



**FACULTY OF ENGINEERING**  
**DEPARTMENT OF MINING ENGINEERING**  
**FINAL YEAR PROJECT**  
**DESIGN AND CONSTRUCTION OF A REAL-TIME SLOPE**  
**MONITORING SYSTEM FOR OPEN PIT MINES**  
**CASE STUDY: NAMEKARA MINING COMPANY LIMITED**

**BY**

**EGESSA JONATHAN**

**BU/UG/2020/1945**

**0779825388/0703237139**

**[jonathanegessa@gmail.com](mailto:jonathanegessa@gmail.com)**

**SUPERVISORS:**

**MR. KIDEGA RICHARD**

**MR. LUBAALE SOLOMON AZARIUS**

*A final year project report submitted to the Department of Mining Engineering, Faculty of Engineering and Technology in partial fulfillment of the requirement for the award of the Bachelor of Science in Mining Engineering of Busitema University*

*May 2024*

## ABSTRACT

In today's current global scenario in open pit mining, the basic question in every mining operator's mind, considering the continuous increase of slope instability issues in the recent past, is mostly about slope safety and stability. Slope stability is a crucial aspect of open pit mining, as it directly affects the safety of mine workers and the overall efficiency of mining operations.

The prevention of slope failures can result in significant economic losses and environmental damage. The only thought haunting every mining operator is when they will be able to ensure the stability of their slopes in real-time, without worrying about potential failures, which can be triggered by changes in the depth and width of discontinuities/cracks. This project describes the design and construction of a real-time monitoring system for open pit mines, a case study of Namekara Mining Company Limited. The system utilizes ultrasonic sensors to detect and monitor changes in the depth and width of discontinuities/cracks and triggers audio signals via a buzzer, visual alerts via LEDs, and SMS alerts via GSM when certain thresholds on depth and width are exceeded. By providing real-time monitoring and alerts, this system aims to prevent slope failures, enhance slope safety, ensure the overall stability of open pit mines, and support informed decision-making by mine operators and authorities.

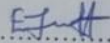
The first chapter comprises the introduction, which clearly shows the problem statement, the objectives of the study, the background, and scope of the study. The second chapter comprises the literature review which elaborately shows how different mines and companies have handled the problem of slope failure around the world including the various monitoring systems that have been implemented to address this problem. The third chapter is comprised of the methodology that this study seeks to apply. It elaborates on how the data collection will be done, how the data collected will be analyzed, and how they analyze the data will be utilized in design and construction of a real time slope monitoring system. The fourth chapter includes the results and discussions of every specific objective. Chapter five involves the conclusion, challenges, and recommendations.

#### DECLARATION

I EGESSA JONATHAN, hereby declare that this report was written by me and is a true picture of what transpired during the proposal development time. I affirm that the research conducted for this report was carried out diligently, employing reliable sources and appropriate methodologies. The external sources used have been appropriately cited, referenced, and credited

This report has not been utilized in the acquisition of an academic award by any individual or any learning institution

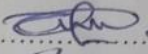
Date.....29th October, 2024.....

Signature..........

### APPROVAL

I EGESSA JONATHAN, submit this report of my final year project to the faculty of engineering in the Department of Mining Engineering for examination with approval of my supervisors.

**Mr. KIDEGA RICHARD**

Signature: ..... 

Date: ..... 29/10/2024 .....

**Mr. LUBAALE SOLOMON AZARIUS**

Signature: ..... 

Date ..... 29-10-2024 .....

## DEDICATION

I like to dedicate this report to my family members, friends, and relatives.

## ACKNOWLEDGEMENT

I take this opportunity to thank the almighty **GOD** for granting me life, good health, and the ability to research and gather information that is integrated in this report

I am deeply indebted to my dear supervisors: **MR KIDEGA RICHARD and MR. LUBAALE SOLOMON AZARIUS** for the time, support, guidance, knowledge, and advice provided to me during the preparation of this research proposal. May the almighty reward you abundantly

