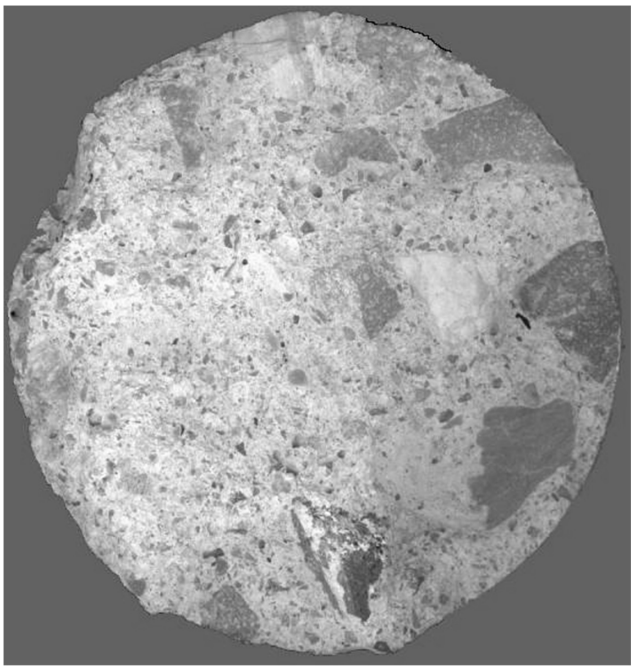
Reinforced Concrete



- Material Properties
  - Aggregate
  - Cement
  - Water
  - Reinforcement
- Strength
  - Compression, f'c
  - Tension, f't
- PCA – Concrete Fundamentals

Constituents of Concrete

- **Aggregate**
- Cement
- Water

Fine aggregate
(Sand)
≤ 1/4"

coarse aggregate
~ 3/8" (small)

coarse aggregate
~ 1/2" to 1" (medium)

coarse aggregate
~ 1.5" (large)

Photos by E*madrazo*

Constituents of Concrete

- **Aggregate**
- Cement
- Water

Characteristics:

- Abrasion resistance
- Freezing resistance
- Sulfate resistance
- Alkali resistance
- Shape and texture
- Grading
- Void content
- Density
- Moisture absorption
- Flexural strength

crushed stone

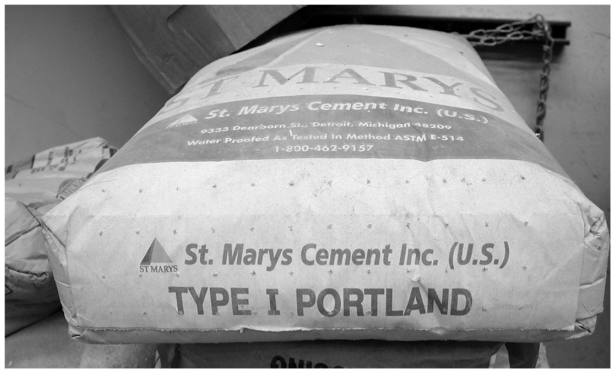
smooth “river rock”

Constituents of Concrete

- Aggregate
- **Cement**
- Water

Ingredients:

- Limestone
- Cement rock
- Clay
- Iron ore
- + (after firing and grinding)
- gypsum



Cement Types

- **Type 1**
  normal portland cement. Type 1 is a **general use** cement.
- **Type 2**
  is used for structures in water or soil containing **moderate amounts of sulfate**, or when heat build-up is a concern.
- **Type 3**
  high early strength. Used when high strength are desired at very early periods.
- **Type 4**
  low heat portland cement. Used where the amount and rate of heat generation must be kept to a minimum.
- **Type 5**
  Sulfate resistant portland cement. Used where water or soil is high in alkali.
- Types IA, IIA and IIIA are cements used to make **air-entrained** concrete.

Constituents of Concrete

- Aggregate
- Cement
- **Water**
  - “potable”
  - No sulfates or organic impurities

Add mixtures:
- Air-entraining
- Water-reducing
- Plasticizers
- Accelerating
- Retarding
- Hydration control
- Shrinkage reducer
- Alkali-silicate inhibitor
- Coloration
- Bonding
- Foaming
- And others…

Constituents of Concrete

batch guidelines

Common Concrete Mix Ratios:

1:2:3 (Cement:Sand:Gravel):

This is a widely used ratio for general construction, offering a good balance of strength and workability.

1:1.5:3 (Cement:Sand:Gravel):

Another popular option, especially for foundations and beams, offering a good balance of strength and durability.

1:4:8 (Cement:Sand:Gravel):

This ratio is preferred for foundations and mass concrete work.

1:1:2 (Cement:Sand:Gravel):

This ratio is used for construction work that requires high-strength concrete.

