

Accepted Manuscript

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PII: S2213-3437(18)30620-1
DOI: <https://doi.org/10.1016/j.jece.2018.10.012>
Reference: JECE 2697

To appear in:

Received date: 22-6-2018
Revised date: 25-9-2018
Accepted date: 6-10-2018

Please cite this article as: Kiventerä J, Sreenivasan H, Cheeseman C, Kinnunen P, Illikainen M, Immobilization of sulfates and heavy metals in gold mine tailings by sodium silicate and hydrated lime, *Journal of Environmental Chemical Engineering* (2018), <https://doi.org/10.1016/j.jece.2018.10.012>

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Immobilization of sulfates and heavy metals in gold mine tailings by sodium silicate and hydrated lime

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Highlights

- Alkali activation of gold mine tailings with NaOH/Na₂SiO₃ and Ca(OH)₂.
- High Immobilization of sulfates and arsenic were achieved with hydrated lime.
- The compressive strength of all samples were suitable for mine backfilling.

Abstract

Gold mining produces hazardous tailings wastes with elevated sulfur content and high levels of heavy metals including oxyanion elements such as V and As. This research investigated activation of these tailings with calcium hydroxide and sodium hydroxide/sodium silicate as a way to stabilize the material and limit leaching of harmful components. The effects of thermal treatment on the reactivity

of the tailings and the use of different activating solutions on the physical properties, microstructure and leaching of harmful components are reported. The effect of adding ground granulated blast furnace slag to the tailings is also assessed. The use of 5 wt % $\text{Ca}(\text{OH})_2$ activating solution produces optimum performance increasing the immobilization efficiency of sulfates, arsenic and the other harmful elements. Heat-treating mine tailings at 900°C slightly improves the reactivity but did not improve the immobilization efficiency. Microstructural analysis by TEM and XRD confirmed that stabilization is based on calcium sulfate and/or ettringite formation during alkali-activation. All materials achieved reasonable compressive strength after 28 days of curing and the potential for using alkali activation as a method to treat tailings from mining is discussed.

Keywords: geopolymer; alkali activated material; immobilization of heavy metals; thermal treatment; STEM, In situ XRD

1. Introduction

Gold mine tailings are produced after extraction and subsequent mineral processing and are a hazardous waste that is normally landfilled close to the mining site. They typically contain high levels of sulfides that are oxidized in the presence of air and moisture to produce sulfuric acid and as a result low pH in surrounding waters. Gold mine tailings also contain Cu, Cr, Cd, Pb, Sb, Ni, Zn, V and As and these leach under the acidic conditions causing additional environmental degradation and risks to human health [1].

Hazardous heavy metal elements, such as Cd, Ni, Cu, Pb and Zn, can be encapsulated and immobilized in alumino-silicate based wastes by using alkali-activation to form monolithic treated waste products [2–11]. Alkali activation of alumino-silicates hydrolyses aluminum and silicon

species into solution. The dissolved species then undergo speciation equilibrium, gelation, reorganization, polymerization and hardening reactions to form a solid alkali-activated monolithic material [12]. The alkali-activated material formed has a 3-dimensional network structure consisting of aluminum and silica tetrahedra. The presence of Al^{3+} ions in the network requires a charge balancing cation from the alkaline solution or the waste material [13]. Heavy metals are immobilized by forming hydroxides in highly alkaline conditions [9] or they can be encapsulated within the network structure [14]. All these methods can occur simultaneously. However high leaching of elements such as As and Cr after alkali activation has also been reported [1,15,16].

Gold mine tailings are reported to have low reactivity and need the addition of co-binder to achieve a strong matrix [17]. Large amount of different cationic elements from gold mine tailings can be immobilized by alkali activation of optimized system [11,18]. High levels of As and V were leached out from the alkali-activated mine tailing materials at the early stage of curing. Longer curing periods improved the immobilization effectively. Poor immobilization of As and V results because of the oxyanionic nature of these elements. For example, As can have oxidation states of +5, +3, 0 and -3 which depends on the environment. The most common states are As (III) and As (V) in groundwater and surface water system [19] when the valence stages 0 and -3 cannot usually be find in natural environment [20]. Oxyanions have high solubility in highly alkaline conditions and are not chemically bound into the alkali-activated alumino-silicate structure. They also cannot precipitate as a hydroxides under highly alkaline conditions [21].

Since alkali activation is not an effective method to stabilize poorly reactive gold mine tailings, other approaches are needed. The present study is divided in two different parts. The first part investigates thermal treatment of mine tailings as a method to increase the reactivity of the material, as shown previously with other materials like clay minerals, and mine tailings [22–24]. The aim is to study if the increased reactivity of the material can enhance the stabilization of mine tailings in alkali activation. The second part investigates the use of $Ca(OH)_2$ as an activator instead of $NaOH/Na_2SiO_3$

in heavy metal and sulfate stabilization. $\text{Ca}(\text{OH})_2$ solution has been used to stabilize expansive clays with good results; the reaction products formed, such as ettringite, have the ability to immobilize sulfates, heavy metals and oxyanions effectively [21].