## TABLE OF CONTENTS

|                                                                      |                                     |
|----------------------------------------------------------------------|-------------------------------------|
| ABSTRACT.....                                                        | i                                   |
| DECLARATION .....                                                    | <b>Error! Bookmark not defined.</b> |
| APPROVAL.....                                                        | <b>Error! Bookmark not defined.</b> |
| DEDICATION .....                                                     | iv                                  |
| ACKNOWLEDGEMENT .....                                                | v                                   |
| 1.0 CHAPTER ONE .....                                                | 1                                   |
| 1.1 BACKGROUND.....                                                  | 1                                   |
| 1.2 PROBLEM STATEMENT.....                                           | 2                                   |
| 1.3 OBJECTIVES OF THE STUDY .....                                    | 3                                   |
| 1.3.1 MAIN OBJECTIVE .....                                           | 3                                   |
| 1.3.2 SPECIFIC OBJECTIVES.....                                       | 3                                   |
| 1.4.0 JUSTIFICATION OF THE STUDY .....                               | 3                                   |
| 1.5.0 SCOPE OF THE STUDY.....                                        | 4                                   |
| 1.5.1 Concept scope.....                                             | 4                                   |
| 1.5.2 Geographical scope.....                                        | 4                                   |
| 1.5.3 Time scope .....                                               | 4                                   |
| 2.0 CHAPTER TWO .....                                                | 5                                   |
| 2.0 LITERATURE REVIEW .....                                          | 5                                   |
| 2.1 SLOPE STABILITY.....                                             | 5                                   |
| 2.1.1 Factors Affecting Slope Stability .....                        | 5                                   |
| 2.2.0 ROCK MASS STRENGTH .....                                       | 9                                   |
| 2.2.1 Shear strength.....                                            | 9                                   |
| 2.2.2 UCS test.....                                                  | 9                                   |
| 2.2.3 Point load test .....                                          | 10                                  |
| 2.3.0 STEREO NET ANALYSIS .....                                      | 10                                  |
| 2.4.0 SLOPE MONITORING SYSTEMS .....                                 | 10                                  |
| 2.4.1 TECHNOLOGIES THAT HAVE BEEN USED IN THE EXISTING SYSTEMS ..... | 11                                  |
| 2.5.0 TRADITIONAL MONITORING SYSTEMS .....                           | 12                                  |
| 2.5.1 VISUAL INSPECTIONS .....                                       | 12                                  |
| 2.5.2 SURVEY MONITORING .....                                        | 12                                  |
| 2.6.0 STATE OF THE ART OF TECHNOLOGIES.....                          | 13                                  |
| 2.6.1 WIRELESS SENSOR NETWORK (WSN).....                             | 13                                  |

|                                                                              |    |
|------------------------------------------------------------------------------|----|
| 2.6.2 Microcontroller technology .....                                       | 13 |
| 2.6.3 Real-time system operation.....                                        | 13 |
| 2.7.0 Existing gaps.....                                                     | 14 |
| 2.8.0 The proposed monitoring system.....                                    | 14 |
| 3.0 CHAPTER THREE .....                                                      | 15 |
| 3.0 METHODOLOGY .....                                                        | 15 |
| 3.1.0 Specific objective one: To assess the slope stability parameters ..... | 16 |
| 3.1.1 Dip and dip direction measurement of the discontinuities .....         | 16 |
| 3.1.2 Roc Science dip 6.0 software .....                                     | 16 |
| 3.1.3 Slope Geometry Determination .....                                     | 17 |
| 3.1.4 Laboratory tests .....                                                 | 17 |
| 3.2.0 Methodology for Specific Objective Two .....                           | 26 |
| 3.2.1 COMPONENT SELECTION .....                                              | 26 |
| 3.2.1 MICROCONTROLLER.....                                                   | 26 |
| 3.2.2 SENSOR SELECTION .....                                                 | 27 |
| 3.2.3 GSM MODULE .....                                                       | 29 |
| 3.2.4 Other components selected include .....                                | 30 |
| 3.2.5 Design of the system .....                                             | 32 |
| 3.2.5.1 Hardware components .....                                            | 33 |
| 3.2.5.2 System casing.....                                                   | 33 |
| 3.2.5.3 Software tools .....                                                 | 33 |
| 3.2.5.4 Code design.....                                                     | 33 |
| 3.2.5.5 Circuit design.....                                                  | 34 |
| 3.2.5.6 Block system diagram .....                                           | 34 |
| 3.2.5.7 Logical design of the system .....                                   | 35 |
| System flowchart .....                                                       | 36 |
| 3.2.5.8 Assembling of the components .....                                   | 37 |
| 3.3.0 Specific Objective Three.....                                          | 37 |
| 3.3.1 Unit testing.....                                                      | 37 |
| 3.3.2 Integration testing .....                                              | 37 |
| 3.3.3 System testing.....                                                    | 38 |
| 4.0 CHAPTER FOUR .....                                                       | 38 |
| RESULTS AND DISCUSSIONS.....                                                 | 38 |

