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# The use of Iron Ore Tailings in the Iron Quadrangle

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**Abstract:**

Large amounts of tailings were being deposited in dams as a result of the processing of this rock to produce the iron ore concentrate. Dam storage became extremely problematic following the dam ruptures. Tailings are increasingly being examined for various storage options, such as dry storage in piles and use as a raw material in other industrial chains, such as civil construction and road paving. The use of Portland cement in the fabrication of civil construction products is limited due to the fine particle size of the tailings. However, Because of their ability to integrate fine-grained components, alkali activated cements should play a significant role. Although alkali activated mortars created from tailings have good properties, they are quite expensive, particularly when sodium silicate costs are high. The use of overburden and other aluminosilicate sources, as well as sodium silicate synthesis from tailings, alternative calcined clays, and the use of the overburden and other aluminosilicate sources, are all being researched in this study with the goal of lowering production costs.

## 1. Introduction

India's main export is iron ore concentrate, which is shipped to a number of nations, including China. It is predicted that one tonne of tailings is created for every tonne of iron ore concentrate produced, resulting in a daily production of 400,000 tonnes. Typically, these tailings were stocked in dams. However, following the ruptures in the Iron Quadrangle, tailings storage in dams became untenable. Other options for the tailings include storing them in piles or using them as raw materials in other manufacturing processes.

Civil construction products should play a significant role since they may utilise vast amounts of tailings. The use of tailings as fine aggregate in Portland cement concrete is limited due to their fine granulometry (Figure 1).

Alkali activated mortars with fine aggregated tailings can develop strong mechanical qualities for use as non-structural concrete, according to one study. For samples of mortars

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constructed using metakaolin, sodium silicate, sodium hydroxide, and 40-60% tailings sedimented obtained compression strengths of up to 43 MPa.

However, as shown in Figure 2, the predicted prices of alkali activated concretes are at least three times more than Portland cement concrete. In terms of cost, sodium silicate is by far the most important raw material, followed by sodium hydroxide. The goal of this study is to develop alkali activated mortars including iron ore processing tailings for the production of non-structural concrete products for civil construction in India at reasonable pricing.

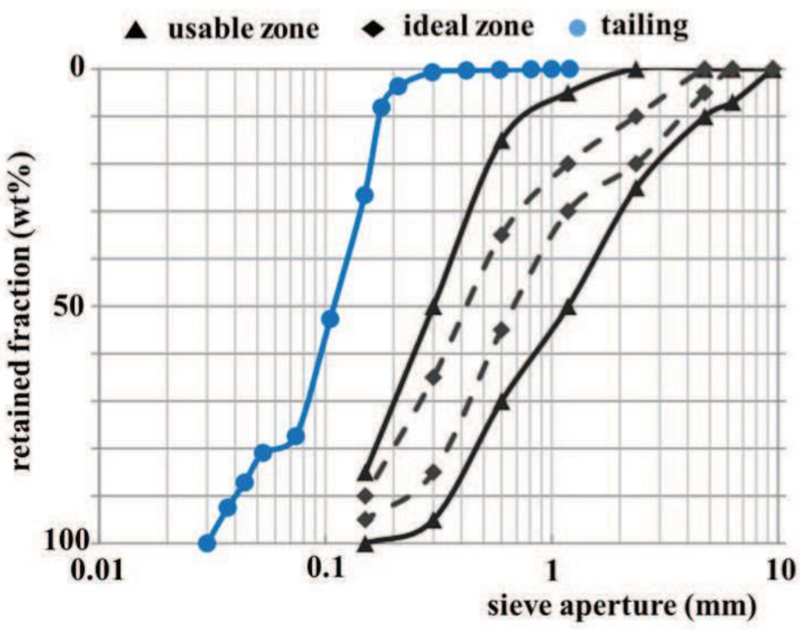


**Figure**1: Comparison of the granulometry distribution of the tailing from iron ore with the requirements for fine aggregate.

Quartz is abundant in the tailings. Because sodium hydroxide is used in huge quantities in the iron ore concentration process, iron ore mining companies often have a well-established supply chain for this raw material.

