levels are identified in Figure 1. Less than 1-inch drop-off can be classified as slide edge drop-off, anywhere between 1-inch to 3-inches drop-off can be classified as moderate edge drop-off and greater than 3-inches drop-off can be classified as extensive edge drop-off. (Khanapuri et al., 2022)

Figure 1: Various Drop-off levels

(Edge Drop-off - LGAM Knowledge Base, n.d.)

Shoulder edge drop-off can occur on roads with both paved and unpaved shoulders. Insufficient maintenance, improper resurfacing, vehicle wheels leaving the road, and erosion by wind and water can result in significant drop-off. Shoulder edge drop off may also be caused by the settlement of shoulder and wind and water erosion material at the pavement's edge. As a result, a sudden transition between the paved lane and the unpaved shoulder might occur. (Jensen et al., 2015)

1.2 Role of Shoulder Edge Drop-off in Road Safety

One of the most alarming problems in the global transportation industry is the number of traffic accidents and fatalities. Shoulder edge drop-off contributes to these traffic accidents significantly. Shoulder drop-off can affect the vehicle's stability. It can result in loss of vehicle control.

According to the National Highway Traffic Safety Administration (NHTSA), there were 38,824 motor vehicle traffic fatalities in the United States in 2020.

Shoulder drop is one of the most frequently cited causes of accidents in these cases. (National Road Safety Week Statistics 2023, n.d.)

In terms of Bangladesh no data is available on shoulder drop-off related crashes and there is not enough data available globally. (Hasanat-E-Rabbi et al., 2014)

Statistics from 2002 to 2004 show that pavement edges may have contributed to up to 18% of rural run-off road crashes on paved roads with unpaved shoulders in Iowa, whereas it was much higher in Missouri, at over 25%. (Hallmark et al., 2006)

1.3 Significance of the Study

The current specification of transportation agencies of Bangladesh does not have any design guideline regarding shoulder drop-off criterion and these agencies did not include shoulder drop-off as a design element. Additionally, clear guidelines regarding assessment of shoulder drop-off conditions are desperately needed.

Findings of this research can be used to address these necessary issues. This study would be helpful in providing a clear picture of the conditions of shoulder drop-off and necessary data to include shoulder drop-off as a geometric design element. At the same time this research would be helpful to automate shoulder drop-off assessment.

1.4 Objectives of the Study

This study is focused on,

- to briefly review condition of shoulder edge drop-off in Bangladesh
- to measure shoulder drop-off comparing rigid and flexible pavement.

Chapter 2 Literature Review

This chapter summarizes the findings of literature review performed on various existing research and studies, AASHTO guideline, and Roads and Highways Department, Bangladesh guideline.

2.1 AASHTO Geometric Design of Highways and Streets

The AASHTO design manual emphasizes the need for routine maintenance to preserve shoulder elevation close to the pavement surface. It doesn't specify the appropriate level of edge drop off. It claims that unstabilized shoulders' elevation will eventually get lower than the pavement surface because they consolidate with time. (AASHTO, 2001).

2.2 Existing Research

Hallmark et al. (2006) discussed the safety impacts of pavement edge drop-off on rural two-lane paved roadways. The study aimed to assess the contribution of pavement edge drop-off to crash frequency and severity. The study also tried to evaluate the existing specifications addressing pavement edge drop-off.

The study found out that edge drop-off related crashes are relatively low in number but more likely to involve fatalities or severe injuries and recommended necessary steps such as conducting training on training on the potential hazards of pavement edge drop-off and on maintenance of shoulder edge drop-off.

In a study, Jensen et al. (2015) reviewed the current methods that are being followed to design and construct and maintenance of pavement drop-offs.

The study also analyzed the factors affecting shoulder drop-off problems and find out necessary measures to mitigate related problems such as reclaim material that has moved away from the pavement edge, add soil and material to raise and to stabilize the shoulder, widen the lane and pave the shoulder etc.

Khanapuri et al. (2022) proposed a low-cost solution to automate the process of shoulder drop-off assessment on highways using cloud data acquired from a 3D solid-state LIDAR sensor mounted on a car traveling at highway speeds.

Figure 2: Lidar Sensor and Mounted Camera Setup

(Edge Drop-off – LGAM Knowledge Base, n.d.)

The paper used statistical, machine learning, and end-to-end deep learning methods to predict the vertical elevation of shoulder drop-off with accuracy greater than 95% which can go up to 96.8% accuracy by using CNN with robust regression smoothing (RSS) and Gramian Angular Fields (GAF) as a pre-processing method.

2.3 Roads & Highways Department Guidance

Although RHD does not have any specifications regarding acceptable level of shoulder drop-off, it is assumed that no elevation difference should be there between pavement and shoulder. But in a study conducted on several national highways it identified that shoulder drop-off is present in the roads. It also identified risky and defective shoulder drop-offs and proposed probable solutions of the identified shoulder drop-offs. (ROAD SAFETY AUDIT REPORT FY 2017-2018, n.d.)