Constituents of Concrete

PCA batch tables

Table 9-16 (Inch-Pound). Proportions by Mass to Make One Cubic Foot of Concrete for Small Jobs

Nominal maximum size coarse aggregate, in.	Air-entrained concrete				Non-air-entrained concrete			
	Cement, lb	Wet fine aggregate, lb	Wet coarse aggregate, lb*	Water, lb	Cement, lb	Wet fine aggregate, lb	Wet coarse aggregate, lb	Water, lb
⅜	29	53	46	10	29	59	46	11
½	27	46	55	10	27	53	55	11
¾	25	42	65	10	25	47	65	10
1	24	39	70	9	24	45	70	10
1½	23	38	75	9	23	43	75	9

*If crushed stone is used, decrease coarse aggregate by 3 lb and increase fine aggregate by 3 lb.

Table 9-17. Proportions by Bulk Volume* of Concrete for Small Jobs

Nominal maximum size coarse aggregate, mm (in.)	Air-entrained concrete				Non-air-entrained concrete			
	Cement	Wet fine aggregate	Wet coarse aggregate	Water	Cement	Wet fine aggregate	Wet coarse aggregate	Water
9.5 (⅜)	1	2¼	1½	½	1	2½	1½	½
12.5 (½)	1	2¼	2	½	1	2½	2	½
19.0 (¾)	1	2¼	2½	½	1	2½	2½	½
25.0 (1)	1	2¼	2¾	½	1	2½	2¾	½
37.5 (1½)	1	2¼	3	½	1	2½	3	½

*The combined volume is approximately ⅔ of the sum of the original bulk volumes.

Constituents of Concrete

W/C ratios

Understanding the w/c Ratio:

- **Definition:** The w/c ratio is the ratio of the weight of water to the weight of cement used in a concrete mix.
- **Importance:** It's a critical factor in concrete mix design, influencing strength, durability, and workability.
- **How it affects strength:**
  - **Lower w/c ratio:** Leads to higher strength and durability, reduced shrinkage, and lower permeability.
  - **Higher w/c ratio:** Results in lower strength and increased permeability, potentially leading to cracking and reduced durability.
- **Typical Range:** The typical w/c ratio for different grades of concrete mix falls between 0.40 and 0.60.
- **Minimum w/c ratio:** The minimum w/c ratio is 0.30 - 0.35.
- **Workability:** A lower w/c ratio can make the concrete mix stiffer and more difficult to work with, requiring the use of plasticizers or superplasticizers to improve workability.

Constituents of Concrete

W/C ratios - Strength

Concrete Strength and w/c Ratio:

Water-Cement Ratio (w/c)	Approximate Compressive Strength (psi)	Notes
0.8	2000	Fairly weak concrete, more water
0.50	—	Maximum for normal strength concrete
0.45	—	Maximum for high strength concrete
0.30 - 0.35	—	Minimum w/c ratio
0.3	Too stiff to handle	Requires superplasticizers

Workability

Measured in inches of "slump" of a molded cone of fresh mix.

- range 1" to 4" with vibration
- 2" to 6" without vibration

Water/Cement Ratio

- range 0.4 to 0.7
- for strength: higher is weaker
- for workability: higher is more workable

Cement Content

- LBS per cubic yard
- range 400-800 lbs/yd^3
- dependent on aggregate
- increases cost

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Constituents of Concrete

Slump and Workability

Slump and Workability:

Slump Test:

The slump test measures the consistency of fresh concrete by observing how much it settles after being poured into a cone.

Slump Range:

- **0-1 inch (0-25 mm):** Very low workability, suitable for dry mixes like pavements.
- **1-2 inches (25-50 mm):** Low workability, suitable for foundations with light reinforcement.
- **2-4 inches (50-100 mm):** Medium workability, suitable for manually compacted flat slabs.
- **4-7 inches (100-175 mm):** High workability, suitable for sections with tight reinforcement or where concrete needs to flow a great distance.

Reinforcing

Grade = Yield strength

- gr. 40 is 40 ksi
- gr. 60 is 60 ksi
- gr. 75 is 75 ksi

Size in 1/8 inch increments

- #4 is ½ inch dia.
- #6 is ¾ inch dia.