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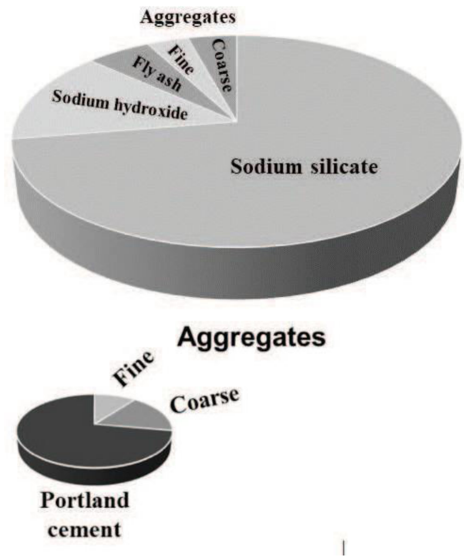


**Figure** 2: Comparison of prices of alkali activated concrete and Portland cement concrete (US prices,adapted fromTempestetal).

To make sodium silicate, combine the tailings and sodium hydroxide. In addition, the overburden that is removed in order to extract the iron ore is rich in clays like kaolin and muscovite (phyllite). It can be used to make an alkali activated cement after being calcined and mixed with sodium silicate derived from tailings as described above. With the addition of tailings to this alkali activated cement, a mortar can be made.

## 2. Materials and Procedures

Vale samples were collected, dried, and X-ray diffractometry and laser granulometry were used to describe them. This tailing contains around 80-90 percent quartz and 10-20 percent iron oxides and clays. This tailing is a very fine aggregate, as illustrated in Figure 1. After dredging, samples were collected, dried, and classified as tiny aggregate according to Brazilian criteria. The tailing is composed of 70-80 percent quartz, 15-25 percent iron oxides, clays, and organic materials.

Technical grade sodium hydroxide flakes were dissolved in local tap water to make a 30M solution, which was then combined with the tailing to make a homogeneous paste. To make powdered solid sodium silicate, this paste is heated for 4 hours at 450°C in a muffle furnace. X-ray diffractometry was used to characterise the sodium silicate.

Sulfal provided us with high-quality kaolin (a local supplier of cosmetic and cleaning materials). For 4 hours, the kaolin and overburden were calcined at 800°C. X-ray diffractometry (DRX) and Fourier-transform infrared spectroscopy were used to characterise the produced metakaolin and calcined overburden (FTIR).

On the local market, alkaline sodium silicate (Getex, SiO2/Na2O= 2.12, solids content 45 wt%) was also purchased.

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**2.1 Mortars with sediment**

The activation solution was made by mixing a 10M sodium hydroxide solution made with tap water and alkaline sodium silicate. The activation solution was combined with metakaolin in a proportion that gave a Si/Al ratio of 1.5. To make a consistent paste, the mixture was done manually with a spatula raised. The tailing was then mixed into the paste to create a homogenous fresh mortar. To remove air bubbles, the fresh mortar was placed in cylindrical moulds (10 cm diameter; 20 cm height) and swirled in an orbital stirrer. The hardening was done at room temperature and in an oven at 60°C for 24 hours. After demoulding, the samples were allowed to cure for 7 and 28 days, respectively.

TABLE1:$2^3$ factorial design for samples of alkali activated mortar with the sediment.

| **Factor** | **Low level code:-1** | **High level code:+1** |
|---|---|---|
| Tailing content | 40wt% | 60wt% |
| Hardening | Room conditions 24hours | 60°C 24hours |
| Curing | 7days | 28 days |

**2.2. Mortars with sodium silicate tailings and solid powered sodium silicate**

A spatula was used to manually make a homogeneous mixture of 62 percent metakaolin and 38 percent solid powdered sodium silicate. The dry tailing was then added and blended to make a homogeneous powder. In regard to the mass of metakaolin plus powdered sodium silicate, two tailings additions were investigated: 79 wt% and 128 wt%. To make a homogenous and workable paste, tap water was added to the powder and stirred with a spatula. This procedure generates a lot of heat, thus water should be added gently to keep the temperature below the boiling point of water. In relation to the mass of metakaolin plus powdered sodium silicate, two water additions were investigated: 54wt percent and 60wt percent. To remove air bubbles, the fresh mortar was placed in cylindrical moulds (10 cm diameter, 20 cm height) and swirled in an orbital stirrer. The process of hardening was carried out. for 24 hours at room temperature The samples were allowed to cure for 7 and 28 days after they were demolded.

