Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

Evaluation and Validation of the Causes for Cobblestone Road Failures in Hawassa City

Tigist Assefa[1]*, Tigist Guracha,[2] Erste Telila[2], Temesgen Aynabeba[2]

[1] *Hawassa University. Institute of Technology*
tgcassefa@gmail.com; tigistassefa@hu.edu.et

Abstract

Potholes, shoddy bonding, and insufficient drainage cause cobblestone roads to become less serviceable. Hawassa city's cobblestone roads are currently in a very bad shape, especially in the study area where problems including inappropriate cross-sectional slopes, clogged drainage systems, and construction flaws are common. The lack of legal load limitations makes these issues even worse by encouraging freight vehicles to utilize the roads excessively, which shortens their lifespan and speeds up deterioration. The main goal of this study is to evaluate the state of Hawassa City's cobblestone roads by examining the reasons behind failures in connection to subgrade strength, traffic volume, and drainage functionality. In order to suggest practical corrective actions, the study employs both primary and secondary data collection techniques. Key aspects of the research include evaluating the subgrade strength through laboratory tests, analyzing traffic volume against recommended standards, and assessing the drainage condition by examining the availability and functionality of ditches. The methodology involves various approaches such as descriptive analysis, laboratory testing, and exploratory studies, using purposive sampling techniques. Field assessments include visual inspections, measuring deteriorated road segments, and capturing photographic evidence. Laboratory analyses focus on determining soil properties such as density, maximum dry density, and California Bearing Ratio (CBR) values by testing representative samples from the study area. The findings reveal that the cobblestone road segments in the study area are in moderate to poor condition. These roads handle traffic volumes exceeding the recommended standards for routes connecting main roads to public areas. The study identifies several causes of failure, including poor cross-sectional slopes, inadequate ditch functionality, lack of timely maintenance, absence of legal load limits, and substandard construction practices. Despite the subgrade soil meeting the recommended standards, the road failures are primarily attributed to the aforementioned issues. To address these challenges, the study recommends that the city municipality implement scheduled road condition surveys, regular maintenance, construction of functional ditches, and the enforcement of legal load limits. These measures are crucial to extending the service life of low-volume roads and mitigating further deterioration.

Keywords: Cobblestone road failures, road condition survey, subgrade strength, California Bearing Ratio (CBR), traffic volume

1 Introduction

Cobblestone road is an emerging and indigenous technology in Ethiopia and it has so many advantages like enhancing the country and local economy, answering the political question raised by community due to increasing the development requirement as a result of the community need for urban infrastructure, minimize the rate of unemployment, creating the job opportunities for youth and especially for women. The cobblestone road construction technology is started from the time when 2005 E.C. The Government and the community participation conduct the project. In developing countries like Ethiopia, federal governments face financial constraints due to factors such as rapid urbanization, limited access to foreign exchange, and the overwhelming need for essential infrastructure, including roads (Tadesse & Desta, 2023)

Road conditions deteriorate over time due to factors such as weather exposure, soil instability, aging, material defects, design errors, construction flaws, and the impact of traffic loads. Understanding the root causes and patterns of these failures is crucial for implementing effective maintenance strategies, which typically include both routine and periodic maintenance activities. (Mengistu & Teshome,2023)

The deterioration of roads is influenced by a combination of environmental factors such as weather, soil properties, and climate, along with issues stemming from aging, material failure, construction defects, design flaws, and traffic stress. Maintenance activities can effectively address these problems by targeting both routine and periodic repairs.Routine maintenance helps in managing daily wear and tear, while periodic maintenance

addresses more extensive damage and restores the road's condition to its optimal state. Factors such as rainfall intensity, traffic volume, and road geometry significantly affect how quickly roads degrade. Effective management of these factors, including proper drainage systems and timely repairs, is essential to prolonging the road's service life.

Cobblestone-paved streets contribute significantly to addressing social and economic challenges in communities across the country, including their particular importance to the newly established Sidama Regional Government and Hawassa city and also such infrastructure supports local development by improving accessibility and fostering economic activities. (Osei and Boateng ,2021) Cobblestones are ease of maintenance and have a longer life span than asphalt roads. (Adamu & Chijioke, 2022) also argued that Cobblestones last a long time.

If maintenance is not carried out the road will continue to deteriorate making passage increasingly difficult, uncomfortable and expensive to road users (World Bank,2021)So, it is very important to preserve and manage the existing paved roads which could be deteriorated because of so many reasons. Preserving this Cobblestone paved streets can also be used as a good base or foundation for asphalt in the long ran as stated that even though the stones themselves may be obsolete surfacing (Goh & Lee, 2021). What so ever may be the reasons; Cobblestone roads in Hawassa city are becoming bad and damaged highly, and deteriorated with in few years after construction. So, the main points raised here in this research paper for discussion will be issues related with the technical evaluation of causes of the cobblestone road and to find the maintenance type based on the type of failures.

The community and the local government are participating in the construction and pavement of the Cobblestones as doing in every activity of local development in a very little participation of other development actors or stakeholders. But this type of participation is not clearly seen or repeated in keeping the safety of the Cobblestone roads by developing the sense of ownership. When people have a direct hand in deciding the course of action to better their environment, they develop a strong sense of ownership that leads to their active involvement in improvement and maintenance activities (African Development Bank,2020).

