Properties of Concrete

CE-203PROPERTIES OF CONCRETE

- Introduction
- Batching, Mixing, transportation and placing of concrete, Properties of fresh and hardened concrete, testing of concrete for various properties. Compaction and curing of concrete

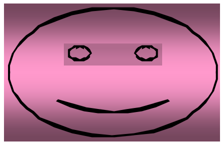
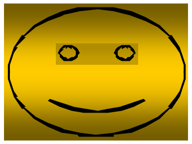
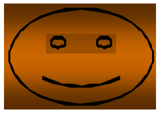
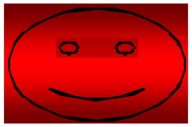
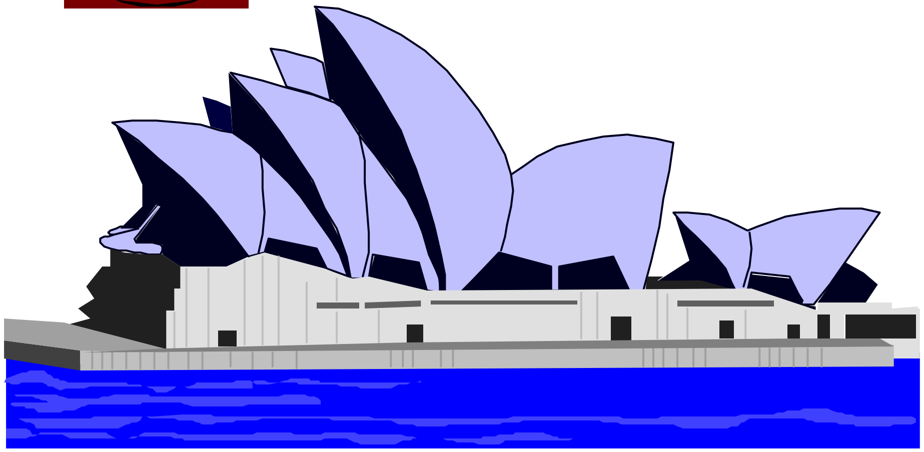
Introduction to use of additives and admixtures in concrete, strength evaluation of existing concrete structures, Quality control in concrete construction, industrialized construction, Rehabilitation and strengthening of existing structures. Design of Concrete mixes.

What is Concrete?

- Is the second most commonly used building material (after timber).
- Concrete is a **composite material** made from several readily available constituents.
- Concrete is a versatile material that can **easily be mixed** to meet a variety of special needs and formed to virtually **any shape**.

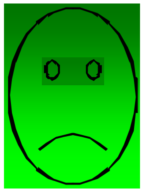
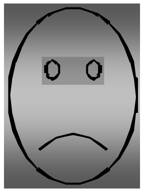
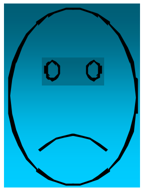
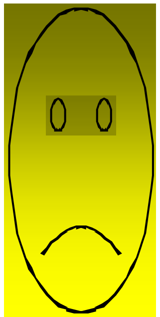
Advantages of Concrete

- Ability to be cast
- Economical
- Durable
- Fire resistant
- **Energy efficient**
- On-site fabrication
- **Composite with other material**

Disadvantages of Concrete

- **Low tensile strength**
- **Low ductility**
- **Volume instability**
- **Low strength to weight ratio**