TABLE 2: $2^3$ factorial design for the samples of alkali activated mortar samples made with powdered sodium silicate and tailings

| **Factor** | **Low level code:-1** | **High level code:+1** |
|---|---|---|
| Tailing content | 79 wt% | 128 wt% |
| Water addition | 54 wt% | 60 wt% |

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| Curing | 7 days | 28 days |
|---|---|---|

2.3 **Alkali activation with calcined overburden**

10M sodium hydroxide and alkaline silicate solutions were used to make the alkali activation solution. This activation solution was mixed with the calcined overburden in a proportion based on metakaolin and metamoskovite concentration. The paste was then poured into cylindrical moulds (5 cm in diameter and 10 cm in height), mixed to eliminate air bubbles, and allowed to cure for 24 hours at room temperature. The samples were demoulded once they had hardened.

**3. Discussion and Conclusions**

In comparison to the tailing from the concentration plant, the tailing has 28 percent powdered material, organic material, and a finer granulometry. This was expected, given that sediments from riverbanks and riverbeds were carried along the tailings after the Fundo dam collapsed. The majority of the powdered solid sodium silicate is made up of Na2SiO3, with tiny amounts of iron oxides and quartz. After calcination, kaolin was completely converted into metakaolin. Amorphous features were found in the calcined overburden, with quartz and rutile as minor phases.

**3.1 Mortars with tailing**

The results of the mortar's compressive strength and water absorption were analysed using the Minitab software. Figure 3 depicts the compressive strength response surface. The shape of the response surface was impacted by the hardening conditions. As the tailing addition was increased, the resistivity of the samples decreased. Curing for 28 days after hardening at 60 °C resulted in samples with greater resistances. The compressive strengths ranged from 19 to 43 MPa.

Figure 4 depicts the mortar's water absorption response surface. The shape of the surface is strongly influenced by the hardening conditions. The water absorption is lower for hardening at 60°C and decreases as the amount of tailing increases. Water absorptions ranging from 19 to 41% were recorded.

Mortar can be utilised to make pavers and other components for pedestrian sidewalks and street pavings, according to these findings. The reported water absorptions are higher than the Indian norms when used as laying mortars.

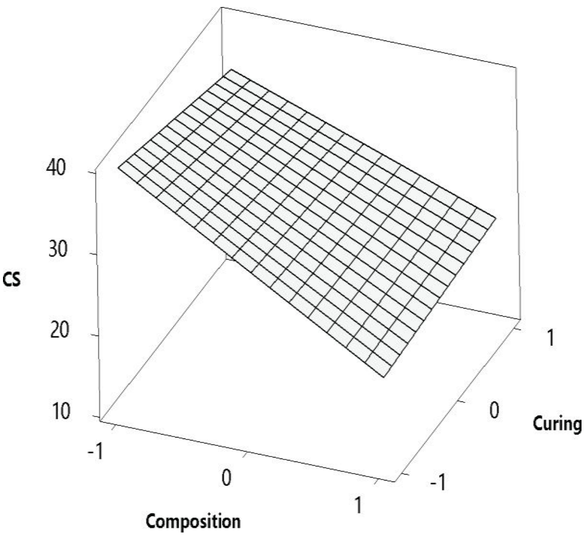
**3.2. Mortars with sodium silicate tailings and solid powered sodium silicate**

The response surface of the compressive strength (CS) of the samples is shown in Figure 5. The inclusion of tailings has no effect on the results. It's a sign that the mortar could use some extra tailing. The strength of the product improves as it cures. The compressive resistance is greatly reduced by a minor increase in water addition (from 54 to 60 wt%). Water is required to stimulate alkali activation processes and to give the mortar workability, although it should be used sparingly.

