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# Assessment of Reusing Gold Tailings as a Substitute for Natural Sand in Brick Making for Construction Materials in Tanzania

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**Abstract:** The mining industry, despite its contributions to the economy of many countries, including developing ones, has caused significant damage to the environment. In this study, gold tailings were used as a potential alternative for natural sand in brick manufacturing. The materials and bricks made from these materials were evaluated both mechanically and environmentally, through particle size distribution, water absorption, compressive strength, and leaching characteristics. The results showed that the particle size of gold tailings was less than 2 mm, with a high percentage of silicon dioxide (71.8%). The compressive strength of the bricks made from gold tailings replacements ranged from 11.67 to 22.33 MPa, with the most promising strength being in T25% replacement. In terms of environmental leaching, the study revealed that most gold tailings replacements did not show any metal leaching, and the levels of metals detected were significantly low. There fore, this study concluded that using gold tailings as a replacement for natural sand in construction industries is a viable and promising alternative. This practice can reduce the disposal of gold tailings on mine sites, contributing to a more sustainable mining industry

**Keywords:** Gold tailings, bricks, compressive strength, replacement, leachate

## I. INTRODUCTION

The gold industry, despite its contribution to the economy of many countries worldwide, also has serious impacts on the surrounding environment. These impacts occur in the land and take up a large space when disposing of mine tailings and other overburden wastes [1],[2]. Due to the rapid growth of mining operations, there is a significant accumulation of high volumes of mine waste, including tailings waste [3]. Annually, more than 5x109 to 14x109 tons of tailings are generated worldwide, utilizing approximately 4x105 km2 of land area [4],[5],[6]. This amount is almost equivalent to the quantity of gold ore in mineral processing [7]. The global mining industry generates billions of tons of waste every day due to its low value, and most of this waste ends up in waste storage facilities, such as waste rock dumps and tailings dams [8].

In normal practices, tailings are typically discharged into tailings ponds due to the fact that they contain toxic elements. As a result, the discharge of tailings often results in significant environmental contamination [9]. However, the unavailability and non-use of options for reuse and recycling leads to a large volume of gold tailings, which can have severe impacts on both the environment and society [7]. It is essential for mining operations to be conducted in a sustainable, economically feasible, and socially acceptable manner [10]. Therefore, waste management techniques that promote the use of green technologies, which can improve environmental and social performance, should be adopted. For instance, the reuse of tailings has been shown to be a viable and environmentally friendly option[11].

The use of tailings in the construction sector or materials should be considered, given the significant reduction in the overall carbon footprint of a building. This can also help mitigate the usage of natural resources and address the issues related to their production[12],[13]. Several studies, such as [14], [15], have reported the use of gold tailings as a viable alternative for brick-making. In South Africa, [16] evaluated the feasibility of using gold tailings for brick-making. Therefore, mine waste can be characterized as hazardous or non-hazardous material, but there are opportunities for reuse and recycling that can provide a sustainable alternative to conventional waste management, as well as minimize or avoid the need for large waste storage facilities[17]. Mine tailings can be used as active additives and fillers for cement and concrete. For example, [18] used gold tailings to partially replace (up to 30%) cement in mortar. Similarly, [19] used tailings to replace 20% cement and demonstrated that they act as a buffer against chemical attack. Therefore, the utilization of tailings in cement and concrete can be beneficial for the environment, both in terms of solid waste processing and reducing the use of virgin materials in the construction industry [20].The construction industry and sand extraction have become global challenges, with the extraction rate of sand from natural systems exceeding the natural replenishment rate [21]. This crisis has led to a shortage in the availability of sand [22],[23],[24]. In fact, studies have reported that a significant amount of sand is consumed daily in construction industries [25].To address this issue, there have been suggestions to use gold tailings, which have a particle size similar to fine sand, as aggregates in brick manufacturing [26]. However, there have been limited studies on the durability performance of concrete prepared with tailings as a sand substitute. Thus, a comprehensive investigation is required to understand the mechanical properties and durability performance of using tailings as a replacement for sand[27]. Previous studies have shown that the use of tailings as a fine aggregate replacement can enhance the density of fresh mixtures due to the higher specific gravity of tailings compared to natural sand [28], [29]. Therefore, this study aimed to investigate the reuse of gold tailings as a substitute for natural sand in brick making for construction materials.