Ethiopia is currently experiencing rapid growth across various sectors, leading to accelerated urbanization and population growth in cities due to economic advancements. The level of a country's development is often evaluated by the distribution and quality of its infrastructure.

Cobblestone road construction is a relatively recent initiative aimed at improving urban infrastructure in Ethiopia. Despite its increasing implementation in urban areas, no specific research has been carried out on this subject in the Sidama region or in Hawassa city, highlighting a gap in understanding the unique challenges and opportunities associated with this development.

Despite their social and economic benefits, cobblestone roads deteriorate due to various factors. After construction, these roads often receive inadequate attention, as responsible authorities fail to prioritize scheduled maintenance. This issue is particularly evident in Hawassa city. The community has expressed dissatisfaction with the government, criticizing the lack of timely maintenance for deteriorating roads.

As discussed by (Charles & Lufump, 2017) many cities in developing regions, particularly in Africa, face significant challenges in providing essential infrastructure such as roads, sanitation, drainage systems, and water supply. The rapid expansion of urban areas often outpaces the development of these critical amenities. To enhance urban infrastructure and establish well-planned urban environments, the fulfilment of basic urban services is essential. However, most developing countries struggle to meet these requirements.

Since the initiation of the cobblestone project in Ethiopia, issues related to the quality and accessibility of these roads have been a major concern. According to (African Development Bank ,2019), the project, while offering benefits such as job creation and urban beautification, has faced challenges in ensuring consistent quality standards and equitable access to infrastructure improvements across communities. Addressing these shortcomings is crucial for sustainable urban development in Ethiopia and other developing nations.

Currently, cobblestone roads are deteriorating over time due to a variety of factors, including inadequate maintenance, failure to control legal load limits, improper cross-sectional slopes, and drainage issues. These challenges are further aggravated by problems associated with the paving process and execution. Although Hawassa city adopted cobblestone road technology a decade ago, the persistence of these issues emphasizes the urgent need for improved maintenance practices and effective infrastructure management to ensure the durability and safety of these roads.

Despite using locally available materials for road construction, many newly built roads face significant problems after their design, launch, and implementation. A key issue is the absence of a planned schedule for monitoring, maintaining, and improving roads once they are open to traffic. This lack of systematic follow-up contributes to accelerated deterioration, reducing the functionality and lifespan of these roads.

The local government primarily focuses on constructing roads, creating employment opportunities for the unemployed, and enhancing the city's cleanliness and aesthetics. However, when roads are neglected, without technical assessments of their condition and periodic maintenance to address underlying issues, they deteriorate to a point where repairs become unfeasible, necessitating costly reconstruction. This neglect not only increases financial burdens but also poses significant risks, including traffic accidents, loss of lives, and delays.

Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

This situation is evident in the case of cobblestone roads in Ethiopia, particularly in Hawassa city. This study aims to conduct a technical assessment to identify and evaluate the causes of road failures. It examines factors such as construction practices, subgrade soil strength, drainage conditions, and traffic volume across the selected route segments. Based on these findings, the study proposes remedial measures for the Hawassa City Roads Authority to address these challenges effectively and improve the sustainability of cobblestone roads. Therefore, the general objective of this study was technical evaluation and validation for the causes of cobblestone road failures at Hawassa city.

2. Materials and Methods

2.1 Description of the study area

Hawassa is the capital of the Sidama Regional State Government. The city is administratively divided into eight sub-cities and 32 Kebeles, with 20 urban and 12 rural Kebeles. The total land area of Hawassa is 15,720 hectares, and the urban part of the city, encompassing the municipal boundaries, covers 65 square kilometers. This administrative structure facilitates local governance and development within the city, ensuring that both urban and rural areas are managed effectively.

2.2. Location

Hawassa is the seat of Sidama Regional State Government found 275km south of Addis Ababa with approximate geographical coordinates of 70 North and 38.50 East

