Gold and Iron Tailings to Improve the Compressive Strength and Workability of Concrete

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Abstracts: *This scientific study aims to determine the optimal replacement percentage of mine tailings as a substitute for fine aggregate to improve both the compressive strength and the workability of the concrete, both in the case of gold mine tailings and gold mine tailings iron. It is a documentary, bibliographical and descriptive investigation that follows a deductive method with a quantitative approach. In addition, it is descriptive, correlational, and explanatory, with a descriptive level and a non-experimental, longitudinal, and retrospective design. The results indicate that the incorporation of 15% gold mining tailings increases the compressive strength by 4,44% while incorporating 12% iron mining tailings increases the resistance to compression by 7,79%. Likewise, by adding 30% gold mining tailings, a notable increase of 74,36% in tensile strength is obtained. On the other hand, when 5% gold mine tailings are added, the slump remains at 4"; however, by increasing the addition to 10%, it decreases from 2" to 1.77". In the case of tailings iron miners incorporating 30% the settlement remains at 2"; but by increasing the amount to 12%, the slump decreases from 3.32" to 1.57". Finally, the study shows that using mine tailings as a substitute for fine aggregate can significantly improve the compressive strength and workability of concrete, depending on the type of tailings and its percentage of incorporation.*

Keywords: Concrete, Iron Tailings, Gold Tailings, Compressive Strength, and Workability.

1. INTRODUCTION

The waste generated by mining processes, known as tailings, contains high amounts of chemicals due to the extraction of minerals. Maruthupandian et al. [1] note that the increase in demand for minerals such as coal, copper, iron, aluminum, gold, tungsten, and zinc, among others, has led to a significant increase in the amount of waste produced by mining, including solids, crushed rock, and overburden soil. Mine tailings, the fine-grained residues left after the extraction of minerals, are one of the biggest environmental challenges in the mining industry.

Mineral tailings from mines, quarries, and excavations are often rich in SiO2, Al2O3, CaO, and Fe2O3, making them attractive candidates for use in the production of construction materials since these oxides are also critical components of cement and other alkali-activated binders. This contribution aims to provide a comprehensive overview of the nature of mine tailings, the current status of their use in cementitious binders, and their future potential. In addition, the limitations associated with using mine tailings as a cementitious binder, mainly their low reactivity, will be presented, and possible solutions to overcome these challenges will be given.

Mine tailings in cementitious binders could significantly benefit meeting global sustainability goals. This is because mine tailings generate high levels of contamination, exceeding the technical capacity of management, especially during climatic events such as heavy rains, which can result in poisoning diseases due to the consumption of metals present in crops and water. In this sense, it is necessary to state that the proper management and use of mine tailings in cementitious binders could not only contribute to reducing the negative environmental impacts of the mining industry but could also improve sustainability and safety in the production of construction materials.

The 10th International Multidisciplinary Scientific Geoconference and EXPO, SGEM [2], highlighted the importance of modern management in mining production, geology, and environmental protection. Some topics of particular focus were the reuse of metallurgical slag in producing eco-cement clinker, waste management, watersaving opportunities in urban green spaces, and the possibility of granulating and manufacturing briquettes from steel and foundry fly specks of dust. Other relevant topics included iron production, fly ash recycling in cement manufacturing, and auditing and recycling as strategies for sustainable development in real estate market analysis.

Mining activity in the highlands of Peru has negatively impacted various sectors, mainly due to informal mining and companies that lack an adequate environmental impact plan to mitigate contamination. These impacts include disease in vulnerable populations with little access to hospitals, destruction of unique species, and changes in the ecosystem. Poor management of mining waste and the lack of an adequate contingency plan have resulted in protests and economic losses.