The mine tailings were treated thermally, and the phase changes during thermal treatment were studied by in situ X-ray diffraction (XRD). The solubility of Si and Al in alkaline conditions was analyzed to show the increase in the reactivity of the materials during thermal treatment. Both untreated and thermally treated mine tailings were activated using sodium hydroxide/sodium silicate solutions and $\text{Ca}(\text{OH})_2$ solution and the mechanical properties were measured. Ground granulated blast furnace slag (GBFS) was used as an additional pozzolanic additive to increase the levels of Al, Si and Ca ions. Leaching of sulfates and heavy metals was analyzed and the microstructure of the specimens produced were characterized by scanning transmission electron microscopy (STEM) and by XRD.

2. Materials and Methods

2.1 Materials

Sulfidic mine tailings (MT) were received as a slurry from a gold mining site in North of Finland. The slurry was dried in oven at 105°C and milled with a vibratory disc mill (Retsch RS 200) for 2 minutes with 1000 rpm to form a fine powder. Part of the powder was heated to 900°C for 6 hours in order to study the effect of calcination on reactivity of tailings and on the efficiency of stabilization. The heat-treated mine tailings were cooled and then reground in the disc mill for 3 minutes at 1000 rpm. A commercial ground granulated blast furnace slag (KJ 400 from Finnsementti) containing a high glassy fraction was used in selected mixes.

The alkali activation has used two different solutions. First solution was formed by mixing solid NaOH pellets ($>99\%$, Merck, Germany) with commercial sodiumsilicate solution (with $\text{Na}_2\text{O}/\text{SiO}_2$

ratio of 3.3) and water. The second activating solution was formed by mixing $\text{Ca}(\text{OH})_2$ pellets (>99%, Merck, Germany) with distilled water to form a 5 wt % $\text{Ca}(\text{OH})_2$ solution.

2.2 Sample preparation

The alkali-activated samples prepared are presented in Table 1. Alkali-activated samples were formed by mixing the mine tailings powder with 0, 10 or 25 wt % of GBFS. The powder mixture were intensively mixing with the alkali-activating solution for 5 minutes. Additional water was added to produce a paste with appropriate workability. The homogeneous pastes were then casted into 25 mm diameter cylindrical molds and cured in 90% relative humidity at room temperature for 7 and 28 days.

2.3 Characterization of the raw materials and specimens produced

The chemical composition of the mine tailings before and after heating were analyzed by Omnia Panalytix Axios X-ray fluorescence (XRF) spectrometer. The content of trace elements was analyzed by microwave-assisted wet digestion using a 3:1 mixture of HNO_3 and HCl for mine tailing and determination was made using an inductively coupled plasma-optical emission spectrometer (ICP-OES) (Thermo Electron IRIS Intrepid II XDL Duo, Thermo Scientific). The particle size distribution was measured using a Beckman Coulter LS 13320. Specific surface area measurement was based on the physical adsorption of gas molecules on a solid surface using a physisorption analyzer (ASAP 2020, Micrometrics) and the results were reported in a form of a BET isotherm.

The phase changes occurring during the thermal treatment of mine tailing were analysed using in-situ x-ray diffraction. An Anton Paar DHS1100 furnace containing the sample was placed inside a Rigaku SmartLab 9 kW XRD equipment. The sample was heated at $20^\circ\text{C}/\text{min}$ to 900°C and the XRD pattern was recorded at 20°C temperature intervals. XRD analysis used $\text{Co K}\alpha$ radiation ($K\alpha_1=1.78892 \text{ \AA}$;

$K\alpha_2=1.79278 \text{ \AA}$; $K\alpha_1/K\alpha_2=0.5$) with a scan rate of $3^\circ/\text{min}$ between 5° and 90° (2θ) with a $0.02^\circ/\text{step}$. For phase identification “X'pert HighScore Plus” (PANalytical software) was used.

Reactivity of the samples were assessed using alkaline solubility tests. All the samples were milled to have an average particle size of between $1 \mu\text{m}$ and $10 \mu\text{m}$. During the solubility test, the sample was mixed with 6M NaOH solution in polypropylene container with a liquid to solid ratio of 40 w/w . The polypropylene container was placed in a horizontal shaking table (IKA KS 260 orbital shaker) under shaking motion ($\text{Mot} = 150/\text{min}$) at $23 \pm 0.5^\circ\text{C}$ for 24 h. At the end of the test, sample was filtered using a $0.45 \mu\text{m}$ filter paper. Filtrate was then acidified with 6M HNO_3 to pH around 2 and was later analyzed by AAS (AAS Perkin Elmer 600) to determine elemental concentrations. For the determination of Si, a wavelength of 251.6 nm with atomization temperature of 2350°C was used. Similar parameters used in case of Al were 309.3 nm and 2300°C respectively.

The compressive strength of the samples produced was determined with Zwick 100 using loading rate of 1.2 kN/s . Three samples of each composition were analyzed and the average of the results calculated. The samples were tested after 7 or 28 days of curing.

The leachability analysis were carried out according to the European standard EN 12457 “Characterization of waste-Leaching-Compliance test for leaching of granular waste materials and sludge.” After being crushed and sieved to a particle size $<4 \text{ mm}$, the samples were placed in bidistilled water with a liquid/solid weight ratio of 10 l/kg and rotated for 24 h. After the extraction and filtration of the leachates, the concentrations of heavy metal ions were determined with ICP-OES. Before ICP-OES analysis, the samples were acidified with HNO_3 to $\text{pH}=2$. The analysis were made after 7 and 28 days of curing. This way it can be analyzed how the samples are strengthening by time and how does it influence to the immobilization of the different components.

