# CONCRETE PHYSICAL & MECHANICAL PROPERTIES

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## Introduction

- Composition
- Physical Properties
- Mechanical Properties
- Defects & Deterioration



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## COMPOSITION



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## Composition

- Portland Cement.
- Aggregate.
- Mixing Water.
- Entrapped Air.
- Admixtures.
- Supplementary Cementing Materials.



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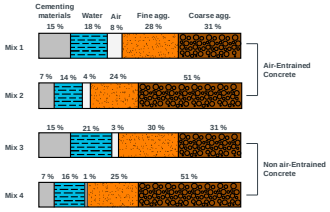
## Proportions of Materials in Concrete



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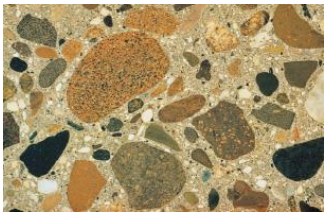
## Cross-section of Concrete





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## Portland Cement

- Invented in 18th century in England and was called Portland cement due to its similarity to Portland stone, a type of building stone commonly used.
- Chemical compound which reacts with water (hydration) to form a stone like mass.

$$C_3S + C_2S + H_2O \longrightarrow C_3S_2H_2 + CH$$



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## Portland Cement

- 73% Limestone
- 23% Clay
- 2% Iron
- 3% Sand




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## Cement Manufacture

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## Cement Manufacture

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## Types of Cement

- Type “GU” – General use.
- Type “GUL” – 1st test project in Alberta in 2022 – 15% limestone added
- Type “HE” – High early strength.
- Type “MS” – Moderate sulfate resistance.
- Type “HS” – High sulfate resistance.
- Type “MH” – Moderate heat of hydration.
- Type “LH” – Low heat of hydration.

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## Water

- Potable water
- Impurities cause
  - abnormal set
  - decreased strength
  - volume change
  - efflorescence
  - corrosion of reinforcement

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## Aggregate





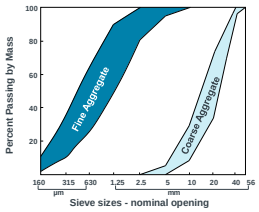
## Characteristics of Aggregate

- Clean & sound.
- Abrasion resistance
- Freeze & thaw resistance
- Wetting & drying properties
- Chemical stability
- Alkali aggregate reactivity
- Shape and surface texture
- Aggregate grading





## Grading Limits








## Fineness Modulus

| Sieve Size | Percentage Retained by Mass |
|---|---|
| 10 mm | 0 |
| 5 mm | 2 |
| 2.5 mm | 15 |
| 1.25 mm | 35 |
| 630 µm | 55 |
| 315 µm | 79 |
| 160 µm | 97 |
| Total | 283 |

**Fineness Modulus = 283/100 = 2.83**

## Air-Entrained Concrete

- Improves freeze-thaw resistance
- Improves workability
- Finishes sooner
- Reduces water
- Reduces segregation and bleeding
- Improves sulfate resistance
- Entrained air content from 5% to 8%

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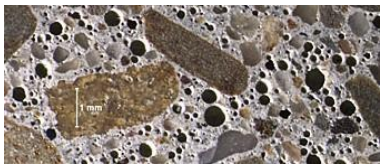
## Air-Entrained Concrete

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## PHYSICAL PROPERTIES

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## Physical Properties

- Thermal expansion:
  - Concrete 9.9 x $10^{-6}$/°C
  - Steel 12.0 x $10^{-6}$/°C
- Volume change due to moisture:
  - Swelling
  - Shrinkage

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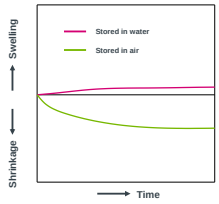
## Swelling/ Shrinkage



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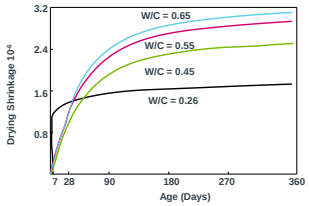
## Water/Cement Ratio & Shrinkage of Paste



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## MECHANICAL PROPERTIES



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## Mechanical Properties

- Strength
  - Compressive (28 day – f' c)
  - Tensile (10% of f' c)
  - Shear (12% to 13% of f' c)
  - Flexural (14% of f' c)
- Abrasion resistance
- Creep
- Fire resistance
- Durability
- Permeability