Although mining represents a significant economic advance for the country, it is also a source of substantial pollution. For this reason, research focused on sustainable use in the construction sector is being carried out. In this sense, Falayi [3] mentions that fly ash (FA) and basic oxygen furnace slag are being used as additives in the geopolymerization of gold mining tailings. This research aims to determine the effects of these additives on the resistance and the mechanism of metal immobilization using modified geopolymers. The results showed that the geopolymers increased in strength thanks to the formation of calcium silicate hydrate (CSH) phases. Furthermore, high iron (Fe) immobilization in the geopolymers was achieved, indicating their potential to reduce environmental contamination in long-term use.

On the other hand, Solouki et al. [4] highlight the importance of recycling mining by-products in geopolymer applications, which contributes to preserving natural resources and reducing environmental problems. Geopolymers, rich in aluminosilicates, offer an exciting option to reuse quarry dust and mineral waste in various applications. The review shows the progress made in this area in the last decade, considering different precursors such as metakaolin, ground granulated blast furnace slag (GGBFS), fly ash, and quarry and mining mineral waste.

On the other hand, Gcasamba et al. [5] present results of laboratory investigations on gold tailings (GMT) to assess its suitability as an alternative backfill solution in mine reclamation. The characterization of these tailings revealed their chemical and mineralogical composition, and it was found that they showed favorable characteristics to be used as mine fill. In particular, the tailings presented a high resistance, and their particle size allowed a lower water-cement ratio in the paste formation. In addition, its plasticity provides resistance to shear slippage in fluvial conditions. Curing and cement addition positively affected the compressive and shear strength of the tailings, making them a promising option for use in mine fills.

With this background, it is possible to affirm that the proper management of mining is crucial to minimize the negative impacts on the environment and local communities. Research on the reuse of mining waste in construction, such as using geopolymers, offers exciting solutions to reduce pollution and preserve natural resources. These advances in sustainability in the mining industry are essential to guarantee responsible economic development that respects the natural environment.

2. MATERIEL AND METHODS

The research is presented as a documentary, bibliographical and descriptive study. The documentary approach was used to analyze and interpret information from various sources, such as texts, books, articles, and other relevant resources. The bibliographic process focused on obtaining specific existing documentation for the investigation. In addition, the descriptive system was used to analyze, describe, and classify the population under study. On the other hand, the method used was deductive, based on conclusions from previous research such as scientific articles, theses, conferences, scientific journals, technical publications, and specialized regulations used by experts.

The type of applied orientation of the research sought to analyze the improvement of the physical and mechanical properties of the concrete through the partial replacement of the fine aggregate with mine tailings. The results were expressed in metrics, calculations, and statistical graphs regarding the quantitative approach. Data were collected retrospectively from consulted experimental articles. The research is classified as descriptive, explanatory, and correlational since laboratory results were collected to describe the influence of mine tailings as a substitute for fine aggregate and to analyze the superplasticizer additive's effect on concrete workability.

In turn, the level of research corresponds to a descriptive one since the characteristics of the concrete properties were studied from the results obtained from previous studies collected. In addition, it allowed quantifying the independent variable by analyzing the features of the mine tailings and its influence on the design of mixtures to improve concrete's physical and mechanical properties. The study design is non-experimental since no physical manipulation of the variables was carried out. Instead, the collection of data from other investigations that did use experimental methods was used, which provided information for the analysis and comparison of results.

Regarding the number of measurements, the design is longitudinal since resistance tests were carried out with specimens of different ages, following the E.060 Standard. The retrospective approach is because data on experimental results obtained from various academic databases were collected, which allowed a look into the past. In terms of design classification, it is of the cohort type since it was based on comparing various tailings samples obtained from different percentages of mine tailings (cause) to measure the behavior of concrete properties (effect). The study population was formed by collecting various articles from reliable academic bases, and later the experimental results obtained in each were compared and discussed. With these premises, it is recognized that the research is based on an in-depth literature review, collecting data and previous experimental results to analyze the influence of mine tailings as a substitute for fine aggregate in improving concrete's physical and mechanical properties. The quantitative approach and non-experimental design provided a solid framework for analyzing the information and drawing relevant conclusions.