The crystalline phases present in samples were identified using a Siemens 5000 X-ray diffractometer. The step interval, integration time, and angle interval used were $0.04^\circ/\text{step}$, 4 s/step , and $10\text{-}50^\circ 2\theta$, respectively. The ICDD-database (PDF-2, 2006) was used to identify the crystal phases of the material. Microstructural analysis of the samples produced were analyzed by scanning transmission electron microscope (STEM) with a LEO 912 OMEGA EFTEM, with an energy-dispersive X-ray spectroscopy (EDS) detector (Oxford Instruments, X-Max 80).

3. Results

3.1. Properties of mine tailings

The mine tailings are rich in silicate, aluminum, calcium and iron (Table 2). They also have fine particle size ($d_{50} 45 \mu\text{m}$). The minor elements present in mine tailings are shown in Table 3. The main problematic elements are sulfur and arsenic, especially sulphur is in leachable form.

3.2 The effect of calcination on tailings' reactivity

Even if the chemical composition of tailings is suitable for alkali activation (Table 2), the mine tailings are naturally-forming minerals and have shown poor reactivity [25]. In order to increase the reactivity of tailings, they were treated thermally.

The chemical composition of mine tailings did not change during the thermal treatment (results not shown). However, there were some mineralogical changes (Fig 1a and 1b). A reduction of the dolomite ($(\text{CaMg}(\text{CO}_3)_2)$) peak can be seen after heat treatment at $\sim 600^\circ\text{C}$ (Fig 1b). Decomposition of dolomite can produce reactive CaO and MgO which can improve the strength of the final material.

Sulfur in the untreated mine tailings is reported to be present in basanite (Fig. 1(a)). Basanite transforms into anhydrite when heated above 400°C [26] and decomposition of anhydrite occurs at temperature between 1050 °C and 1150 °C [24]. Hence, sulfur is not removed during thermal treatment to 900 °C. The quartz content remained constant apart from a small reduction at ~650 °C ((Fig. 1(b)). Other crystalline phases such as albite, muscovite, and clinocllore have high temperature stability (Fig 1a and 1b).

Alkali-reactivity of the material was found to increase during the heat treatment (Fig. 2). Initially, the material can be considered inert (<0.5% Al dissolution), and the amount of reactive Si gradually increased to 4% while that of Al 6.8%.

3.3. Stabilization of tailings by sodium hydroxide/sodium silicate solution

Thermal treatment had clear effect on strength of sodium hydroxide/sodium silicate (NaOH/Na₂SiO₃) activated mine tailing samples (Fig. 3). The sample containing 25 % of GBFS had strength of approximately 10 MPa and when treated mine tailings were used; the compressive strength achieved almost 20 MPa. However, the leaching of sulfur, arsenic and vanadium remained at high level before and after the thermal treatment (Table 4). Samples activated by sodium hydroxide / sodium silicate activator increased also the leaching of Zn, Sb an Pb. Ba was stabilized most effectively by sodium hydroxide / sodium silicate solution. Since alkali-activation with sodium hydroxide / sodium silicate solution was not promising alternative for the stabilization, this work focused more on stabilization by hydrated lime.

3.4. Stabilization of tailings by hydrated lime

The tailings stabilized by hydrated lime ($\text{Ca}(\text{OH})_2$) with GBFS content of 10 and 20 % achieved the strength of approximately 10 MPa during 28 days of curing (Fig. 4.) which is good level when considering for example mine backfilling, which requires strength of below 5 MPa. Higher slag content increased the strength of all samples which was noticed also in the previous work [17]. The heat treatment did not significantly affect the strength of the lime activated materials.

As it was previous mentioned, mine tailing powder was found to have high levels of S, As, V, Cr, Cu, Ni, Zn, Sb, Pb and Ba content (Table 3). Using $\text{Ca}(\text{OH})_2$ solution as an activator the immobilization of these elements were achieved (Table 5). The leaching was constant after longer curing period. When comparing the theoretical total amount in the geopolymer based on the value of the starting material (MT) and the leachable amount of the element from the geopolymer structure the immobilization efficiency were almost 100 % by $\text{Ca}(\text{OH})_2$ activation after 28 days of curing (Fig. 5). Heat treatment did not improve the stabilization of any elements (Table 4).

Sulfates were stabilized more effectively with higher slag content in the matrix (Table 5). Higher slag content increases the reactive amount of Si and Al and provides more available Ca ions into the reaction. When sulfates react with calcium coming from slag or lime, it can form calcium sulfates. Calcium sulfates have much lower water solubility than sodium sulfates which can be the reason for the lower leachability of the sulfates. On the other hand calcium can react with aluminum and sulfates producing pozzolanic products such as ettringite which have an ability to immobilize sulfates effectively [21]. Arsenic stabilization is possible when precipitated as $\text{Ca}_3(\text{AsO})_2$ [28]. On the other hand ettringite formation is known to be able to stabilize also oxyanions such as As, B, Se and V [29]. Lime acts as a cementitious agent yielding alkaline conditions to the reaction. Available alumina, coming from blast furnace slag or partly from mine tailings, reacts with Ca ions and sulfates producing ettringite ($3\text{CaO} - \text{Al}_2\text{O}_3 - 3 \text{CaSO}_4 - 32\text{H}_2\text{O}$) structure [21]. Ettringite consist of columns $\{\text{Ca}_6[\text{Al}(\text{OH})_6]_2 \cdot 24\text{H}_2\text{O}\}$ and channels $\{(\text{SO}_4)_3 \cdot 2\text{H}_2\text{O}\}^{6-}$ [30]. In the structure Ca^{2+} , Al^{3+} or SO_4^{2-} can

be replaced by other metal ions such as Fe^{3+} , Cr^{3+} , Sr^{3+} , Mg^{2+} , Zn^{2+} , Co^{2+} , or by some ion group being suitable to stabilize heavy metals effectively in the matrix. Oxyanions such as As can also be substituted either by reacting with surface sites of the ettringite matrix or by substituting into the ettringite channels replacing sulfate. The substitution of the different elements is based on the ion charge and ion size [31]. When multiple anions are present the dominant anion will form ettringite more likely than the others [21].

