What is Concrete?

- Ingredients
- Portland Cement
- Water
- Aggregates
- Admixtures
- Mix Proportioning
- Curing
- Properties of Concrete
- Concrete Testing
- How does this apply to Concrete Canoe?

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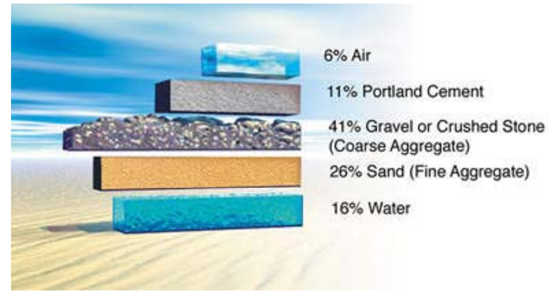
Ingredients of Concrete

- Portland cement, water, coarse aggregate, fine aggregate, and admixtures and air.



Courtesy of Portland Cement Association

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Portland Cement

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- Portland cement comes to life with water
  - Made from limestone and is essentially fine powder consisting of mainly calcium silicates and aluminum silicates.
  - Cement and water form paste that coats each particle of stone and sand.
  - Through chemical reaction called *hydration*, cement paste hardens and gains strength.
  - Character of concrete determined by quality of paste and strength of the paste depends on ratio of water to cement.
  - Water-cement ratio is weight of mixing water divided by weight of the cement.
  - High-quality concrete produced by lowering water-cement ratio as much as possible without sacrificing workability of fresh concrete. Generally, using less water produces a higher quality concrete provided the concrete is properly placed, consolidated, and cured.
  - Other than admixtures (used in very small quantitie), cement is most expensive ingredient in concrete.

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Water

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- Water required for hydration process.
  - Quality of hardened concrete greatly influenced by amt of water used relative to amt of cement. Higher water contents dilute cement paste (the glue of concrete).
  - Advantages of reducing water content:
    - Increased compressive and flexural strength
    - Lower permeability, thus increased watertightness and lower absorption
    - Increased resistance to weathering
    - Better bond between concrete and reinforcement
    - Less volume change from wetting and drying
    - Reduced shrinkage and cracking
    - Aggregates
  - Water-to-cement ratio (w/c) usually between 0.40 and 0.70 by weight.
    - For hydration process, a minimum w/c = 0.25 is required. Usually, w/c > 0.25 required to enhance mobility of water during hydration process and enhance workability of the concrete mix.

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Aggregates


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- Aggregates are classified by ASTM C 33 (AASHTO M 6/M 80) as fine or coarse.
  - Fine aggregate (sand): any material that passes through a No. 4 sieve (a sieve that has four openings per linear inch). Particles are typically smaller than 5mm or 0.2 in.
  - Coarse aggregate consists of either (or a combination of) gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed concrete, with particles generally larger than 5 mm (0.2 in.)
  - Depending on member dimensions and spacing of reinforcement bars in a concrete member, maximum size for coarse aggregate is usually 1-1/2 in.
  - Use of different aggregate sizes can lead to densely packed mix and thus reduce quantity of cement required. Aggregates usually constitute 60 to 70% of the total volume of a hardened concrete.

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Admixtures


Courtesy of Portland Cement Association

- Admixtures are ingredients in concrete other than portland cement, water, and aggregates that are added to mixture immediately before or during mixing to:
  - Reduce cost of concrete construction
  - Modify properties of hardened concrete;
  - Ensure quality of concrete during mixing, transporting, placing, and curing;
  - Overcome certain emergencies during concrete operations.

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Admixtures


Courtesy of Portland Cement Association

- Five Functions:
  - Air-entraining: to purposely place microscopic air bubbles into concrete
  - Water-reducing: reduce required water content by ~5-10% so concrete needs less water to reach required slump, and has lower w/c ratio. Can make higher strength concrete w/o increasing amt of cement (cheaper).
  - Retarding: keep concrete workable during placement and delay initial set of concrete. Most retarders also function as water reducers and may entrain some air in concrete. Good for hot weather.
  - Accelerating: increase rate of early strength development, reduce time required for proper curing and protection, and speed up start of finishing operations. Good for cold weather.
  - Plasticizers (superplasticizers): high-range water reducers (HRWR) reduce water content by 12 to 30% and can be added to concrete with low-to-normal slump and w/c ratio to make high-slump flowing concrete. Flowing concrete (highly fluid but workable concrete) can be placed with little or no vibration or compaction.
  - Other: for corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, workability enhancement, bonding, damp proofing, and coloring

