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Production of M-S-H cement using talc mine tailings as a source of magnesia

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Occasion

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Background and Introduction

Magnesium silicate hydrate (M-S-H) cements are alternative low-carbon cements usually formed from MgO or $Mg(OH)_2$ combined with a source of amorphous/reactive silica in the presence of water. M-S-H cements can also have specialist applications such as the stabilization of heavy metals [1].

One main hindrance in the development of M-S-H cements is the availability of the Mg-source which is, normally, scarce magnesium carbonate ($MgCO_3$). The formation of M-S-H cement from precursors such as MgO or $Mg(OH)_2$ and reactive silica is slow [2]; thus, limiting its application.

Our previous study showed that it is possible to accelerate M-S-H formation through the addition of water-soluble alkali carbonates (i.e., $NaHCO_3$) [2]. An acceleration of approximately 8 times was observed where $Mg(OH)_2$ was almost completely consumed after 7 days, instead of 56 days, when cured at 35°C [2].

Ferroan-magnesite rich talc mine tailings are formed when the talc ore is crushed, milled and chemically processed in order to recover the talc and Ni concentrate from the gangue material. In the present work, calcined Finnish talc mine tailings, originally consisting mainly of iron-bearing magnesite ($(Mg,Fe)CO_3$), are tested for use as precursors to produce M-S-H cement.

Due to the COVID-19 pandemic, characterisation of the produced cement samples was not possible and only visual inspection of physical properties was conducted.

Objectives

- Valorise talc mine tailings through assessing the potential for using them as precursors for the manufacture of M-S-H cement.
- Characterise the ferroan-magnesite rich talc mine tailings.
- Calcine the tailings to produce a source of reactive MgO.
- Test both silica fume (microsilica) and rotary-calcined clay (metakaolin) to supply the necessary SiO_2.
- Test the acceleration of M-S-H formation from the tailings through the addition of sodium bicarbonate ($NaHCO_3$).
- Visually inspect the rate of hardening of samples cured for 3, 7, and 14 days.

Materials and Methods

Materials

- Ferroan magnesite mine tailings — Renotech Ltd.
- Silica fume — Elkem Microsilica 940-U
- Metakaolin — BASF MetaMax (52% SiO_2, 45% Al_2O_3)
- Sodium bicarbonate — $NaHCO_3$ Sigma-Aldrich ≥99% purity

Methods

- Thermogravimetric (**TG**) analysis was carried out on 30 mg of sample in a PerkinElmer Pyris 1 TGA under N_2 gas flow of 20 mL/min. The sample was heated from 30°C to 950°C at 10°C/min.
- X-ray fluorescence (**XRF**) analysis was conducted using PANalytical's Zetium. The PANalytical Omnian package was used to determine the elemental concentrations. A Claisse LeNeo Fluxer was used for the formation of 40 mm beads prepared by mixing 1 g of sample in 10 g of lithium tetraborate salt.
- Inductively coupled plasma – optical emission spectrometry (**ICP-OES**) was also used for compositional analysis of the tailings. A Spectro-Ciros-Vision optical emission spectrometer was used for the measurement.
- The talc mine tailings were calcined in a muffle furnace for two hours in air at 900°C.
- Further information can be provided upon reasonable request.