All harmful components stabilized more efficiently by $\text{Ca}(\text{OH})_2$ activation compared to $\text{NaOH}/\text{Na}_2\text{SiO}_3$ activation, with the exception of barium. Stabilization results were improved across the board with longer curing period and the immobilization can be expected to increase further more by longer curing time [11]. Leaching of harmful components were all below the Finnish regular waste law limits and most of them under inert waste law limits after only seven days of curing when activated by $\text{Ca}(\text{OH})_2$ (Table 4).

3.5 Microstructure analysis of the samples

The main peaks quartz, albite and muscovite were found by XRD in all samples after 7d and 28d of curing indicating that they are inert in alkali activation (Fig. 5). Ettringite were found in all samples which can be the one reason for higher immobilization of hazardous element. Dolomite were not found from untreated mine tailings based samples, which is in line with the in situ XRD-analysis results.

Almost all phases that were identified by XRD were also confirmed by TEM analysis (Fig. 6). TEM analysis show that calcium and sulphur form together calcium sulfates. As stated earlier, sulfate preferably form sodium sulfates during alkali activation with $\text{NaOH}/\text{Na}_2\text{SiO}_3$ solution. Whereas activation by $\text{Ca}(\text{OH})_2$ promotes the existence of calcium sulfate with lower solubility than sodium

sulfate [32,33]. Other phases found from TEM observation includes Fe_3O_4 , FeSO_4 , $(\text{CaMg})\text{Fe}_2\text{O}_4$, and CaCO_3 .

Even though the immobilization of several elements was efficient, the stabilization mechanism and the long-term durability warrants further research. For example, sulfate ettringite is stable at pH between 10.5 – 13. When other components are substituted into the ettringite structure pH stability is affected making long term stability analysis of high importance. High amount of sulfates and heavy metals in starting material may cause expansion, cracking and increase porosity of the final material when leaching out from the structure.

4. Conclusion

Activation of sulfidic gold mine tailings with $\text{Ca}(\text{OH})_2$ and 10-25% of GGBFS can effectively stabilize sulfates and arsenic that are the most problematic elements in these mining residues. Over 90 % of sulfates and more than 99 % of arsenic can be stabilized only after a week of curing. The high immobilization of other harmful substances can be also achieved. On the other hand, alkali activation with $\text{NaOH}/\text{Na}_2\text{SiO}_3$ does not produce stabilized products. Thermal treatment of the tailings increases the reactivity, but does not significantly improve stabilization of harmful components.

The most probable mechanisms for the effective immobilization by $\text{Ca}(\text{OH})_2$ is formation of calcium sulfate and As precipitation as $\text{Ca}_3(\text{AsO})_2$. In this study, calcium sulfate was found by microstructural analysis (TEM) and it is known to have low solubility in comparison to sodium sulfates. Other form of potential immobilization is ettringite formation, and the presence of ettringite was confirmed by XRD in all $\text{Ca}(\text{OH})_2$ activated samples. All final materials had reasonable compressive strength and could be used for example as mine backfilling materials. The results are encouraging for the

utilization capability of sulfidic mine tailings but long-term durability and the immobilization mechanism warrants further research.