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Admixtures

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Type of Admixture	Standard Specifications	Desired Effect
Air-entraining admixture	ASTM C 260 and C 233 (AASHTO M 154 and T 157).	To stabilize microscopic bubbles in concrete, which can provide freeze-thaw resistance and improve resistance to deicer salt scaling.
Water reducing admixture (WR)	ASTM C 494 (AASHTO M 194)	Reduce the water content by 5 to 10%, while maintaining slump characteristics.
Mid-range water reducer (MRWR)	ASTM C 494 (AASHTO M 194)	Reduce the water content by 6% to 12%, while maintaining slump and avoiding retardation.
High-range water reducer (HRWR) (also called superplasticizer)	ASTM C 494 (AASHTO M 194), ASTM C 1017	Reduce the water content by 12% to 30%, while maintaining slump.
Retarding admixture	ASTM C 494 (AASHTO M 194)	To decrease the rate of hydration of cement.
Accelerating admixture	ASTM C 494 (AASHTO M 194)	To increase the rate of hydration of cement.
Shrinkage-reducing admixtures		Reduce drying shrinkage (and related cracking) in concrete
ASR-inhibiting admixtures		Reduce or eliminate deleterious expansion due to alkali-silica reaction
Corrosion inhibitors	ASTM C 1582	Minimize steel reinforcement corrosion

Mix Proportions

- Key to achieving strong, durable concrete is in careful proportioning and mixing of ingredients.
  - Mixture with not enough paste to fill voids between aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete.
  - Mixture with excess cement paste will be easy to place and will produce a smooth surface; but the resulting concrete will likely shrink more and be uneconomical.
- Properly designed concrete mixture will possess desired workability for fresh concrete and required durability and strength for hardened concrete.
  - Typically, mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent.

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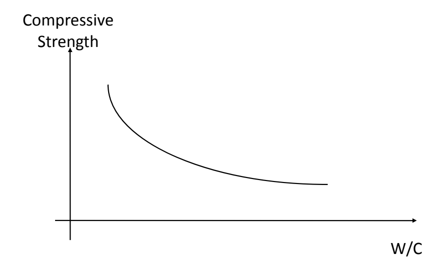
Mix Proportions

- The proportion of different ingredients in a mix is determined with the following considerations.
- ***Strength:*** The higher the w/c, the lower the strength will be of the concrete.



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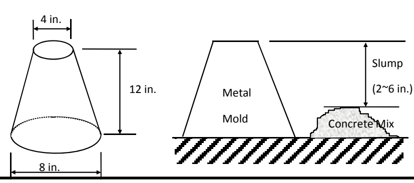
Mix Proportions

- ***Workability:*** The higher the w/c is, the higher the workability of the mix. Measured by slump tests.
  - Slump Tests: Conducted by means of cone-shaped metal mold. Top and bottom of mold are open. Metal mold is set on flat surface and filled with wet concrete mix. Removed by lifting, and concrete mix allowed to slump. Slump is measured with respect to top of mold and generally specified to be between 2 and 6 in.
  - Too much slump implies excessive water. Too low a slump means poor workability.. Slump tests should always be conducted prior to the casting of concrete members.



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Mix Proportions

Table 11.7 SUGGESTED TRIAL MIXES FOR CONCRETE OF MEDIUM CONSISTENCY (3 to 4 in. slump*)