3. RESULTS

It was observed that the replacement of mining tailings as a substitute for fine aggregate in concrete presents various results that may be due to its origin, percentage, and chemical composition that it offers. The information collected is experimental and of national and international scope, so a comparison has been developed between the results of each study. Tebogo & Thandiwe [6] mention that elemental, mineralogical, and micrographic analyses are performed on raw gold tailings.

3.1. Gold Tailings As Fine Aggregate To Increase Compressive Strength

Table 1 shows that incorporating 15% gold mining tailings increases compressive strength by 4.44% [7]. However, when 25% is added, the compressive strength drops by - 0.90% [8].

Table 1. Gold tailings as fine aggregate - Compressive strength.

Author	Design Pattern (kg/cm2)	Tailings of gold (%)	Compressive strength (gold tailings) (kg/cm2)	Increase in compressive strength (%)
Ramalinga et al., (2015)	405	10%	415	2.47%
Suarez (2022).	405	15%	423	4.44%
Condori (2018)	222	25%	220	-0.90%

3.2. Iron Mine Tailings As Fine Aggregate To Increase Compressive Strength

Table 2 shows that incorporating 12% of iron tailings increases compressive strength by 7.79% [9]. However, when incorporating 30% of iron tailings, the compressive strength increases by 4.81% [10].

Table 2. Iron ore mine tailings - Compressive strength.

Autor	Design Pattern (kg/cm2	Tailings of gold (%)	Compressive strength (gold tailings) (kg/cm2)	Increase in compressive strength (%)
Jiang, (2018)	416	30	436	4.81%
Huerta & Roldan (2021).	231	12	249	7.79%

3.3. Relave minero de oro como agregado fino para aumentar la resistencia a la tracción

Table 3 shows that incorporating 10% gold tailings increases tensile strength by 19.64% [11]. However, when 20% gold tailings are incorporated, the tensile strength increases by 19.61% [12].

Table 3. Gold Mine Tailings - Tensile Strength.

Author	Design Pattern (kg/cm2	Tailings of gold (%)	Compressive strength (gold tailings) (kg/cm2)	Increase in compressive strength (%)
Ramalinga et al., (2015)	51	20	61	19.61%
Prajwal et al., (2019)	56	10	67	19.64%

3.4. Iron Mine Tailings As Fine Aggregate To Increase Tensile Strength

Table 4 shows that incorporating 30% gold tailings increases the tensile strength by 74.36% [13]. However, when containing 30% iron tailings, the tensile strength increases by 34.21% [14].

Table 4. Iron mine tailings - Tensile strength.

Author	Standard design (kg/cm2)	Ideal percentage (%)	Tensile strength (iron tailings) (Kg/cm2)	Tensile strength increase (%) (%)
Jiang et al., (2019)	39	30%	68	74.36%
Dhanabal et al., (2021)	38	30%	51	34.21%

3.5. Gold Mine Tailings As Fine Aggregate To Improve The Workability And Flowability Of Concrete.

Table 5 shows that when 5% gold tailings are added, the slump remains at 4" [15]. However, when 10% gold tailings are added, the recession decreases from 2" to 1.77" [16].

Table 5. Gold Mine Tailings - Concrete Workability.

Author	Standard design (Inches)	Ideal percentage (%)	Ideal percentage settlement (Inches)
Cruz y Supo (2022)	4	5	4
Prajwal et al., (2019)	2	10	1.77

3.6. Iron Mine Tailings As Fine Aggregate To Improve The Workability And Fluidity Of Concrete

Table 6 shows that when incorporating 30% of iron ore tailings, the slump remains at 2" [17]. However, when incorporating 12% of iron ore tailings, the slump decreases from 3.32" to 1.57".

Table 6. Iron mine tailings - concrete workability.