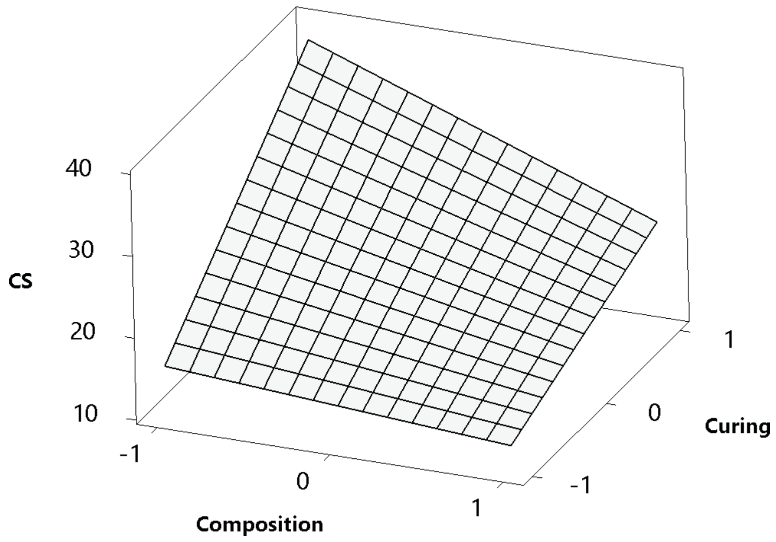
### 3.3. Activation of the alkali with the calcined overburden

So yet, just the feasibility has been proved in this example. After 30 days of curing at room temperature, the samples showed no cracks or efflorescence. Because it is available in considerable amounts inside the mine region, overburden is seen as a suitable raw material for alkali activation.

As shown in this paper, alkali activation with overburden and solid powdered silicate derived from tailing could also be considered for tailing pile stability.




Hardening at room temperature,24 hours




Hardening at 60°C,24 hours

**Figure**3: Response surface of the compressive strength (CS, in MPa) of alkali activated mortars with the addition of 40 wt% (-1) and 60 wt% (-1) of tailing for 7days (-1) and 28 days (+1) of curing and hardening at room temperature and at 60°C.

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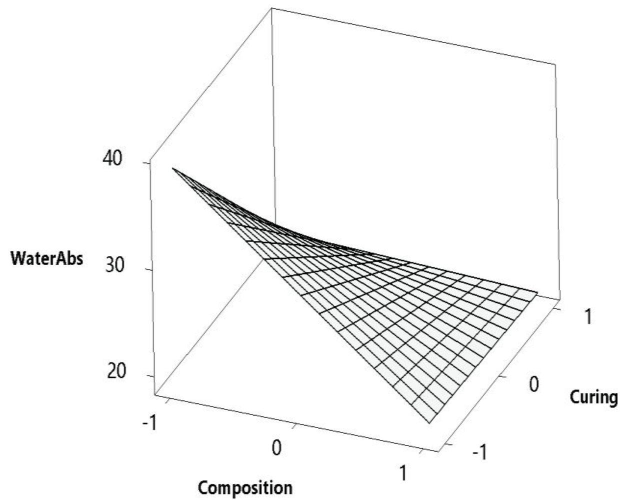
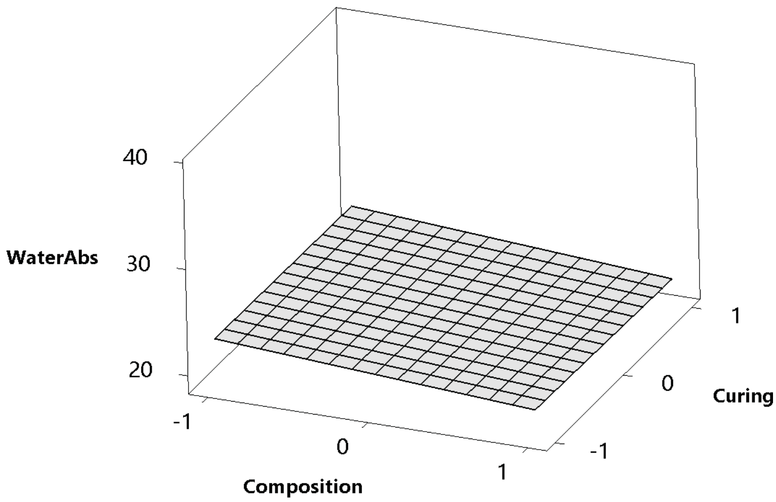
**4. Conclusions**

