Concrete

Basic ingredients of concrete are cement, water, and aggregate. Water is a naturally available material. Cement and aggregate, however, require a manufacturing process.

Cement production plant

Concrete is stored either in bags or in silos.

Aggregates are produced in crushing plants. Preferred geologic material for aggregate to be used in concrete is limestone.

Cement / aggregate / crushing plant / production plant / bag / silo / limestone

Types of Cement

Cements are considered hydraulic because of their ability to set and harden under or with excess water through the hydration of the cement’s chemical compounds or minerals.

There are two types:

1. Those that activate with the addition of water
2. Pozzolanic: That develop hydraulic properties when the interact with hydrated lime (Ca(OH)_2)

Pozzolanic: Any siliceous material that develops hydraulic cementitious properties when interacted with hydrated lime.

There are 5 major categories of construction materials:
- Concrete
- Steel
- Wood
- Masonry
- Glass

Concrete / timber / wooden / steel rebar / H-beam / glass / brick / masonry

Cement

Definition: "Cement is a hydraulic compound of calcium silicates and other calcium compounds having hydraulic properties" (Madhuban, 2005).

Cement production plant

Portland cement

Calcium silicate / compound / lime / clay / volcanic ash / crystalline / binding / mortar

Cement is a key raw construction material serving as a binding and plasticising material in building mortars.

Calcination: Refractory material in an industrial oven

History
- Lime and clay have been used as cementing material on constructions through many centuries.
- Romans are commonly given the credit for the development of hydraulic cement, the most significant incorporation of the Roman's was the use of pozzolan-lime cement by mixing volcanic ash from the Mt. Vesuvius with lime.
- Best known surviving example is the Pantheon in Rome.
- In 1824 Joseph Aspdin from England invented the Portland cement.

Calcination: Original Roman cement. Only a small quantity is manufactured in the U.S. Mix of pozzolans with lime.

Cementitious materials: Portland cement where other materials have been added primarily to impart plasticity.

Aluminous cements: Limestones and basalt are the main raw materials. Used for refractory applications (such as cementing furnace bricks) and certain applications where rapid hardening is required. It is more expensive than portland. There is only one producing facility in the U.S.

Clinker: The cementing material is made by mixing Clinker with gypsum in a 95:5 ratio.

Portland cement: Artificial cement. Made by the mixing Clinker with gypsum in a 95:5 ratio.

Portland-limestone cements: Large amounts (6% to 35%) of ground limestone have been added as a filler to a portland cement base.

Blended cements: Mix of portland cement with one or more SCM (supplementary cementitious materials) like pozzolans additives.

Pozzolana: Pozzolanic cements: Original Roman cements. Only a small quantity is manufactured in the U.S. Mixes of pozzolans with lime.

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Bauxite: Main source of aluminum

Clinker: Gypsum / calcination / additive / plasticity / refractory / bauxite / hardening

hydration / harden / calcination / argillaceous / interbedded / clay / shake / quarry

Concrete, Steel, Romans are commonly given the glass. Best known surviving example is the Masonry. Lime and clay hydration / harden naturally available material. Cement and aggregate, however, require a manufacturing process.

Any few materials: Limestones, argillaceous / interbedded / clay / shake / quarry from China Porcelain. And those made from argillaceous limestones or interbedded limestone and clay or shale with few raw materials. It is not commonly used anymore. Clay / shale / quarry

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Technical English - I
9th week
Construction Materials

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Cement

The fundamental chemical compounds to produce cement clinker are:

Lime (CaO)
Silica (SiO₂)
Alumina (Al₂O₃)
Iron Oxide (Fe₂O₃)

Raw materials used in the production of clinker cement

<table>
<thead>
<tr>
<th>Source of oxides</th>
<th>Oxidation state</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>CaO</td>
<td>Calcium oxide</td>
</tr>
<tr>
<td>Silica</td>
<td>SiO₂</td>
<td>Silicon oxide</td>
</tr>
<tr>
<td>Alumina</td>
<td>Al₂O₃</td>
<td>Alumina oxide</td>
</tr>
<tr>
<td>Iron Oxide</td>
<td>Fe₂O₃</td>
<td>Iron oxide</td>
</tr>
</tbody>
</table>

Fly ash: by-product of burning finely grounded coal either for industrial application or in the production of electricity

Fly ash in the plant

clinker / fly ash / waste material / grounded coal

Aggregate

Aggregates are broadly classified as:

- Fine aggregates
- Coarse aggregates

All natural aggregate particles are originally formed from a part of a larger parent mass.