Figure 3: Risky & Defective Shoulders

(ROAD SAFETY AUDIT REPORT FY 2017-2018, n.d.)

2.4 Summary of the Literature Review

Existing work that has been done on shoulder drop-off is not significant. Current specification of transportation agencies of Bangladesh does not have any design guideline regarding shoulder drop-off also and these agencies did not include shoulder drop-off as a design element. As a result, there is a desperate need for study and data to assess shoulder drop-off conditions and take necessary measures. Therefore, this topic remains the subject of considerable discussion and research.

Chapter 3 Data Collection Method

3.1 Data Collection Tool: Profilometer

For this study, an indigenously made profilometer was used. An Arduino-based profilometer was built to measure and identify risky shoulder edge drop-offs on different highways. The profilometer could measure the shoulder drop-off along with the drop-off angle.

Figure 4: The Profilometer

3.2 Details of the Profilometer

3.2.1 Wheels

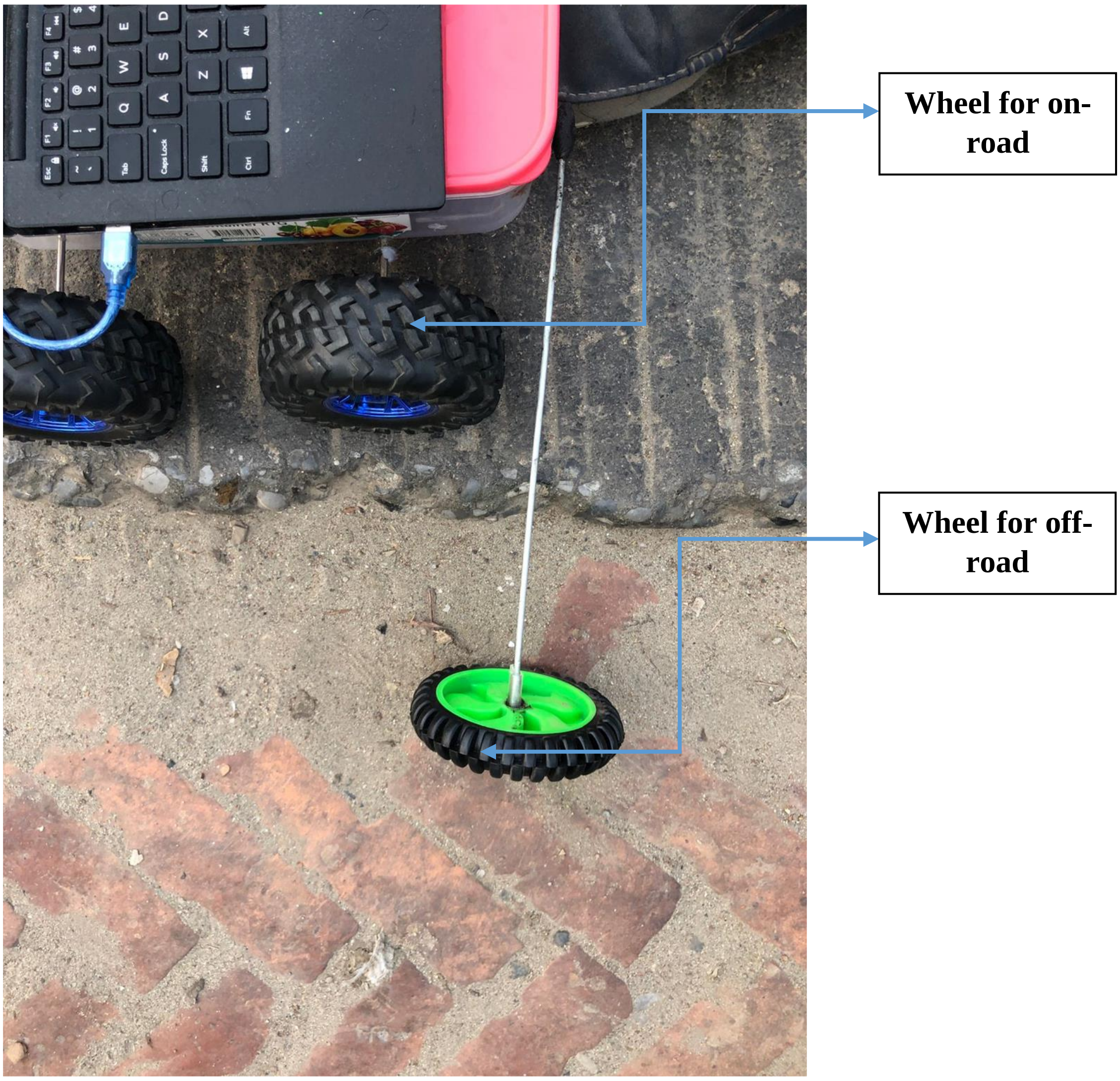

Figure 5: Wheels

3.2.1.1 Wheel for on-road

This wheel is placed on the road surface for measuring the travelled distance. It is used in the vehicle to calculate and provide accurate readings of the distance travelled. The wheel rotates as the vehicle moves, and the number of rotations is measured to determine the distance travelled.

