Hazardous Jarosite Waste's Potential for use as a Construction Material in Civil Engineering

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Abstract: The rate of industrialization is a good indicator of a country's progress. Large quantities of trash and by-products are produced as a result of several operations, including those that are industrial, mining, municipal, agricultural, and many others. In addition, these materials are being explored for potential use as filler in embankment design, as well as sub-base or base layers in road building. Use of potentially dangerous jarosite waste mixed with steel industry waste is advocated in the present research.

Keywords: Jarosite waste, industrialization, construction, steel industry.

1. Introduction

Environmental issues need that all sorts of industrial sectors ensure the proper disposal of all pollutants, whether they be in solid, liquid, or gaseous form, and that they manage waste efficiently and affordably. Land disposal is a common traditional way for trash removal; but, as garbage output increases, so does the amount of space needed to accommodate it, making land scarcity a common problem. Waste management is a popular modern solution to the issue of limited available land.[1]

The majority of the waste management program consists of implementing the 4 R's of waste management: reducing, reusing, recycling, and reclaiming rubbish; recovering energy from trash; and disposing of trash in an eco-friendly way. In recent decades, a wide variety of industrial wastes, including marble dust, coal, rice husk ash, phospho gypsum, dust from cement kilns, copper slag, slag from blast furnaces, bagasse ash, ceramic dust, waste steel chips, and brick dust, have been successfully to use as stabilizing agents, regardless of the addition of a tiny proportion of cementing agent like a binder, to improve end up wasting management and utilization.[2-3]

When it comes to designing, building, and maintaining physical structures, civil engineering is one of the most important and rapidly developing subdisciplines of engineering. The construction business is expanding fast, necessitating green building materials that are both long-lasting and environmentally benign. This is why formerly worthless hazardous waste materials are being investigated for possible use in the building sector. In civil engineering, jarosite waste is one example of a potentially useful hazardous waste material.[4-5]

Jarosite is a byproduct of the mining industry that occurs when sulfide ores are processed. It is produced as a byproduct of iron or sulfuric acid reactions. Crystalline jarosite is made up of of potassium, iron, & sulfate. Because of its acidity and potential for environmental harm, it

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is considered a hazardous waste item. Yet, new research indicates that jarosite waste has special qualities that make it useful as a construction material.[6-7]

There are several benefits to using jarosite waste in building projects. For starters, it may lessen the damage that mining waste does to the natural world. Second, it may be used in lieu of more traditional, but environmentally unfriendly, building materials like cement and concrete. Energy-intensive cement and concrete manufacturing is a major contributor to global warming because of the emissions of greenhouse gases. Hence, the building industry's carbon impact may be reduced by making use of jarosite waste.[8-9]

Jarosite waste may be used as a building material because of its desirable mechanical and physical qualities. Due to its great density, jarosite may be used as a structurally sound building material. Because to its crystalline form, it is also resistant to compression, thus it can hold its own under pressure. Waste jarosite can also endure lateral stresses because of its high shear strength. In addition, jarosite waste may aid in the reduction of building energy use due to its high thermal insulation characteristics.[10]

2. Material and Methods

The purpose of this research is to determine the effect of pozzolanic material as well as an activator on the properties of stabilized jarosite for application in Civil Engineering construction. Ten percent, twenty percent, thirty percent, and forty percent of GGBS have been mixed together with the dry jarosite. The jarosite-GGBS combination may be made with a lime concentration of 2.5, 5.0, 7.5, or 10% by weight of jarosite. After 24 hours of drying in an oven at 105 °C, the jarosite brought in from the zinc industry was ground to remove any remaining lumps.

Research on GGBS and lime-stabilized jarosite waste has included unconfined compressive or split tensile strength tests, a freezing-thawing analysis, and a leachate analysis.

3. Results

- **Compaction Study**

MDD or OMC were among the compaction characteristics tested with the use of Sridharan and Sivapullaiah's Micro Compaction Mould.

Compaction Parameters and the Impact of GGBS

Dry density of jarosite blends is shown to vary with the quantity of GGBS added (a). The MDD and OMC of jarosite were observed to change after blending with GGBS, with the former being 1.13 Mg/m3 and the latter being 42%, with up to 30% GGBS. An uptick in OMC or a decrease in MDD were seen when higher levels of GGBS were added. When jarosite is mixed with various concentrations of GGBS, the MDD and OMC both change.

