Cement Properties and Characteristics

**Oxides**

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂ (silicon dioxide)</td>
<td>cap rock</td>
</tr>
<tr>
<td>CaO (calcium oxide)</td>
<td>limestone</td>
</tr>
<tr>
<td>Al₂O₃ (aluminum oxide)</td>
<td>clay</td>
</tr>
<tr>
<td>Fe₂O₃ (ferric oxide)</td>
<td></td>
</tr>
</tbody>
</table>

Oxides used to calculate theoretical cementitious compounds: C₃S, C₂S, C₃A and C₄AF

**Compounds**

Tricalcium Silicate (C₃S) hardens rapidly and is largely responsible for initial set and early strength. In general, the early strength of portland cement concrete is higher with increased percentages of C₃S.

Dicalcium Silicate (C₂S) hardens slowly and contributes largely to strength increases at ages beyond 7 days.

Tricalcium Aluminate (C₃A) liberates a large amount of heat during the first few days of hardening and, together with C₃S and C₂S may somewhat increase the early strength of the hardening cement (this effect being due to the considerable heat of hydration that this compound evolves). It does affect set times.

Tetracalcium Aluminoferrite (C₄AF) contributes very slightly to strength gain. However, acts as a flux during manufacturing. Contributes to the color effects that makes cement gray.

**Tests**

Magnesium Oxide (MgO) causes delayed expansion when present in large amounts. ASTM limits all cements to 6.0%.

Sulphuric anhydride (SO₃) is an indirect measure of the amount of gypsum or calcium sulphate (CaSO₄) in the cement. Gypsum is added to cement for the purpose of regulating setting time. Too much gypsum can cause expansion and, therefore, SO₃ is generally limited to 3.5% in Type I cement with a C₃A content greater than 8% and limited to 3.0% in Type II cement with a C₃A content less than 8%. Gypsum predominantly affects concrete set times by delaying the hydration of C₃A which typically "flash sets" on contact with water.

Ignition loss (LOI) represents the % weight loss suffered by a sample of cement after heating to 1832 F. Any water bonded to hydrated cement particles is expelled above this temperature. The higher the LOI, the less strength the cement will develop. ASTM limits the LOI to 3.0%.

Insoluble Residue represents that a fraction of cement which is insoluble in hydrochloric acid. Almost all of the clay compounds present in the raw mix of cement are insoluble in acids. After reactions with lime, these compounds are soluble making this test an indication of the efficiency of the burning process. (I.E. Determines the amount of unburnt raw materials and contamination from gypsum or storage.) ASTM limit is 0.75%.

Alkalies - The alkali content of cement (mostly chloride) is reflected in the amounts of potassium oxide (K₂O) and sodium oxide (Na₂O). Large amounts can cause certain difficulties in regulating set times of cement. Low alkali cements, when used with calcium chloride in concrete can cause discoloration in trowelled flatwork surfaces. ASTM has an optional limit in total alkalies of 0.60%, calculated by the equation Na₂O + 0.658 K₂O.

False set - Is a test to determine if the cement has abnormal early stiffening. This is an optional requirement of ASTM-150. False set is not a problem with transit mixing, where the concrete is continuously agitated before placing or where the concrete is remixed prior to placement, as with pumping. ASTM minimum is 50 percent.

Autoclave Expansion - This provides an index of potential delayed expansion caused by the hydration of CaO or MgO or both. It is impossible to tell exactly how much CaO fails to combine into clinker minerals during the burning process. CaO that does not combine is called free lime, too much of which can cause delayed expansion. Because of the difficulty in determining the exact amount of free lime ASTM-150 requires a soundness test which measures the volume stability of cement. An autoclave expansion test where bars of cement paste are subjected to pressure of about 295 psi and temperatures of about 420 F. The change in length is limited to 0.80% for all cements.

Air Content - All cements when mixed with water and sand have a tendency to entrain air. The air content of concrete is influenced by many factors, including the potential for air entrainment from cement. ASTM limit is 12%.