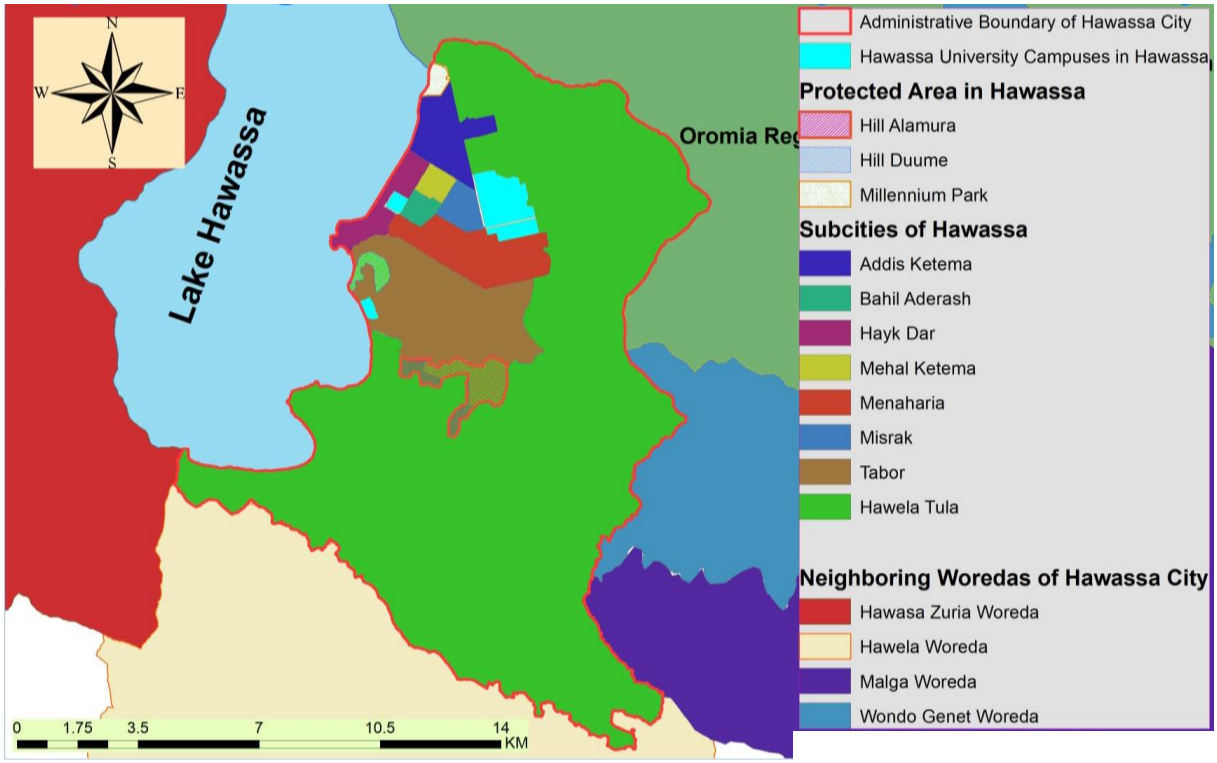


Figure 1. Location map of the study Area

2.4. Research materials

To address the objectives of this research on the study area leveling equipment, digital camera, tape, sacks and laboratory equipment's were used for assessing the condition of study area cobblestone road.

2.5. Research methods

To work with the objectives of these studies descriptive type of research methods has been used. Descriptive type focuses on assessing the condition of selected area cobblestone road segments through following a two step process. The first step is to define the different types of deterioration that affect the different road surface types and the second is quantify them.

The research follows several key stages, including data collection, analysis, and interpretation of the results. It then discusses the findings and draws conclusions based on the data. Finally, the study provides recommendations derived from the results, aimed at addressing the identified issues and improving future practices. These steps are crucial in ensuring that the research is thorough, evidence-based, and provides actionable insights for stakeholders involved in the study.

2.6. Data collection

2.6.1. Types and source of data

The data source of this study is both primary and secondary. The primary source of data was obtained from field survey, by different techniques, sample collection and laboratory analysis. The secondary source of data gathered form municipality and review documents

2.7. Study subject and design strategy

Cobblestones have been a prevalent choice for roads and sidewalks for developing and developed countries. Cobblestones are small to medium-sized rounded, square stones used as pavement material for roads and walkways. (Smith & Patel 2021)

In Ethiopia Cobblestone is a developing technology, which makes perfect sense for expanding urban roads. It is labor-intensive, creating jobs as well as opportunities for construction entrepreneurs. It uses natural and local materials that are plentiful. It is also cost-effective compared to concrete and asphalt roads, easy to maintain and has a much longer lifespan. Moreover, it is easy to replicate elsewhere, because the investment needed is relatively small and production skills are easy to learn. (World Bank, 2022).

