



FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF WATER RESOURCES ENGINEERING

FINAL YEAR REPORT

**OPTIMIZING THE PHYSICAL AND MECHANICAL PROPERTIES OF CEMENT-STABILIZED RAMMED EARTH CONSTRUCTION BLOCKS.**

BY

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*Final year report is submitted to the department of mining and water resources engineering in partial fulfilment of the requirement for the award of Bachelors of Science degree in water resources engineering at Busitema University.*

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## **ABSTRACT**

This research focuses on the improvement of the physical and mechanical properties of cement-stabilized rammed earth (CSRE) blocks. The approach included characterizing soil samples using sieve analysis to assess soil particle size distribution, moisture content tests, and maximum dry density evaluations to determine the best achievable compaction characteristics.

These tested samples were taken from a total of three different soil samples that were prepared with different concentrations of cement (0, 2, 4, 6, and 8 percent) to determine the influence of the cement proportion on the blocks' strength and durability.

The blocks were compacted and cured for a duration of 7, 14 and 28 days, then they underwent compressive strength testing using a Universal Testing Machine (UTM) and water absorption measurement for durability.

The data was analyzed to find the most beneficial cement-soil ratio that would achieve maximum strength while remaining within economical limits. The results showed the possibility of CSRE blocks being used as a construction material that is cost-effective while being mechanically reliable.

## DECLARATION

### DECLARATION

I BIRUNGI AMINAH, registration number BU/UP/2021/0286, declare that the work in this final year report is my original work and has not been presented to any higher institution of learning for any academic award.

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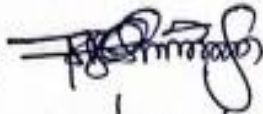
## APPROVAL

### APPROVAL

I hereby certify that this project is original report of BIRUNGI AMINAH, BU/UP/2021/0286. It has been done under my supervision and is ready for submission to the department of water resources and mining engineering.

SUPERVISOR: MR TIGALANA DAN

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15/05/2025

## **DEDICATION**

I dedicate this report to my Parents professor Twaibu Ssemwogerere and Mrs. Sophie Namwanje,  
my siblings and my friends

## **ACKNOWLEDGEMENT**

I would like to express my heartfelt gratitude to the Almighty for His constant guidance, protection, and blessings throughout this journey

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## 5.4. References

- Asrah, H., Naufal, D., Boyd, J., Abidin, Z., Mirasa, A. K., & Han, L. C. (2022). Optimization of The Green Interlocking Earth Brick Mix Design Using Response Surface Method. *Myjms.Mohe.Gov.MyH Asrah, MDNJ Boyd, SMISZ Abidin, AK Mirasa, LC HanInternational Journal of Advanced Research in Engineering Innovation, 2022•myjms.Mohe.Gov.My, 4(3), 18–26.*  
<https://doi.org/10.55057/ijarei.2022.4.3.2>
- Babalola, O. E., Awoyera, P. O., Tran, M. T., Le, D. H., Olalusi, O. B., Vilorio, A., & Ovallos-Gazabon, D. (2020). Mechanical and durability properties of recycled aggregate concrete with ternary binder system and optimized mix proportion. *Journal of Materials Research and Technology, 9(3), 6521–6532.* <https://doi.org/10.1016/J.JMRT.2020.04.038>
- Cardenas-Haro, X., Todisco, L., Leon, J., Sarmiento, N., & Samaniego, C. (2021). Influence of additives on the structural performance of cement-stabilised rammed earth.  
*Https://Doi.Org/10.1680/Jstbu.20.00279, 176(3), 163–176.*  
<https://doi.org/10.1680/JSTBU.20.00279>
- Danso, H. (2016). *Use of agricultural waste fibres as enhancement of soil blocks for low-cost housing in Ghana.* University of Portsmouth, School of Civil Engineering and Surveying.
- Faraj, R. H., Mohammed, A. A., & Omer, K. M. (2023). Microstructure characteristics, stress--strain behaviour, fresh properties, and mechanical performance of recycled plastic aggregate self-compacting concrete modified with nano-silica. *Construction and Building Materials, 383, 131371.*
- Hall, M., & Djerbib, Y. (2004). Moisture ingress in rammed earth: Part 1—the effect of soil particle-size distribution on the rate of capillary suction. *Construction and Building Materials, 18(4), 269–280.*  
<https://doi.org/10.1016/J.CONBUILDMAT.2003.11.002>
- Jayasinghe, C., & Kamaladasa, N. (2007). Compressive strength characteristics of cement stabilized rammed earth walls. *Construction and Building Materials, 21(11), 1971–1976.*
- Khadka, B., & Shakya, M. (2016). Comparative compressive strength of stabilized and un-stabilized rammed earth. *Materials and Structures, 49, 3945–3955.*
- Kumar, A., & Singh, G. J. (2023). Improving the physical and mechanical properties of recycled concrete aggregate: A state-of-the-art review. *Engineering Research Express, 5(1), 012007.*  
<https://doi.org/10.1088/2631-8695/ACC3DF>
- Maniatidis, V., & Walker, P. (2008). Structural capacity of rammed earth in compression. *Journal of Materials in Civil Engineering, 20(3), 230–238.*
- Mechanics, S., & Barcelo, J. (2022). *A Systematic Literature Review of Rammed Earth Walls. October 2021.* <https://doi.org/10.1007/s11204-021-09742-y>
- Meng, Y., Ling, T.-C., & Mo, K. H. (2018). Recycling of wastes for value-added applications in concrete blocks: An overview. *Resources, Conservation and Recycling, 138, 298–312.*
- Niroumand, H., Akbari, R., Khanlari, K., Gültekin, A. B., & Barcelo, J. A. (2021). A systematic literature review of rammed earth walls. *Soil Mechanics and Foundation Engineering, 58, 295–301.*

- Sánchez-Haro, J., Lombillo, I., Capellán, G., Fernández, B., & Gaute, Á. (2024). Simplified Model for Analyzing Soft Impacts on Structures: Validation on Steel Beams. *Journal of Structural Engineering*, 150(12), 4024176.
- Selvamuthu, D., & Das, D. (2018). *Introduction to statistical methods, design of experiments and statistical quality control*. <https://link.springer.com/content/pdf/10.1007/978-981-13-1736-1.pdf>
- Sharma, A., Leib-Day, A. R., Thakur, M. M., & Penumadu, D. (2021). Effect of particle morphology on stiffness, strength and volumetric behavior of rounded and angular natural sand. *Materials*, 14(11), 3023.
- Steinberg, D., Reference, R. K.-W. S. S., & 2014, undefined. (n.d.). Response surface methodology. *Wiley Online Library*DM Steinberg, RS KenettWiley StatsRef: Statistics Reference Online, 2014•Wiley Online Library. Retrieved October 20, 2024, from <https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118445112.stat04105>
- Taghiloha, L. (2013). *Using rammed earth mixed with recycled aggregate as a construction material*. Universitat Politècnica de Catalunya.
- Taylor, P., & Luther, M. B. (2004). Evaluating rammed earth walls: a case study. *Solar Energy*, 76(1–3), 79–84.
- Tyoden, J. N., Lawan, A., & Ejeh, S. (2023). An evaluation of the compressive strength of nanosilicate hollow crete blocks. *Engineering Proceedings*, 56(1), 40.