

Identifying the Workmanship Elements That Affect the Cobblestone Road Quality in the Case of the Mekelle City

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Abstract

This paper presents the identification of the workmanship elements that affect the cobblestone road quality in the case of Mekelle City. It aims to investigate the key to identifying the workmanship elements that affect the cobblestone road quality in the case of Mekelle City. The study employs a methodology that combines questionnaire surveys and case studies. Besides, a total of 47 questionnaires were distributed, with 46 successfully collected. The respondents included 9 clients, 7 consultants, and 30 contractors, all of whom have direct involvement in cobblestone road construction projects. Additionally, a case study was conducted at 8 selected sites, consisting of three sites with various defects, two sites with minor defects, and three ongoing projects. Moreover, the collected data was subjected to both quantitative and qualitative analysis using the Statistical Package for the Social Sciences (SPSS). The Relative Importance Index (RII) was utilized to identify the most affecting factors. The findings reveal that several workmanship factors significantly affect cobblestone road quality. The top influencing factors, as determined by RII, include mal-practices, degree of compaction, sub-base filler grading, California Bearing Ratio (CBR) test, course thickness, base-course aggregate size, cobblestone parent rock, base-course aggregate grading, sub-base filler size, optimum moisture content, filler dust (00) grading, experience (skills), faulty specification, tree roots removal, cobblestone's joint thickness, measurements accuracy, cobblestone shape, and cobblestone pattern layout. Finally, the results of this study provide valuable insights for road construction professionals, policymakers, and stakeholders involved in cobblestone road projects in Mekelle City.

Keywords: Cobblestone Roads Quality, Road Infrastructure, Road Network

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1. Introduction

The attainment of acceptable quality levels in the construction industry has long been an endless problem. Significant amounts of time, money, & resources, both human and material, are wasted each year due to inefficient or nonexistent quality management procedures (1-3).

One of the construction industries is the construction of roads, and cobblestone roads in particular, cobblestone roads are roads with the finishing surface of cobblestone. Nowadays cobblestone roads are one of the basic infrastructures in the world. They have a great advantage in providing roads with improved surfaces, providing good service for society, creating job opportunities & minimizing unemployment in urban areas, and so on (4-6). Cobblestone paving in Ethiopia starting from 2007, the idea of cobblestone paving particularly in secondary cities, has really taken off. The concept is simple local resources are used in a very labor-intensive process, saving the foreign currency needed to purchase the components of asphalt and at the same time providing jobs to large numbers of Ethiopians (7-9).

The cobblestone road is a kind of strengthened test road by placing the cobblestones with a certain size into the crushed stone densely and regularly. The cobblestone road is the most used reliable and durable road, which can provide a better distribution of load for the whole vehicle. Cobblestone roads have similar construction techniques as gravel roads, except they are to some extent more labor-intensive to install because each cobble must be paved individually and has additional layers (10-12).

Construction of cobblestone roads normally begins with excavation and earthwork to bring the subgrade layer to the required level. Subgrade, sub-base, base coarse, thin bedding layer, and pavement (cobblestone surface) are layers of cobblestone roads. Crushed stones are supposed to be the material for the thin and finishing layer and cobbles for the pavement layer. For any urban development, constructing new infrastructures and managing,

maintaining, and improving the existing infrastructure are very important. Urban infrastructural provision includes cobblestone roads, drainage, solid waste landfills, etc. Housing development, urban business development, and strengthening cities' capacity to self-govern are strategic interventions necessary to create conditions for economic development and create employment and reduce poverty (13-16).

2. Materials and Methods

2.1 Description of the Study Area

This research study is conducted in Mekelle city cobblestone road construction projects. Mekelle City is one of the ancient and largest cities in the country located in the Northern part of Ethiopia. Mekelle City is situated in Tigray Regional State at about 783 km away from Addis Ababa the capital city of Ethiopia.

Despite the city having a long history of foundation for more than a hundred years, the level of development of public infrastructures is not satisfactory. The road sector is mainly dominated by earthen roads that constitute more than 50% of the total road networks. Even though, Asphalt roads are found in many areas/routes/ mainly among the main routes and all outlets of the cities. In recent years, the city has taken initiatives to develop main routes with standardized asphalt concrete roads and cobblestones for inner roads. However, the Mekelle city administration of Capital Investment Plan for Infrastructure (CIP), 2019/2020 came up with a high magnitude of cobblestone roads with a severe condition and this initiates this study to be done in Mekelle city cobblestone project as shown in Figure 1.

