Assessment of the potential use of waste siltstone saw dust as an SCM for concrete materials

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1. Introduction

Material from Eidsvold Siltstone were received by the University of Melbourne on 7th February 2025. The suitability of the calcined material as a supplementary cementitious material (SCM) as per AS 3582.4:2022 standard was assessed by the University of Melbourne.

2. Tests Methods

Following tests were performed to assess the calcined material as per AS 3582.4:2022 standard. General purpose cement conforming to AS 3972-2010 was used for strength index and water demand tests.

Tests as per AS 3582.4:2022

Table 1: Tests performed and the respective standards/methods

Test performed	Standard/Method
Moisture Content	AS 3582.2
Loss on Ignition	AS 3583.3
Relative Water Requirement	AS 3583.6
Strength Index	AS 3583.6
Relative Density	AS 3583.5
Fineness	Mastersizer 3000 equipment
Chemical Composition	X-Ray fluorescence (XRF)

Additionally, Thermal Gravimetric analysis (TGA) was performed on the raw material. Furthermore, R3 test (as per ASTM C1897-20) was permed on calcined material. Details of these tests are included below.

X-Ray fluorescence method (XRF)

X-ray fluorescence (XRF) is a widely used analytical technique for determining the elemental composition of cementitious materials. In this method, a sample is exposed to high-energy X-rays, causing the elements within the sample to emit secondary (or fluorescent) X-rays. By measuring the energy and intensity of these emitted X-rays, XRF can identify and quantify the elements present in the sample. This technique is particularly valuable in the cement industry for quality control and optimization, as it provides rapid, accurate, and non-destructive analysis of key elements present in the material.

Thermal Gravimetric Analysis (TGA)

Thermogravimetric analysis (TGA) is a technique for studying the thermal stability and composition of cementitious materials. In TGA, a sample is heated at a controlled rate (from room temperature to 1000°C at a rate of 10°C/min in this study) while its mass is continuously measured. This allows for the identification of various phases and components based on their thermal decomposition patterns. For potential SCMs that needs calcination, this technique provides information on quantification of particular phases (ex: kaolinite

content in clay material) through analysing the mass loss at specific temperature ranges. It can also provide insights on the calcination temperature that is required for optimal calcination.

R3 Test

The R3 test, also known as the Rapid, Reliable, and Relevant test, is a standardized method used to assess the chemical reactivity of supplementary cementitious materials (SCMs) in Portland cement blends conducted as per as per ASTM C1897-20. This test measures the cumulative heat release of hydrated pastes composed of the SCM, calcium hydroxide, calcium carbonate, potassium sulfate, and potassium hydroxide, cured at 40°C. The R3 test provides a reliable indication of the reactivity of SCMs, which is crucial for predicting their performance in concrete applications. By evaluating the reactivity, the R3 test helps in optimizing the use of SCMs to enhance the durability and sustainability of cementitious material.

3. Calcination

Further Grinding

As the material passed the fineness requirement (as indicated in

Table 4 below), any additional grinding was not required. The material was calcined as received.

Optimum Calcination temperature

As the first step, Thermal Gravimetric Analysis (TGA) was performed on the raw sample to obtain the optimal calcination temperature. The test revealed that complete calcination would occur at 800°C (Plots of TGA included in the appendix). Therefore the material calcined in two separate regimes:

a. At 650 °C, as per the initial request

b. At 800 °C, as per the results of TGA

Error! Reference source not found. below shows the material before and after calcination.