Tailings Characterisation Data

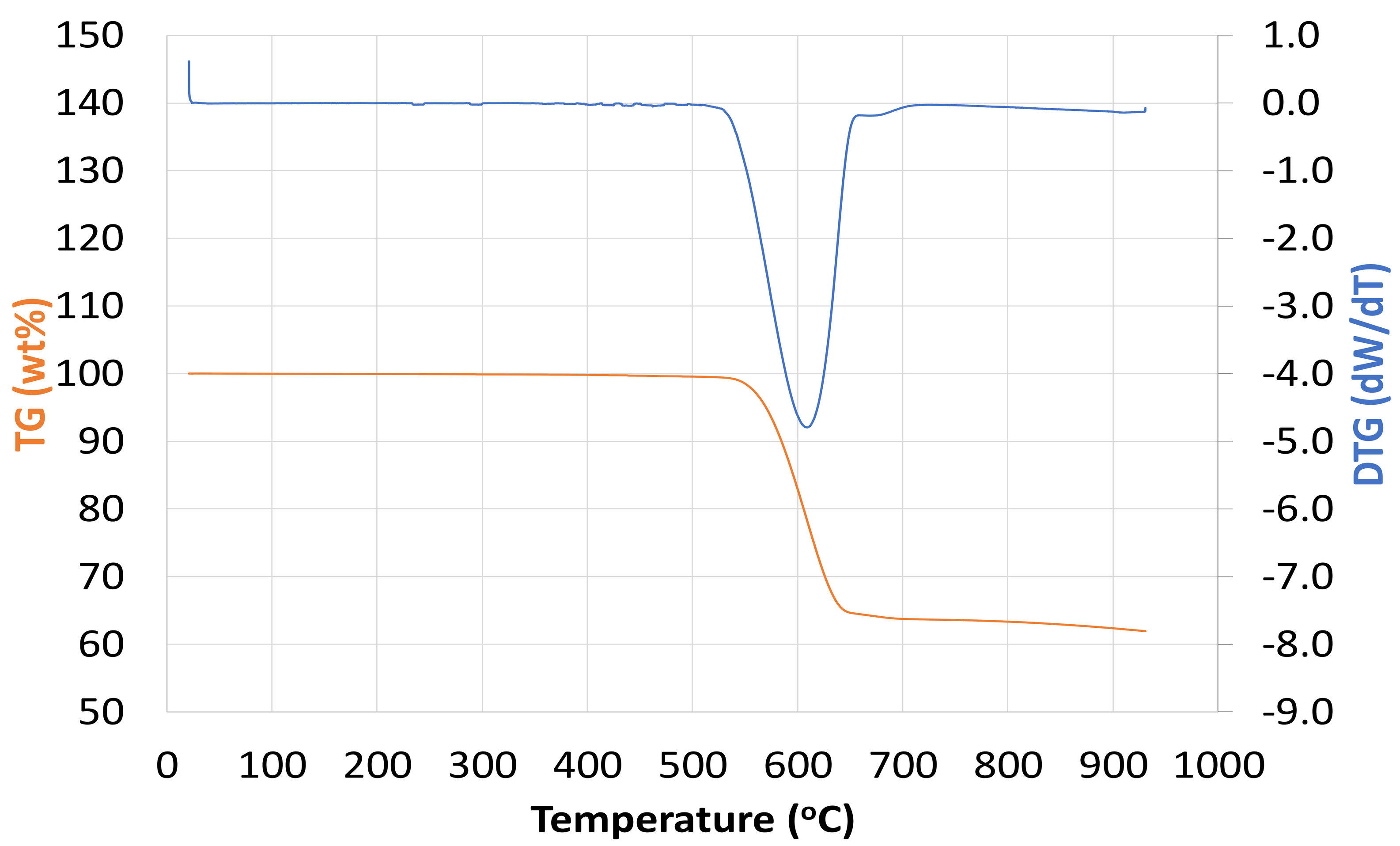

Figure 1: TG analysis of ferroan magnesite rich tailings.

Table 1: XRF analysis of ferroan magnesite rich tailings (weight %). N.B. Although Fe is presented as Fe_2O_3, the iron may exist in other oxidation states.

MgO	SiO_2	Fe_2O_3	SO_3	Al_2O_3	CaO	Na_2O	TiO_2	Mn_3O_4	NiO	Cr_2O_3
38.5	15.1	8.2	1.1	0.9	0.6	0.6	0.1	0.1	0.1	0.1

Table 2: ICP-OES analysis of ferroan magnesite rich tailings (weight %).

Mg	Si	Fe	Ca	Al	S	Cl	Cr	Mn	Ni
18.7	7.0	4.6	0.4	0.3	0.3	0.1	0.1	0.1	0.1

Sample Preparation

- As magnesium silicates are also present in the tailings, TG data was used to estimate MgO contents which were as carbonates.
- Weighing of the materials in crucibles before and after calcination in muffle furnace agreed with the TG data.
- Four samples were produced as shown in Table 3.
- The amount of water, SiO_2 (Elkem) and $NaHCO_3$ (Sigma-Aldrich) were based on a previous formulations [2].
- The rotary-calcined metakaolin was made up of 52% SiO_2 so the amount of microsilica used was to ensure a similar SiO_2 content.
- Samples were mixed by hand. Cements 3 and 4 were initially difficult to mix so an additional 22 g of water was added to each.
- The samples were put into centrifuge tubes, sealed and placed in the drying oven at 35°C for 3, 7, and 14 days.
- The physical properties of each of the samples were examined visually after these time intervals.

Table 3: Composition of cement samples. 100 g of dry tailings was used in all samples.

Sample	Calcined tailings (MgO) /g	Silica fume (SiO_2) /g	Calcined clay/g	$NaHCO_3$/g	Water /g
1	32.6	47.2	-	-	109
2	32.6	47.2	-	9	109
3	32.6	-	90.8	-	109 (+22)
4	32.6	-	90.8	9	109 (+22)

Results and Conclusions

- The LOI (950°C) of the tailings is 38% and the tailings are composed of mainly magnesium, silicon, and iron oxides.
- After 3 days, cements 1 and 2 were still soft; but, cement 3 had hardened and 4 contained some harder parts, but was mostly soft.
- After 7 days, 1 and 2 were still soft but cements 3 and 4 were hard.
- After 14 days, 1 was soft, 2 was soft but contained some harder parts, 3 was very hard and 4 was hard.

Talc mine tailings can be used to produce hardened cement. Samples containing calcined clay hardened the quickest. $NaHCO_3$ addition seems to have caused the sample to harden faster when microsilica is used. However, the addition of $NaHCO_3$ seems to have resulted in slower hardening in the metakaolin cement.

References

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