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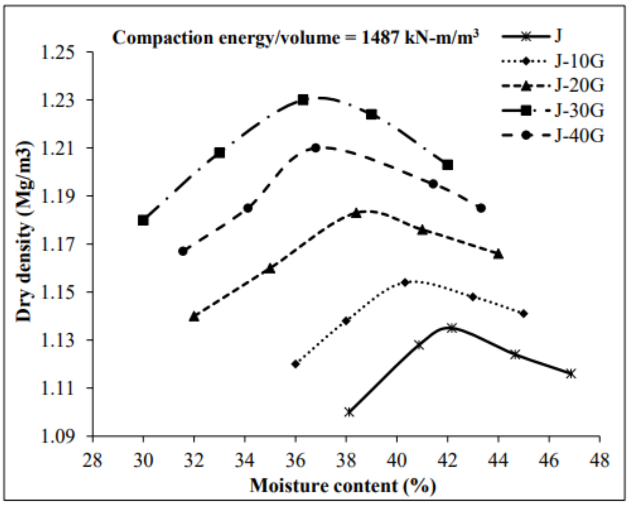
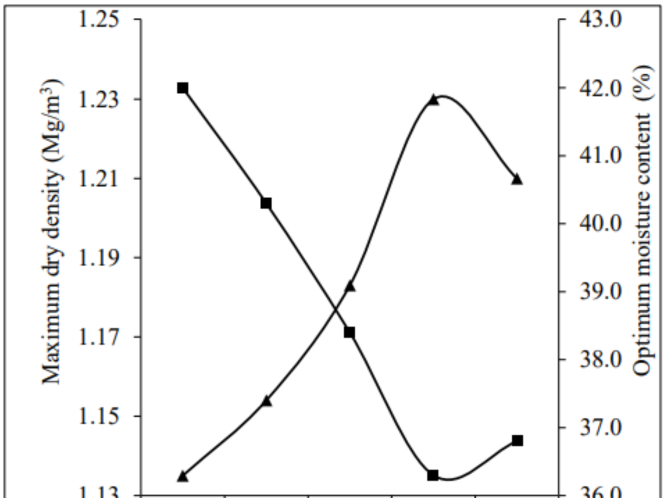


(a)



	J	J-10G	J-20G	J-30G	J-40G
MDD	1.135	1.154	1.183	1.230	1.210
OMC	42.0	40.3	38.4	36.3	36.8

(b)

Fig. 1: GGBS's impact on jarosite's dry density and moisture content; GGBS's influence on MDD and OMC variation.

Changes in MDD and OMC are often driven by variations in particle arrangement, however this is not always the case. The matrix shifts from a flocculated to an evenly dispersed structure after the empty spaces between jarosite nanoparticles are filled with the GGBS particles, leading to an increase in MDD for concentrations up to roughly 30% GGBS. As the particles are now more readily segregated in the matrix, the MDD decreases as a result of the higher GGBS concentration.

Because to its glassy structure and lower specific surface area compared to jarosite, the introduction of GGBS produces a drop in the OMC of the jarosite-GGBS combination. That's why MDD may be achieved with a lower moisture content. Particle segregation also

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increased the OMC when 40% GGBS was applied.

Lime and GGBS's impact on compaction parameter

All of the jarosite-GGBS mixes (2.5, 5.0, 7.5, and 10 percent GGBS) were then combined with varied concentrations of hydrated lime. Using the Eades and Grim test technique , the minimum lime percentage needed for jarosite stabilization was established to be 2.5%. Nevertheless, 5, 7.5, and 10% of lime content were also utilized based on the worldwide experiences with soil-lime stabilization . Figures show the OMC and MDD fluctuations for different mixtures of jarosite, lime, and GGBS, respectively. It can be seen that the OMC increases and the MDD decreases when lime is added to GGBS modified jarosite. As lime has a lower specific gravity than jarosite and GGBS, more water is needed to adequately lubricate the composite mix's particles and achieve its MDD and OMC. In addition, the greater moisture content sped up the pozzolanic processes and necessitated the addition of hydrated lime with GGBSincreased the compactness of treated jarosite, making the usage of GGBS and lime favorable in the stabilization of jarosite. Table provides an overview of how the use of GGBS and lime as binders in jarosite affects various compaction characteristics.