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## II. MATERIALS AND METHODS

### Materials

The materials used in this study for making bricks included gold tailings, sand, and cement. Gold tailings were obtained from a small-scale mining company in Chunya, Mbeya, Tanzania. They were then air-dried and taken to the BRU laboratory in Mwenge, Dar es Salaam for determination of physical properties. Other gold tailing samples were also sent to the Environmental Engineering laboratory for chemical composition analysis. The sand used in this study was natural sand, procured from local vendors in Lufungira and transported to the BRU laboratory. The cement used was Twiga EXTRA, purchased from a local supplier in Dar es Salaam.

Figure 1: Gold tailings used for bricks manufacturing

### Physical and chemical properties of material

Physical properties of the gold tailings were determined for parameters including; Particle size distribution, pH, water absorption, compressive strengnt and heavy metals

### Particle size distribution

The following steps were carried out to determine the particle size distribution in this study:

samples were air-dried on plastic bags until completely dry; the small dry samples were weighed and recorded as the initial weights, with 300g for each sample; the sieves were arranged in order of decreasing mesh size, with the largest mesh size on top (starting with 4mm and ending with 0.063mm); the samples were placed on the top sieve, and the set of sieves was shaken for a fixed time of 10 minutes using a mechanical sieve shaker; after shaking, the samples retained on each sieve were carefully collected, weighed, and recorded; the percentage of samples retained on each sieve was calculated by dividing the weight of samples retained on each sieve by the initial weight of the soil sample and multiplying it by 100; the particle size distribution curves for both samples were plotted on one graph by connecting the percentages of samples retained on each sieve with the corresponding size of the sieve opening.

### Experimental setups for bricks production

The experiment aimed to investigate the potential replacement of sand with different ratios of gold tailings, ranging from 0% to 100%. The ratios used were 0%, 25%, 50%, 75%, and 100%.

Table 1: Mixing Proportion Design for Brick Making

| % Gold Tailings Replacement | Sample Name | Cement [g] | Sand [g] | Gold tailings[g] |
|---|---|---|---|---|
| 0 | T0 | 200 | 1200 | 0 |
| 25 | T25 | 200 | 900 | 300 |
| 50 | T50 | 200 | 600 | 600 |
| 75 | T75 | 200 | 300 | 900 |
| 100 | T100 | 200 | 0 | 1200 |

**Water absorption of bricks**

The bricks were dried in a ventilated oven at a temperature of 105°C to 115°C until it reached a substantially constant mass. The bricks were then cooled to room temperature and their weight (W1), which is the weight of the dry bricks, was recorded. The dried brick was then fully submerged in clean water at room temperature for 24 hours. After 24 hours, the brick was removed and any remaining traces of water were wiped off with a damp cloth. The weight of the specimen after it was removed from the water (W2) was then recorded..

Water absorption in percentage was calculated as (%) ={ (W1 -W2)/W2} x 100

**Compressive strength of bricks**

The bearing surface of the compressive machine plate was cleaned to remove any loose grit. The bricks were placed horizontally between plates of the testing machine. The final check was made to ensure that the brick was placed in the correct position and that the brick was axially loaded. Load was applied axially at a uniform rate of 14 N/mm2 (140 kg/cm2) per minute until failure occurred and the maximum load at failure was noted. The load at failure is the maximum load at which the brick fails to produce any further increase in the indicator reading on the testing machine. The bricks were prepared as per ASTM C140 and were tested for compressive strength at 3, 7, and 28 days in MPa.

**Leaching test**

The leaching test was conducted on a brick to assess the potential release of heavy metals and other pollutants. The bricks were ground into small pieces and then soaked in distilled water for 24 hours. After conditioning, heavy metal levels were measured using AAS.

## III. RESULTS AND DISCUSSION

**Particle size distribution of materials**

Based on the results obtained from the sieve analysis method as presented in Figure 1, it can be observed that the particle size distribution of gold tailings shows that most particles are smaller than 1 mm at D90. In comparison, the sand sample's particle size distribution shows that most particles are smaller than 1.5 mm at D90.