|                                                                                                 |    |
|-------------------------------------------------------------------------------------------------|----|
| 4.1.0 Results and discussions for specific objective one .....                                  | 38 |
| 4.1.1 Determination of the geological and stability parameters that affect slope stability..... | 38 |
| 4.1.2 Nature of infilling of the discontinuities .....                                          | 39 |
| 4.1.3 KINEMATIC FAILURE ZONES.....                                                              | 40 |
| 4.1.5 Results for slope angle, bench width, and bench height.....                               | 43 |
| 4.2.0 Specific Objective Two .....                                                              | 47 |
| 4.2.1 Functional analysis.....                                                                  | 47 |
| 4.2.2 Requirement analysis.....                                                                 | 47 |
| 4.2.3 System design .....                                                                       | 48 |
| 4.2.4 Circuit diagram.....                                                                      | 48 |
| 4.3.0 Specific Objective Three.....                                                             | 49 |
| 4.3.1 Design and Development Platforms .....                                                    | 49 |
| 5.0 CHAPTER FIVE.....                                                                           | 51 |
| CONCLUSIONS AND RECOMMENDATION.....                                                             | 51 |
| 5.1 CONCLUSIONS.....                                                                            | 51 |
| 5.2 RECOMMENDATIONS.....                                                                        | 51 |
| 5.3 CHALLENGES .....                                                                            | 52 |
| REFERENCES.....                                                                                 | 53 |
| APPENDIX.....                                                                                   | 55 |
| The code for the system .....                                                                   | 55 |
| Discontinuity data .....                                                                        | 59 |
| Laboratory tests .....                                                                          | 62 |

## List of Figures

|                                                                                      |    |
|--------------------------------------------------------------------------------------|----|
| Figure 1; Slope failure at the Namekara open pit .....                               | 3  |
| Figure 2; conceptual diagram.....                                                    | 4  |
| Figure 3; slope geometry ( slope angle, bench height, and bench width .....          | 6  |
| Figure 4; geological structures that affect slope stability .....                    | 7  |
| Figure 5; stereo net graph .....                                                     | 10 |
| Figure 6; Arduino Uno microcontroller .....                                          | 27 |
| Figure 7; HC-SR04 Ultrasonic sensor .....                                            | 29 |
| Figure 8; SIM800C GSM module.....                                                    | 30 |
| Figure 9;16x2 LCD module 12C module .....                                            | 31 |
| Figure 10; jumper wires .....                                                        | 31 |
| Figure 11; 3.7v rechargeable li-ion battery .....                                    | 31 |
| Figure 12; active buzzer.....                                                        | 32 |
| Figure 13: LEDs.....                                                                 | 32 |
| Figure 14: a map of Namekara open pit for regions where samples were collected ..... | 38 |
| Figure 15: discontinuities with infilling.....                                       | 39 |
| Figure 16: discontinuities without infilling.....                                    | 40 |
| Figure 17: stereo net analysis for planar sliding .....                              | 40 |
| Figure 18: stereo net analysis for wedge sliding.....                                | 41 |
| Figure 19: stereo net analysis for direct toppling.....                              | 42 |
| Figure 20: Circuit Diagram.....                                                      | 49 |

## **List of abbreviations**

|       |                                        |
|-------|----------------------------------------|
| UCS   | Uniaxial compressive strength          |
| SDG   | Sustainable Development Goal           |
| LiDAR | Light Detection and Ranging            |
| WSN   | wireless sensor network                |
| LCD   | Liquid Crystal Display                 |
| LEDs  | Light Emitting Diodes                  |
| SG    | Specific Gravity                       |
| AHP   | Analytical Hierarchy Process           |
| GSM   | Global System for Mobile Communication |
| IDE   | Integrated Development Environment     |
| GPS   | Geographical Positioning System        |
| MDD   | Maximum Dry Density                    |
| OMC   | Optimum Moisture Content               |
| PI    | Plasticity index                       |
| CBR   | California Bearing Ratio               |
| PL    | Plastic Limit                          |
| LL    | Liquid Limit                           |
| PSD   | Particle Size Distribution             |
| LS    | Linear Shrinkage                       |