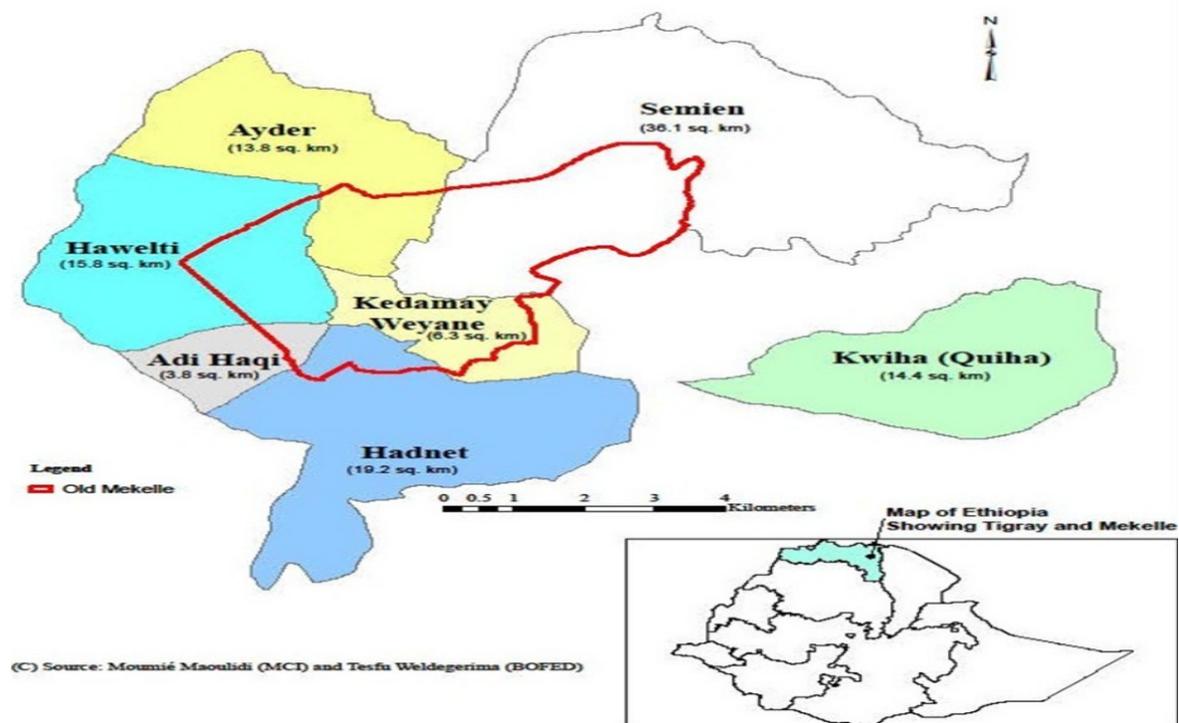


Figure 1. Location of Mekelle city, Tigray - Ethiopia

2.2 Research Design

This research followed a different stage process; having established the objective of the study, necessary data were collected and analyzed, and conclusions and recommendations were made based on the findings.

The methods of data collection employed for this research were a literature review, case study, and questionnaire survey. The case study analyzed theoretical propositions, and the responses obtained from the questionnaire survey were analyzed using the descriptive statistics method.

The strategy followed in this research first started with problem identification that had been done through a literature review, case study, and informal discussion with colleagues and professionals in the sector; then data

and information sources were determined based on the formulated research design. Based on the data and information sources, the research instruments decided; and available documentary sources relevant to the research reviewed. The review includes books, journals and articles, internet sources, and archival document searches such as progress and completion reports within Mekelle City municipality the client of the project.

Finally, after an in-depth review of different literatures and practices, a questionnaire survey was designed and distributed to contractors, consultants, and clients. Upon obtaining the desired data, checking and sorting of data has been done for the selected method of analysis. It enabled us to obtain the result followed by comprehensive discussions in order to draw a conclusion and to forward recommendations based on the findings of the research study.