3.2.1.2 Wheel for off-road

Placed on the shoulder for measuring the height of the drop-off with respect to the road surface. This wheel is connected to a rotary encoder, which is used to ensure accuracy in measuring the height difference between the road surface and the surrounding shoulder.

3.2.2 Rotary Encoders for Measuring Height

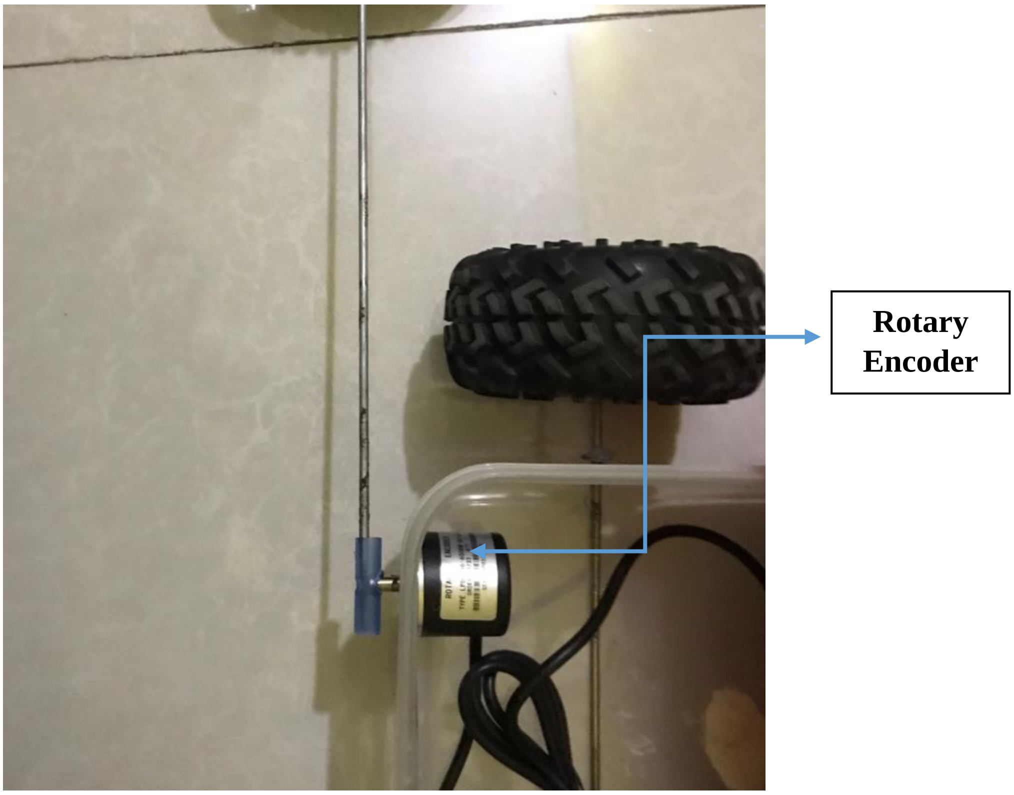

Figure 6: Rotary Encoders for Measuring Height

This rotary encoder can measure the actual height of the shoulder drop-off regarding the road surface. This angular encoder can provide node values with optimal precision. These obtained values are then converted in height (cm) using the Arduino IDE.

