BRIEFLY...

Concrete is an artificially engineered material made from a mixture of portland cement, aggregates (such as sand or gravel) and water. It is the most commonly used construction material in the world. It is strong, cheap and durable.

Portland cement combines (hydrates) with water to bond the aggregates together into a solid whole. Portland cement is made from limestone and chalk, combined with silicates and a large amount of heat.

HISTORY

Although cement materials were used by the ancient Egyptians and Romans, portland cement was patented by Joseph Aspdin, a builder in Leeds, England, in 1824. It was named after a quarried stone it resembled from the Isle of Portland.

MANUFACTURING CHEMISTRY

Portland cement requires a source of calcium (usually limestone, sometimes chalk) and silicates with aluminates (clay, shale or sand). The raw materials are ground and mixed, then roasted in a rotary cement kiln up to 1480 degrees C (2700 degrees F).

Two reactions occur. First, the limestone or calcium carbonate turns into lime and carbon dioxide. Then the lime combines with the silicates to make dicalcium silicate (25%) and tricalcium silicate (55%) and with the aluminates to make tricalcium aluminate (10%) and tretracalcium aluminoferrite (8%). This is cooled and the resulting clinker is ground to a fine powder and mixed with gypsum (to control the setting speed), resulting in portland cement.

MIXING CHEMISTRY

When water is added to portland cement, the silicates combine with the water, rapidly at first. The process slows down but never completely stops if there is moisture present. If concrete sets in one day, it will be more than four times as hard after a week, six times as hard in a month, and more than eight times as hard after five years.

The two silicates mentioned earlier contribute most to the strength of portland cement when they combine with water to make calcium silicate hydrates and calcium hydroxide. The tricalcium aluminate also hydrates, but contributes little to the strength. The tetracalcium aluminoferrite contributes nothing to the cement except the gray colour. If this is removed, white portland cement is the result, with no loss of strength.

Before adding water, portland cement is usually mixed with aggregates, typically sand and gravel, to make concrete for walls, floors, pillars, roadways or sidewalks. Ratios in the construction industry vary from 1:2:3 (cement:sand:gravel) to 1:2:4 to 1:3:5. Mortar for laying bricks or blocks is usually a mixture of cement and sand with lime.

The amount of water to be added to the mix is critical, knowing that the drier the mix the stronger the result. Water is usually one to one and a half times the volume of the cement.

There are many other possible additives in the mix:
air entraining chemicals for workability and frost resistance
latex for strength
plastic fibres (eg Fibermesh) to control shrinkage cracks
plasticizers which allow less water and therefore more strength
steel reinforcing bars or mesh can also be placed in the concrete, resulting in reinforced concrete

glass fibres (alkali resistant) for tensile strength
silica fume (a waste product from manufacture of metals) increases compressive strength and decreases permeability
metakaolin also increases strength, decreases permeability and improves shrinkage
pigments for colour

WHAT HAPPENS NEXT

As the cement hydrates it hardens, holding the aggregates together, including any steel reinforcing. The concrete should be kept damp for several days (small items for as long as a week) as most of the curing/hardening takes place then.
Concrete has great strength in compression, but little tensile strength. Steel has great tensile strength, so the two are combined in bridges, buildings and other engineered projects. But even in small scale art work, steel wire and mesh can be used to reinforce the structure, particularly in unsupported spans. Alkali resistant glass fibres are sometimes added for tensile strength, substituting for steel rebar. This is useful for thin applications.
In the first 24 hours most shrinkage cracks occur, which is why polypropylene fibres can be added to the original mix. Glass fibers serve the same purpose. They prevent these cracks from becoming too large.
Because cement is hard, but has little tensile strength, it can also be brittle and chip easily. Latex can be added (or substituted) for water in the mix, to increase toughness, as well as contribute to watertightness. Both plastic fibres and latex are used in concrete canoe construction (see links page) and could have applications in art work.