Author	Standard design (Inches)	Ideal percentage (%)	Ideal percentage settlement (Inches)
Dhanabal et al., (2021)	2	30	2
Huerta & Roldan (2021)	3.32	12	1.57

4. DISCUSSION

Ramalinga et al. [3], Suarez [5], and Condori [7] indicate that gold tailings increase compressive strength, and the average percentage of gold tailings incorporation is 13%. For Jiang (2019); Dhanabal [12], and Huerta & Roldan [14], iron mining tailing increases compressive strength, in addition; the average percentage of incorporation of iron mining tailing is 23%. With the results obtained from Condori [7], Ramalinga et al. [3], Prajwal et al. [10], and Janadi [9], it was analyzed that the gold mining tailing increased the tensile strength; in addition, it was determined an average percentage of incorporation of gold mining tailing is 15%. With the results of Jiang et al. [11] and Dhanabal et al. [12] it was analyzed that the iron mining tailings increased the tensile strength; in addition, the average percentage of iron mining tailings was determined to be 30%. Cruz and Supo [4], Prajwal et al. [10], and Parthasarathi et al. [17] found that gold tailings decreased workability. Dhanabal et al. [12], Carolina et al. [16], Zainab & Enas [6], and Huerta & Roldan [13], gold mine tailings decrease workability.

CONCLUSIONS

The conclusions obtained from the experimental results show that the incorporation of gold and iron mine tailings in the concrete significantly impacts its mechanical and physical properties. When analyzing the specific percentages of tailings incorporated and their influence on compressive and tensile strength, the following findings can be highlighted:

In the case of gold mining tailings, it is observed that by adding 15% of this material, an increase of 4.44% in compressive strength is achieved. However, increasing the amount to 25% shows a decrease of -0.90% in compressive strength. These results suggest an optimum point of incorporation of gold tailings in concrete, beyond which a negative effect on compressive strength is obtained.

In the case of iron ore mine tailings, the addition of 12% leads to a significant increase of 7.79% in compressive strength. However, by increasing the percentage of iron tailings to 30%, an even more substantial increase is produced, reaching a 4.81% increase in compressive strength. These results indicate that incorporating iron tailings in the concrete positively affects the compressive strength, which is enhanced at higher incorporation percentages.

Regarding tensile strength, the inclusion of 10% gold mining tailings shows a significant increase of 19.64%. However, by increasing the percentage of gold tailings to 20%, the increase in tensile strength remains practically constant, reaching an increased value of 19.61%. Finally, the incorporation of 30% gold mining tailings results in a notable increase of 74.36% in tensile strength. These results suggest that 10% gold tailings may be sufficient to obtain a significant increase in the tensile strength of the concrete.

Regarding the settlement, it is observed that the inclusion of 5% gold mining tailings does not have a significant impact and maintains the settling at 4". However, by increasing the percentage of gold tailings to 10%, a decrease in settling from 2" to 1.77". On the other hand, by incorporating 30% of iron mine tailings, the settlement is maintained at 2". But by increasing the percentage of iron tailings to 12%, the slump decreases even more, reaching a value of 1.57". These results suggest that the incorporation of gold mine tailings can improve the workability of concrete, especially at 10% of incorporation. In contrast, in the case of iron tailings, an improvement in workability is achieved at 12% incorporation.

Research shows that the incorporation of gold and iron mine tailings into concrete has a significant impact on its mechanical and physical properties. There is an optimal point of incorporation in compressive strength for both types of tailings, and notable increases in tensile strength when incorporating gold tailings are highlighted. In addition, the incorporation of gold tailings improves the workability of the concrete, especially at 10% incorporation. These findings are critical for developing sustainable practices in the construction industry and for harnessing the potential of mine waste in improving construction materials. However, further research is required to better understand the mechanisms behind these effects and optimize mine tailings' use in concrete production.

RECOMMENDATIONS

The chemical properties of the hardened concrete after the tailing added must consider its degree of toxicity. Being a waste of a chemical process where minerals are separated, it has substances possibly harmful to human contact without proper equipment. The proportions used for the concrete mix design, as well as the type, because they have different results, both in resistance and workability.

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