MITIGATION OF CARBON DIOXIDE BY FURTHER ENHANCED SEQUESTRATION IN CONCRETE

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Sustainability Issues of Cement & Concrete

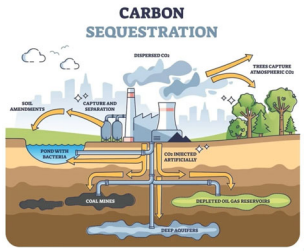
- What is **Concrete**?
  - An artificial composite material
  - Most widely used construction material across the globe
  - Made of **Cement**, **Sand**, **Aggregates** and Water

- Why does concrete production make so much greenhouse gas?
  - Accounts for **8%** of the total global emissions every year
  - **Limestone**, **clays** and other materials are heated in a huge kiln at **1450°C**
  - Kiln heats limestone, producing into **calcium oxide** and CO_2, releasing into our **atmosphere.**

- **How to reduce CO2 emissions:**
  - Supplementary Cementitious Materials (**SCM**s) like **fly ash** and **slag.**
  - **recycled aggregate** can help make our concrete more sustainable.
  - **Research** into making **concrete** more **sustainable** is **lacking** that concrete producers will happily adopt that is both cost effective and good for the environment.

Carbon Sequestration, Concrete Carbonation, & Serpentine

- **Carbon sequestration** is:
  - CO_2 removed from the atmosphere and held in solid or liquid form.
  - **Mineral Sequestration** - CO_2 reacting with metal oxides (e.g., Mg^{2+} or Ca^{2+}) to form stable carbonates (CO_3).
- **Concrete carbonation** is:
  - cement's hydration products reacting with CO_2 to form carbonates:
    $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$
  - Concrete **naturally** sequesters CO_2, but **not enough** to offset total carbon emissions.

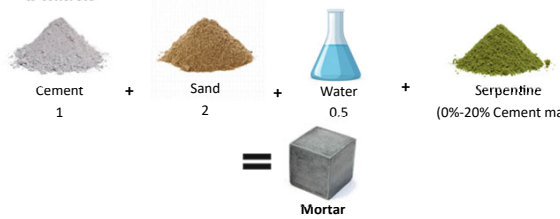


- **Serpentine** is:
  - A green-coloured rock that is rich in Magnesium (Mg).
  - Can form stable carbonates when reacting with CO_2:
    $\frac{1}{3}Mg_3Si_2O_5(OH)_4 + CO_2 \rightarrow MgCO_3 + \frac{2}{3}SiO_2 + \frac{2}{3}H_2O$
  - Can **enhance** concrete's natural CO_2 sequestration.
  - Antigorite polymorph has high compressive strength and density as a concrete aggregate.

- **Advantages** include:
  1. Increasing sequestered CO2 in concrete can **further reduce carbon footprint**.
  2. Maintain desired compressive strength of concrete while reducing the amount of cement used in concrete mix.

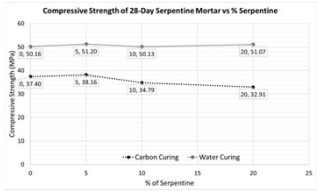
Mortar Mix Design & Key Testing Procedures

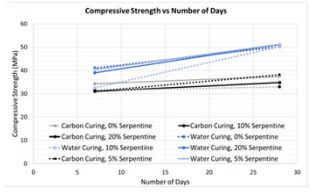
- What is **Mortar** and why use it for testing serpentines effects as an additive in concrete?
  - **Mortar** is the combination of **Cement**, **Sand** and Water
  - **Mix Ratio - Cement** : **Sand** : Water : **Serpentine** → **1** : **2** : **0.5** : **x%** Cement Mass
  - Serpentine is crushed into powder (10 microns) to maximise reactive surface area.
  - By using Mortar, we can save materials by reducing aggregate use and appertain our results to concrete



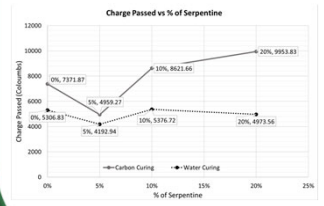
- Two types of curing: Water Curing and Carbon Curing
- What are the **key testing** procedures and what do they tell us?
  - Compression Test: Indicates how **strong** our mortar is
  - Water Permeability Test: Tells us how our mix **resists** water penetration
  - Rapid Chloride Penetration Test: Stipulates the **durability** of our mix over time
  - Calorimeter Test: Indicates how our mix performs during **hydration**
  - Phenolphthalein PH test: Visually demonstrates the **carbonation depth** inside our samples

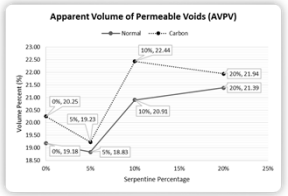
Results



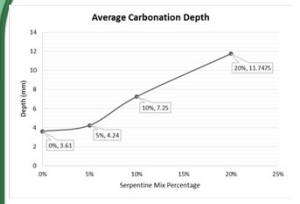


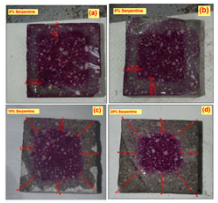
- **Chloride ion penetration depth**

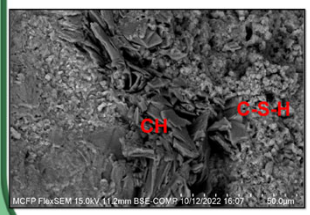




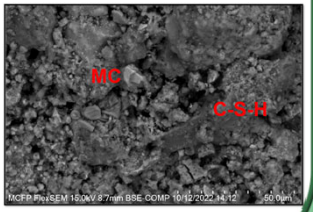
Carbon Sequestration Levels



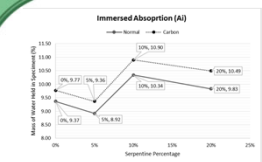


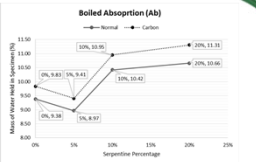


20% normally cured sample

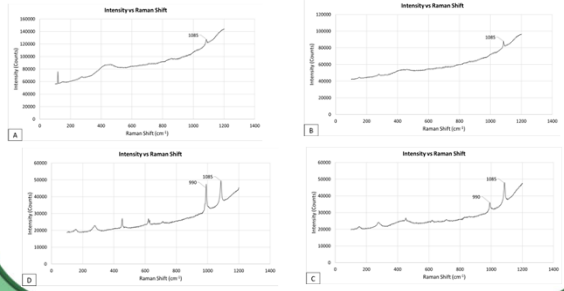


20% carbonated sample





Raman Spectra of 1-hour hydration samples for (A) 0% mix, (B) 5% mix, (C) 10% mix, (D) 20% mix



Conclusions

1.Compressive strength under normal curing is **UNAFFECTED** with an increase in % of serpentine.
2.Durability of cement-based specimens is **DECREASED** due to greater carbonation depths induced by the addition of serpentine.
3.Carbon sequestration of samples is **INCREASED** when % of serpentine is increased in samples.
4.Cement hydration is **SLIGHTLY** impacted by the addition of serpentine in mortar specimens.