BRIDGE MATERIALS

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CONCRETE

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What is Concrete?

- A mixture of various components which chemically react to form a strong construction material
- Unit Weight – normal 2400 kg/m^3 or semi 1900 kg/m^3
- Component Ratios:
  - Cement (10 to 15%)
  - Aggregate (75 to 80%)
  - Water and Air (remainder)
  - Admixtures

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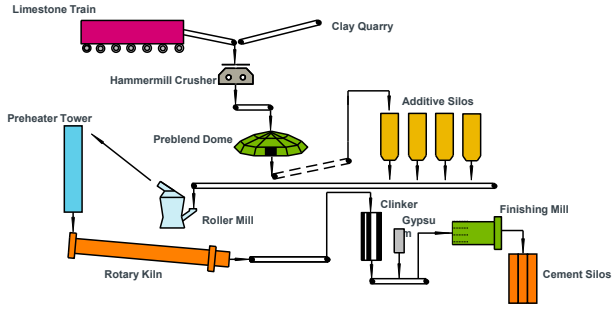
Cement Manufacturing



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Aggregate

Aggregate qualities for strong and durable concrete:

- Abrasion resistance
- Freeze/thaw resistance
- Chemical stability
- Cleanliness and even gradation

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Water

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Entrained Air

- Entrained air 5% to 8%
- Improves freeze thaw resistance
- Improves workability
- Reduces segregation and bleeding
- Improves sulfate resistance

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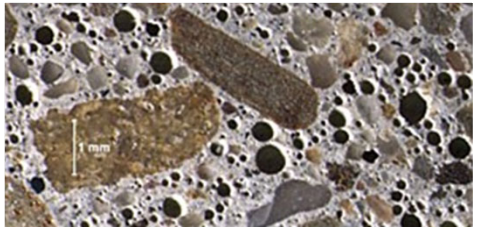
Air-Entrained Concrete



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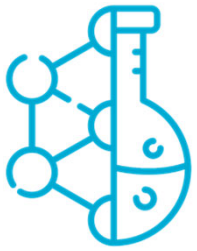

Admixtures

- Ingredients used to modify certain properties of concrete to have a desired function
- Two types of admixtures:
  - Mineral admixtures
  - Chemical admixtures

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Mineral Admixtures

Fly Ash

- Reduces heat of hydration & increases workability
- Increases set time & reduces strength

Silica Fume

- Increase strength & abrasion resistance
- Increases water demand
- Reduces **permeability** & workability

Limestone

- First used in trial project in 2022. GU replaced with GUL (up to 15%)
- Part of a “green initiative”, more environmentally friendly to produce.

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Chemical Admixtures

- Water Reducers – reduces water demand
- Super Plasticizers – increases slump, workability, strength
- Accelerators – decreases set time
- Retarders – increases set time

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Physical Properties

• Compressive strength (f'c)	(28 day) (e.g. HPC = 45 Mpa)
• Tensile strength	(6 to 7% f'c)
• Shear strength	(12-13% f'c)
• Flexural strength	(14% f'c)

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Physical Properties (Cont'd)

How to increase Compressive Strength

- Increased cement content
- Increased aggregate strength
- Decreased water/cement ratio
- Decreased entrapped air
- Increased curing time
- Use of admixtures

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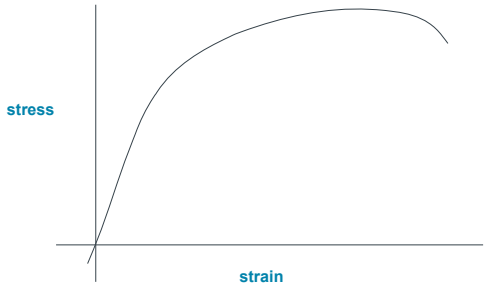
Concrete Stress-Strain Diagram



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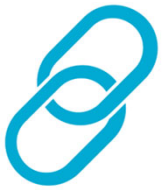
Physical Properties (Cont'd)

- Creep
- Fire resistance
- Durability
- Isotropy
- Permeability
  - Affected by
    - evaporation of bleed water
    - excess water
    - micro-cracking
    - porous aggregates
    - improper mixing, finishing