Table 1: A comparison of the several jarosite-GGBS-lime combinations in terms of their compaction properties

Mixtures	**MDD(Mg/m^3)**	**OMC(%)**	**Proportions**
Jarosite	1.110	42.47	J+5.0%L
	1.125	42.23	J+2.5%L
	1.135	42.09	Untreated
Jarosite-Lime	1.080	42.89	J+10%L
	1.100	42.63	J+7.5%L
Jarosite-GGBS	1.154	40.32	J+10%G
	1.138	41.53	J+10%G+5.0 %L
	1.144	41.09	J+10%G+2.5 %L
Jarosite-GGBS-Lime		1.129	J+10%G+10 %L
	1.133	41.96	J+10%G+7.5 %L

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Jarosite-GGBS	G+2.5%L J+20%	1.176	39.11
		1.183	J+20%G
	G+5.0%L J+20%	1.171	39.70
Jarosite-GGBS-Lime	G+10%L J+20%	1.160	40.47
	G+7.5%L J+20%	1.165	40.23
Jarosite-GGBS	G+2.5%L J+30%	1.225	36.91
	J+30%G	1.230	36.30
	G+5.0%L J+30%	1.220	37.54
Jarosite-GGBS-Lime	G+10%L J+30%	1.206	38.55
	G+7.5%L J+30%	1.214	37.93

- **Strength Study**

The GGBS's Impact on a Jarosite-GGBS Blend

qu and split tensile strength (qt) were conducted on jarosite-GGBS mixtures at a variety of curing times to determine the impact of GGBS on the strength characteristics.

Table also provides supporting evidence for the claim that the compaction parameters (MDD , OMC) change with an increase in GGBS concentration. Because of mechanical alternation in the particles of GGBS and jarosite, the MDD rises with up to 30% GGBS and the OMC decreases in comparison to jarosite alone, which may explain the improvement in the strength properties. Yet, it is shown that the MDD drops and the OMC rises at 40% GGBS. Hence, so does power. Figure shows that the strength increases with longer curing times , which makes sense given that the pozzolanic material GGBS displays self-hardening time-dependent properties that expand with curing length. Similar findings were discovered by Sharma and Sivapullaiah, but for different causes.

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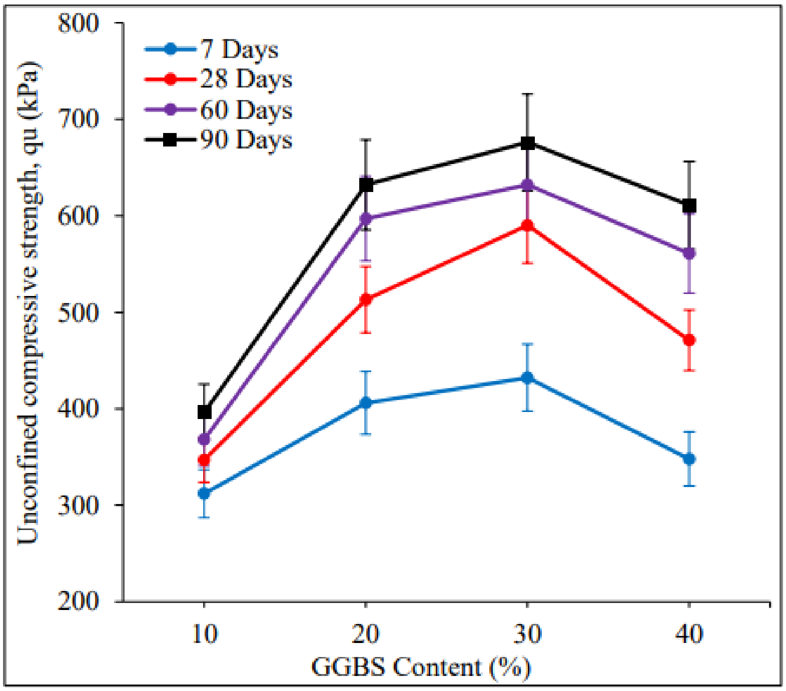
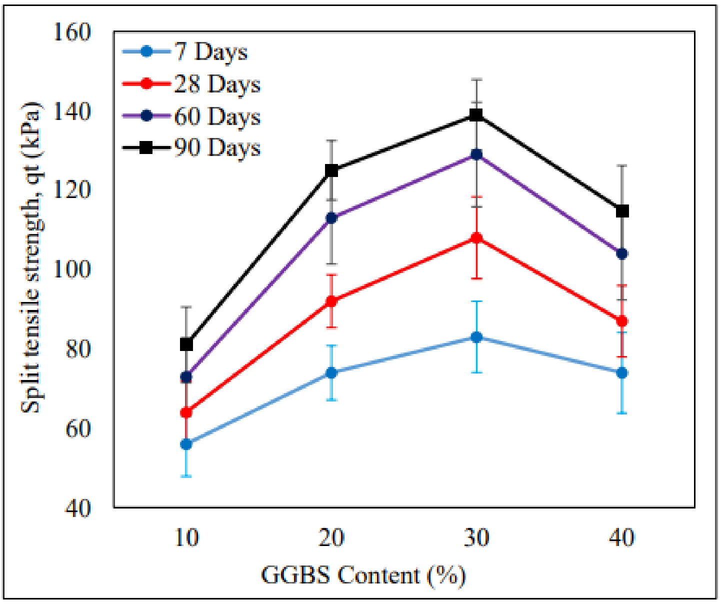