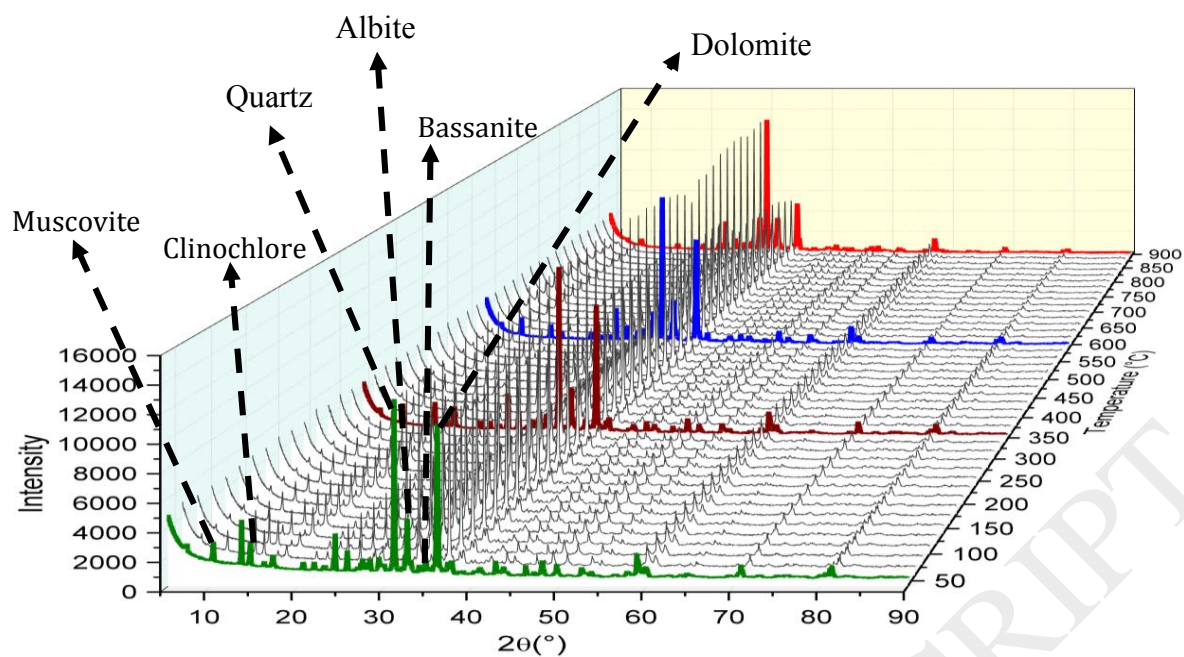
Acknowledgements

This work was conducted as part of the ERA-MIN project entitled 'GEOSULF,' which is supported by the Finnish Agency for Technology and Innovation (TEKES); the Portuguese National Funding Agency for Science, Research and Technology (FCT); The National Centre for Research and Development (BR); and various companies (Outotec, Agnico Eagle, and First Quantum Minerals). The authors would like to thank the Renlund Foundation for its financial support. The support of Jenny ja Antti Wihuri Foundation is also appreciated. Ms Katri Piekkari is acknowledged for her contributions to laboratory analyses.

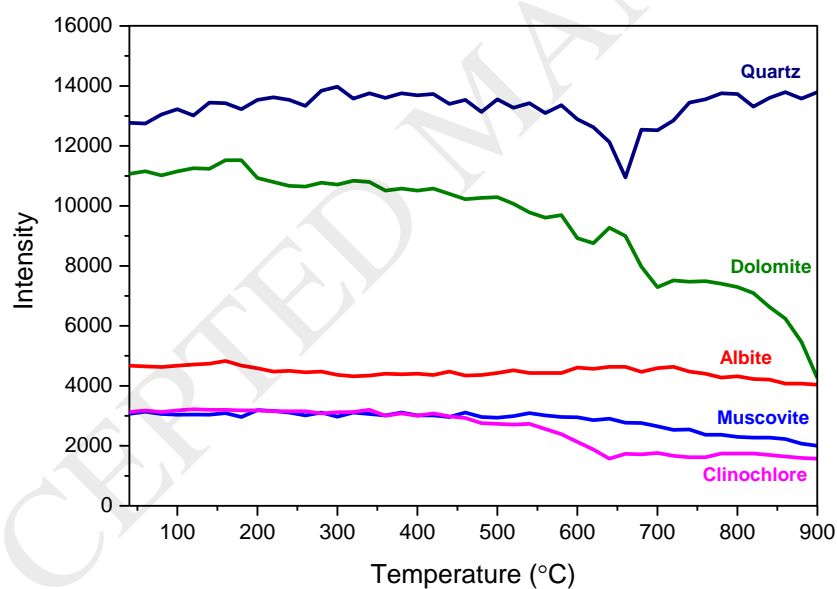
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(a)



(b)

Fig. 1. (a) In-situ XRD analysis of mine tailings during heat treatment. (b) Intensity variation (based on the highest intensity) for some major components.

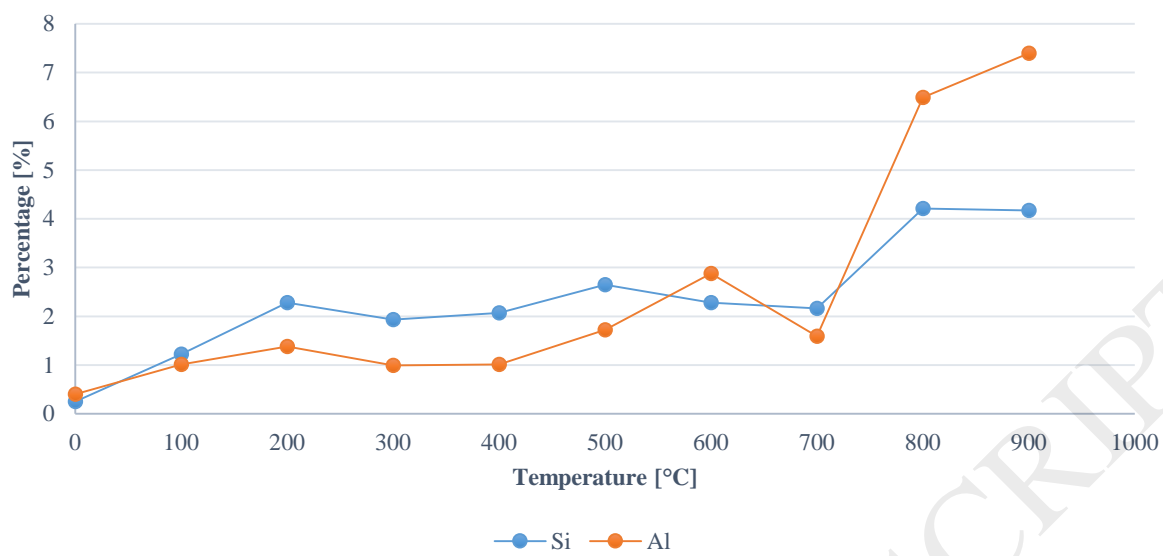


Fig. 2. The amount of reactive Si and Al in mine tailings during the heat treatment.