3.2.3 Other Parts

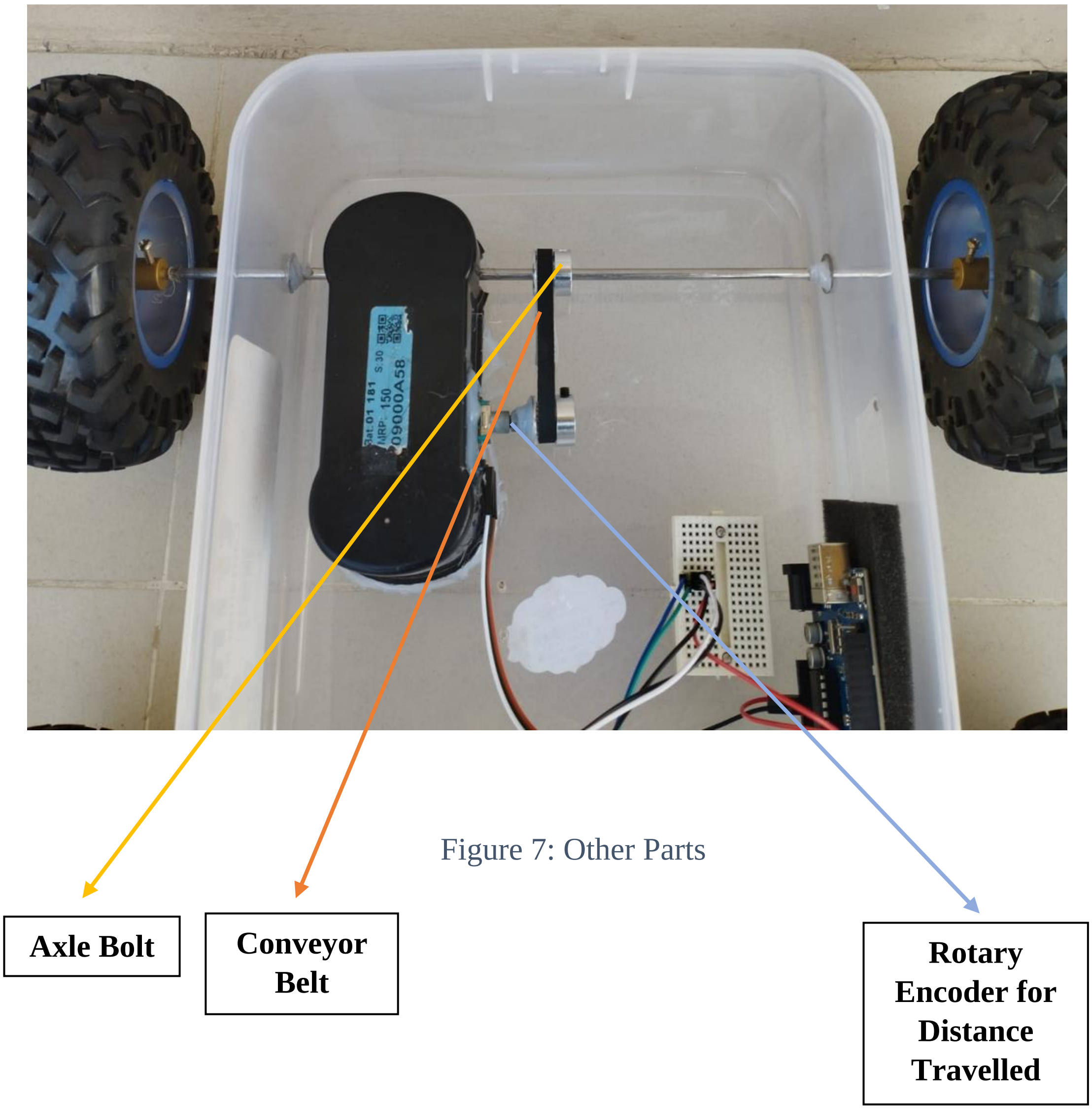

Figure 7: Other Parts

3.2.3.1 Axle Bolt

A bolt is connected to the axle. As a result, the bolt must rotate when the axle rotates. It transfers the rotational motion to the rotary encoder through the conveyor belt.

3.2.3.2 Conveyor Belt

A belt connects the rotary encoder with the axle bolt. So, the rotary encoder can measure the rotational motion of the axle. Moreover, the belt acts as a connector between the axle bolt and the rotary encoder.

3.2.3.3 Rotary Encoder

The rotary encoder measures the travelled distance. It determines the distance travelled by measuring the number of rotations. The round surfaced bolt that is connected with the axle transfers rotational motion to the rotary encoder. The conveyor belt connects the rotary encoder with the axle bolt which ensure accurate measurement of the distance travelled using the rotary encoder.

Chapter 4 Data Collection and Findings

Data was collected from three locations: two with flexible pavement and one with rigid pavement. T-scale measurements were used to evaluate shoulder drop-off, and a comparative analysis was conducted to validate the profilometer data.

4.1 Location 01

The type of pavement under consideration is classified as flexible pavement. The site is situated at the front of IUT, along the Dhaka-Mymensingh Highway (N4).

