Factor affecting Strength of Concrete

1. w/c ratio and Degree of Compaction
2. Cement/Aggregate ratio
3. Age of Concrete
4. Properties of Aggregate
5. Influence of Temperature

Factor affecting Strength of Concrete [1]

Water/cement ratio and degree of compaction

- **Strength of concrete primarily depends upon the strength of cement paste.**
- **The strength of cement paste depends upon the dilution of paste or in other words,** the strength of paste increases with cement content and decreases with air and water content.
- In 1918; Abrams' law states that **"assuming full compaction, and at a given age and normal temperature, strength of concrete can be taken to be inversely proportional to the water/cement ratio"**

Factor affecting Strength of Concrete [2]

Influence of Aggregate/Cement Ratio

- **The aggregate/cement ratio, is only a secondary factor in the strength of concrete but it has been found that**, for a constant water/cement ratio, a leaner mix leads to a higher strength.
- **Some water may be absorbed by the aggregate: a larger amount of aggregate absorbs a greater quantity of water,** the effective water/cement ratio being thus reduced.
- **A higher aggregate content would lead to lower shrinkage and lower bleeding, and therefore to less damage** to the bond between thee aggregate and the cement paste
- **As a result, in a leaner mix,** the voids form a smaller fraction off the total volume of concrete, and it is these voids that have an adverse effect on strength

Factor affecting Strength of Concrete [2]

G_{max}

Effect of Maximum size of Aggregate

- **The larger the aggregate the lower is the total surface area and, therefore**, the lower is the requirement of water for the given workability.
- **The use of larger size aggregate did not contribute to higher strength as expected from** the theoretical considerations due to the following reasons.
- **The larger maximum size aggregate gives lower surface area for developments** of gel bonds which is responsible for the lower strength of the concrete.
- **Secondly bigger aggregate size causes a more heterogeneity in the concrete** which will prevent the uniform distribution of load when stressed.

Factor affecting Strength of Concrete [3]

Age of Concrete

- **With an increase in age, the degree of hydration generally increases** the gel/space ratio so that strength increases
- **Increase in the strength of concrete** (at same w/c ratio) with increase in early age (from 1 to 28 days) of concrete.

Age of Concrete	7 days	14 days	28 days	3 months	6 months	1 year	2 year	5 year
Strength Ratio	0.67	0.86	1.00	1.17	1.23	1.27	1.31	1.35

Factor affecting Strength of Concrete [4]

Influence of Properties of Coarse Aggregate

- **The relation between the flexural and compressive strengths depends on the type of coarse aggregate because the properties of aggregate, especially** its shape and surface texture, affect the ultimate strength in compression very much less than the strength in tension or the cracking load in compression.
- **In experimental concrete, entirely smooth coarse aggregate led to a lower compressive strength**, typically by 10 per cent, than when roughened.
- **The influence of the type of coarse aggregate on the strength of concrete varies in magnitude** and depends on the water/cement ratio of the mix.

Factor affecting Strength of Concrete [4]

Influence of Properties of Coarse Aggregate

For water/cement ratios below 0.4, the use of crushed aggregate has resulted in strengths up to 38 per cent higher than when gravel is used.

With an increase in the water/cement ratio to 0.5, influence the **of aggregate falls off**, presumably because strength the of the hydrated cement paste itself becomes **paramount and, at a water/cement ratio of 0.65**, no difference in the strengths of concretes made with crushed rock and gravel has observed.

Factor affecting Strength of Concrete [5]

Influence of Temperature on Strength

- **The rise in the curing temperature speeds up the chemical reactions of hydration** and thus affects beneficially the early strength of concrete without any ill-effects on the later strength.
- **Rapid initial hydration appears to form products of a poorer physical structure,** probably more porous, so that a proportion of the pores will always remain unfilled.
- **The gel//space ratio rule that this will lead to a lower strength compared with a less porous,** though slowly hydrating, cement paste in which a high gel//space ratio will eventually be reached.

Curing of Concrete

The process of maintaining a satisfactory moisture content and favorable temperature in concrete during the period immediately following placement. It is necessary to achieve

- strength
- water tightness
- abrasion resistance
- freeze-thaw resistance
- volume stability