2.3 Population

The research population was thirty-five cobblestone road projects, which were under construction in Mekelle city that were completed during this year (2021GC). Three contracting parties were involved in the cobblestone road construction projects those are; clients, contractors, and consultants. The total population used in this research study is 47, comprising 30 for the contractor's representative, 10 for the client's representative, and 7 for the consultant's representative.

3.4 Sources of Data

Three research instruments were used for the collection of relevant information. To identify and rank the workmanship factors causing quality problems on cobblestone road construction in Mekelle city, a case study approach and questionnaire survey were carried out in addition to information from different literatures.

3.5 Data Processing and Analysis

In this research descriptive statistical method is used for analysis of data collected from various sources through questionnaire. The case study is analyzed using the theoretical propositions and respondent's information. A flow diagram that shows the components and sequence of analysis is shown in Figure 2. Data is analyzed using relative important index (RIIS) technique, the relative importance index, (RIIS) computed for each factors to identify the most significant. The factors are ranked based on RIIS values, from the ranking assigned to each workmanship factors causing quality problem.

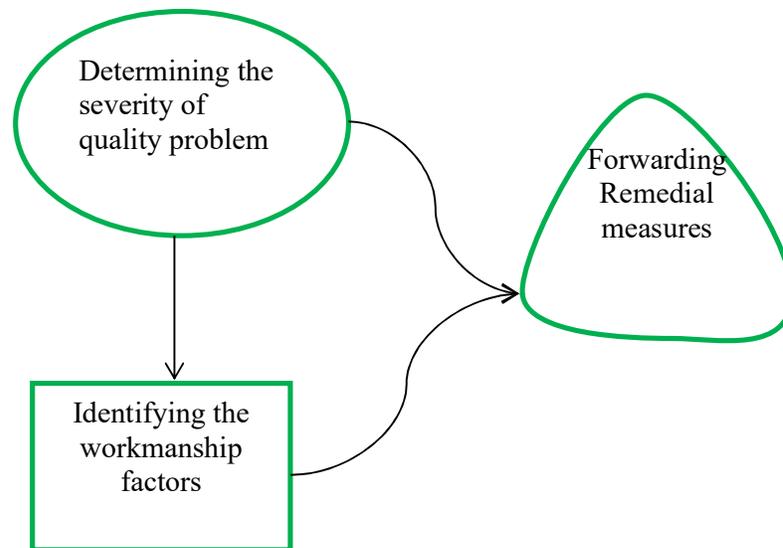


Figure 2. Analysis diagram for workmanship factors affecting quality

3. Results and Discussions

This section presents the findings derived from the data analysis of the collected questionnaires and case studies, providing a comprehensive overview of the results and engaging in a thorough discussion of their significance. The section begins with a summary of the characteristics of the sample population and the response rate for the questionnaires. It then proceeds to present the descriptive statistics and analysis of the questionnaire data, highlighting the key findings related to workmanship factors affecting cobblestone road quality.

3.1 Questionnaire survey results

A questionnaire survey was designed based on the objectives of the study, which is Identification of Workmanship Factors Affecting Cobblestone Roads Quality - A Case of Mekelle City. Likewise, a questionnaire was sent to get the opinion and understanding of the client, consultant, and local contractors.

The questionnaire was classified into three main sections: the first section is Section “A” which includes the respondent’s name, background, address, and organization details. The Second section is Section “B” which includes a degree of influence, degree of occurrence, and the reasons for the occurrence of the Workmanship Factors. The last section is Section “C” which includes the workmanship defects degree of occurrence, reasons of occurrence, testing, inspection, and miscellaneous concerns.

The reliability, significance, and validation of the collected questionnaires were tested on SPSS 16 grouping the participants into three categories. As discussed in this research, the Spearman rank correlation coefficient is applied to test the reliability and uses the p-value for testing significance. The validity is also checked to determine whether there is missing data or not and if nothing is left the raw data is valid as shown in Table 1.