(a)



(b)

Fig. 2: The influence of GGBS on (a) ultimate compressive strength (qu) & (b) split tensile strength in jarosite over all curing periods (qt)

After 7 days, the unrestricted compressive strength of lexeme samples with 30% GGBS is 473.54 kPa, 567.45 kPa, 598.23 kPa, and 622.87 kPa, respectively, compared with untreated jarosite (187 kPa). After 7 days, jarosite-GGBS samples containing 30% GGBS had a split tensile strength of 118.45 kPa, 136.12 kPa, and 143.28 kPa, compared to 96.32 kPa . Curing period (90 days) was correlated with strength properties in both studies.

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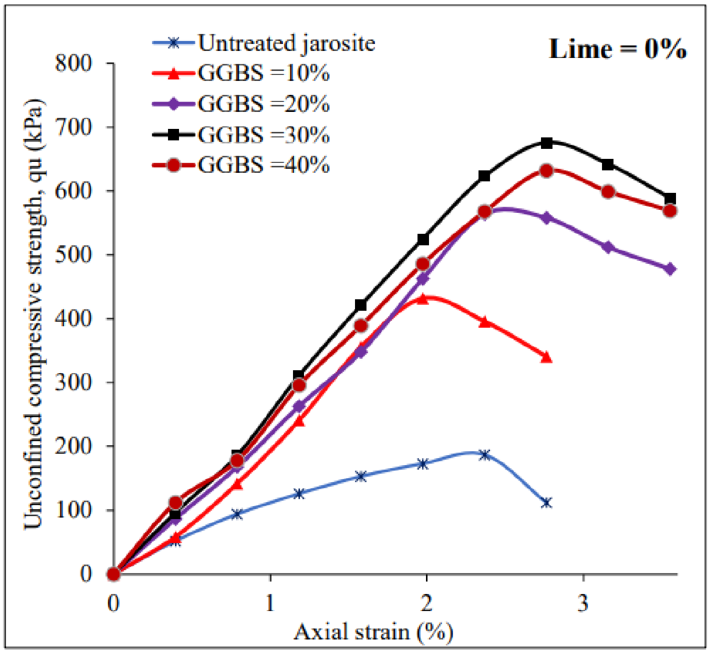
The Lime's Impact on Jarosite-GGBS-Lime Slurry

The stress-strain curve for UCS is shown in Figure, and the variations in split tensile strength for jarosite that result from adding lime and curing it for 28 days are shown in Figure, both with varied percentages of GGBS.



