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Topic 1 Concrete

Concrete is made by mixing

- Cement
- water
- Coarse & fine aggregates, and
- Admixtures (if required)

The amount of each material (ie. cement, water and aggregates) affects the properties of fresh and hardened concrete.

Manufacture of Portland Cement

- *Dry Method - Most Common*

Limestone (CaCO_3) is crushed, usually in two progressively smaller crushers.

Add iron ore or fly ash and ground, mixed and fed to a cement kiln. Heat to about 1500 C. Elements unite to form a new substance called clinker, gray balls about the size of marbles.

The cooked clinker is inter-ground with gypsum in a ball mill consisting of several compartments with progressively smaller steel balls.

- *Wet method* - raw materials are ground with water before being fed into the kiln.

Limestone (CaCO_3) is crushed, usually in two progressively smaller crushers, then fed into a ball mill with the clay dispersed in water. There the comminution of the limestone is completed, and the resultant cement slurry is pumped into storage tanks. The slurry is a liquid of creamy consistency, with a water content of between 35 to 50%. The lime content of the slurry is adjusted by blending with slurries from different storage tanks.

The slurry is passed into a rotary kiln where pulverized coal is blown in by an air blast to temperatures from 1300 to 1500 C.

At first water is driven off and CO_2 is liberated: further on the material becomes liquid and lime, silica and alumina recombine to become 'clinker' - hard balls of ceramic-like material. The cooled clinker is inter-ground with gypsum in a ball mill consisting of several compartments with progressively smaller steel balls.

Chemical composition of Portland cement – raw materials consists mainly of **lime, silica, alumina and iron oxides**.

Hydration of cement

In the presence of water, the silicates and aluminates form products of hydration, which in time produce a firm and hard mass - the hardened cement paste.

The C2S provides most of the ultimate long term strength and C3S gives the high early strength.

Hydration of cement starts at the surface of the cement particles, it is the total surface area of cement that represents the material available for hydration.

Cement

The cement powder, when mixed with water, forms a paste. This paste acts like glue and holds or bonds the aggregates together.

6 major types of cements sold in Australia:

- GP (general purpose Portland Cement)
- GB (General purpose Blended Cement)

- HE (High Early Strength Cement)
- LH (Low Heat Cement)
- SR (Sulphate Resisting Cement)
- SL (Shrinkage Limited Cement) Most

common are Type GP and Type GB.

Blended cements contain Portland cement and more than **5%** of either fly ash, ground slag, silica fume, or a combination of these (**SCMs - supplementary cementitious materials**).

Type GP - General Purpose Portland Cement

Use in most forms on concrete construction where there is no exposure to sulfates in the soil or groundwater, and where special properties of other types - such as high early strength, low heat of hydration- are not required. May contain up to 5% of approved mineral additions - CaCO₃, fly ash and slag. More economical and more uniform product.

Type GB - General purpose blended cement

Contain greater than 5% of slag, fly ash or both and / or up to 10% silica fume. very little concrete used in general building construction which does not contain a proportion of fly ash or slag.

Type HE - High early strength cement

The 3 day strength is of the same order as the 7-day strength of the GP cement. The increased rate of gain of strength is achieved by a higher CS₃ content and by finer grinding of the cement clinker. The use of HE cement is indicated where a rapid development is desired, e.g. early removal of formwork. The rapid strength development is usually accompanied by a higher rate of heat evolution, and should not be used in thick concrete sections or in mass construction.

Type LH - Low heat cement

For use in large gravity dams in the US and is usually used in large concrete pours to limit the rate of heat generation.

Type SR - sulfate resisting cement

Has a low C₃A (tricalcium aluminate) content (less than 5%). Type SR cement is intended primarily for use where resistance to ground waters containing sulfates in solution is required.

AS3972 replaced the limit on C₃A for sulfate resisting portland cement by a performance test and a performance limit after tests have shown that limiting the C₃A content was not appropriate.

Type SL -shrinkage limited cement

Does not change in volume owing to drying shrinkage, e.g. road pavements and bridge structures.

Off-white and White Portland Cement

Principally used for architectural purposes.

Coloured cements - consists of cement and inorganic pigment interground or mixed together.

Strength development - Ultimate compressive strength takes several years to achieve, but for practical purposes 28-day strengths are used as indicators for the 'final strength of most cements and are specified in cement standards all over the world.

Compressive strengths of cement is determined by crushing tests on prisms made from the standard mortar (1:3 cement:sand mix of 0.5 water-cement ratio)

Fly ash and slag blended cement gain strength more slowly than portland cements at early ages, but they exhibit more strength gain over a longer period. Ultimate strength of blended cements can be higher than that