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Concrete Damage & Deterioration

1. CRACKS

A crack is a linear fracture in concrete

- Working Cracks
- Structural Cracks
  - Flexure cracks
  - Shear cracks

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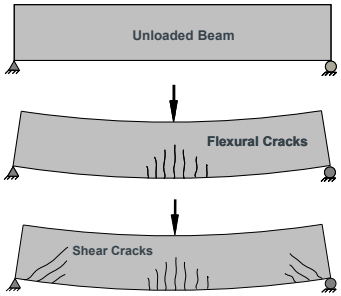
Structural Cracks



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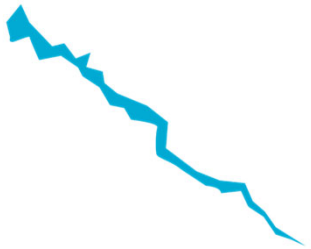
Concrete Damage & Deterioration

Non-Structural Cracks
- Crazing cracks
- Temperature cracks
- Shrinkage cracks

Crack Size
- Hairline — less than 0.1 mm
- Narrow — ≥ 0.1 mm < 0.3 mm
- Medium — ≥ 0.3 mm < 1.0 mm
- Wide — ≥ 1.0 mm



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Map Cracking in Concrete Deck

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Shrinkage Cracks in Concrete Curb

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Hairline Transverse Crack in Sidewalk

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Concrete Damage & Deterioration

2. SCALING

Scaling is a gradual loss of mortar and aggregate

Categories of Scaling

- Light scaling — loss of surface mortar 6 mm deep
- Medium Scaling — loss of surface mortar 6 to 13 mm deep
- Heavy scaling — coarse aggregate exposed
- Severe scaling — loss of coarse aggregate

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Light Scaling

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Medium Scaling

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Heavy Scaling

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Freeze/Thaw Deterioration of Deck

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Concrete Damage & Deterioration

3. POP-OUTS
Due to porous aggregate

4. ABRASION
Due to wheel wear

5. SPALLING
Expansion of corroding rebar and overstressing

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Expansive Aggregate Pop-out

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Abrasion Damaged Girders

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Concrete Damage & Deterioration

6. DELAMINATION

Delamination is the separation of the paste layer within concrete (i.e. an internal crack). Delamination leads to spalling. Typically caused by the volumetric expansion of corroding rebar.

7. STAINING

Includes rust, efflorescence, or water stains leaching through cracks

8. ALKALAI AGGREGATE REACTION

9. CARBONATION

10. EFFLORESCENCE

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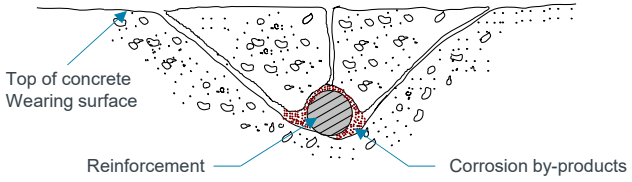
Delamination Mechanism



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Delamination & Corroded Rebar

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Longitudinal Cracks & Corroded Rebar

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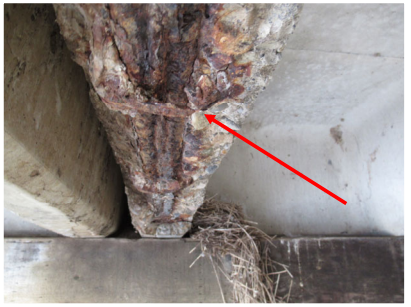
Spalled Concrete – Corroded Rebar and Broken Stirrup



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Calcium Carbonate Deposits

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Concrete - Steel Combination

Reinforced Concrete

- Concrete has high compressive strength and low tensile strength
- Typically cracks under tensile load
- Traditional reinforcing steel (rebar) carries tensile load

Prestressed Concrete

- Use of both rebar and high-strength steel strands
- Concrete is pre-compressed as a result of pre-tensioning the steel strands
- Carries load without cracking

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STEEL

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What is Steel?