					With Fine Sand Fineness Modulus = 2.50			With Coarse Sand Fineness Modulus = 2.90		
Water-to-Cement Ratio, lb per lb	Maximum Size of Aggregate, in.	Air Content, Percent	Water, lb per yd³ of Concrete	Cement, lb per yd³ of Concrete	Fine Aggregate, Percent of Total Aggregate	Fine Aggregate, lb per yd³ of Concrete	Coarse Aggregate, lb per yd³ of Concrete	Fine Aggregate, Percent of Total Aggregate	Fine Aggregate, lb per yd³ of Concrete	Coarse Aggregate, lb per yd³ of Concrete
Air-Entrained Concrete										
0.40	3/8	7.5	340	850	50	1250	1260	54	1360	1150
	1/2	7.5	325	815	41	1060	1520	46	1180	1400
	3/4	6	300	750	35	970	1800	39	1090	1680
	1	6	285	715	32	900	1940	36	1010	1830
	1½	5	265	665	29	870	2110	33	990	1990
0.50	3/8	7.5	340	680	53	1400	1260	57	1510	1150
	1/2	7.5	325	650	44	1200	1520	49	1320	1400
	3/4	6	300	600	38	1100	1800	42	1220	1680
	1	6	285	570	34	1020	1940	38	1130	1830
	1½	5	265	530	32	980	2110	36	1100	1990
0.60	3/8	7.5	340	565	54	1490	1260	58	1600	1150
	1/2	7.5	325	540	46	1290	1520	50	1410	1400
	3/4	6	300	500	40	1180	1800	44	1300	1680
	1	6	285	475	36	1100	1940	40	1210	1830
	1½	5	265	440	33	1060	2110	37	1180	1990
0.70	3/8	7.5	340	485	55	1560	1260	59	1670	1150
	1/2	7.5	325	465	47	1360	1520	51	1480	1400
	3/4	6	300	430	41	1240	1800	45	1360	1680
	1	6	285	405	37	1160	1940	41	1270	1830
	1½	5	265	380	34	1110	2110	38	1230	1990

*Increase or decrease water per cubic yard by 3% for each increase or decrease of 1 in. in slump, then calculate quantities by absolute volume method. For manufactured fine aggregate increase percentage of fine aggregate by 3 and water by 15 lb per cubic yard of concrete. For less workable concrete, as in pavements, decrease percentage of fine aggregate by 3 and water by 8 lb per cubic yard of concrete.

From *Design and Control of Concrete Mixtures*, 11th ed., Portland Cement Association, Skokie, IL.

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Curing

Courtesy of Portland Cement Association

- Strength increases with age of concrete.
  - Concrete usually reaches 70% of its mature strength by end of first week after start of hydration process.
  - Final strength of concrete depends on humidity and temperature conditions during this initial period.
  - Maintenance of proper conditions during this time is called curing.
  - Concrete should be protected from loss of moisture for at least 7 days after casting.
  - For quality control, compressive strength of concrete is usually measured at age of 28 days using concrete cylinders cured in temperature and humidity conditions specified in ASTM standards.
  - Strength increase after 28 days is normally small for ordinary concrete. However, concrete with large proportion of fly ash (20% by weight) can gain strength very slowly over a period much longer than 28 days.

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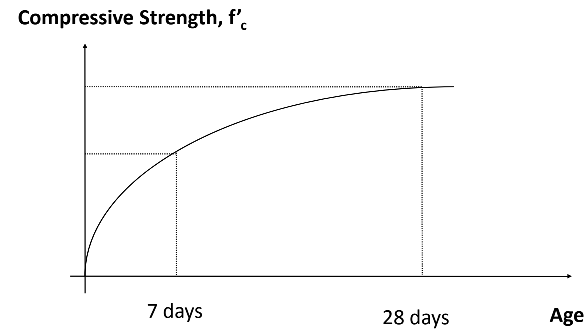
Curing

Courtesy of Portland Cement Association



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Reinforcement

- Concrete is strong in compression, as aggregate efficiently carries compression load. However, weak in tension as cement holding the aggregate in place can crack, allowing structure to fail.
- Reinforced concrete solves these problems by adding metal reinforcing bars, glass fiber, or plastic fiber to carry tensile loads.

http://en.wikipedia.org/wiki/Image:Trebar.jpg

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Properties of Concrete

- **Strength**
  - Concrete has relatively high compressive strength, but significantly lower tensile strength (about 10% of compressive strength).
  - Without compensating, concrete would almost always fail from tensile stresses even when loaded in compression.
  - Concrete elements subjected to tensile stresses must be reinforced with materials that are strong in tension
- Ultimate strength is influenced by the w/c ratio, design constituents, and mixing, placement and curing methods.
  - All things being equal, concrete with lower w/c ratio makes a stronger concrete than that with a higher ratio.
- The density varies, but is around 150 pounds per cubic foot (2400 kg/m^3)

