



**FACULTY OF ENGINEERING**

**DEPARTMENT OF MINING ENGINEERING AND TECHNOLOGY**

**OPTIMIZATION OF BLAST DESIGN TO IMPROVE BLASTING EFFICIENCY**

**CASE STUDY: ROKO QUARRY MINES**

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*Final year Project Report Submitted to the Department of Mining Engineering in Partial  
fulfilment of the Requirement for the Award of a Bachelor of Science Degree in Mining  
Engineering at Busitema University*

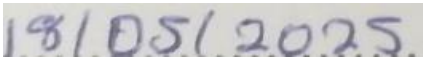
**MAY 2025**

## **ABSTRACT**

Blasting efficiency in quarry operations play a crucial role in achieving optimal fragmentation, reducing secondary breakage, minimizing operational costs and environmental impacts. The study focused on optimizing blast design at Roko Quarry Mines using advanced software tools such as Wipfrag and O-pit Blast to enhance fragmentation outcomes. Wipfrag enables accurate fragmentation analysis by assessing the particle size distribution, D20, D50, D80, D90 and many others, while O-pit Blast facilitates precise blast design optimization for improved results. Poor fragmentation, characterized by oversized boulders exceeding the desired 200-600 mm range increase secondary breakage costs and affect the downstream processing efficiency and productivity. Fragmentation refers to the process of breaking down solid in-situ rock masses into smaller pieces during excavation/ material handling operations. This study focused on optimizing blast design to enhance blasting efficiency at Roko Quarry Mines in Mukono district. The study involved analyzing the current blast design parameter values to identify factors affecting blasting efficiency, optimizing blast design parameters, and testing the effectiveness of the optimized blast design parameters. The study refined parameters, including burden, spacing, powder factor, sub drilling length, explosive quantity, stemming length, and burden-spacing-ratio to achieve more uniform fragmentation by integrating with advanced blast design fragmentation and optimization software solutions. A Comparative analysis of pre-and post- optimization fragmentation results provided insights into the effectiveness of software-driven blast design improvements. The findings contributed to formulating best practices for optimizing blasting efficiency at Roko Quarry Mines and other similar operations.

## DECLARATION

I **KOBUSINGE JAMILAH**, declare to the best of my knowledge that all the work in this report is entirely the results of my strength under the guidance of my project supervisor MR. **KIDEGA RICHARD** and has not been plagiarized from any source.

Signature...  ..... Date... 

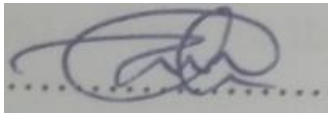
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## APPROVAL.

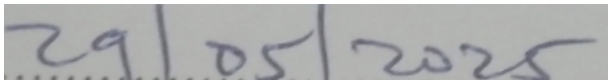
This Project report has been submitted to the faculty of engineering in the department of Mining Engineering for examination with approval from my supervisor mentioned below.

**MR. KIDEGA RICHARD**

Signaturee



Date and Stamp



## ACKNOWLEDGEMENT

I thank the Almighty God for giving me strength, good health, wisdom, and protection throughout achieving my bachelor's degree in mining engineering.

I would like to recognize the valuable assistance extended to me at all stages towards accomplishment of my project, my sincere thanks go to my supervisor, **MR. KIDEGA RICHARD**, and **others** for the support and guidance they have given me throughout my project journey.

I send my vote of thanks to my classmates, Hamza, my roommates, my parents, engineer Rahman, Omirambe James, and friends for the support, guidance and counseling they have given me towards my academic journey, am forever grateful.

Special thanks goesb to Roko Stone Quarry Mines for the unlimited permission, support, and knowledge, granted to me towards assessing the quarry for my research.

## **DEDICATION**

I dedicate this report to my beloved family members, mum and dad for the financial support, prayers they have offered to me throughout my academic journey.

I also dedicate this report to my mentors, course mates and friends who have guided me and inspired me to peruse my goals.

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## LIST OF ACRONYMS

|      |                               |
|------|-------------------------------|
| ANFO | Ammonium Nitrate and Fuel Oil |
| UCS  | Uniaxial Compressive Strength |
| SG   | Specific Gravity              |
| GPS  | Global Positioning Satellite  |
| RWS  | Relative weight Strength      |
| RQD  | Rock Quality Index            |
| VOD  | Velocity of detonation        |

|     |                               |
|-----|-------------------------------|
| PF  | Powder factor                 |
| PSD | Particle Size Distribution    |
| KN  | Kilo newton                   |
| B   | Burden                        |
| S   | Spacing                       |
| SDG | Sustainable Development Goals |
| Cal | Calibration                   |

The use of drone-based satellite imaging should be integrated to improve data collection accuracy for both fragmentation analysis in wipfrag and O-Pit Blast.

Future optimization should include environmental impact indicators such as vibration levels, fly rock distance, and noise emissions, to ensure compliance with regulatory standards and improve community relations around the mine site.

Future projects should expand the model with geotechnical variability and machine learning predictive models using historical blast data so as to enable pre-blast simulations that account for geological heterogeneity, allowing even finer control over fragmentation and cost outcomes.