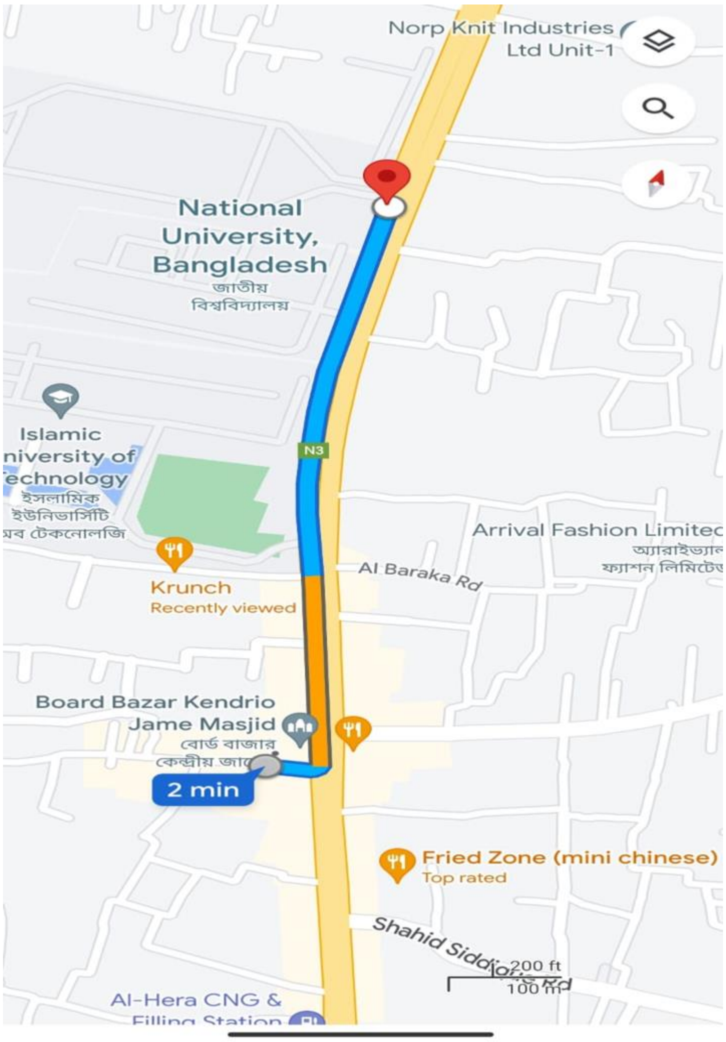

Figure 8: Location 01

(Google Maps)

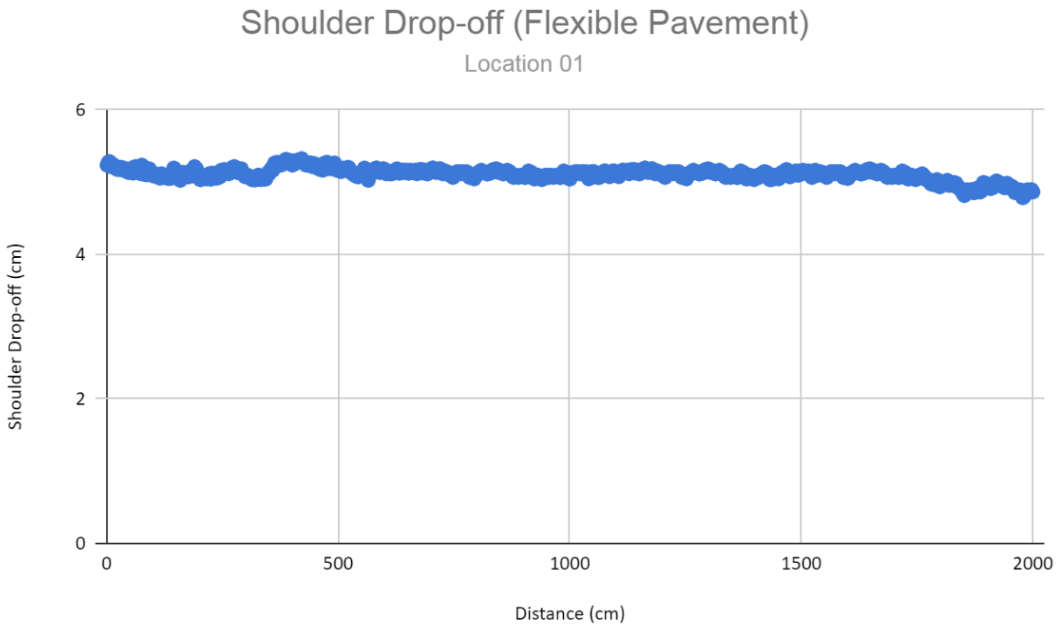

Figure 9: Shoulder Drop-off in Location 01

Figure 10: Shoulder Drop-off in Location 01
(Using t-scale)

The shoulder drop-off measured using the profilometer was in the range of 4.75 cm to 5.30 cm, where the average shoulder drop-off is 5.10 cm. and the shoulder drop-off measured using a t-scale was 4.95 cm.

4.2 Location 02

The type of pavement under consideration is classified as rigid pavement. The site is situated at the Dhaka - Demra Staff Quarter Road (Meradia Main Road).

