LIMESTONE BLENDED CEMENTS
AND LIMESTONE POWDER IN
CONCRETE MIXES

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THANK YOU TO ACI!!!

Ecole des Ponts - ParisTech

At the base of the Eiffel Tower
LIMESTONE BLENDED CEMENT - OUTLINE

• What are limestone blended cements?
• How do they compare with Type I/II cements?
• Benefits of limestone blended cements and limestone powder
• Current research
• Creep studies
• Future research
Limestone powder can be blended and interground with Portland cement or it can be added as an aggregate to the concrete mix.

Limestone blended cements (Type II) are classified through ASTM C595. ASTM C595 was recently modified to allow for 15% of cement clinker to be replaced with ground limestone by mass.

Separately to Type II, precast suppliers in GA have been using ground limestone powder with Type III cements as a concrete additive similar to fly ash, slag, etc.
Unlike fly ash or slag, limestone powder is not reactive. However, cement hydration is influenced by the percentage and fineness of limestone powder by three main effects:

- **Filler** – wider dispersion of cement grains leads to improved packing when finely ground
- **Nucleation** – additional precipitation sites increases solid surface area
- **Dilution** – less reactive filler increases effective w/c ratio which increases porosity and decreases strength
Compared with ordinary Portland cement, limestone powder and fly ash are comparable in reducing respiratory inorganics and CO$_2$ atmospheric release.
In GA, limestone is more readily available than fly ash.

Due to EPA regulations, only 40% of fly ash produced can be used in concrete.
In GA, limestone is more readily available than fly ash.
LIMESTONE POWDER - BENEFITS TO PRECAST

- Improved workability - less segregation/more uniform distribution of aggregate/no clumps
- Improved finished product - less patching
- Cheaper than fly ash ($5/ton)
- Less abrasive = less wear and tear on equipment compared with fly ash
- Increase or decrease in compressive strength and set time – depending on fineness
RESEARCH STUDIES

The fineness and percentage of the limestone can influence the amount of heat released during the hydration process and autogenous shrinkage (during hydration).

- Finely ground Type II cements increase the heat of hydration and have increased autogenous shrinkage compared with Type I from the same plant.
Do Type IL cements creep more than Type I cements?

Parameters:
• Long term concrete creep study following ASTM C512
• Cylinders cast (cements A, AL, C, and CL) with a w/c ratio of 0.32
• Cylinders were demolded at 24 hours, placed in a saturated lime bath at 21°C (70°F) for 48 hours
• After curing, the cylinders were loaded at 40% of their compressive strength in a room at 23°C (73.5°F) and 50% RH
• Creep measured over one year
With Nanoindentation creep, creep in the cement paste is measured and then the results are upscaled to the concrete level

Parameters:
- Small scale creep tests lasting less than 24 hours
- 20mm diameter cylinders were cast w/c ratio of 0.32
- Cylinders were demolded after 24 hours and cured for 48 hours in environmental chamber at 21°C (70°F) at 100% RH
- After curing, small discs from the center of the cylinders were cut, ground and polished for testing
Nanoindentation tests were performed on a Micro Materials Ltd Nanoindenter using a Berkovich tip.

Tests were conducted on a 12x12 grid spaced at 100µm.

Samples were loaded for 30 seconds until reaching a load of 475mN, the load was held constant for 180 seconds (3 minutes), and the load was removed over 30 seconds.

During loading, holding and unloading, the penetration depth is measured and recorded.
During the hold phase, the depth of penetration, $h$, and contact radius, $a$, is measured and plotted over time.

\[ L(t) - \frac{1}{M_0} = \frac{2a_\text{eff} \Delta h(t)}{P_{\text{max}}} \]
Based on the slope of the contact creep curves, you can upscale to the level of concrete to determine the rate of creep for concrete.

- Two methods are used to upscale from the level of cement paste to concrete:

  - Mori Tanaka:

    $$ C_{i,\text{con}} = C_i \frac{2 + 3f_{\text{agg}}}{2(1 - f_{\text{agg}})} $$

  - Vu et al.:

    $$ C_{i,\text{con}} = C_i \left(1 - \frac{f_{\text{agg}}}{f_{\text{agg,m}}}\right)^{-1.43} $$

<table>
<thead>
<tr>
<th>Cement</th>
<th>slope</th>
<th>$C_i$ (GPa)</th>
<th>$f_{\text{agg}}$</th>
<th>$C_{i,\text{con}}$ (GPa) Mori Tanaka</th>
<th>$C_{i,\text{con}}$ (GPa) Vu et al.</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>7.213</td>
<td>138.6</td>
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<td>C</td>
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<td>139.4</td>
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<tr>
<td>CL</td>
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<td>135.6</td>
<td>0.68</td>
<td>855.8</td>
<td>996.818</td>
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</table>
Nanoindentation creep studies on cement paste show little difference in the rate of creep between Type I and Type II cements.

Long-term creep studies on concrete specimens show inconclusive results between Type I and Type II cements.
LIMESTONE BLENDED CEMENTS – FUTURE RESEARCH

With funding from the Precast Concrete Institute

- Effect of Type IL cements on self-consolidating concrete
- Effect of limestone powder fineness on SCC
- Effect of limestone powder percentage (0-30%) on SCC
Thank you!!

Questions???