Steel is an alloy of iron, carbon and other trace metals

Carbon and trace metal ratios:

- Carbon 0.15 to 0.3%
- Manganese 0.50 to 2.0%
- Phosphorus 0.02 to 0.2%
- Sulphur 0.02 to 0.06%
- Silicon 0.15 to 0.8%

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Iron

- Iron in the pure form is a soft, shiny metal like aluminum.
- However, it is never found in this state.
- Iron oxidizes extremely easily.
- In nature it is always found as an oxide.

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Steel Making Process

- Iron ore, coke and limestone are major raw materials.
- Raw material is charged into Blast furnace which has a temperature of 1600°C.
- Iron melts and settles at the bottom.
- Solidified iron is called “Pig Iron”
- Molten metal from blast furnace and silicon is taken into Basic Oxygen furnace
- Chemical analysis of the molten material is done
- Steel billets are heated to 1200°C for rolling and finished products.

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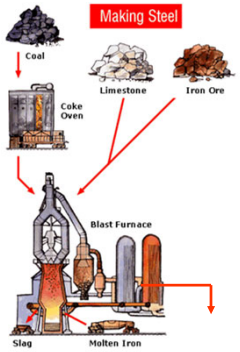
Bridge Materials



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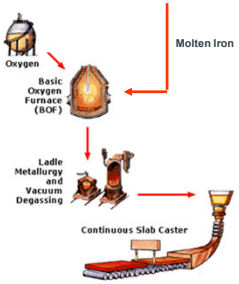
Bridge Materials



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Effects of Various Elements

Effects of Carbon in steel:

- Increases strength and hardnessand improves hardenability
- Reduces ductility (brittleness increases), toughness, machinability and weldability once heat treated

Effects of Phosphorus in steel:

- Increases strength and hardenability
- Reduces ductility and weldability

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Effects of Various Elements

Effects of Manganese in steel:

- Increases strength, hardenability and notch toughness
- Reduces weldability
- Reduces ill effects of sulfur

Effects of Sulfur in steel:

- May cause porosity and hot cracking in welding
- Can cause brittleness

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Effects of Various Elements

Silicon in steel:
- Increases strength, hardenability, and notch toughness
- Reduces weldability
- Deoxidizer in steel making
- Certain amounts of silicon can considerably affect hot-dip galvanizing

Copper, Chrome, Nickel:
- Weathering steel (Cor-ten)

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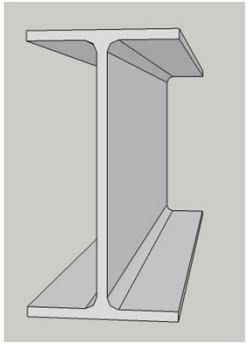
Common Steel Shapes

- Wires
- Cables
- Steel Plates
- Steel Bars
- Rolled Beams
- Built-up Shapes



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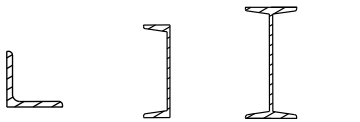
Rolled Sections



Angle Channel Rolled I Beam

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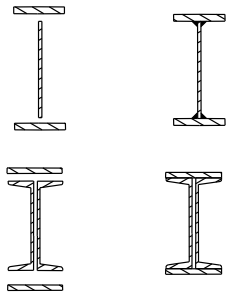
Built-up Sections



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Important Physical Properties

- Strength
  - Compression
  - Tension
  - Fatigue
- Ductility
- Notch toughness
- Weldability
- Fire Resistant
- Corrosion Resistant

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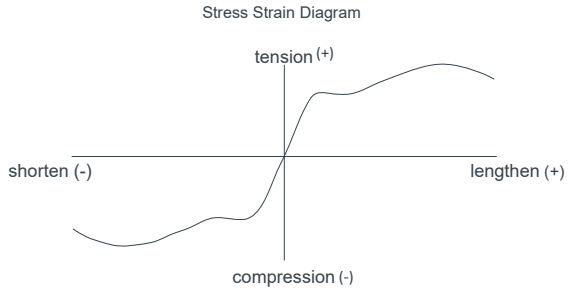
Tension & Compression



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Steel Damage and Deterioration

Corrosion

- Environmental corrosion
- Stray current corrosion
- Stress corrosion

Cracking

- Fatigue
- Impact
- Excessive loading
- Steel may also crack when flows are present, especially if near the surface.