## REFERENCES

- Bye, A. R., & Bell, F. G. (2001). Stability assessment and slope design at Sandsloot open pit, South Africa. *International Journal of Rock Mechanics and Mining Sciences*, 38(3), 449–466. [https://doi.org/10.1016/S1365-1609\(01\)00014-4](https://doi.org/10.1016/S1365-1609(01)00014-4)
- Call, R. D., & Savely, J. P. (1990). Open pit rock mechanics. *Surface Mining*, 860–882.
- Cawood, F. T., & Stacey, T. R. (2006). Survey and geotechnical slope monitoring considerations. *Journal of the Southern African Institute of Mining and Metallurgy*, 106(7), 495–501.
- Dewedree, S., & Jusoh, S. N. (2019). Slope stability analysis under different soil nailing parameters using the SLOPE/W software. *Journal of Physics: Conference Series*, 1174(1). <https://doi.org/10.1088/1742-6596/1174/1/012008>
- Fung, W. H. T., Kinsil, R. J., Jamaludin, S., & Krishnan, S. (2014). Early warning and real-time slope monitoring systems in west and east Malaysia. *Landslide Science for a Safer Geoenvironment: Volume 2: Methods of Landslide Studies, July 2014*, 569–575. [https://doi.org/10.1007/978-3-319-05050-8\\_88](https://doi.org/10.1007/978-3-319-05050-8_88)
- Khalili, N., Russell, A., & Khoshghalb, A. (2014). Slope stability. *Unsaturated Soils: Research & Applications*, 1225–1225. <https://doi.org/10.1201/b17034-178>
- Mittapally, S. K., & Marichamy, R. K. (2023). *Wireless Sensor Networks and Real-Time Slope Monitoring: A Brief Review*. Atlantis Press International BV. [https://doi.org/10.2991/978-94-6463-252-1\\_131](https://doi.org/10.2991/978-94-6463-252-1_131)
- Mohammed, M. M. (2021). A Review On Slope Monitoring And Application Methods In Open Pit Mining Activities. *Lume*, 10(02), 2. [www.ijstr.org](http://www.ijstr.org)
- Mukrimaa, S. S., Nurdyansyah, Fahyuni, E. F., YULIA CITRA, A., Schulz, N. D., غسان, د., Taniredja, T., Faridli, E. M., & Harmianto, S. (2016). No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, 6(August), 128.
- Park, S., Lim, H., Tamang, B., Jin, J., Lee, S., Chang, S., & Kim, Y. (2019). A Study on the Slope Failure Monitoring of a Model Slope by the Application of a Displacement Sensor. *Journal of Sensors*, 2019. <https://doi.org/10.1155/2019/7570517>
- Pavlovich, A. A., Korshunov, V. A., Bazhukov, A. A., & Melnikov, N. Y. (2019). Estimation of rock mass strength in open-pit mining. *Journal of Mining Institute*, 239, 502–509.

<https://doi.org/10.31897/PMI.2019.5.502>

Sachdeva, S. (2019). *SENSORS BASED EARLY WARNING SYSTEM*. 6(4), 1411–1414.

Sensor, W., For, N., & Monitoring, S. (2012). *Nurul amirah binti ali*. September 2011.

Sharon, R. (2020). *Slope performance monitoring: system design, implementation and quality assurance*. 17–38. [https://doi.org/10.36487/acg\\_repo/2025\\_0.02](https://doi.org/10.36487/acg_repo/2025_0.02)

Smarsly, K., Georgieva, K., & Law, K. H. (2012). Monitoring of Slope Movements Coupling Autonomous Wireless Sensor Networks and Web Services. *Proceedings of the First International Conference on Performance-Based Life-Cycle Structural Engineering*. Hong Kong, China, 2009, 1–7.

Teh Chang, D. T., Tsai, Y.-S., & Yang, K.-C. (2013). Study of Real-Time Slope Stability Monitoring System Using Wireless Sensor Network(WSN). *TELKOMNIKA Indonesian Journal of Electrical Engineering*, 11(3), 1478–1488.  
<https://doi.org/10.11591/telkomnika.v11i3.2230>

Wang L, Nishie S, Seko I, & Uchimura T. (2013). *Study on field detection and monitoring of slope instability by measuring tilting motion on the slope surface Détection et surveillance in situ des phénomènes d'instabilités de pente par mesure locale des mouvements de surface*. 2277–2280.

Wessels, S. D. N. (2009). *Monitoring and Management of a Large Open Pit Failure*. 1–88.

A.E.E. Escobar; P. Farina; L. Leoni; C. Iasio; N. Coli, *Innovative use of slope monitoring radar as a support to geotechnical modelling of slope in open pit mines 2013, Australian Centre for Geomechanics: Australia*

Blodgett, J., M. Ikehara, and G. Williams, *Monitoring land subsidence in Sacramento Valley, California, using GPS*. *Journal of Surveying Engineering*, 1990. 116(2): p. 112-130.

Ding, X., et al. *An intelligent data acquisition and management system for open pit slope deformation monitoring*. in *Proceedings of 8th FIG International Symposium on Deformation Measurements*. 1996.

Harries, N., D. Noon, and K. Rowley, *Case studies of slope stability radar used in open cut mines*. *Stability of Rock Slopes in Open Pit Mining and Civil Engineering Situations*, 2006: p. 335- 342