Concrete Constituents

(1) Portland Cement

(2) Water

(3) Aggregates

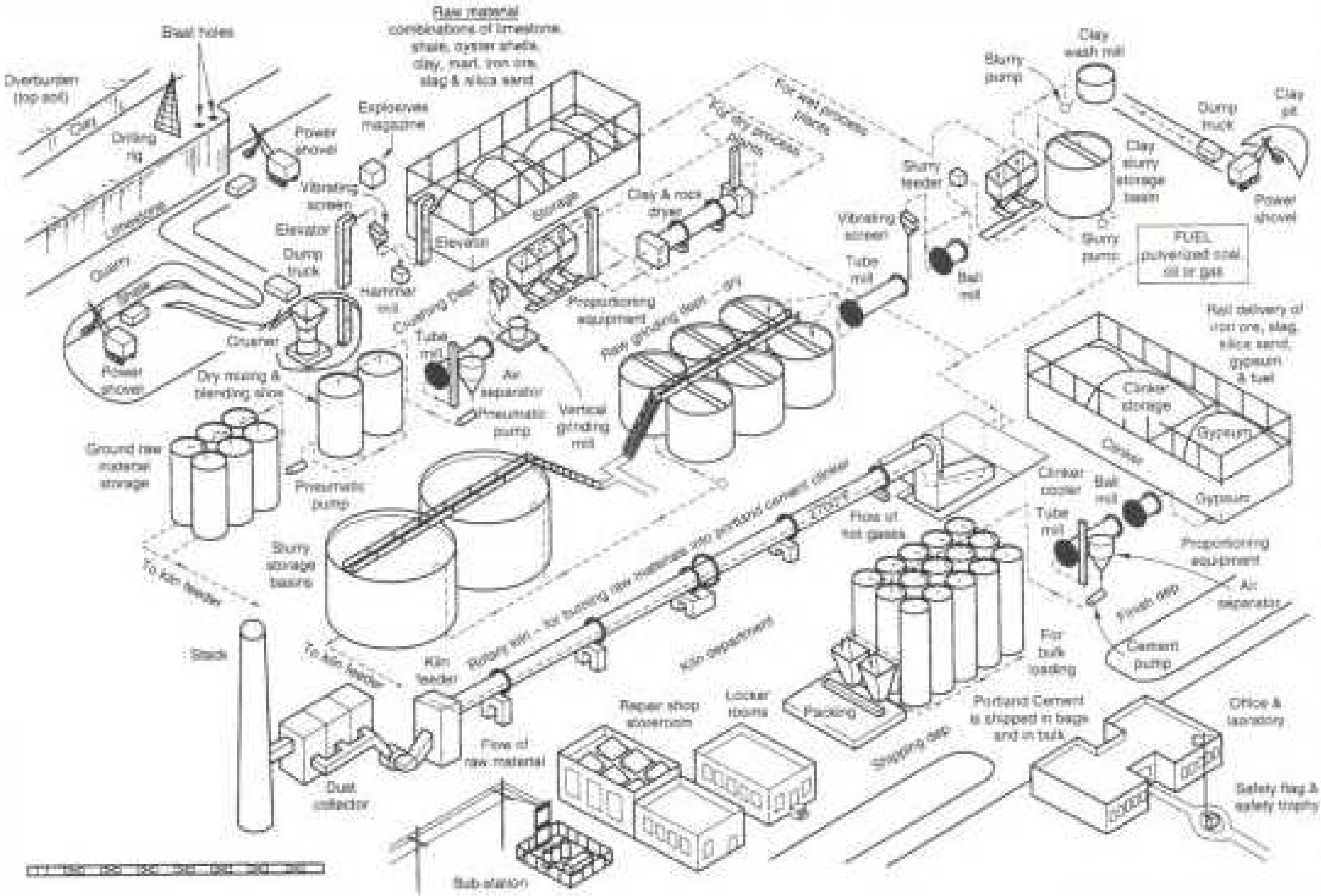
(4) Air

(5) Admixtures

(1) Portland Cement

- Patented by Joseph Aspdin in 1824
- The name is the result of its similarity to limestone quarried in Portland, England.
- Prime ingredients are limestone and clay.
- Ingredients are crushed, ground, blended and burned.

