Thermogravimetric Analysis of Silicate Cement Component Content

Background

Cement is one of the most widely used construction materials across industries including infrastructure, transportation, agriculture, and marine engineering. Among cement types, **silicate cement** holds a dominant role due to its versatility, durability, and long-standing industrial adoption.

The primary phase of silicate cement clinker comprises silicate minerals, with **alite (C_3S)** and **belite (C_2S)** accounting for over 75% of its composition. Upon exposure to atmospheric conditions, these components react with moisture and carbon dioxide to form secondary products such as:

- **Ettringite**
- **C-S-H gel**
- **Calcium hydroxide ($Ca(OH)_2$)**
- **Calcium carbonate ($CaCO_3$)**

Each of these phases decomposes at distinct temperatures, making **thermogravimetric analysis (TGA)** a powerful technique to identify and quantify cement hydration and carbonation products based on characteristic mass loss behavior.

Experimental Method

Thermogravimetric analysis was performed using the **AMI TGA 1000** under the following conditions:

- **Sample Mass**: ~20 mg
- **Crucible**: Platinum
- **Atmosphere**: Nitrogen (50 mL/min)
- **Heating Program**: 30°C to 1000°C at 10°C/min

The analysis focused on the thermal decomposition behaviors of **$Ca(OH)_2$** and **$CaCO_3$**, allowing their relative quantities to be determined based on water and CO_2 release, respectively.

133 East Main Street, Twin Lakes, WI 53181• 262-877-3600 (Voice) • 262-877-3699 (Fax)
Email: info@ami-instruments.com

Results and Discussion

Figures 1 and 2 present the TGA profiles for two silicate cement samples (Sample A and Sample B). The thermograms can be interpreted in four distinct mass loss stages:

Stage 1: < 200°C

- **Mass Loss**: ~5.25%
- **Cause**: Evaporation of free moisture and decomposition of low-temperature hydration products such as **C-S-H gel** and **ettringite**.

Stage 2: 400–480°C

- **Cause**: Dehydration of **calcium hydroxide ($Ca(OH)_2$)**.

Stage 3: 500–800°C

- **Cause**: Decomposition of **poorly crystalline $CaCO_3$**, which typically forms via environmental carbonation during curing.

Stage 4: > 800°C

- **Cause**: Breakdown of **highly crystalline $CaCO_3$**, typically from the original clinker phase or long-term carbonation.

Comparative Analysis: Sample A vs. Sample B

- Both samples exhibit **comparable amounts of highly crystalline $CaCO_3$**.
- **Sample B** shows a **higher content of $Ca(OH)_2$**, indicating a more advanced hydration stage or higher water-to-cement ratio.
- **Sample A** shows a **greater amount of poorly crystalline $CaCO_3$**, suggesting more surface carbonation or environmental exposure during curing.

These results demonstrate that the AMI TGA 1000 provides excellent resolution for differentiating **hydration** and **carbonation products** in cement and allows for reliable quantitative analysis based on thermal decomposition behavior.

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Conclusion

Thermogravimetric analysis using the **AMI TGA 1000** enables clear and reliable identification of key hydration and carbonation phases in silicate cement. The system's high sensitivity and stability allow differentiation between loosely and strongly bound components across a broad temperature range — from ettringite and $Ca(OH)_2$ to amorphous and crystalline $CaCO_3$.

The relative amounts of $Ca(OH)_2$ and $CaCO_3$ reflect hydration progress and carbonation extent, both of which impact durability and performance in real-world environments.

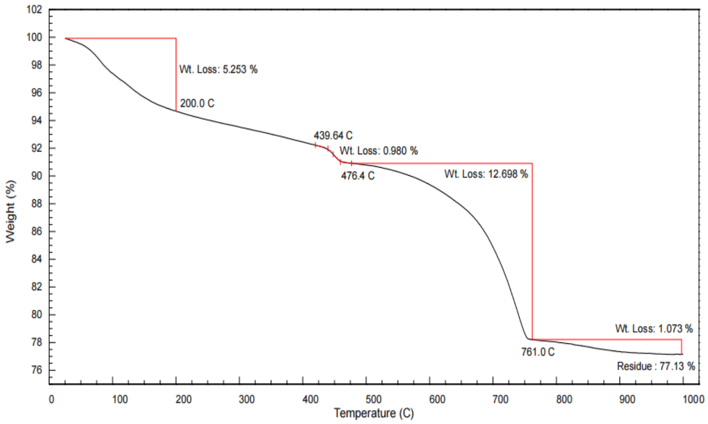

Figure 1: TGA of Silicate Cement Sample A

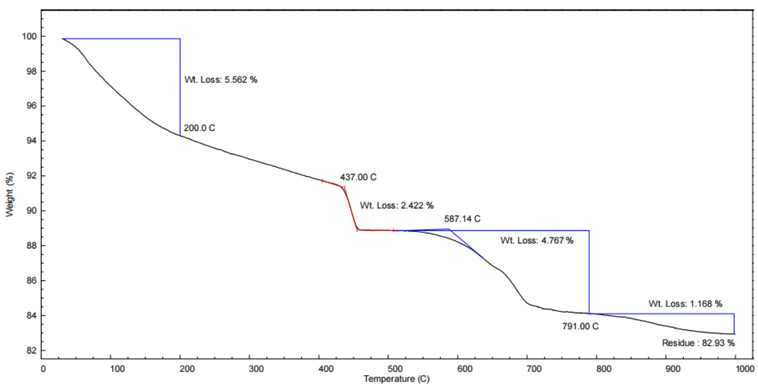

Figure 2: TGA of Silicate Cement Sample B