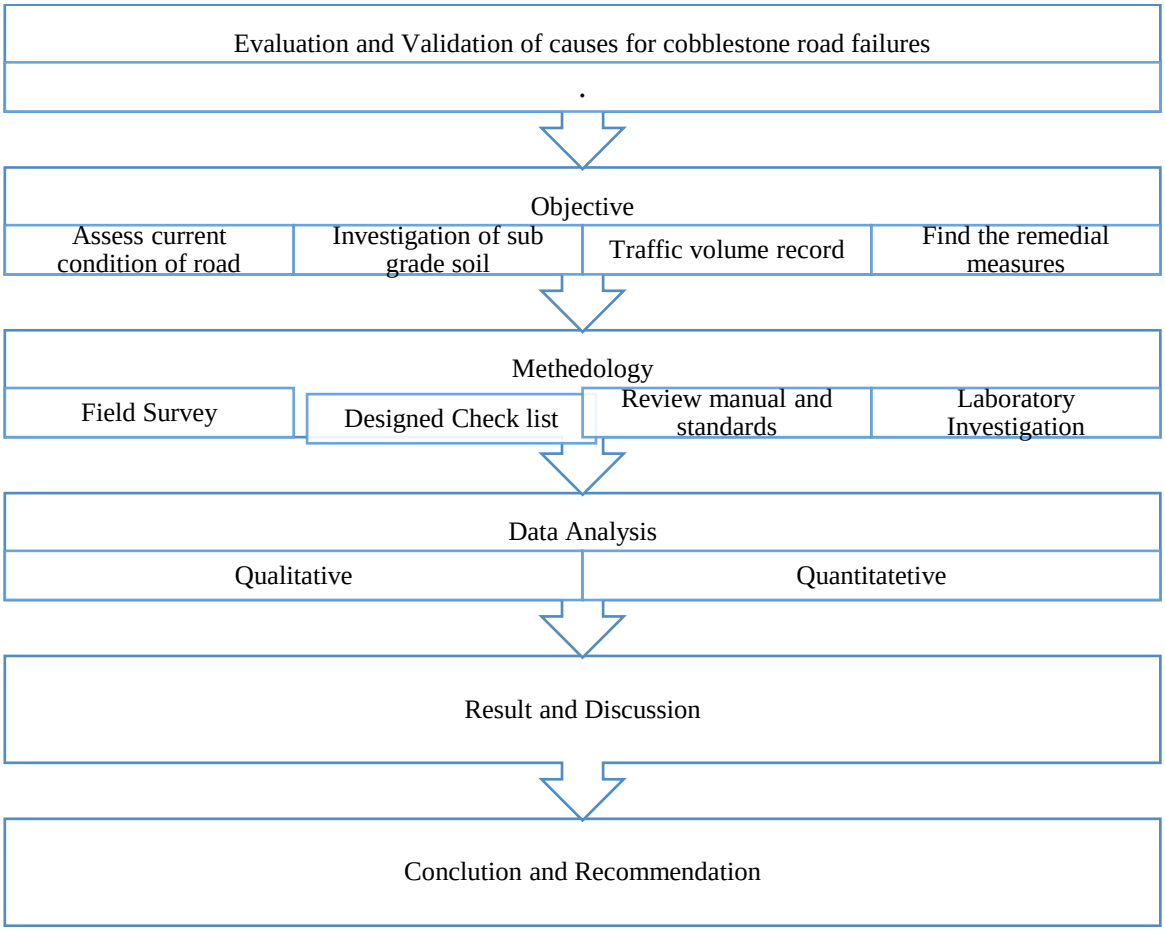


Figure 2. Design sequence of the research work flow chart

Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

2.9. Study type

The study type of this research is both quantitative and qualitative. The quantitative study method is used to measure the California Bearing Ratio (CBR) of the sub surface soil, determine the traffic volume for the types of vehicle using the selected routes, measure the cross-sectional slope provided and the clogged ditch depths. The other type of study used in this research is qualitative study method

Based on the total number of routes that found on study area the researchers follow purposive sampling method to determine the sample size for the study.

2.9.2. Sampling techniques (procedure)

The researchers interested in evaluation and validation of the causes for cobblestone road failures. , Through having field observation for checking current condition of road, drainage condition considering crossectional slope, vehicles type recording and taking soil sample for lab investigation. Hence, purposive sampling techniques was employed in the selection of routes

2.10. Relation of Subgrade Strength California Bearing Ratio (CBR)

The strength of subgrade soils is dependent on the type of soil, density, and moisture content. The design CBR of the subgrade soil, therefore, should be evaluated at the moisture content and density representative to the subgrade condition during the service time of the pavement structure.

2.11. Data Analysis

2.11.1. Analysis on the current condition of cobblestone

The analysis on this research is work with the four sub cities of the Hawassa city selected cobblestone road segment. The total area of the selected sub city route and the deteriorated one is calculated and then use indicator scales for rating the types of deterioration in the form of level.

2.11.3. Traffic Volume data

For this study the video and manual counting data are used to determine the current value of the total vehicles that handled on the selected routes and the collected traffic data is for three days taking the peak and normal traffic flow time morning and afternoon two week days and one weekend and he crossectional slope is analyzed based on the field data collected using leveling equipment.

3. RESULTS AND DISCUSSIONS

3.1. Cobblestone road condition of the study area

The cobblestone roads of Hawassa Town are in a deteriorating state, presenting significant challenges for both pedestrians and vehicles. Many sections are marked by uneven stones, deep cracks, and gaps that not only compromise the aesthetic appeal of this vibrant area but also pose safety hazards for travelers. Rutted surfaces and pooling water during rains exacerbate the situation, making navigation difficult and uncomfortable. This neglect impacts local commerce and tourism, hindering the town's potential for economic growth and affecting the overall quality of life for residents. Urgent attention to the infrastructure is needed to restore the roads and ensure safe and efficient transportation for everyone in Hawassa.

Table 1. Survey condition result

	Route	Total route Area (m2)	Deteriorated Route Area (m2)	Deteriorated Area (%)
Bahil Adarash	RDC-LR-BA-HA-415 (BA 1)	7000	840	12
	RDC-SR-BA-HA-409 (BA 2)	3000	420	14
	RDC-SR-BA-AD-408 (BA 3)	5000	798	15.96

Misrak	RDC-PR-MS-TE-813 (Dagim Gym)	5000	1904	38.08
	RDC-SR-MS-TE-812 (Yeshi-campas)	5000	2100	42
	RDC-PR-MS-TE-814 (Mis 1)	5000	1602	32.04
Menehariya	RDC-SR-MN-ML-273 (yeshi)	5000	2000	40
	RDC-SR-MN-ML-274 (Yeshi tele)	5000	2100	42
	RDC-SR-MN-ML-272 (YS3)	5000	1900	38
Tabor	RDC-CR-TA-HT-145 (Fulgospel)	7000	840	12
	RDR-SR-TA-DU-180 (Sankofa)	3000	300	10
	RDR-SR-TA-DU-181 (koci)	2000	204	10.2

The dteriorated area of the Bahil Adarash sub city for the route BAR1 is 840 m^2 from total area of 7000 m^2 which is 12% , for Misrak sub city route of Dagim gymnasim 1904m^2 which is 38% from 5000 m^2 , menehariya route of yeshi to main campus 2100 m^2 from 5000m^2 which is 42% and Tabor sub city rout near to fulgospe church 840m^2 from 7000m^2 which is 12% (Table 3) and this results are based on the total area the study area route in comparition of the failure area .