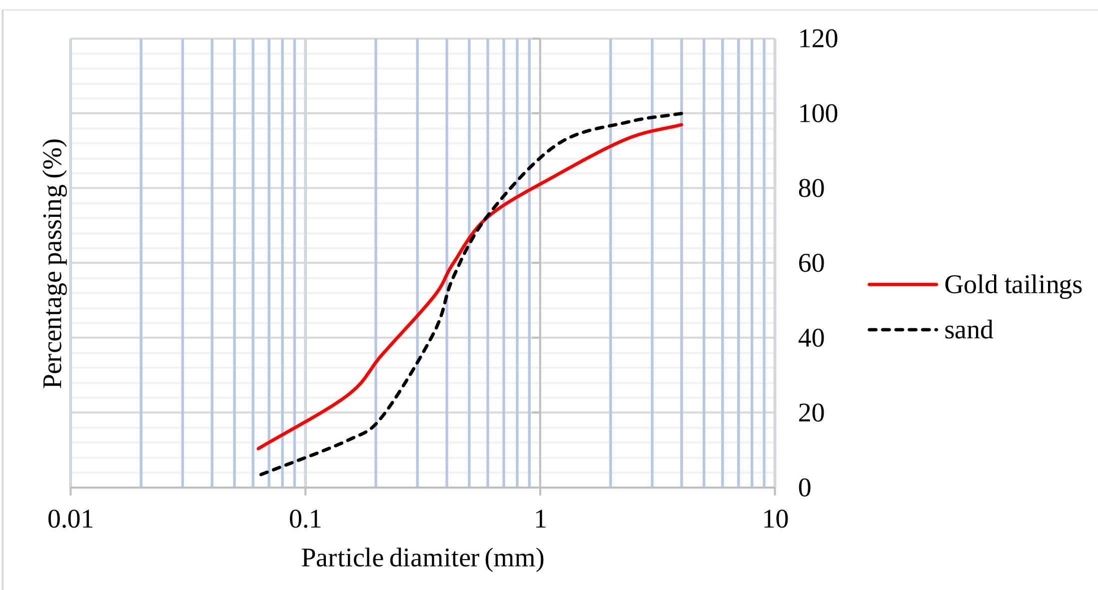


Figure 1: Particle size distribution of gold tailing and sand.

In this study, it was observed that the particle size distribution of sand and gold tailings was between 1.5 and 2 mm, respectively.In a study conducted by [30], it was reported that 90% of the materials from tailings were 0.17 mm, while in natural sand, it was 1.8 mm. In this study, it was observed that the particle size of sand and tailings were not significantly different and could be suitable replacements for each other. Another study by [31] also reported that tailings can replace sand due to their similar properties, such as particle size distribution.

**Oxides composition in gold tailings, sand and cement**

In determination of the chemical composition of gold tailings and other materials, the results presented in Figure 2 reveal that the gold tailings have a high content of SiO2, with minor amounts of CaO, Fe2O3, and Al2O3

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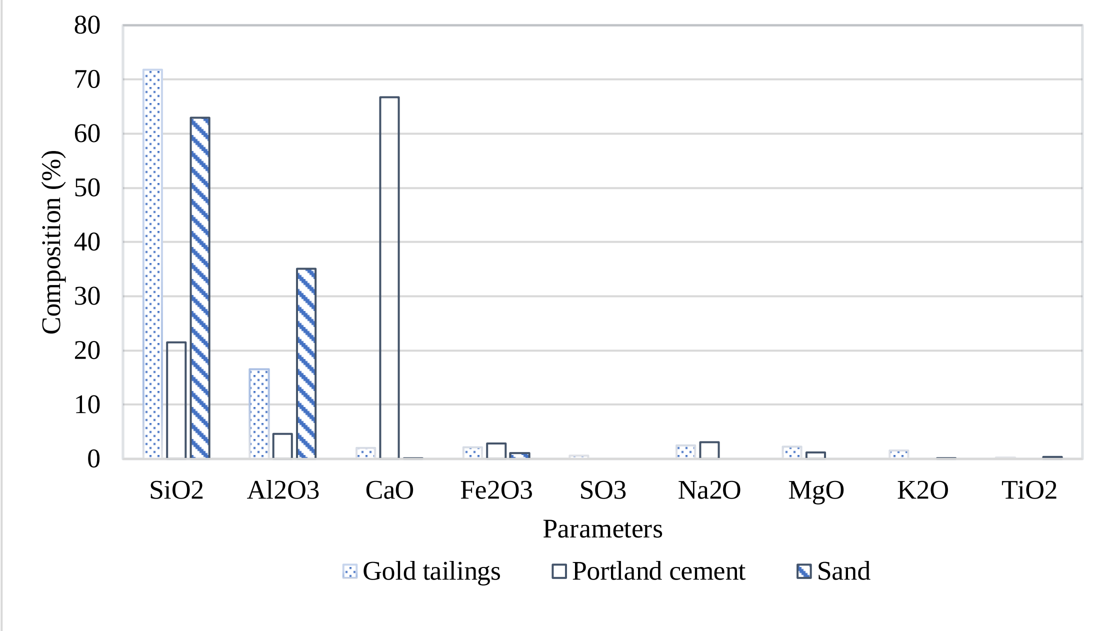