Table 1. Correlation and P-value of Workmanship Factors vs. Different Groups

Group	Client & Contractor	P-Value	Consultant & Contractor	P-Value	Client & Consultant	P-Value
	Correlation Coefficient		Correlation Coefficient		Correlation Coefficient	
Factors	0.768	0.011<0.05	0.819	0.019<0.05	0.729	0.004<0.05

As shown in Table 1, it can be concluded that there is a strong relation between the responses of the respondents. This means that the respondents have similar perceptions thus results also indicated that there is a strong agreement between client, consultant and contractors.

The results obtained from the questionnaires regarding the occurrence of defects in cobblestone roads in Mekelle City are as shown in Figure 3 (in descending order of mean scores).

These results shed light on the prevalent defects observed in the cobblestone roads. Erosion emerged as the most frequently occurring defect, indicating the need for effective measures to mitigate erosion and ensure the long-term stability of the roads. Depression and ditch blockage were also identified as significant defects, emphasizing the importance of proper drainage systems and maintenance practices to prevent water accumulation and subsequent road deterioration.

Cracking was another notable defect reported in the questionnaires. It is crucial to address this issue promptly, as cracks can compromise the structural integrity of the roads. Implementing appropriate design considerations and construction techniques can help minimize cracking and enhance the durability of the road surfaces.

Corrugation and swelling were identified as relatively less common defects. However, they should not be overlooked, as they can still impact the ride quality and overall performance of the roads. Mitigation measures should be taken to address these defects and maintain a smooth and safe road surface for users.

By understanding and addressing these defect occurrences, stakeholders can prioritize maintenance and repair efforts to improve the overall condition of cobblestone roads in Mekelle City. Proper inspection, timely repairs, and proactive maintenance strategies can help minimize defects and ensure the longevity and usability of the road infrastructure as shown in Figure 3.

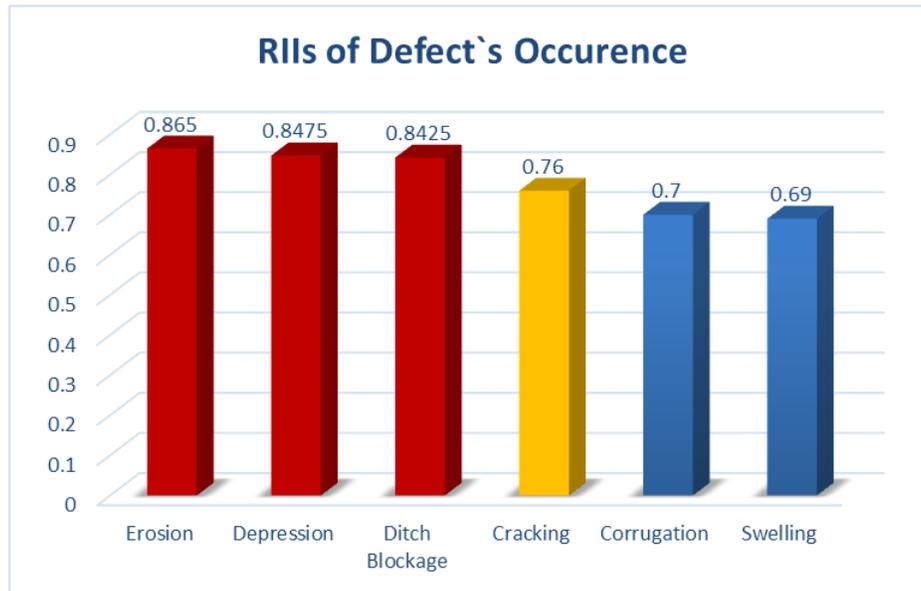


Figure 3. Relative importance index of defect's occurrence

3.2 Case Study Results

A case study was conducted on the cobblestone roads categorized in three aspects, cobblestone roads with various defects, with little defects, and ongoing projects in Mekelle city.

Prior to selecting sites for a case study, a random pilot survey was conducted to see the selection criteria. The documents referred to during the case study include construction plans, specifications and maintenance records in addition to direct observation of site conditions, and correspondences from discussions and interviews for selected sites.

The case study focuses on Mekelle City, covering a total of 5.5 kilometers of cobblestone roads with various defects, 1.5 kilometers with little defects, and 3.0 kilometers of ongoing projects. The aims of the case study are to assess the severity of quality problems in the selected road sections, to identify the workmanship factors contributing to the observed quality problems, and to provide remedial measures for improving road quality based on the findings.