The type of failures that observed in the study area are lifting of cobblestones, surface depression and failure of cobblestone edging.

3.2. Cobblestone road failure types on the study area

The observed failures on the study area cobblestone roads during the research are poor drainage, lack of bonding and carriage way slope.

Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

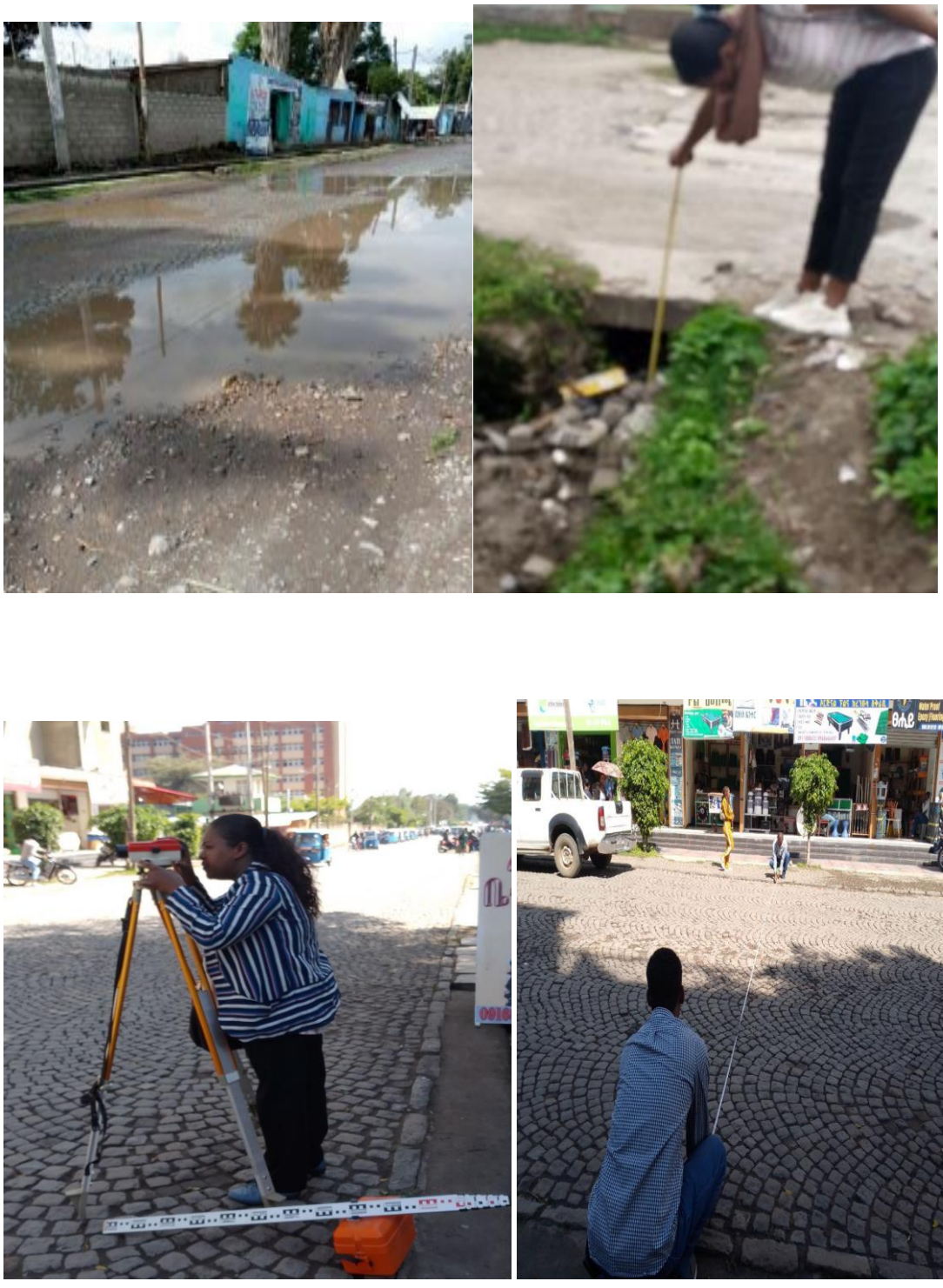


Figure 3. Failure pictures on the study area