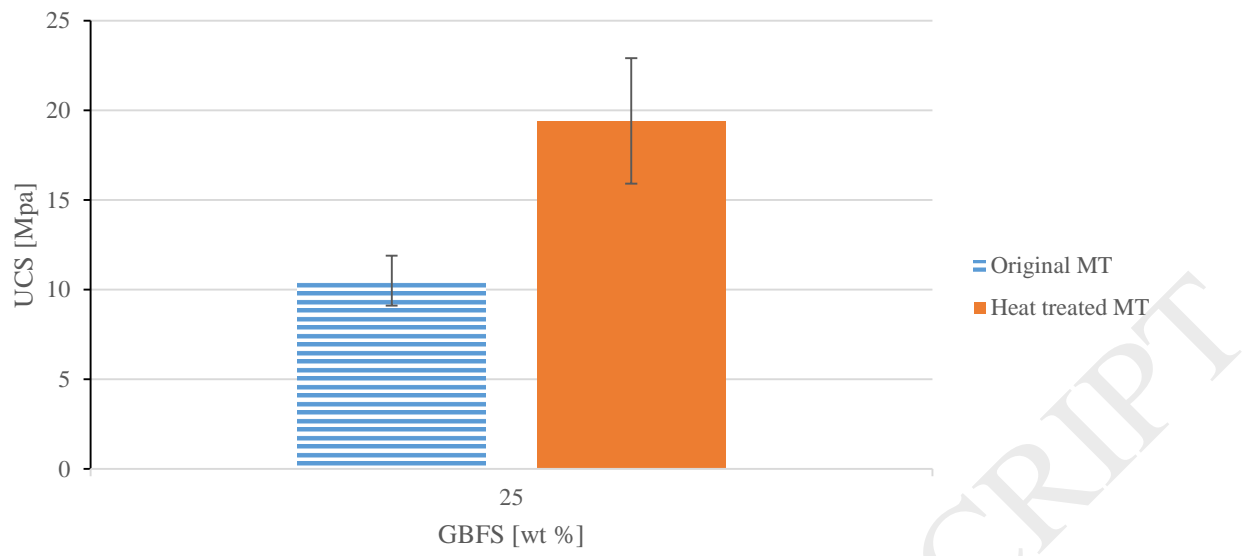


Fig. 3. UCS of the sodium hydroxide / sodium silicate activated samples after 28 days of curing.

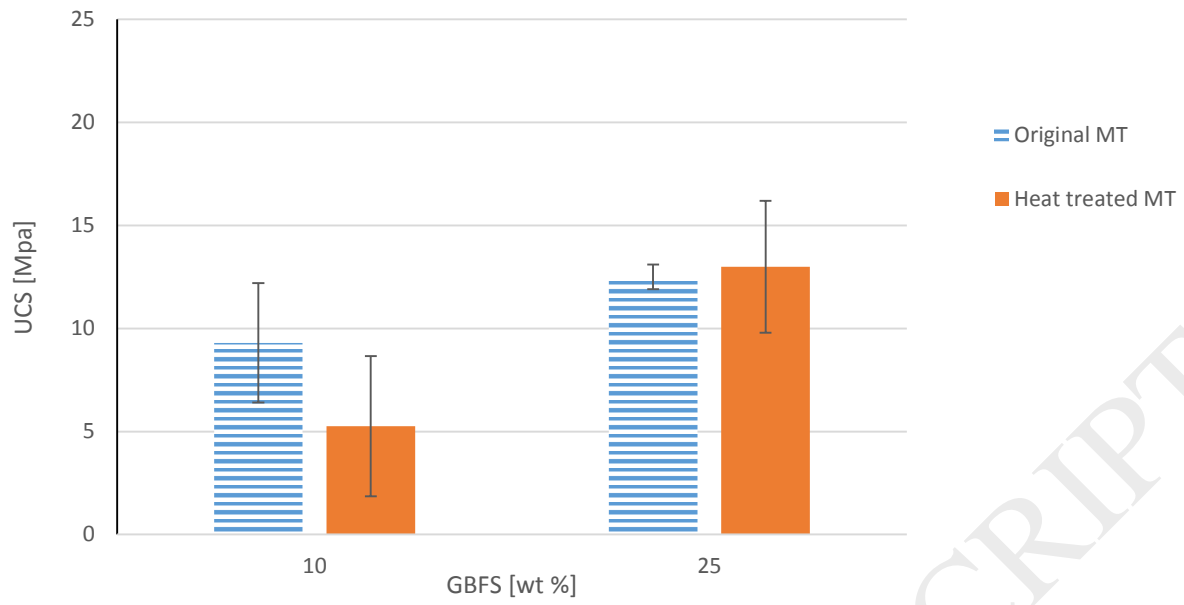


Fig. 4. UCS of the Ca(OH)_2 activated samples after 28 days of curing.