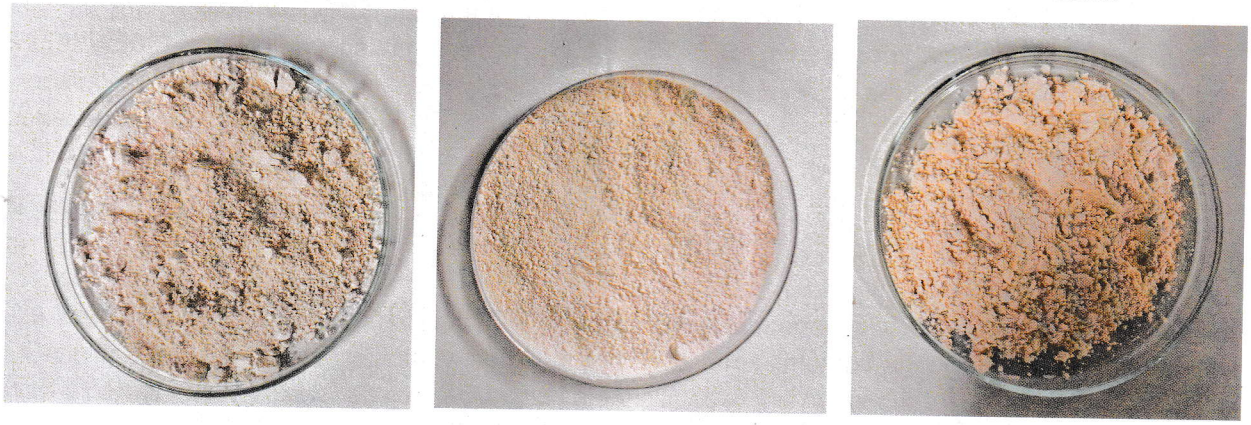

Figure 1 (left to right): Raw material as received, calcined at 650°C and calcined at 800°C

4. Results

Chemical composition

The chemical composition of the material (obtained through X-ray fluorescence method) is indicated in Table 2. The analysis was performed on un-calcined (raw) material.

Table 2: Chemical Composition of the received material

	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	K_2O	MgO	CaO	P_2O_5	ZrO_2	SO_3	SrO	ZnO	BaO	V_2O_5
wt(%)	73.73	23.26	0.84	0.75	0.58	0.53	0.06	0.06	0.05	0.04	0.03	0.03	0.01	0.01

Empirically, for a material to be a successful candidate as an SCM, two conditions need to be satisfied: (i) Al_2O_3 content >18 and (ii) Al_2O_3/SiO_2 > 0.3. Siltstone saw dust passes both these criteria, displaying the potential as a successful SCM for concrete applications.

R3 test

The cumulative heat release curves from the R3 test are indicated in Figure 2 below. A higher cumulative heat release indicates a higher initial reactivity of the calcined clay material. As indicated, the sample calcined at 800°C had the higher heat release compared to the sample calcined at 650°C. This result is an indication of expected high reactivity of the sample calcined at 800°C.

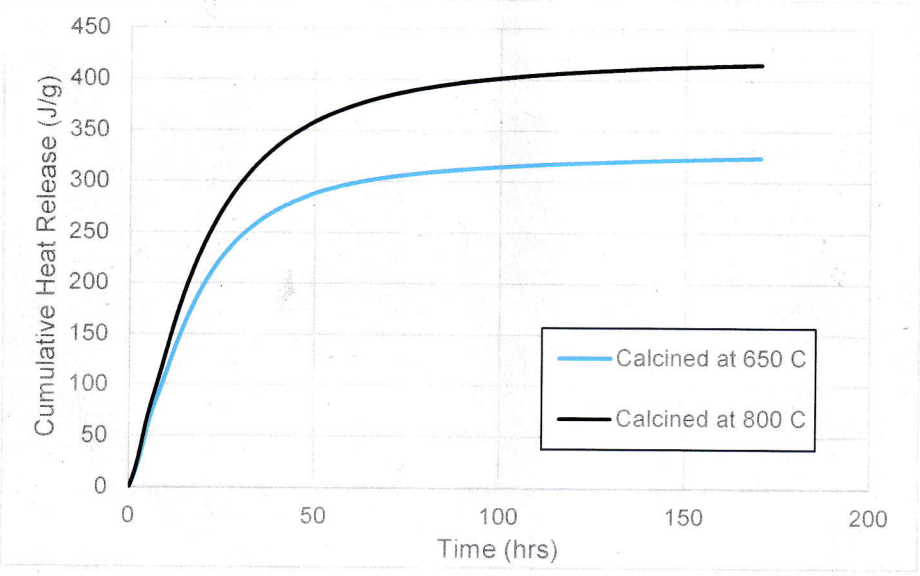

Figure 2: Cumulative heat release curve from the R3 test

Particle Size Distribution

The particle size distribution data and the respective curve are indicated in Table 3 and Figure 3 below.