Figure 2: Chemical composition of materials

The major constituents of the gold tailings in this study are shown in Figure 2. The highest value was found to be silicon oxides, comprising 71.8%, followed by sand at 63%. A previous study by [32] also reported a high amount of silicon dioxide, at 77.7%, in gold mine tailings. Additionally, [33] suggested that a high percentage of silicon dioxide, around 70%, can contribute to the pozzolanic reaction, potentially leading to desirable properties in gold tailings as a replacement for sand. With the high concentration of silicon dioxide in gold tailings, it is possible that its incorporation in bricks could increase their strength.

**Characteristics of leachate formed from gold tailing bricks made**

The physical-chemical characterization of gold tailing bricks is presented in Table 2. The pH was measured to be 8.5, while the concentrations of metals such as Zn, Mn, Pd, Cr, and Ba were found to be below the standard limits [Table 2]. This study suggests that the leachate formed from the bricks made of gold tailings does not pose a significant threat to the environment, as the levels of pollutants are very low.

Table 2: Leachate characteristics of gold tailings bricks produced

| **% Replacement of gold tailings** | **Parameters** | | | | | | **TZS 860:2006** |
|---|---|---|---|---|---|---|---|
| | pH | Zn | Mn | Pb | Cr | Ba | 6.5 - 8.5 |
| 0 | 7.1 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 5 |
| 25 | 7.3 | 0.11 | 0.1 | 0.001 | 0.001 | 0.001 | 5 |
| 50 | 7.9 | 0.1 | 0.1 | 0.001 | 0.001 | 0.001 | 0.1 |
| 75 | 8.1 | 0.1 | 0.1 | 0.001 | 0.001 | 0.001 | 1 |
| 100 | 8.5 | 0.1 | 0.1 | 0.001 | 0.001 | 0.001 | 1.5 |

Based on the results of this study [Table 2], the leaching from bricks produced showed low levels of selected parameters [metal concentrations] and complied with TZS 860:2006 effluent standards. Most of the parameters, such as pH, were close to neutral in all replacement materials and the levels of metals in the leachate were found to be below the detection limit of the instrument. These results are consistent with those published by [34], which reported that concentrations of chemical compositions in the leachate of bricks made from tailings were significantly low. [35] also suggested that the low concentrations may be due to the stabilization of deposited materials.

**Compressive strength tests of bricks produced**

The compressive strength of the bricks produced conventionally and replaced with T25, T50, T75, and T100 of gold tailings is presented in Figure 3 and Table 3. The results of this study showed that T25 has a higher compressive strength compared to other replacements. Additionally, as the curing days increased, there was an increase in the compressive strength of the bricks produced [Table 3]. The study also observed the lowest compressive strength with a replacement of T100.

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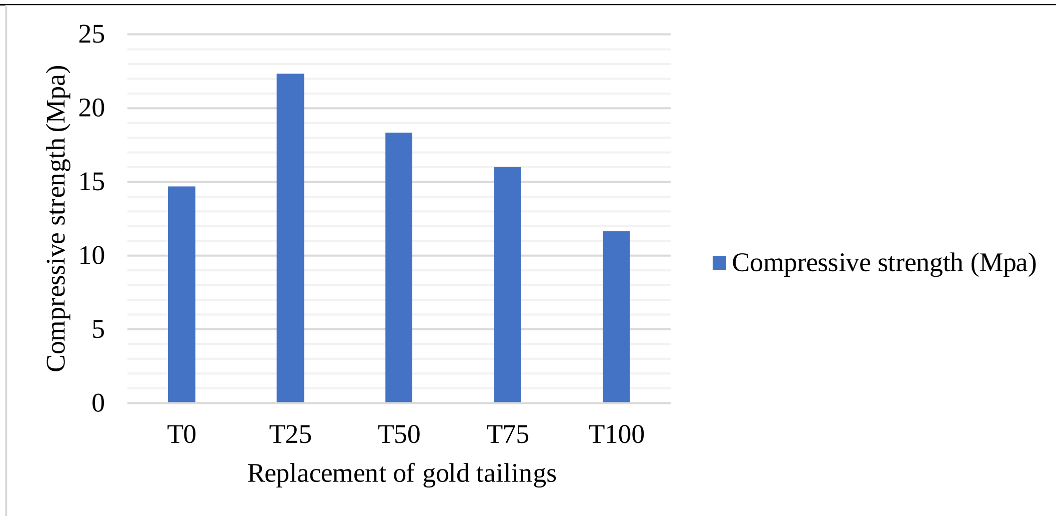