## REFERENCES

- Agyei, G., Ghansah, M. A., & Area, A. R. (2023). *Optimal Design Blast Parameters for an Effective Rock Fragmentation* \*. 1, 44–52.
- Atlas, A. (2021). *Suppliers Target UN 2030 Agenda SDGs*. June, 2030.
- Bonissone, P. P. (2019). Machine learning applications. *Springer Handbook of Computational*

- Intelligence*, 783–821. [https://doi.org/10.1007/978-3-662-43505-2\\_41](https://doi.org/10.1007/978-3-662-43505-2_41)
- Cunningham, C. V. B. (2018). *The Kuz-Ram fragmentation model – 20 years on*. 4.
- Dotto, M. S., & Pourrahimian, Y. (2024). *The Influence of Explosive and Rock Mass Properties on Blast Damage in a Single-Hole Blasting*. 168–188.
- Ebenezer Oyedele, A. (2020). Importance of Blast-Design in Reduction of Blast-Induced Vibrations. *International Journal of Science, Technology and Society*, 2(3), 53. <https://doi.org/10.11648/j.ijsts.20140203.14>
- Gebretsadik, A., Kumar, R., Fisssha, Y., Kide, Y., Okada, N., & Ikeda, H. (2024). Enhancing rock fragmentation assessment in mine blasting through machine learning algorithms : a practical approach. In *Discover Applied Sciences*. Springer International Publishing. <https://doi.org/10.1007/s42452-024-05888-0>
- Kolapo, P., Ogunsola, N., Munemo, P., & Akinola, A. (2022). *Application of Improved Blasting Techniques in Open Pit Mining for Application of Improved Blasting Techniques in Open Pit Mining for Maximum Productivity : A Case of Oakyam Quarry Limited , Ogun State , Nigeria*. June, 11–23. <https://doi.org/10.11648/j.sjee.20221002.11>
- Lapčević, V., Torbica, S., Stojanović, M., & Vojinović, I. (2023). Development and Validation of Universal 3D Blast Fragmentation Model. In *Applied Sciences (Switzerland)* (Vol. 13, Issue 14). <https://doi.org/10.3390/app13148316>
- Lijojo, L. (2021). *Simulating the Influence of Blast Geometry and Rock Geology on Rock Fragmentation*. <https://wiredspace.wits.ac.za/bitstreams/09d7ee0e-0ccb-46a6-809082a2d85a7704/download>
- Manmit Rout, & Chinmay Kumar Parida. (2019). *Optimization of Blasting Parameters in Opencast Mines*. 01–79.
- Manuel, J., & Monterio, F. (n.d.). *A Mine-to-Crusher Framework for Aggregate Operations Blessing Taiwo and Andrew Palangio, WipWare Inc. José Manuel and Francisco Monterio, O-Pitblast Nuno Fernandes and Diogo Fonseca, dstgroup quarry*.

- Mboyo, L., Huo, B., Mulenga, F. K., Fogang, P. M., Kalenga, J., & Kasongo, K. (2024). *Assessing the Impact of Surface Blast Design Parameters on the Performance of a Comminution Circuit Processing a Copper-Bearing Ore*.
- Michael, B., Cunningham, D., Michael, B., & Cunningham, D. (2019). *UNIVERSITY OF SOUTHAMPTON University of Southampton by. September*.
- Milanović, S., Simić, N., Kričak, L., Negovanović, M., & Đokić, N. (2024). Optimization and analysis of drilling and blasting parameters using O-Pitblast software. *Podzemni Radovi*, 44(44), 51–67. <https://doi.org/10.5937/podrad2444051m>
- Nanda, S., & Naik, H. K. (2023). A Review of the Blast Fragmentation Analysis Techniques used in Surface Mines. *Journal of Mines, Metals and Fuels, March*, 2445–2454. <https://doi.org/10.18311/jmmf/2023/28601>
- Otokiti, M. O., & Adebayo, B. (2024). *Evaluation of Rock and Explosive Properties for Fragmentation Characterization : An Application of WipFrag*. 12(1), 13–32.
- Properties, R. M., Parameters, M., Conditions, B., & Parameters, J. (2020). Chapter 6 Rock Mass Properties and. *Interface, Terzaghi*.
- Providing, W. E. A. R. E., Solutions, T. H. E., & Your, F. O. R. (2021). *BLASTING PERFORMANCE OPTIMIZATION AND*. 1–6.
- Pyra, J., & Gądek, K. (2020). Possible ways of optimizing blasting operations using O-Pitblast software. *Materiały Wysokoenergetyczne / High Energy Materials*, 12(2), 124–138. <https://doi.org/10.22211/matwys/0194>
- Torres, V. F. N., Castro, C., Valencia, M. E., Figueiredo, J. R., & Silveira, L. G. C. (2022). Numerical Modelling of Blasting Fragmentation Optimization in a Copper Mine. *Mining*, 2(4), 654–669. <https://doi.org/10.3390/mining2040035>
- Turyahabwe, R., Asaba, J., Mulabbi, A., & Osuna, C. (2021). Environmental and Socioeconomic Impact Assessment of Stone Quarrying in Tororo District, Eastern Uganda. *East African Journal of Environment and Natural Resources*, 4(1), 1–14. <https://doi.org/10.37284/eajenr.4.1.445>
- Yost, B.-, & Peter, C. (n.d.). \ *L AF ET y ii. I*.

- Yussupov, K., Myrzakhmetov, S., Aben, K., Nehrii, S., & Nehrii, T. (2021). Optimization of the drilling-and-blasting process to improve fragmentation by creating of a preliminary stress in a block. *E3S Web of Conferences*, 280. <https://doi.org/10.1051/e3sconf/202128008015>
- Zhang, Z. (2020). *Challenges and potentialities of rock blasting in mining engineering*. December 2019.
- Zhou, J., Zhang, Y., & Qiu, Y. (2024). State-of-the-art review of machine learning and optimization algorithms applications in environmental effects of blasting. In *Artificial Intelligence Review* (Vol. 57, Issue 1). Springer Netherlands. <https://doi.org/10.1007/s10462-023-10636-8>