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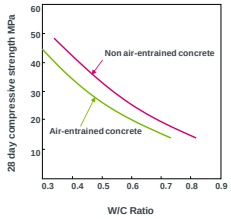
## Water/Cement Ratio vs. Strength



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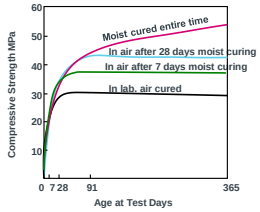
## Effect of Curing on Strength



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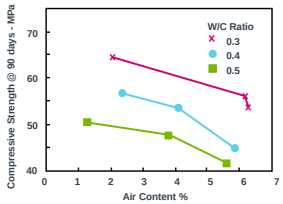
## Compressive Strength & Air Content



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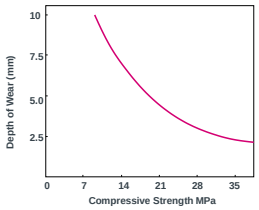
## Wear vs. Strength



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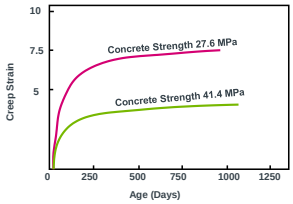
## Concrete Strength & Creep



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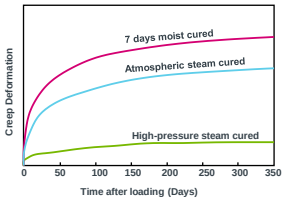
## Curing Method & Creep



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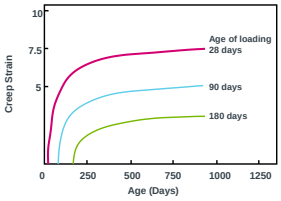
## Age of Loading & Creep



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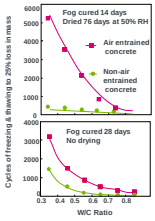
## Freeze/ Thaw Resistance, Air & W/C Ratio



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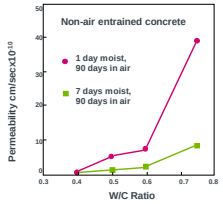
## Permeability, W/C Ratio & Curing

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## DEFECTS AND DETERIORATION

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## Deterioration Stains

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## Staining, Efflorescence & Corrosion

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## Deck Ponding

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## Freeze – Thaw Damage

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## Scaling Damage

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## Light Scaling

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## Medium Scaling



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## Heavy Scaling



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## Deteriorated Concrete Approach Slab



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## Surface Abrasion



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## Sound Concrete Deck



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## Sound Concrete Deck Underside



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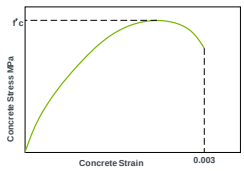
## Concrete Stress- Strain Relationship




Strain = Δ L/L
Δ L = 0.003x300 = 0.9 mm



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## High – Performance Concrete

- High strength.
- High modulus of elasticity.
- High abrasion resistance.
- Low permeability and diffusion.
- Resistance to chemical attack.
- High resistance to frost.
- Ease of placement



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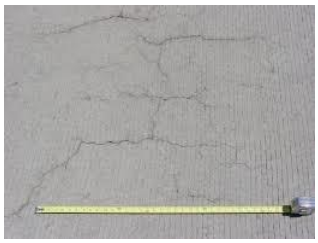
## Self – Compacting Concrete

- Able to flow and consolidate on its own.
- Must be cohesive to fill spaces without segregation.
- Useful wherever placing is difficult.
- SCC reduces the need for vibration.
- It is based on increasing the amount of fine material without changing the water content.





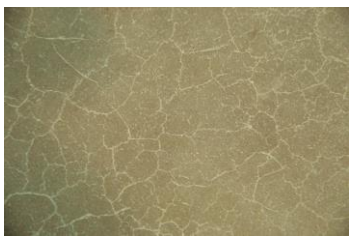
## Shrinkage Cracks







## Map Cracking







## Flexural Cracks

## Construction Joint

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## Corrosion Spalls & Pop – outs

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## Corrosion Spall

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## Corrosion Spall

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## Alkali Aggregate Reaction

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## High Load Impact

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## High Load Damage

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## Severe High Load Damage

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