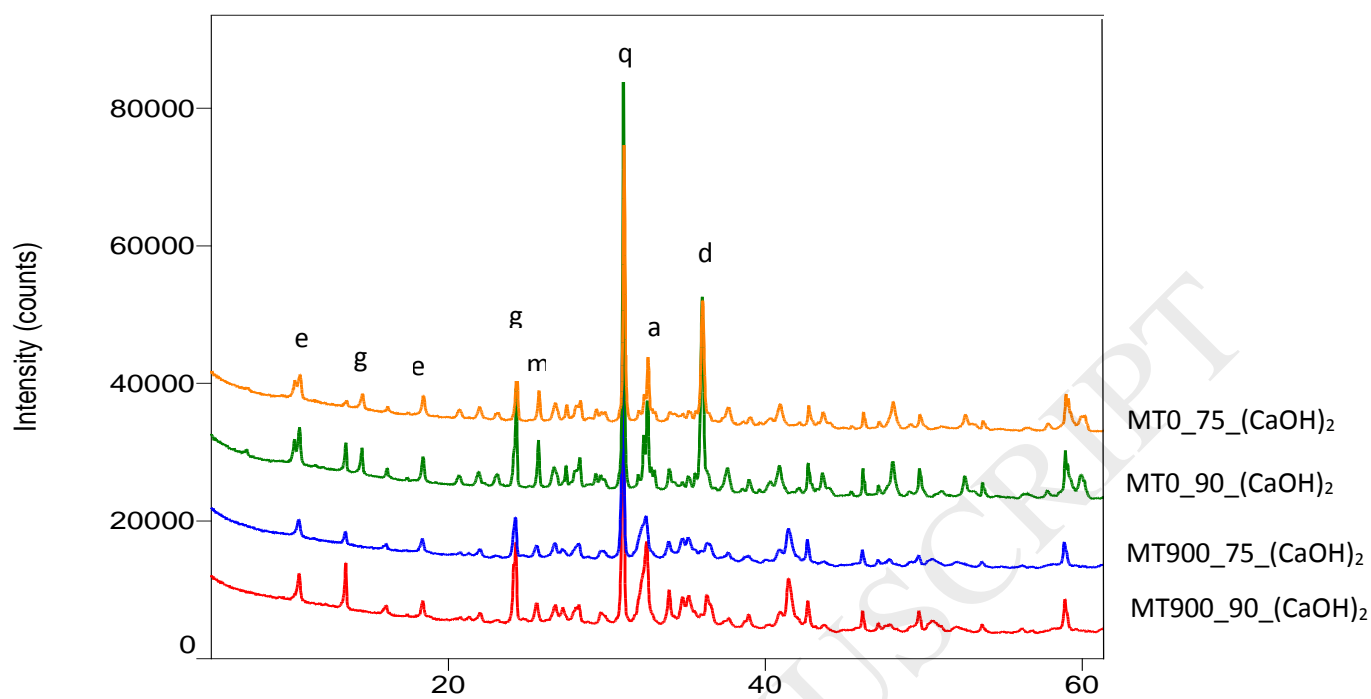


Fig. 5. XRD analysis of the samples after 7d of curing. (q = quartz, e=ettringite, a=albite, d=dolomite, g=gypsum, m=muscovite.)

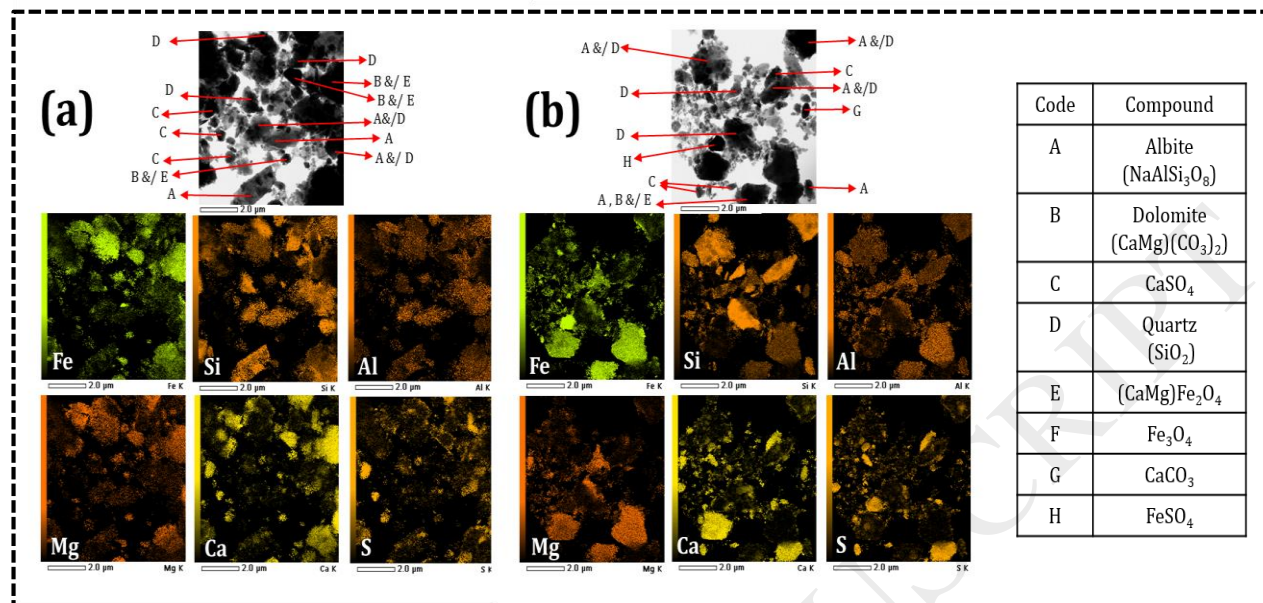


Fig. 6. STEM Dark-Field Images of two different regions (a and b) after 28d of curing.