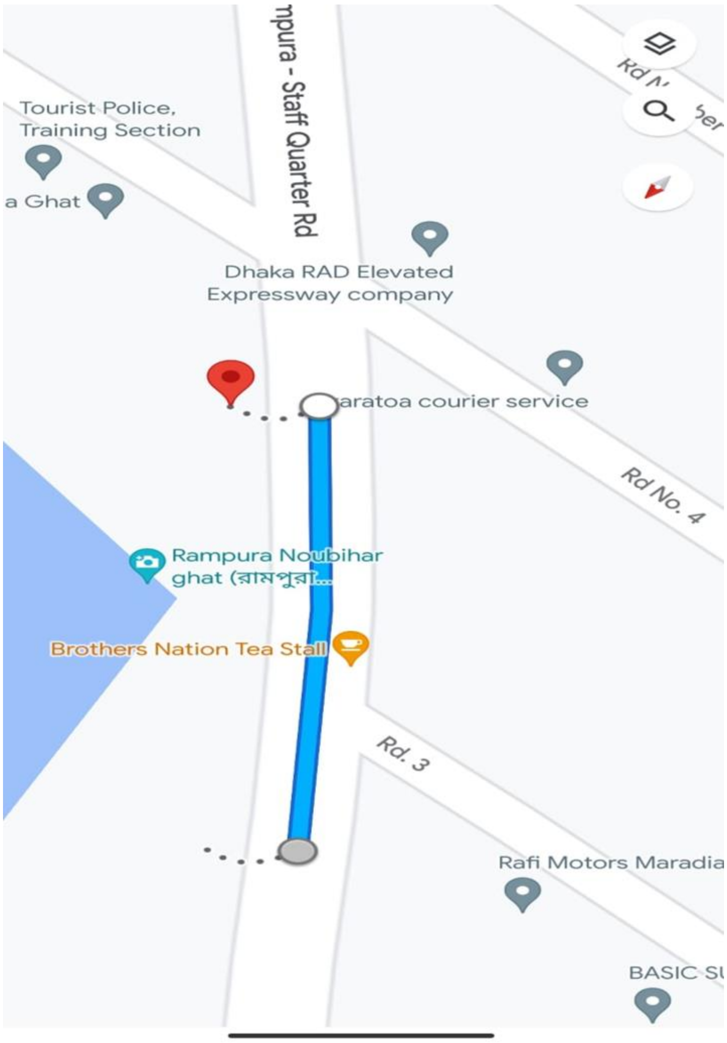

Figure 11: Location 02

(Google Maps)

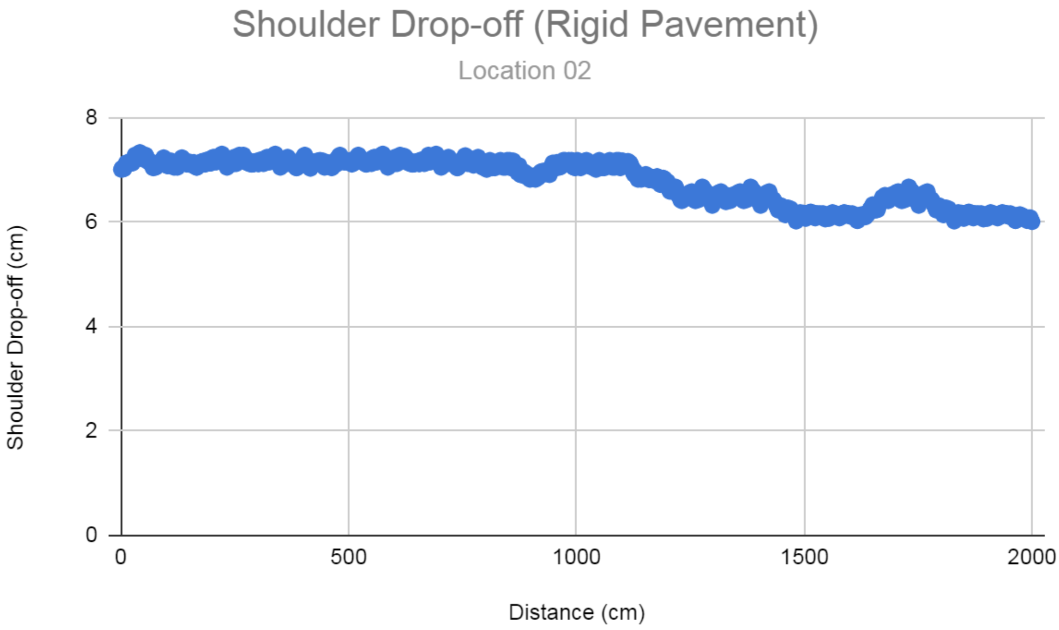

Figure 12: Shoulder Drop-off in Location 02

Figure 13: Shoulder Drop-off in Location 02 (Using t-scale)

The shoulder drop-off measured using the profilometer was in the range of 5.90 cm to 7.40 cm, where the average shoulder drop-off is 7.09 cm. and the shoulder drop-off measured using a t-scale were 5.90 cm and 6.70 cm.