Note: Any crack in a steel member is serious

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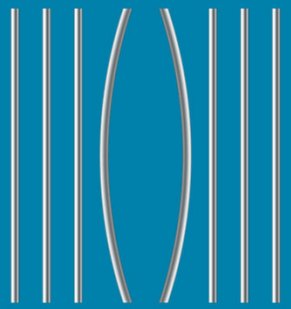
Steel Damage and Deterioration

- Deformation
- Excessive loading
- Heat damage
- Impact



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Corrosion Perforations in Tie Plate – BF 9315

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Alberta

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Soil Side Corrosion in Culvert Barrel

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Alberta

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Crack initiated by Bolt Hole

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Alberta

55

Crack in post base initiated by expanding frozen water

56

Alberta

56

Crack in post initiated by expanding frozen water

57

57

Collision damaged steel girder.

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58

Fire Damaged Truss

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59

Fire Damaged Truss.

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UNCONTROLLED
WELDING
IS NOT ALLOWED
ON BRIDGE
STRUCTURES

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TIMBER

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Wood

What is wood?

- A naturally occurring non- homogeneous material.

Composition of timber:

- Carbohydrate fibres
- Water

Classification of timber:

- Hardwood
- Softwood

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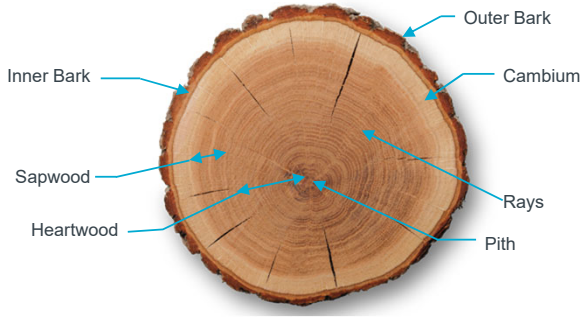
Cross Section of Tree



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Growth Features

Growth features

- Knots
- Splits, Checks

Moisture content

- Moisture affects dimensional stability
- 19% moisture content is considered seasoned wood

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Checks

- Occur naturally
- Not generally considered a defect in timber
- Can be differentiated from cracks by the presence of creosote or other preservatives visible on the inside surface of the check
- Cracks that have formed after application of the wood preservative will have not have preservative present at the inside surface.

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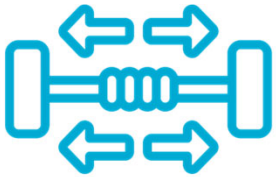
Physical Properties

- Compression
  - perpendicular to grain
  - parallel to grain
- Tension
- Bending
- Fatigue
- Shrinkage
  - 60% radially
  - 2% longitudinally



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Timber Damage & Deterioration

- Decay and fungal growth
- Abrasion
- Warping
- Splits
- Wide checks or checks within wet / dry zone of pile (> 25 mm)
- Cracking
  - Flexural
  - Horizontal Shear
- Fire Damage
- Collision Damage

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Timber Damage & Deterioration

- Decay is caused by fungi
  - Fungi need the following to grow:
    - Oxygen
    - Temperature
    - Food
    - Moisture
  - Fungal growth will not occur while wood remains submerged under water or buried deep in ground (oxygen depleted environments).
- Insects – Pine beetles can be a serious problem in Alberta

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Protective Systems

- Water repellents
- Preservatives
  - Creosote
  - Cromated Copper Arsenate (CCA) – green color
  - Alkaline Copper Quaternary (ACQ) – brown color
  - Ammoniacal Copper Zinc Arsenate (ACZA)
- Paint

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Warping due to Drying Shrinkage

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Horizontal Shear Crack.

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Fungal Growth and Beginning Rot

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Rot in Stringer End

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Fire Damaged Timber

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Questions?

Classification: Protected A

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