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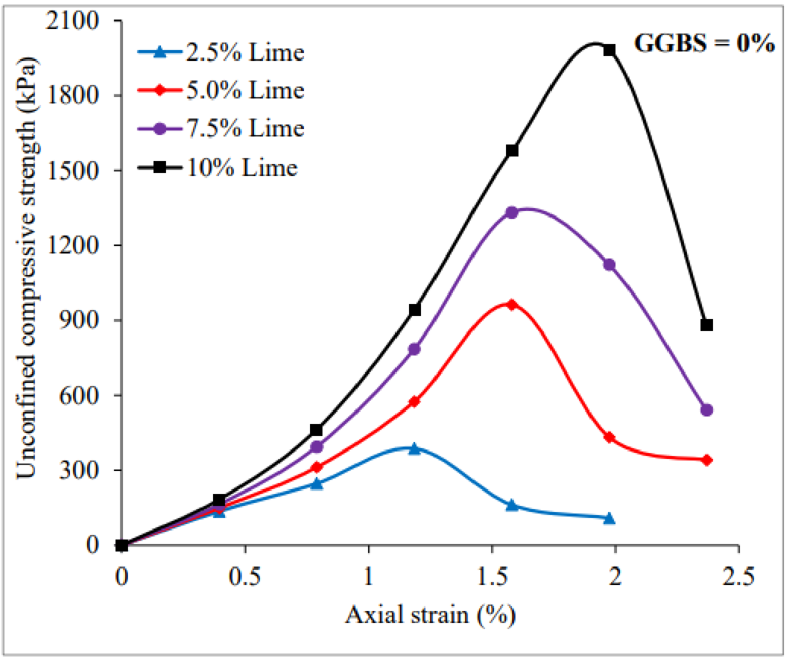
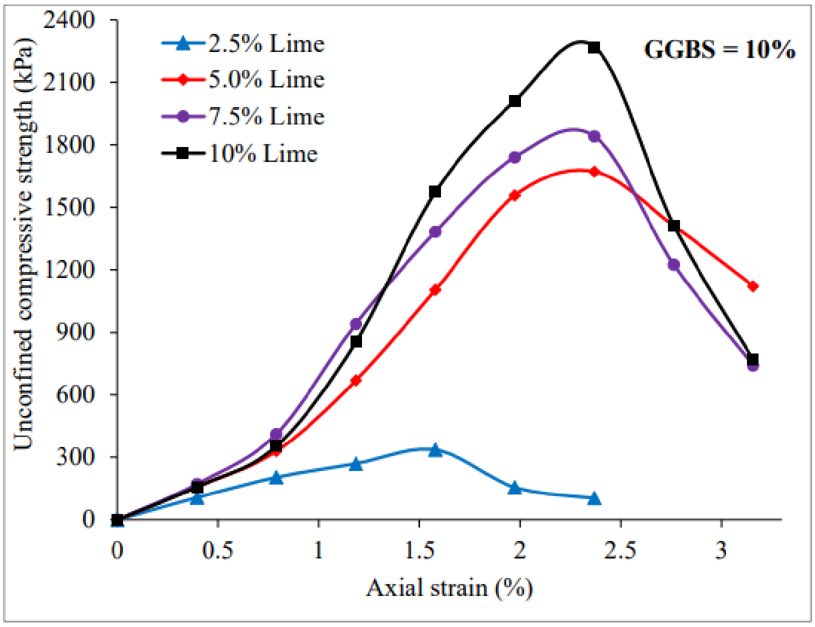
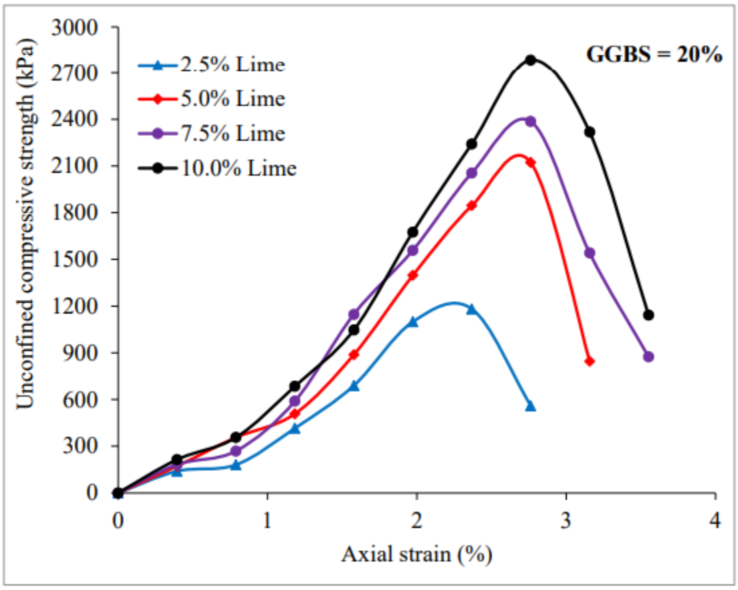


(b)


GGBS = 10%
2.5% Lime
5.0% Lime
7.5% Lime
10% Lime
Unconfined compressive strength (kPa)
Axial strain (%)
0
300
600
900
1200
1500
1800
2100
2400
0
0.5
1
1.5
2
2.5
3

(c)


GGBS = 20%
2.5% Lime
5.0% Lime
7.5% Lime
10.0% Lime
Unconfined compressive strength (kPa)
Axial strain (%)
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
0
1
2
3
4

(d)