Alkali activation materials are more effective than Portland cement for incorporating finely granulated tailings from iron ore mining. By reacting the tailing with sodium hydroxide, which is commonly accessible at iron mining operations, solid powdered sodium silicate can be formed. The "simply add water approach" allows for one-part alkali activation with tailings inclusion. Mortars can be made by activating alkali and adding tailings, and they can be used to make pavers for paving streets and pedestrian sidewalks. The overburden could be used as a starting point for alkali activation.




Hardening at room temperature, 24 hours




Hardening at 60°C, 24 hours

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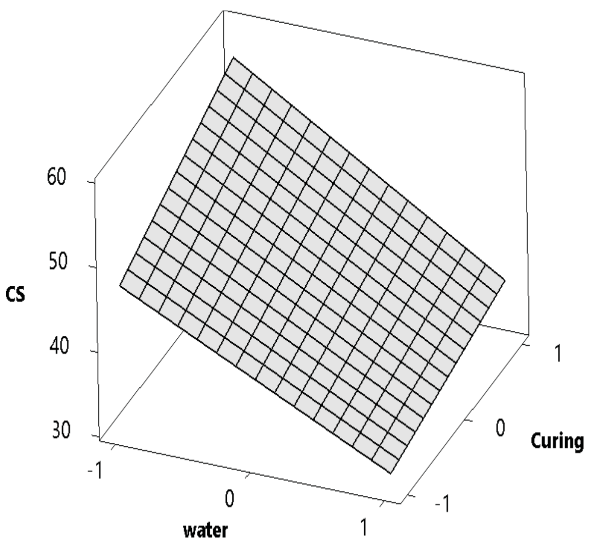
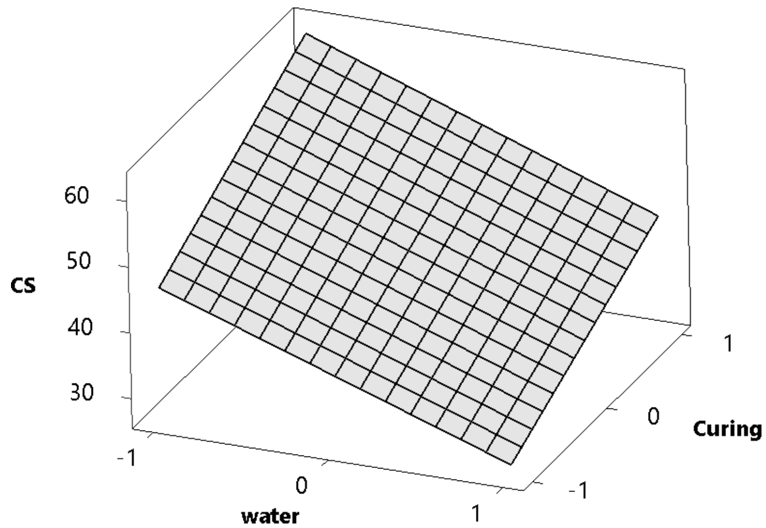
**Figure** 4: Response surface of the absorption (Water Abs, in wt%) of alkali activated mortars with the addition of 40 wt% (-1) and 60 wt% (-1) of tailing for 7days (-1) and 28 days (+1) of curing and hardening at room temperature and at 60°C.




Tailing addition:79 wt%




Tailing addition:128wt%

Figure 5: Response surface of the compression strength (CS in MPa) of alkali activated mortars made with solid powdered sodium silicate with addition of 54 wt% (-1) and 60 wt% (+1) of water for 7 days and 28 days of curing.

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