Delayed Curing

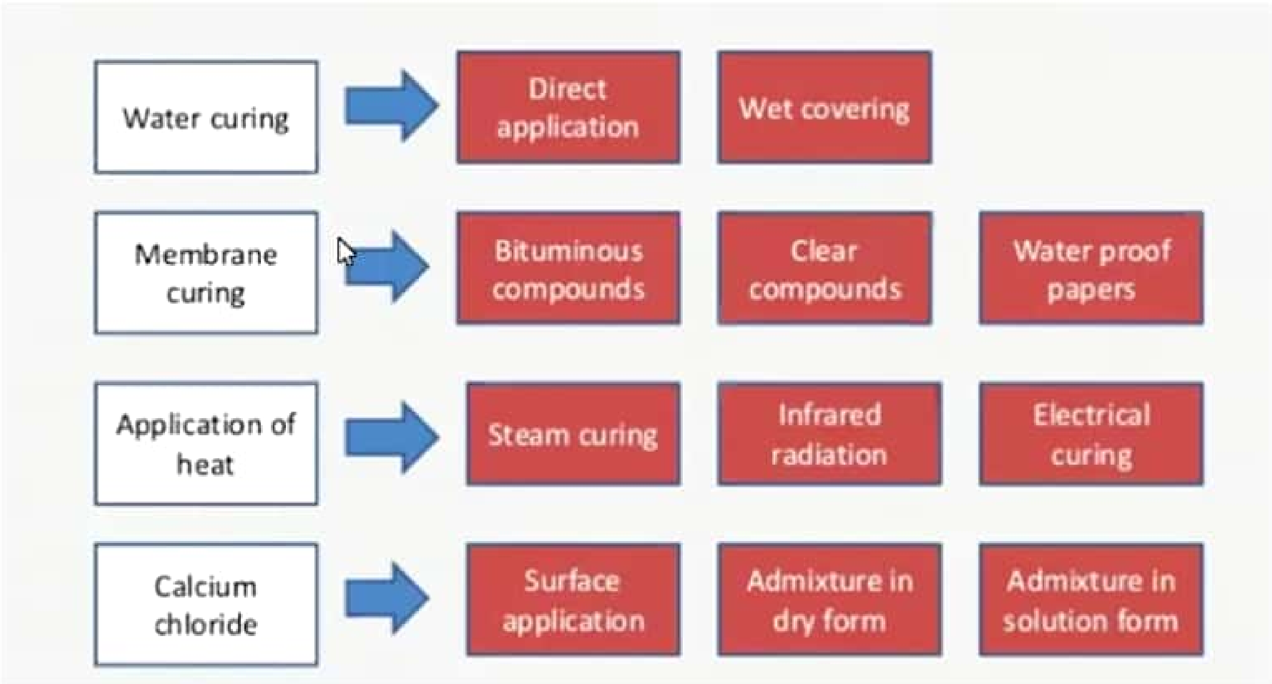
- Curing started after 3 days reduces,

  7 day strength by 12 %
  28 days strength by 10 %

- Air exposed concrete will reduce 50 % strength as compared to moist cured concrete.

ul ISLAM's screen

Methods of Curing



Methods of Curing

Methods of Curing

Steam Curing

Membrane Curing

Gel/Space Ratio

The strength can correctly be related to solid product of hydration to the space available for formation of the product

C = Cement weight in gm
W_0 = Water volome in ml

- Power's experiment showed that the strength of concrete bears a specific relationship with the gel/space ratio.
- He found the relationship to be 240 x^3, where x is the gel/space ratio and 240 represents the intrinsic strength of the gel in MPa for the type of cement and specimen used.
- Calculation of gel/space ratio for complete hydration

$$Gel/space\ ratio = \frac{volume\ of\ gel}{Space\ Available} = \frac{0.657C}{0.319C + W_o}$$

- Calculation of gel/space ratio for partial hydration

$$Gel/Space\ ratio = \frac{volume\ of\ gel}{Space\ Availabe} = \frac{0.657C\propto}{0.319C\propto + W_o}$$

Gel/Space Ratio

w/c ratio = 0.5

$\therefore$ Vol. of mixing water w_0 = 300 m.l.

$$\therefore \text{Gel/space ratio} = \frac{0.657\,C}{0.319\,C + w_0}$$

$$= \frac{0.657 \times 600}{0.319 \times 600 + 300}$$

$$= \frac{394.2}{191.4 + 300} = \frac{394.2}{491.4} = 0.8$$

$\therefore$ Theoretical strength of concrete = $240\,(0.8)^3$ = 123 MPa

Maturity of Concrete

One of the methods to determine the strength of concrete is to find maturity of concrete. Maturity of concrete is defined as Summation of product of age and temperature

Hydration can take place at minimum of -10° C, below this water crystals (ice) do not react with cement.

Maturity of Concrete

Concrete Maturity = ∑ (Time x Temperature)

$$\%\, Strength = A + B\, log_{10} \frac{Maturity}{1000}$$

Strength	A	B
<17.5 MPa	10	70
17.5-35 MPa	21	61
35-52.5 MPa	32	52
52.5-70 MPa	43	43

Maturity of Concrete

Strength of fully matured concrete is **40 Mpa**. Find strength of identical concrete at age of 7 days when cured at and average temperature during day at **20^0C**, night at **10^0C**

Maturity at 7 Days = 7 x 12 x [20 - (-10)] + 7 x 12 x [10 - (-10)]

= 4200 ^{0}Ch

A, B = 32, 52

$$\% \text{ Strength}_7 = 32 + 52\, log_{10} \frac{4200}{1000} = 64.41$$

$$\text{Strength}_7 = 40 \times \frac{64.41}{100} = \mathbf{25.76\ Mpa}$$