Many properties of the aggregates depend entirely on the properties of the parent rock. E.g. chemical and mineral composition, petrological character, specific gravity etc.

Some properties are possessed by the aggregates but absent in the parent rock: particle shape and size, surface texture, and absorption.

Particle shape classification for aggregates and soils

Formation of sand, gravel and other size soils as parent rock disintegrates as a result of weathering processes under atmospheric effects.

Natural Aggregates

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Uses of Aggregates

- Aggregates are used in concrete as a filler material.
- Aggregates provide dimensional stability to reduce and overcome: shrinkage, thermal changes.
- Aggregates greatly affect strength and stiffness of the concrete.
- Economy is obtained using aggregates since amount of cement in concrete is reduced in this manner.
- Aggregates, if used in a properly designed concrete, make the concrete denser.

Coarse Aggregates

Aggregates that are retained on 75mm (No.4) sieve. Most commonly used fine aggregates are sand, crushed stone, and ash.

Ranges of particle sizes found in aggregates for use in concrete

Soils for particle size analysis of aggregates and soils

Fly ash in the plant

clinker / fly ash / waste material / grounded coal

Sedimentary

Fine aggregates

Aggregates are broadly classified as:

- Fine aggregates
- Coarse aggregates

Originates from the biological deposition of shells and skeletons of plants and animals.

Massive beds accumulated over millions of years. In the cement industry limestone includes calcium carbonate and magnesium carbonate.

Most industrial quality limestones is of biological origin.

The ideal cement rock 77 to 78% CaCO₃, 14% SiO₂, 2.5% Al₂O₃ and 1.75% Fe₂O₃. Limestone with lower content of CaCO₃ and higher content of alkalis and magnesia requires blending with high grade limestone

sedimentary deposit / marine origin / high grade / cement rock / deposition

Sources of CaCO₃

- Sedimentary deposits of marine origin (limestones)
- Metamorphic (metamorphosed limestones)
- Chalk
- Shale
- Mud
- Coral
- Oyster
- Travertine
- Tyrfi

Limestones

Originates from the biological deposition of shells and skeletons of plants and animals.

Massive beds accumulated over millions of years. In the cement industry limestone includes calcium carbonate and magnesium carbonate.

Most industrial quality limestones is of biological origin.
Diatomite

Other sizes:

Crushed Concrete

The specific gravity is determined according to ASTM C 127 and 128 and is an essential weight of the aggregate that would fill a unit volume is named as Concrete

Damp Cubes : British standard 150x150x150 mm

Grading is the distribution of particles among various sizes. It is obtained by means of Scoria

\[ \sigma = \frac{P}{A} \]

Examples of Aggregates Used

<table>
<thead>
<tr>
<th>Weight</th>
<th>Examples of Aggregates Used</th>
<th>Uses for the Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra-light</td>
<td>Vermiculite, diatomite, diatomite, pumice, scoria, perlite</td>
<td>can be sawed or nailed, also used for insulating purposes (350 to 450 kg/m³)</td>
</tr>
<tr>
<td>Light</td>
<td>Expanded clay, shale or slate, crushed brick</td>
<td>used primarily for making lightweight concrete for structures, also used for insulation (150 to 500 kg/m³)</td>
</tr>
<tr>
<td>Normal</td>
<td>Crushed limestone, sand, river gravel, crushed recycled concrete</td>
<td>used for regular concrete projects</td>
</tr>
<tr>
<td>Heavy</td>
<td>Barite, magnetite, steel or iron shot, steel or iron pellets</td>
<td>used for making high density concrete for shielding against nuclear radiation</td>
</tr>
</tbody>
</table>

Examples of Aggregates Used

- Expanded clay
- Crushed brick
- River gravel
- Crushed limestone
- Crushed concrete

Absorption and Surface Moisture

The absorption and surface moisture of aggregates should be determined using ASTM C 70, C 127, C 128, and C 566 so that the total water content of the concrete can be controlled and the batch weights determined. The moisture conditions of aggregates are:

- Oven dry
- Air dry
- Saturated surface dry (SSD)
- Damp or wet

Fire Resistance and Thermal Properties

- The fire resistance and thermal properties of concrete depend on the mineral constituents of the aggregates. Lightweight aggregates are more fire resistance than normal weight aggregates due to their insulation properties.
- Concrete containing calcareous coarse aggregates performs better under fire exposure than siliceous aggregate (granite or quartz).