Table 1. Geopolymer formulations from a mixture of mine tailings (MT) and blast furnace slag (GBFS). All the samples were made from Original and heat treated mine tailing powder.

		MT/GGBFS_75/25	MT/GGBFS_75/25	MT/GGBFS_90/10
		NaOH/NaSil	CaOH2	CaOH2
MT	(g)	75	75	90
GBFS	(g)	25	25	10
NaOH	(ml)	30	0	0
NaSil	(ml)	50	0	0
Ca(OH) ₂	(ml)	0	30	30

Table 2. The chemical composition of the original mine tailing (MT) and GBFS powder.

Component	MT (original)	GBFS
SiO ₂ (%)	49.9	32.3
Al ₂ O ₃ (%)	10.4	9.6
Fe ₂ O ₃ (%)	9.1	1.2
CaO (%)	11.7	38.5
SO ₃ (%)	3.9	3.9
MgO (%)	6.8	10.2
K ₂ O (%)	1.3	0.5
TiO ₂ (%)	1.2	2.2
BET surface area (m ² /g)	7.2	
pH	9.6	
LOI 525°C	0.7	
LOI 950°C	12.9	
Particle size d ₅₀ (μm)	45	10.8

Table 3. The total amount in MT powder, leaching amount from MT powder and waste law limits of minor elements.

Component	Total amount in MT (mg/kg)	Leaching from MT (mg/kg)	Inert waste limit (mg/kg)	Regular waste limit (mg/kg)
S	18900	> 20 000	1000	20 000
As	1520.0	1.5	0.5	2
Cd	<0.3	0.05	0.04	1
Cr	74.0	0.5	0.5	10
Cu	120.0	0.05	2	50
Ni	100.0	0.5	0.4	10
Mn	1500	< 0.3		
Pb	4.3	0.1	0.5	10
Zn	71.0	0.1	4	50
B	9.6			
Be	<1	< 0.02		
Co	22.0	0.03		
Mo	1.5	0.1	0.5	10
Sb	32.0	0.2	0.06	0.7
Se	<3	0.06	0.1	0.5
Sn	<3	< 0.1		
V	59.0	0.05		
Ba	29	0.09	20	100

Table 4. The total concentration, leachable amount from MT powder, and leachable amount from sodium silicate/sodium hydroxide activated samples after 28d of curing.

	S	As	V	Cr	Cu	Ni	Zn	Sb	Pb	Ba
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Total concentration in MT powder	> 20 000	1520	59	74	120	100	71	32	4,3	29
Leaching from MT powder	> 20 000	1,5	0,05	0,1	0,05	0,5	0,1	0,3	0,1	0,09
Original MT MT/GGBFS_75/25	20 000	70,7	16,7	0,5	0,25	0,25	0,5	0,75	0,75	0,25
Heat treated MT										
MT/GGBFS_75/25	19 000	28	29	1	0,5	0,5	1	1,5	1,5	0,5

Table 5. The total concentration, leachable amount from MT powder, and leachable amount from Ca(OH)₂ activated samples.

	S	As	V	Cr	Cu	Ni	Zn	Sb	Pb	Ba
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Total concentration in MT powder	> 20 000	1520	59	74	120	100	71	32	4,3	29
Leaching from MT powder	> 20 000	1,5	0,05	0,1	0,05	0,5	0,1	0,3	0,1	0,09
Original MT										
MT/GGBFS_90/10 (7d)	8 700	0,37	0,47	0,19	0,19	0,2	0,19	0,18	0,19	1
		(±2%)	(±3%)	(±0,12%)		(±0,4%)	(±0,3%)	(±0,1%)	(±0,2%)	(±9%)
MT/GGBFS_90/10 (28d)	5 500	0,3	0,33	0,19	0,2	0,2	0,23	0,2	0,2	0,7
		(±10%)	(±10%)	(±0,12)	(±10%)	(±0,12%)	(±10%)	(±10%)	(±10%)	(±10%)
MT/GGBFS_75/25 (7d)	2 800	0,6	0,52	0,2	0,2	0,22	0,21	0,2	0,2	1,5
		(±4%)	(±3%)	(±0,12%)	(±0,08%)	(±0,3%)	(±0,3%)	(±0,04%)	(±0,1%)	(±13%)
MT/GGBFS_75/25 (28d)	1500	1	0,44	0,2	0,2	0,2	0,23	0,19	0,19	0,68
		(±10%)	(±10%)	(±0,12%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)
Heat treated MT										
MT/GGBFS_90/10 (7d)	13 000	0,3	0,49	0,2	0,2	0,2	0,2	0,19	0,19	1,6
		(±1%)	(±3%)	(±1%)	(±0,1%)	(±0,1%)	(±0,3%)		(±0,1%)	(±14%)
MT/GGBFS_90/10 (28d)	7600	0,44	0,26	0,49	0,25	0,23	0,25	0,23	0,23	0,94
		(±8%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)	(±0,3%)	(±10%)
MT/GGBFS_75/25 (7d)	9300	0,19	0,17	0,19	0,18	0,19	0,19	0,2	0,17	1,7
		(±0,2%)	(±3%)	(±0,3%)	(±0,1%)	(±0,1%)	(±0,3%)		(±0,2%)	(±15%)
MT/GGBFS_75/25 (28d)	3400	0,19	0,46	0,18	0,19	0,18	0,2	0,17	0,18	0,94
		(±8%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)	(±10%)	(±0,3%)	(±10%)