3.3. The Sub grade strength of study area road sections with relation to CBR values

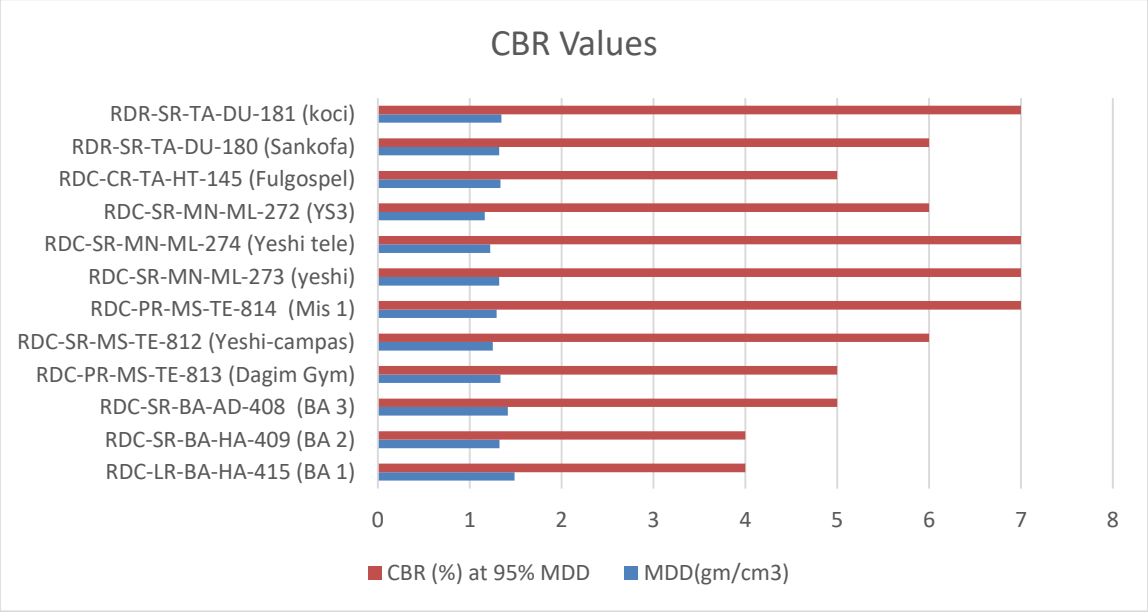
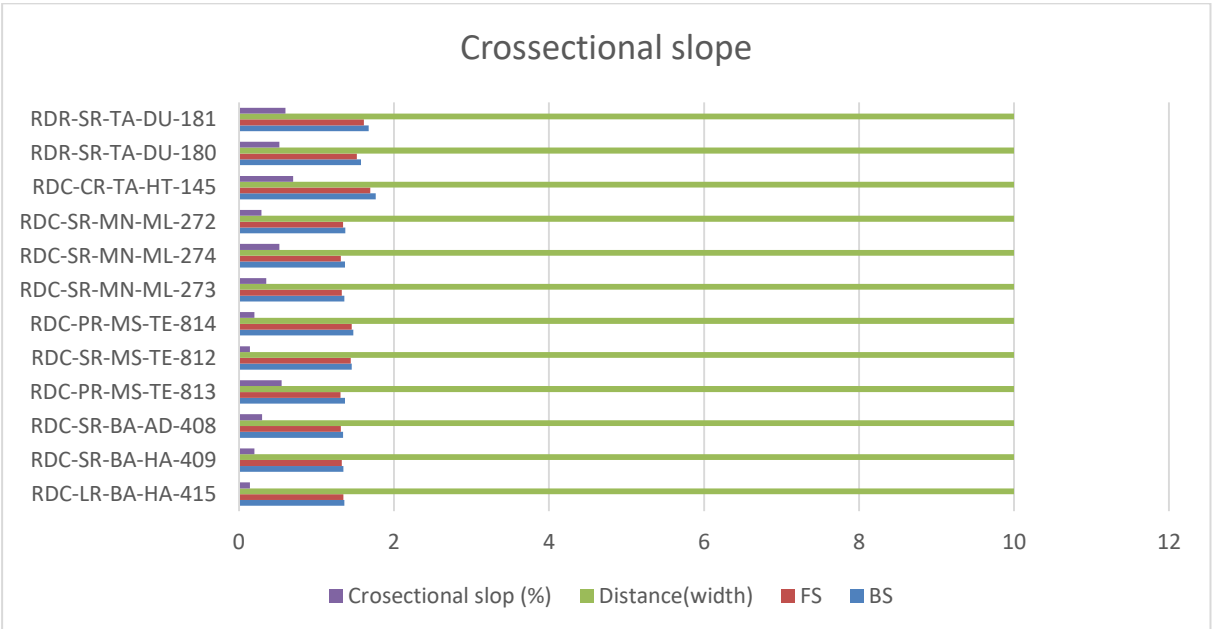


Figure 4. Laboratory Test CBR values of study area sub cities

Based on the laboratory analysis the CBR values determined at 95% of MDD, for the routes taken from Bahil Adarash subcity is 4%,4% and 5 % and the Tabor subcity 5%,6% 7% for Misrak sub city 5%, 6% and 7% for Menehariya sub city 7%,7% and6% (Chart 3.1) which fulfil the recommended standard for low volume road.