3.3 Summary of Questionnaire survey and Case study

3.3.1 Findings on Severity of Quality Problems

Erosion is the most frequently reported defect in the cobblestone roads. Erosion occurs when the natural forces of water or wind wear away the road surface, leading to the loss of material and stability. Addressing erosion is crucial as it can result in uneven road surfaces, reduced ride comfort, and decreased road lifespan. Depression is the most frequently reported defect next to erosion, it can be caused by various factors, including inadequate compaction during construction, poor maintenance, or prolonged heavy traffic. Depressions can lead to water pooling, reduced surface drainage, and increased risk of further damage. Ditch silted / blockage is the most frequently reported defect next to depression refers to the accumulation of Wastes (debris, sediment, or other materials) in roadside ditches, impeding the proper flow of water. Besides, corrugation is reported as the least occurred defect, which refers to the formation of small waves or ridges along the road surface, often caused by repeated vehicle traffic, inadequate compaction, or improper grading.

3.3.2 Findings on Identification of Workmanship Factors

The collected questionnaires survey shows Practices, Degree of Compaction, Sub-base Filler Grading, CBR Test, Course Thickness, Base-course Aggregate Size, Cobblestone Parent Rock, Base-course Aggregate Grading, Sub-base Filler Size, Optimum Moisture Content, Filler Dust (00) Grading, Experience (Skills), Faulty Specification, Tree Roots Removal, Cobblestone's Joint Thickness, Measurements Accuracy, Cobblestone Shape, Cobblestone Pattern Layout are reported the most important workmanship factors that affect the cobblestone roads quality. The case study findings demonstrate the severity of quality problems in the cobblestone roads of the selected areas in Mekelle City. The identified workmanship factors are, Mal-practices between contractors and consultants, poor compaction, poor graded materials, thin course thickness, non-optimum moisture content, non-experienced contractors, faulty Specification, improper site clearing, improper

Cobblestone Joint Thickness, improper - Cobblestone Shape, nonstandard Curbstone Size, poor policies & intensives, small Size Cobblestone, Organizational in Efficiency, no Health & Safety tools, Faulty Design.

4. Conclusions

This study developed the identification of the workmanship elements that affect the cobblestone road quality in the case of Mekelle City. Based on interpretations and discussions of the simplified results, the major findings were summarized as follows: Based on the questionnaire survey and case study findings the cobblestone roads in Mekelle City exhibit a range of defects, including cracks, corrugation, depressions, silted ditches, erosion, and swelling. The identified defects in cobblestone roads, such as cracks, corrugation, and depressions, not only reduce the aesthetic appeal of the roads but also pose safety risks to pedestrians and vehicles. Silted ditches and erosion further contribute to the degradation of road conditions.

Moreover, the presence of cobblestone parent rock and poor graded materials can lead to uneven surfaces and compromised stability, making it challenging for road users to navigate through these areas. The faulty design of cobblestone roads, including non-uniform cobblestone size, improper joint thickness, and non-standard curbstone size, indicates a lack of attention to detail and adherence to standardized construction practices. The identified factors affecting cobblestone road quality include poor compaction, below-standard thickness, cobblestone parent rock, poor graded materials, faulty design, non-uniform cobblestone size, improper joint thickness, and non-standard curbstone size. Malpractices between contractors and consultants, lack of experienced contractors, and inadequate adherence to specifications contribute to the observed defects. Insufficient maintenance practices and a lack of maintenance records have resulted in the deterioration of cobblestone roads over time. There is a discrepancy between proposed and actual users, with vehicles exceeding the recommended weight limit using the roads. Finally, the lack of maintenance records and insufficient maintenance practices have resulted in the progressive deterioration of cobblestone roads over time. Without proper upkeep, the defects become more severe, leading to increased repair costs in the long run. The discrepancy between proposed and actual users of cobblestone roads, with vehicles exceeding the recommended weight limit, puts additional stress on the roads and accelerates their degradation. By addressing the identified workmanship factors and implementing the recommended measures, Mekelle City can enhance the overall quality, safety, and resilience of its cobblestone road infrastructure.

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