Mechanical Properties of Concrete

- The basic method of verifying that concrete complies with the specifications is to test its strength using cubes or cylinders made from samples of fresh concrete.
- Concrete behaves as a brittle material.

Compressive Strength

Cylinder : ASTM C470

- Cubes : British standard 150x150x150 mm³

\[ \sigma = \frac{P}{A} \]

- Other sizes:
  - Cylinder: 100 x 200 or 150x300 mm
  - Cubes: 100 x 100 x 100 mm³

The alkali–silica reaction (ASR), more commonly known as "concrete cancer", is a swelling reaction that occurs over time in concrete between the highly alkaline cement paste and the reactive non-crystalline (amorphous) silica found in many common aggregates, given sufficient moisture.

Negative influence of harmful aggregates on long term stability of the concrete

Some tests on aggregates:

- Grading is the distribution of particles among various sizes. It is obtained by means of sieve analysis. Fineness modulus (ASTM C125) is an indication for how coarse is the aggregate. Maximum size is the smallest sieve through which 100% of a particular aggregate batch passes through. Nominal size, however, is the smallest sieve size that majority (90%) of the aggregate must pass.
- Weight of the aggregate that would fill a unit volume is named as bulk density (ASTM C-29). The term «bulk» is used to indicate that the volume is occupied by both the aggregates and voids.
- The specific gravity is determined according to ASTM C 127 and 128 and is an essential parameter in certain mixture proportioning and control calculations.

alkali-silica reaction / amorphous / fineness modulus / batch / bulk density / specific gravity
For 150 mm cubes fill in 3 layers compact each layer 35 times.

For 100 mm cubes fill in 3 layers compact each layer 25 times.

No need for capping.

capping / uniaxial compression test machine / mold / compaction rod

For 150 x 300 mm cylinder, fill in 3 layers compact each layer 25 times.

Capping to obtain a plane and smooth surface (thin layer \( \approx 3\)mm), using:
Stiff Portland cement paste on freshly cast concrete, or mixture of sulphur and granular material, or high-strength gypsum plaster on hardened concrete.

curing tank / stiff / cylindrical mold / high-strength gypsum plaster / hardened concrete

\[ \sigma = \frac{2P}{bL} \]

Split tensile test to determine tensile strength of hardened concrete.

\[ I_{MC} = \frac{\sigma}{E} \]

Test set-up for determination of stress-strain response of concrete by which elasticity modulus can be deduced.

Three-point loading test to determine flexural strength of hardened concrete.

Although concrete is capable of resisting large compressive stress, reinforcement is necessary in order to add ductile stress-strain characteristics since structural elements made of concrete are usually subject to shear, tensile, bending and compressive stresses at the same time.

plastic deformation / yield point / elastic / compressive strength / ductile / moist curing

Steel

steel construction / truss system / steel frame

Steel construction techniques

Steel construction / rivet / stop pin / bolt / welding / butt weld / fillet weld

Old style rivet (above)

Standard bolt (left)

Welding (below)
Wood frame construction

- Wood construction / wooden / wood / timber

Brick and stone masonry

- Brick wall
- Stone wall
- Masonry / brick / stone / wall

Glass and aluminum material for construction

- Glass / aluminum / exterior wall / aluminum frame

Other materials for construction

- Plastic siding and roof cladding
- FRP (Fiber Reinforced Plastic)
- Fiberglass mesh for plastering
- Textile (or geo-textile)

- Plastic / siding / cladding / fibre or fiber / fiberglass / reinforced / geo-textile / plaster

Stirrup / bending rebar / elastic / column section / beam section / hook

Ribbed / stirrup / assembly rebar / column-beam connection / slab
Sample reinforcement to details for slabs

Concrete cover to protect rebars from corrosion

- 1/4" (6 mm) for interior slabs, pan joists, and other light floor systems, protected against deleterious substances;
- 1/2" (10 mm) for most interior exposures, including main members;
- 3/4" (19 mm) for normal exterior exposures, with additional cover recommended for particularly aggressive environments;
- 1" (25 mm) for concrete cast against earth.

- General framing layout of the pan joint system.

- Reinforcement detail / slab

- Concrete cover to protect rebars from corrosion

- Sample reinforcement to details for slabs