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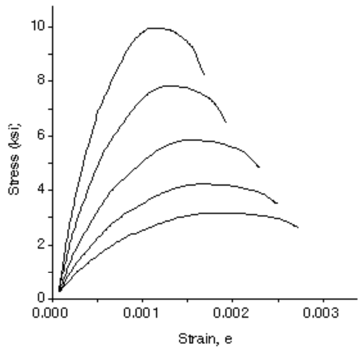
Properties of Concrete



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Properties of Concrete

- **Elasticity**
  - Modulus of elasticity of concrete is function of modulus of elasticity of aggregates and cement matrix and their relative proportions.
  - Relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops.
  - The elastic modulus of the hardened paste may be in the order of 10-30 GPa and aggregates about 45 to 85 GPa.
  - The concrete composite is then in the range of 30 to 50 GPa.

$$E = 57,000\sqrt{f_c'}$$

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Properties of Concrete

- **Expansion and shrinkage**
  - Concrete has a very low coefficient of thermal expansion. If no provision is made for expansion, very large forces can be created, causing cracks.
  - As concrete matures it continues to shrink, due to ongoing reaction (rate of shrinkage falls relatively quickly and keeps reducing over time (for all practical purposes concrete is usually considered to not shrink due to hydration any further after 30 years
  - Because concrete is continuously shrinking for years after it is initially placed, it is generally accepted that under thermal loading it will never expand to its originally placed volume.

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Properties of Concrete

- **Cracking**
  - All concrete structures will crack
  - Concrete cracks due to tensile stress induced by shrinkage or stresses occurring during setting or use.
  - To overcome this:
    - Fiber reinforced concrete: uses fine fibers distributed throughout the mix or larger metal/reinforcement elements to limit the size and extent of cracks.
    - In many large structures joints or concealed saw-cuts are placed in the concrete as it sets to make the inevitable cracks occur where they can be managed and out of sight.
    - Water tanks and highways are examples of structures requiring crack control.
    - AND CONCRETE CANOE'S!!!

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Properties of Concrete

- **Creep**
  - Permanent movement or deformation of a material in order to relieve stresses within the material.
  - Concrete which is subjected to long-duration forces is prone to creep
  - Short-duration forces (such as wind or earthquakes) do not cause creep.
  - Creep can sometimes reduce the amount of cracking that occurs in a concrete structure or element, but it also must be controlled.
  - The amount of primary and secondary reinforcing in concrete structures contributes to a reduction in the amount of shrinkage, creep and cracking.

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Concrete Testing

- Engineers usually specify the required compressive strength of concrete, which is normally given as the 28-day compressive strength in MPa or psi.
- 3-day and 7-day strengths can be useful to predict the ultimate 28-day compressive strength of the concrete.
  - A 25% strength gain between 7 and 28 days is often observed with ordinary Portland cement mixtures

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Concrete Canoe

- **Ingredients we use:**
  - ***Cementious Materials***
    - Portland Cement
    - Metakaolin
    - Silica Fume
    - Fly Ash
  - ***Aggregates***
    - Poraver (0.1 mm - 0.3 mm)
    - Poraver (0.25 mm - 0.5 mm)
    - Poraver (0.5 mm - 1 mm)
    - Poraver (1 mm - 2 mm)
    - K1 Glass Bubbles, B-Lites
  - ***Water***
  - ***Admixtures***
    - Plasticizer
    - Latex

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Concrete Canoe

- **Key rules for Mix Design:**
  - Cementious materials - maximum of 50% by mass of hydraulic cement in any concrete mix
  - Cementious materials - no more that 400 lb/yd^3 total (hydraulic cement)
  - Aggregates - minimum of 15% of the total weight of any concrete mixture.
  - Aggregates - no more than 5% by weight may pass No. 100 sieve (0.15 mm)
  - Aggregates - recycled material content of at least 25%
  - Water - Maximum allowable water to cement ratio for any concrete mixture is 0.40.
  - Air - minimum required air content for any concrete mixture is 6.0%

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Questions?

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