Table 2. *Traffic volume analysis result*

		Vehicle			
Sub City	car	Pick up	Bus	Truck	Total
Menehariya	658	64	16	24	762
Misirak	567	48	27	32	674
Tabor	192	11	0	0	203
Bahil Adarash	133	16	0	0	149



Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

Figure 5. *Cross-sectional slope condition*

The carriage way slope for the routes taken from Bahil Adarash subcity is 0.14%,0.2% and 0.3 % and the misrak subcity 0.55%,0.14% 0.2% for menehariya sub city 0.35%,0.52% and 0.29% for Tabor sub city 0.7%,0.52% and 0.6% (Chart 3.3) which all doesn't attain the recommended standard.

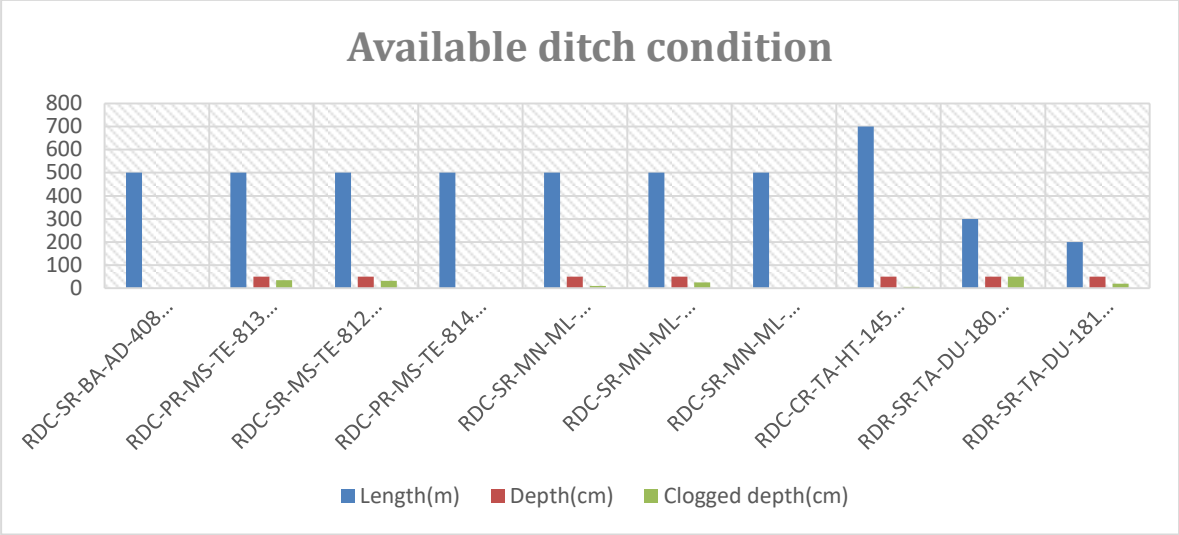


Figure 6. Study area ditch condition

Therefore, as shown in the chart and the technical assessment made on the research area side ditch more ditches are failed to give the required service and it is one of the reason for cobblestone road failure at Hawassa city.

4. Conclusion

The cobblestone road condition in the case of Bahil Adarash and Tabor sub city routes fail under moderate condition which is level 3 found between the range 10% and 16% and of world bank standard manual that recommend the moderate condition when the deteriorated area is between 6% to 20% of the total route area in the other side the researchers observe low problem with lifting of cobblestones, lack of bonding and surface depression. In Misrak and Menehariya sub city routes the cobblestone road condition fail under poor condition (level 4) with range of 38% and 42% which is under 21% to 50% with regard of world bank standard manual in addition high problem on lifting of cobblestone and surface depression failures are observed.

The condition of the cobblestone roads in the Bahil Adarash and Tabor sub-city routes falls under "moderate condition" (Level 3) as defined by the World Bank standard manual. This condition corresponds to a deterioration level where 10% to 16% of the total route area is affected, aligning with the manual's range for moderate conditions (6% to 20%). Observations in these areas revealed minor issues such as the lifting of cobblestones, weak bonding, and surface depressions.

In contrast, the cobblestone roads in Misrak and Menehariya sub-city routes are classified as being in "poor condition" (Level 4), with deterioration affecting 38% to 42% of the total route area. This falls within the World Bank's standard range for poor conditions (21% to 50%). These routes exhibit more severe problems, including significant lifting of cobblestones and pronounced surface depression failures. These findings highlight the need for targeted maintenance strategies to address the varying levels of road degradation in these sub-cities.

The sub grade strength of the study area road condition is acceptable for low volume roads since the result of laboratory test is above the allowable range 3% as the recommended standard of Ethiopian Roads Authority manual and from this the researchers conclude that as the failures is not due to poor soil strength. The traffic volume of the study area road condition of Misrak and Menehariya sub city is not acceptable for low volume road construction since the traffic analysis result is beyond allowable range which is greater than 400 traffic volume per day. In other way traffic is acceptable for tabor and Bahil Adarash sub cities of selected areas. From

this, the researchers conclude that the study area is in moderate condition with low traffic volume and poor with high traffic volume.

The construction of cobblestone paving process of study area condition comparing with respect to standard is concluded as poor based on site investigation.