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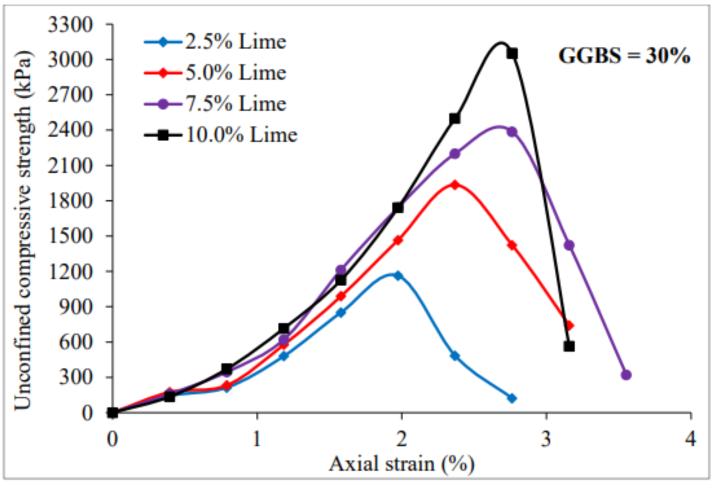

(E)

Fig. 3: Stress-strain behavior of stabilized samples after 28 days of curing, as affected by lime concentration in the UCS test.

Analysis of Toxicology of Leachate Using the TCLP Method

TCLP developed by the United States Environmental Protection Agency (USEPA) was used for the assessment of heavy metals and hazardous substances. In GGBS-lime stabilized jarosite waste blends, the concentrations of the aforementioned heavy metals and hazardous components are found to be below the permitted levels indicated by USEPA. Table displays the obtained data. Stabilized jarosite has more heavy metal immobilization capability than untreated jarosite hazardous waste, as shown in Figure (a) and (b), respectively, before and after durability testing.

By forming cementitious gels (C-S-H), heavy metals in hazardous waste are immobilized during the solidification/stabilization process. These metals are first converted into low soluble precipitates, like carbonates, silicates, or hydroxides, and then are physically encapsulated between the solids' surfaces (Portland cement association, 1991

Table 2: Concentration of Hazardous Elements in Leachate (TCLP) Extract from Raw and Stabilized Composites of Jarosite

Heavy Metals	Untreated Jarosite	Concentration (ppm)(Beforedurability)				Concentration (ppm)(Afterdurability)				USEPA Limit (ppm)
		J-10L	J-10L-10G	J-10L-20G	J-10L-30G	J-10L	J-10L-10G	J-10L-20G	J-10L-30G	
Ag	27.95	3.93	3.03	2.03	0.53	8.30	6.45	2.09	1.31	5.0

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Cd	20.05	0.04	0.04	0.03	0.02	0.16	0.06	0.05	0.05	1.0
Cr	36.41	1.69	1.21	0.48	0.24	11.8	8.98	2.67	2.18	5.0
Pb	30.88	0.41	0.33	0.23	0.18	0.45	0.42	0.18	0.23	5.0
As	6.75	1.58	1.37	0.54	0.25	1.60	1.57	0.87	0.46	5.0
Zn	287.69	18.56	10.89	7.88	5.67	32.56	25.88	15.32	11.45	500
Fe	118.56	34.58	26.44	15.55	12.56	52.33	35.36	26.88	18.54	30

According to Table 1, the Ag, Cd, Cr, Pb, and As leachate contents in untreated jarosite waste are 27,.95, 20.05, 36.41, 30.88, & 6.75 ppm, respectively. The amounts of leachate in raw jarosite waste much beyond the limits set by the US EPA. For this reason, jarositeaste is included in the category of hazardous waste. The Ag, Cd, Cr, Pb, or As leachate concentrations in the 30% GGBS-10% lime stabilised jarosite product before and after the durability study are, respectively, 0.53 ppm, 0.04, 0.24 ppm, 0.18 ppm, and 0.25 ppm. This means that the concentrations among all heavy metals and toxic components in GGBS-lime stable jarosite waste blends are well below the levels permitted by USEPA, making them suitable for use in environmentally friendly civil engineering projects.

4. Conclusion

Each developing nation on the road to becoming a developed nation is characterized by a development toward industrialisation. Yet, technological advancements in this area have generated a substantial amount of trash and by-products. This study adds to the development of a cement-free, stabilized jarosite material that is superior to the status quo in terms of durability, strength, immobilization of heavy and toxic metals, and cost. As an added bonus, this costs less than the previously-published information (jarofix). In addition, this innovative stabilized material has practical uses in the civil engineering industry.

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