Table 3: Particle size distribution data for the clay sample

Dx (10) (µm)	Dx (25) (µm)	Dx (50) (µm)	Dx (75) (µm)	Dx (80) (µm)	Dx (90) (µm)	Dx (100) (µm)	**Passing 45 µm (%)**
2.23	4.51	18.7	69.0	95.0	210	851	67.7

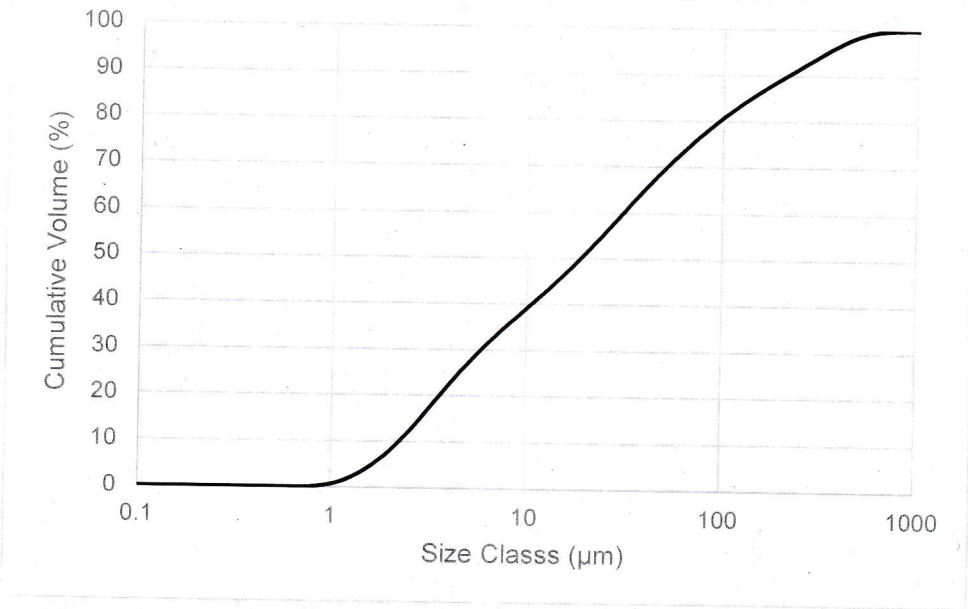

Figure 3: Particle size distribution of the material

AS 3582.4:2022 specifies the percentage passing through 45 µm to be greater than 65% for Grade 1 material, or greater than 50% for Grade to material. Siltstone saw dust passes the particle size distribution requirements for a Grade 1 material.

Assessment against AS 3582.4:2022

Table 4 below shows the summarised test results against the requirements of AS 3582.4:2022. Pictures of the samples cast for the strength activity index, as well as pictures obtained while performing the flow value test as a part of relative water requirement testing are included in the Appendix.

Table 4: Summary of Test Results

Test	Requirement of AS 3582.4:2000		Results	
	Grade 1	Grade 2	Calcined at 650°C	Calcined at 800°C
Fineness by mass passing 45 µm sieve, min %	65	50	67.7	67.7
Moisture Content, max %	0.5	0.5	0.34	0.2
Loss on Ignition, max %	6.0	6.0	2.7	0.3
Relative Water Requirement, max %	120	120	105	98
Strength Index, min %	85	75	To be obtained	91.8
Magnesia Content (MgO)	5	5	0.53	0.53
Chloride Ion Content	0.1	0.1	0.0	0.0
Sulphate Content (SO_3)	3.0	3.0	0.04	0.04
Relative Density	-	-	2.4	2.2

As per the summarized results indicate in Table 4, The material calcined at 800°C passes all requirements of a Grade 1 SCM. Add details on 650C Material

5. Conclusion

As per above test results, we confirm that the calcined material satisfies the requirements of a Grade 1 pozzolanic material as per AS 3582.4: 2022.