Manufacturing Process of Portland Cement



Typical Chemical Makeup - four main compounds

1. ~50% **Tricalcium Silicate** ($3Ca0\text{-}Si0_2$ or C_3S). Fast reaction with water. Provides most of the early strength (first 3-4 weeks).
2. ~25% **Dicalcium Silicate** ($2CaO\text{-}SiO_2$ or C_2S).
3. ~12% **Tricalcium Aluminate**($3CaO\text{-}Al_2O_3$ or C_3A). Fast reaction with water.
4. ~8% **Tetracalcium aluminoferrite** ($4CaO\text{-}Al_2Fe_2O_3$ or C_4AF).
5. ~3.5% Calcium sulfate dihydrate (gypsum) ($CaSO_4\text{-}H_20$ or CSH_2). Slows the reaction of C_4AF.

Hydration Reaction of Cement

- Cement **hardens** as the result of a chemical surface reaction (hydration) with water.
- Tricalcium silicate hydration reaction:

$3CaO.SiO_2 + H_2O = \mathbf{2CaO.SiO_2.x\ H_2O} + Ca(OH)_2$

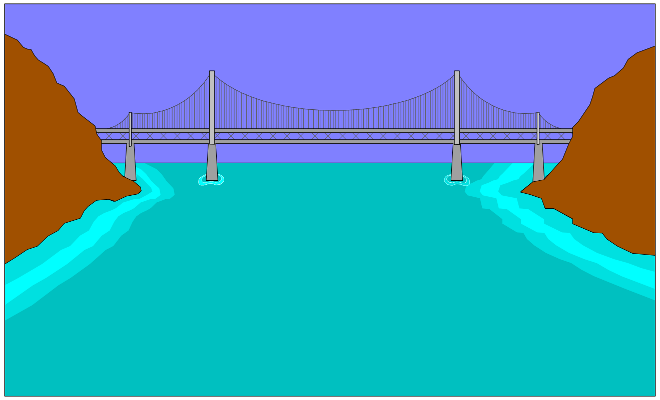
↑ hydrated calcium silicate

- Concrete does not "dry", it "sets".
- Hydration is an exothermic reaction.

Types of Portland Cement
as defined by ASTM C 150

- Type I - Normal
- Type II - Modified
- Type III - High Early Strength
- Type IV - Low Heat
- Type V - Sulfate Resistant
- Types with an "A" added to their number have an air entrainment additive included.

(2) Water



- Rule of Thumb:

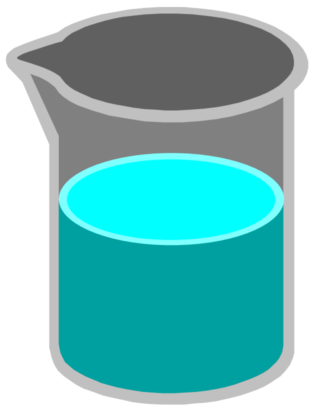
  "If you can drink it, you can make concrete with it."
- Some soluble inorganic salts may retard the setting and curing.
- Dissolved organic material may retard hydration and entrain excessive amounts of air.

Quality of Water

- Suspended solids of clay or silt up to 2000 ppm.
- Acidic waters can be used to a pH around 3.0.
- Sea water lowers strength 10-20%, corrodes reinforcing steel and causes problems with efflorescence.

Determine the Quantity of Water

- The **free** or **surface moisture of an aggregate** becomes a part of the mixing water, and must be taken into account in determining the quantity of water.

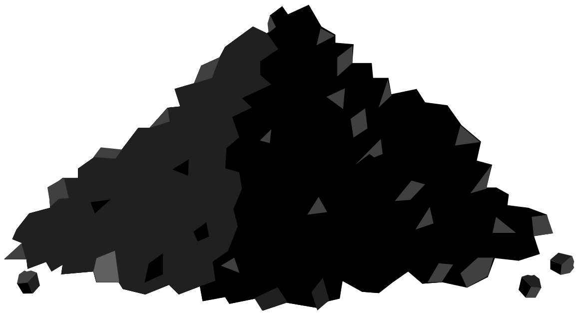


- A dry aggregate **absorbs** some of the mixing water.
- In the proportioning and batching of concrete mixes, all calculations are based on the **saturated surface-dry condition**.