Figure 3: Compressive strength of blocks

Table 3: Compressive strength with curing days

| % Replacement of gold tailings | Name of sample | Compressive strength [Mpa] | | |
|---|---|---|---|---|
| | | 3 -days | 7-days | 28-days |
| 0 | T0 | 9.24 | 11.25 | 14.67 |
| 25 | T25 | 12.85 | 17.42 | 22.33 |
| 50 | T50 | 10.22 | 13.42 | 18.33 |
| 75 | T75 | 8.72 | 12.41 | 16 |
| 100 | T100 | 6.12 | 7.91 | 11.67 |

In Figure 3, it is evident that bricks with a 25% gold tailings replacement have a higher compressive strength compared to other replacement percentages. The lowest compressive strength is seen with a 100% gold replacement after 28 days of curing [Table 3].A similar study by [36] found a compressive strength of 24.81 Mpa when using a 25% replacement of gold tailings. [37] also investigated the effect of replacing sand with varying percentages of iron tailings on the compressive strength of concrete. They observed that concrete with tailings had a higher compressive strength than the reference concrete. The authors attributed this to the finer particles of tailing material, which aided in binding the particles.In a related study, [27] found that the physical properties of tailings, when used as a sand replacement, greatly influenced the fresh and hardened properties of concrete.Overall, the use of tailings as a replacement for sand can improve the compressive strength of concrete

**Water absorption**

Water absorption of gold tailings replacement was presented in Figure 4. Generally, all replacements showed a water absorption value of below 10%. The highest water absorption value was observed in the replacement of T100 by 10.65%, while without replacement (T0), the water absorption value was recorded as 7.87%.

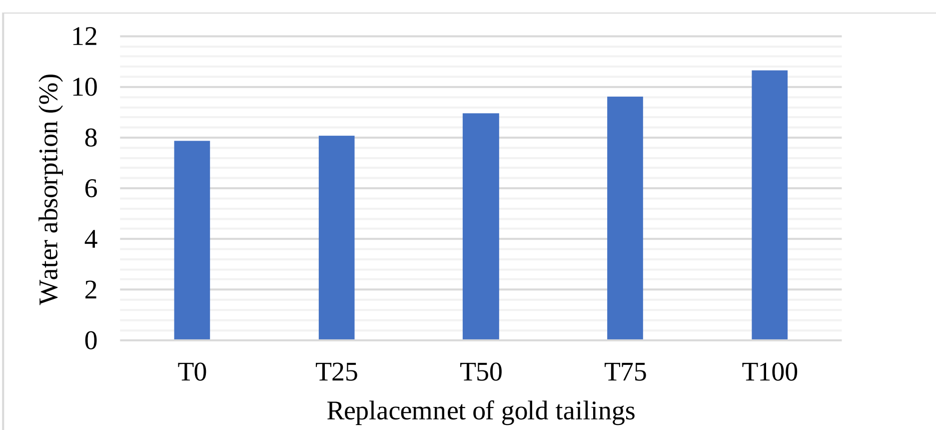


Figure 4: Water absorption of blocks

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In this study, it was found that the water absorption increased when gold tailings were used as a replacement for T100. This is consistent with other studies, which have also shown that using 70% of tailings as a replacement can lead to an increase in water absorption [31]. The water absorption of the gold tailing replacement materials in this study ranged from 7.87 to 10.65%. These results are in line with [14], who reported that the water absorption for mill tailings content was less than 20%. They noted that higher tailings content may result in higher water absorption.

## IV. CONCLUSION

The aim of this study was to assess the reuse of gold tailings as an alternative for natural sand in brick making. The mechanical strength and chemical composition of the gold tailings bricks were analyzed to determine their suitability. Results showed that bricks with 25% gold tailings replacement had a promising compressive strength after 28 days of curing. Furthermore, there were no chemical releases observed in the leachate from the gold tailings bricks. Thus, the use of gold tailings as a substitute for sand in construction materials was found to be both mechanically and environmentally viable. The study suggested that using gold tailings not only reduces the environmental impact of disposing mine tailing wastes, but also creates a circular economy for mine waste management in the construction industry. This study found that there is a need for further investigation into the use of various environmental conditions in order to optimize mix proportions and assess the long-term durability and potential leaching of contaminants.

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