Appendix

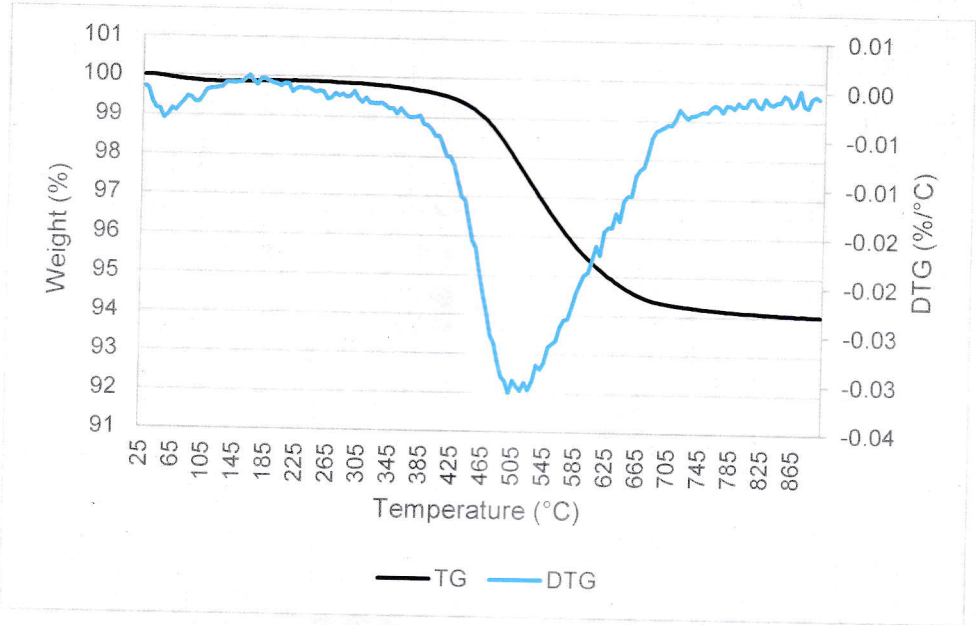

Figure 4: Thermal gravimetry (TG) and first derivative of thermal gravimetry (DTG) curves for the raw sample

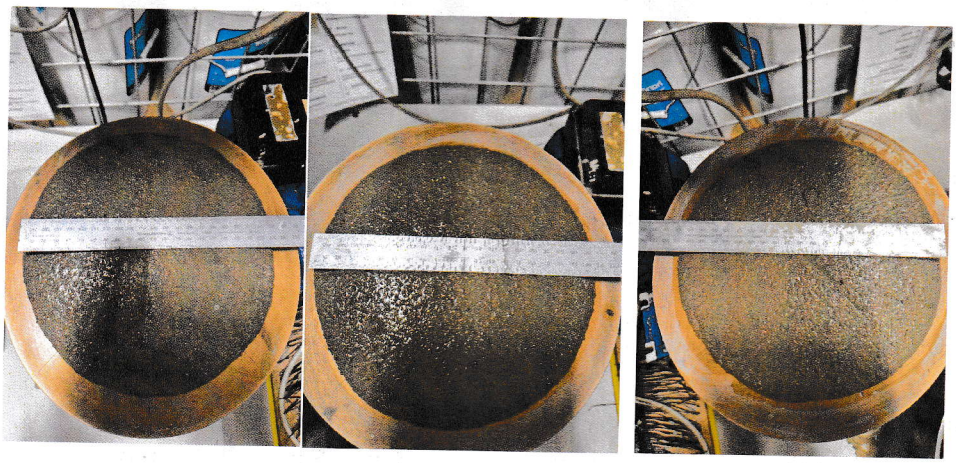

Figure 5: Pictures of the relative water requirement test (fresh mortar in flow table): Figures from left to right indicates GP control, mortar with 650°C calcined clay and mortar with 800°C calcined clay respectively

Figure 6: Mortar cubes for the strength index test: Figures from left to right indicates GP control, mortar with 650°C calcined clay and mortar with 800°C calcined clay respectively

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