Approximate Absorption Capacities of various Aggregates

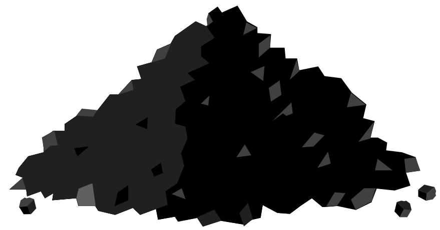
Aggregate	Absorption capacity (% by mass)
Average concrete sand	0 to 2
Granitic-type rocks	0 to 0.5
Average gravel & crushed limestone	0.5 to 1
Sandstone	2 to 7
Lightweight porous materials	Up to 25

(3) Aggregates



- Occupies 70-80% of the volume
- **Strength** of concrete is generally **independent** of aggregate strength.
- **Durability** may be affected by aggregate strength
- Should be free from impurities
- More angular aggregates require more cement paste than rounded aggregates.

More about Aggregates



- Generally two size categories:
  Fine and Coarse
- **Gradation** is important.
- Maximum size of aggregate is controlled by opening size between reinforcing bars and forms.
- The larger the aggregate size, the lower the volume of paste that is required.

(4) Air

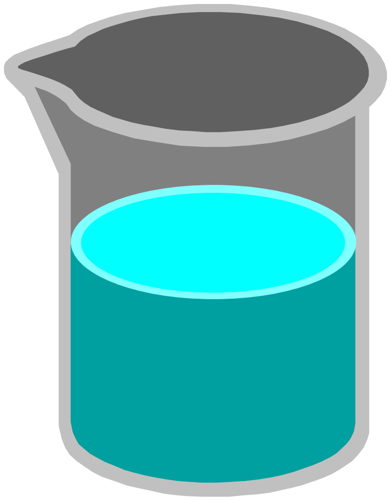
- Generally 1-2% with out using an air entraining admixture.
- For good freeze-thaw durability the concrete should have between 4-7% entrained air.
- Increasing the air content improves workability.

(5) Admixtures

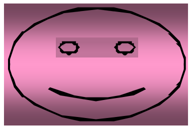
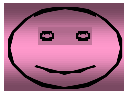
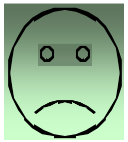
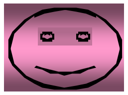
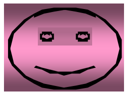
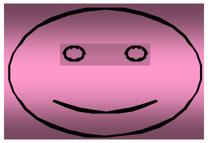
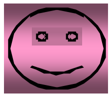
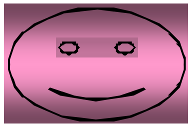
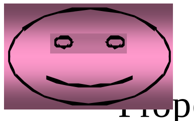
- Admixtures are used to enhance a particular property such as strength, workability, freeze-thaw durability, time to set, etc…
- Two important admixtures:

(a) Air Entrainment

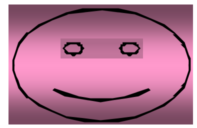
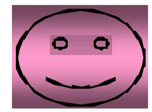
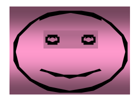
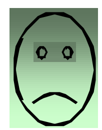
(b) Calcium Chloride ($CaCl_2$)



(a) Air Entrainment

- Increases workability 
- Decreases density 
- Decreases strength 
- Reduces bleeding 
- Reduces segregation 
- Increases durability (10 times or more) 
- Allows reduction in sand (fine aggregate) content 
- Allows reduction in water content. 
- Increases resistance to surface scaling resulting from salt. 

(b) Calcium Chloride

- Accelerates setting 
- Increases strength up to a year. 
- Reduces bleeding 
- Lowers resistance to sulfate attack 
- Increases dry shrinkage 
- Increases expansion under moist curing 
- Increases heat. Warning: Do not use as an antifreeze. It will not produce enough heat.  ? 
- Increases expansion of Alkali aggregates 
- Corrodes reinforcing