4.3 Location 03

The type of pavement under consideration is classified as flexible pavement. The site is situated at the Jahurul Islam Avenue (Aftabnagar Main Road).

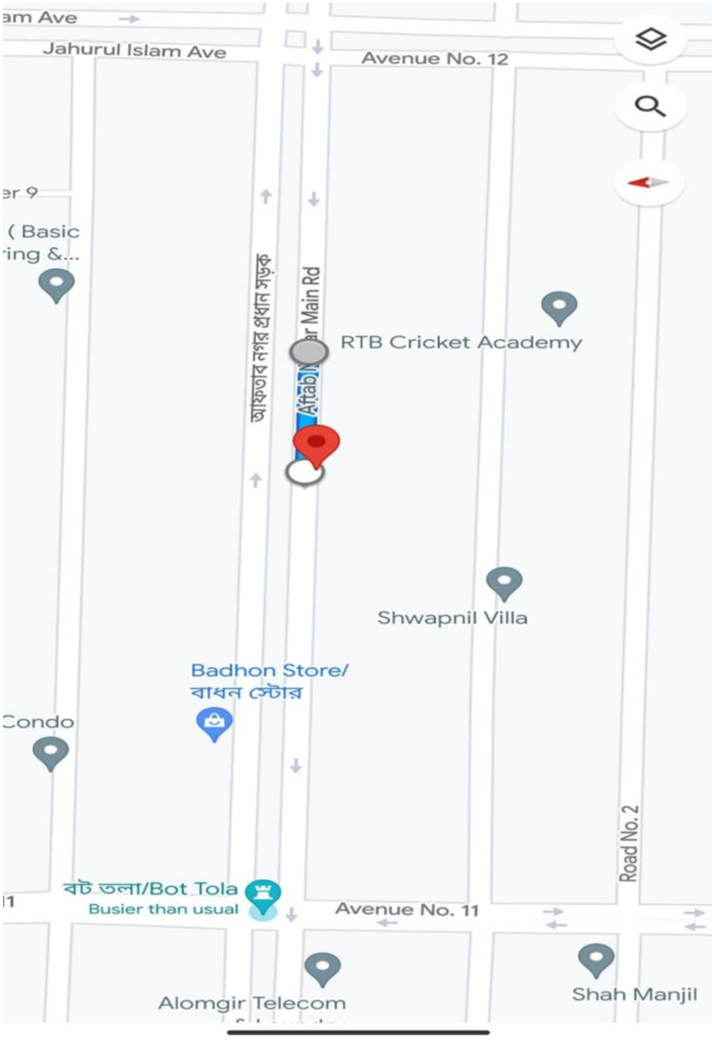

Figure 14: Location 03

(Google Maps)

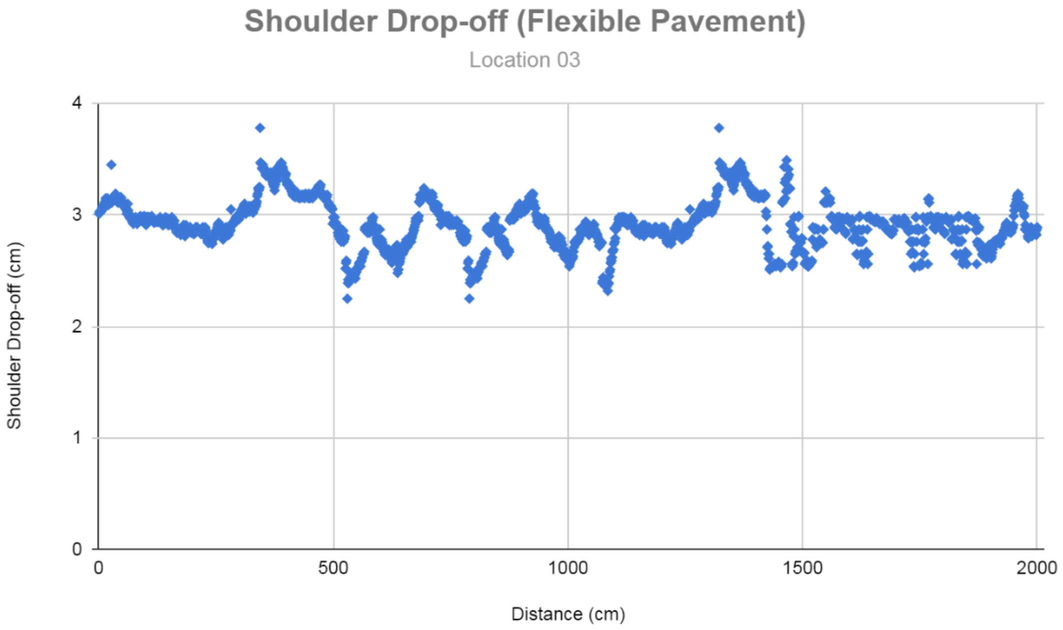

Figure 15: Shoulder Drop-off in Location 03

Figure 16: Shoulder Drop-off in Location 03 (Using t-scale)

The shoulder drop-off measured using the profilometer was in the range of 2.40 cm to 3.60 cm, where the average shoulder drop-off is 3.07 cm. and the shoulder drop-off measured using a t-scale was 3.45 cm.