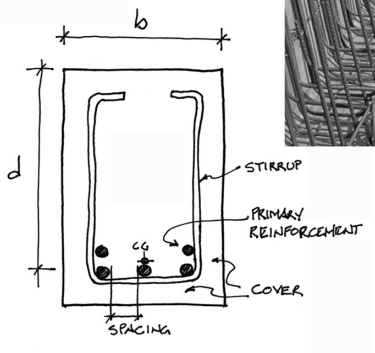
Deformation Patterns

- add to bond with concrete

Minimum Spacing

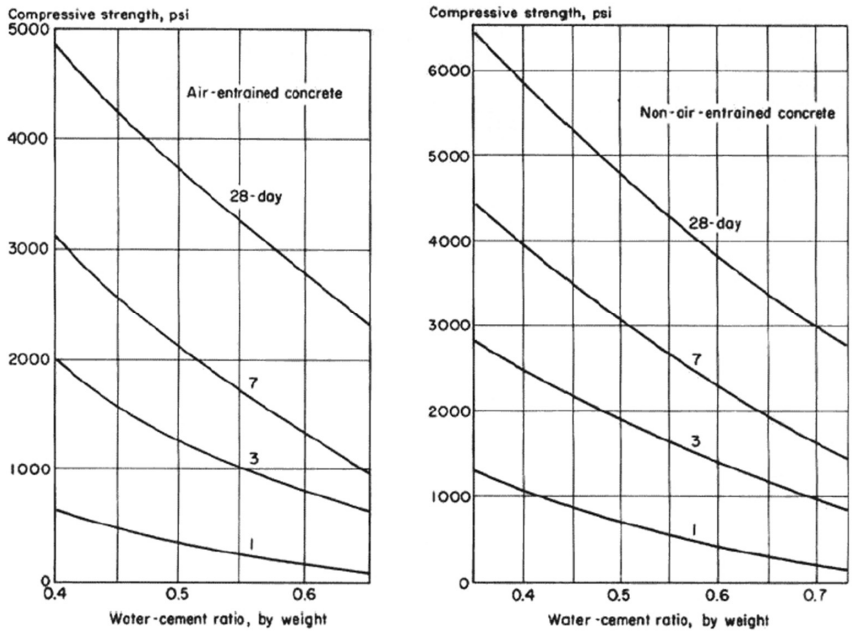
- between bars (horizontal)
  the greatest of the 3
  is the minimum
  - Bar diameter
  - 1”
  - 5/4 x max aggregate size
- between layers (vertical)
  1”
- cover
  - 3” against soil
  - 1.5”-2” exterior
  - 3/4” interior

Reinforcement of Weidatalbrücke photo by Störfix



Curing

Strength increases with age. The "design" strength is 28 days.



Portland Cement Association

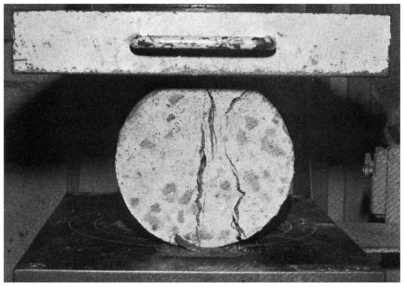
Strength Measurement

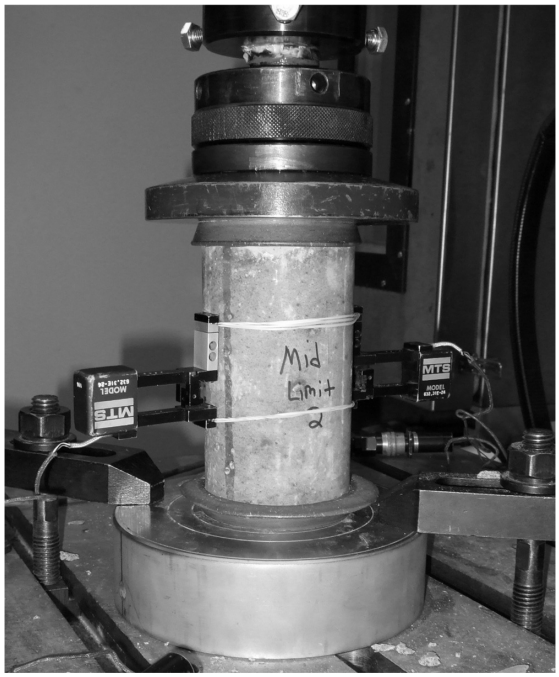
Compressive strength f_c'

- 12"x6" cylinder
- 28 day moist cure
- Ultimate (crushing) strength

Tensile strength f_t'

- 12"x6" cylinder
- 28 day moist cure
- Ultimate (failure) strength
- Split cylinder test
- ca. 10% of f'c





Young's Modulus

Depends on density and strength

$$E_c = w_c^{1.5} 33 \sqrt{f_c'}$$

w_c = concrete density

f'_c = concrete compressive strength

For normal weight concrete (144 PCF)

$$E_c = 57000 \sqrt{f_c'}$$

Examples:

f'_c	E_c
10000 psi	5,700,000 psi
8000 psi	5,098,000 psi
6000 psi	4,415,000 psi
4000 psi	3,605,000 psi
3000 psi	3,122,000 psi