The drainage system of the cobblestone roads in the study area is often obstructed by soil and various types of dry waste from the city, rendering it partially functional. This blockage contributes significantly to the failure and deterioration of the roads. Based on the study's findings, the researchers recommend that the municipality office take countermeasures, including conducting regular condition surveys, implementing measures to prevent further road deterioration, and addressing damaged areas using appropriate repair techniques tailored to the specific types of damage identified. These actions are critical to ensuring the long-term functionality and sustainability of the cobblestone roads.

If the deterioration type of a given route is lifting of cobblestones to correct the route first lift out cobblestones in demarcated area and then clean the bed, lay down a layer of clean graded sand and compact, and lay new cobblestones. If the deterioration type is surface depression lift out cobblestone in demarcated area, clean the bed, add sub-base material and compact, lay a sand bed and compact and then lay new cobblestones. If the deterioration type is failure of cobblestone edging lift out cobblestone in demarcated area, clean the bed, add sub-base material if required and compact, lay a sand bed and compact then lay new cobblestones.

In the other way for those with lack of ditch municipality office should have plan and construct. And for those available ditches but clogged should have to clear out the ditch and make functional.

In majority of the road segments the high failures that faced beyond the extent is due to poor routine and scheduled maintenance method the city road municipality office need to have scheduled maintenance time.

The types of failures such as cobblestone lifting is caused due to high and large tone vehicles so hawassa city roads authority must allow the recommendable traffic volume and vehicle with less than 5 tone weight and set policies and rules for those didn't consider and follow the legal load limit and be care of the route from failures before attaining the service life and being the cause of extra maintenance and rehabilitation cost which lead the city and country to unwanted economic wastage.

Acknowledgments

First and foremost, we are deeply grateful to God for providing us with the opportunities and resources needed to complete our study.

We extend our heartfelt gratitude to the Hawassa University Research Office for offering this opportunity, as well as for their support and encouragement, particularly in creating chances for female researchers.

Our sincere appreciation also goes to the Hawassa City Municipality Office, especially the Infrastructure Development Office. We would like to give special thanks to Engineer Amare Adisu, Coordinator of the Infrastructure Development Office, and Engineer Netsanet, Supervisor of Cobblestone Road Construction, along with their colleagues in the Infrastructure Development Asset Management Team. Their invaluable cooperation, provision of necessary information, and support were integral to the success of this research.

REFERENCES

Adamu, A., & Chijioke, O. (2022). Cobblestone pavements as a sustainable urban infrastructure solution in Africa: Case studies from Ethiopian cities.

African Development Bank. (2019). urban infrastructure challenges in Africa: Lessons from cobblestone projects and other urban initiatives. African Urban Development Journal, 26(4), 45-59.

African Development Bank. (2020). Community participation in infrastructure development: Enhancing sustainability and ownership in road projects. African Infrastructure and Development Journal, 17(1), 45-58

Charles Leyeka & Lufump, (2017), Rapid urbanization and the growing demand for urban infrastructure in Africa

Goh, H., & Lee, M. (2021). Cobblestone pavements as a foundation for sustainable urban road infrastructure: Case studies from Southeast Asia and Africa. Journal of Sustainable Construction and Development, 18(2), 56-71.

HCM,2000 Transportation research board international council

Magdi M.E. Zumrawi1 (2013), Survey and Evaluation of flexible Pavement Failures International Journal of Science and Research (IJSR) 1 University of Khartoum, Department of Civil Engineering, Khartoum, Sudan

Mengistu, B., & Teshome, F. (2023). Assessing the factors contributing to road deterioration and maintenance strategies in Ethiopia. International Journal of Transportation Engineering,

Hawassa University Journals

Volume IV
Pages: 15-25
Article Number: 1088-Article Text-5990-1-4-20240423

www.journals.hu.edu.et/hu-journals/index.php/ejet/index

Ethiopian Journal of Engineering and Technology

Nyein Nyein Thant1, Soe Soe War2 (2019), Study on Distress Patterns, Causes and Maintenance of Flexible Pavement for Selected Portions International Journal of Trend in Scientific Research and Development (IJTSRD) Volume 3

Oluwasinaayomi Faith Kasim1, Muluneh Woldetisadik Abshare (2018), Truphena Eshibukule Mukuna1 and Bolanle Wahab, Land Use and Ambient Air Quality in Bahir Dar and Hawassa, Ethiopia

Osei, P., & Boateng, D. (2021). The role of cobblestone pavements in addressing infrastructure challenges in sub- Saharan Africa

Smith, J., & Patel, A. (2021). Cobblestone pavements in urban development: A global perspective on sustainability and infrastructure. Journal of Urban Infrastructure and Development, 45(2), 112-128.

Tadesse, A., & Desta, S. (2023). The economic challenges and infrastructure needs in Ethiopia: A review of current trends. Journal of Development Studies,

World bank,(2016) second urban local government and development program asset management plan manual the federal democratic republic of ethiopia ministry of urban development and housing.

World Bank. (2021). The importance of road maintenance in developing countries: A global perspective. Transport and Infrastructure Review, 29(3), 112-125.

World Bank. (2022). Advancements in urban infrastructure: The role of cobblestone roads in Ethiopia's sustainable development. African Infrastructure Review, 40(1), 34-47.

www.nyu.edu/classes/bkg/objectsblog/archives/cobblestones.pdf (Accessed in October, 2014).

.