Chapter 5 Conclusion

Data were collected from three different locations and subsequently compared to measurements collected using the t-scale. The findings of this comparison led to the conclusion that the profilometer is capable of measuring shoulder drop-off accurately.

Considering the significant level of accuracy performed by the profilometer, it is a viable tool for the nationwide measurement and prediction of shoulder drop by road agencies in the country.

Chapter 6 Future Scope

The profilometer can be improved to become a dependable and resilient device capable of sensing shoulder drop-off over extended distances (for example, 50-100 km).

Furthermore, to automate the measurement procedure, this profilometer can be modified into a line-following robot.

This would improve data collecting efficiency and accuracy while also increasing overall safety. It will also save time and resources in the long run.

References

[1] Hallmark, S. L., Veneziano, D., McDonald, T., Graham, J., Bauer, K. M., Patel, R., & Council, F. M. (2006). Safety Impacts of Pavement Edge Drop-off. *AAA Foundation for Traffic Safety, Washington, DC*.

[2] Jensen, W., & Uerling, N. (2015). Mitigating pavement edge drop off.

[3] Khanapuri, E., Manasreh, D., Rechtin, M., Sharma, R., Kim, D., & Nazzal, M. (2022). Low-Cost Shoulder Drop-off Prediction for Highways Using Learning-Based Methods.

[4] Edge Drop-off - LGAM Knowledge Base. (n.d.). Retrieved April 20, 2023, from http://lgam.wikidot.com/edge-drop-off.

[5] National Road Safety Week Statistics 2023. (n.d.). Retrieved April 20, 2023, from https://safety4life.org/national-road-safety-week-statistics-2023/.

[6] Hasanat-E-Rabbi, Shahnewaz & Ahmed, Ishtiaque & Hoque, Md. (2014). Heavy Truck Rollover Model for Single Vehicle Run–off–Road Crashes in Bangladesh. Jurnal Teknologi. 70. 10.11113/jt.v70.3484.

[7] AASHTO (2001). A Policy on Geometric Design of Highways and Streets. American Association of State Highway and Transportation Officials, Washington, D.C. 20001

[8] ROAD SAFETY AUDIT REPORT FY 2017-2018. (n.d.). rhd.portal.gov.bd. Retrieved January 11, 2023, from https://rhd.portal.gov.bd/sites/default/files/files/rhd.portal.gov.bd/page/0516306c_acec_43f9_a524_bac73f38ddd7/2021-03-02-17-03-4afb511c15e2d949662959dd290f5243.pdf

9% Overall Similarity

Top sources found in the following databases:

- 8% Internet database
- 2% Publications database
- Crossref database
- Crossref Posted Content database
- 3% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	rosap.ntl.bts.gov Internet	1%
2	s-space.snu.ac.kr Internet	<1%
3	dot.state.mn.us Internet	<1%
4	coursehero.com Internet	<1%
5	eprints.qut.edu.au Internet	<1%
6	content.edgar-online.com Internet	<1%
7	mir.cs.illinois.edu Internet	<1%
8	wpost.com Internet	<1%

9	Sri Lanka Institute of Information Technology on 2016-12-04 Submitted works	<1%
10	ideals.illinois.edu Internet	<1%
11	Eshaan Khanapuri, Dmitry Manasreh, Michael Rechtin, Rajnikant Sharm... Crossref posted content	<1%
12	s3-eu-west-1.amazonaws.com Internet	<1%
13	slidelegend.com Internet	<1%
14	techrxiv.org Internet	<1%
15	mospace.umsystem.edu Internet	<1%

Excluded from Similarity Report

- Bibliographic material
- Cited material
- Manually excluded text blocks
- Quoted material
- Small Matches (Less then 8 words)

EXCLUDED TEXT BLOCKS

the safety impacts of pavement edge drop-offon rural two-lane paved roadways

dot.state.mn.us

statistical, machine learning, and end-to-end deep learningmethods to predict the ...

www.techrxiv.org

Department of Civil and Environmental EngineeringIslamic University of Technolog...

www.inderscience.com

this thesis

Loughborough University on 2011-09-05