BRIDGE MATERIALS

CONCRETE

What is Concrete?

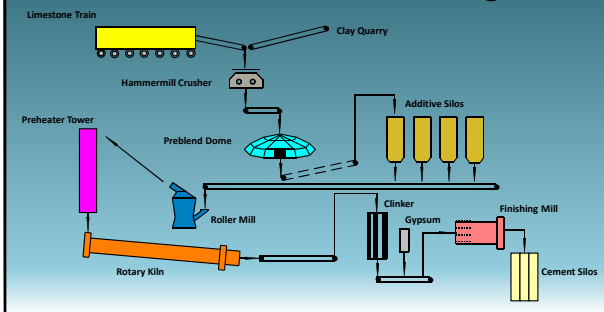
A mixture of various components which chemically react to form a strong construction material

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

Cement Manufacturing



Aggregate

Aggregate qualities for strong and durable concrete:

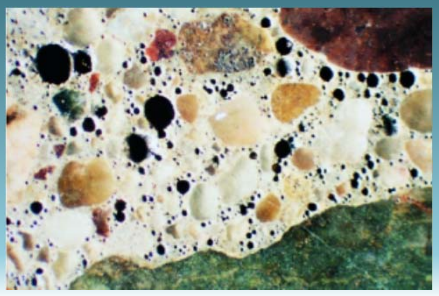
- Abrasion resistance
- Weather resistance
- Chemical stability
- Cleanliness and even gradation

Water

Entrained Air

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

Air-Entrained Concrete



Admixtures

Ingredients used to modify certain properties of concrete to have a desired function

Two types of admixtures:

- Mineral admixtures
- Chemical admixtures

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

Chemical Admixtures

Water Reducers – reduces water demand

Super Plasticisers – increases slump, workability, strength

Accelerators – decreases set time

Retarders – increases set time

Physical Properties

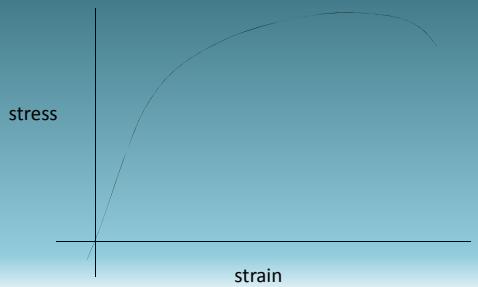
Compressive strength (f'c)	(28 day)
Tensile strength	(10% f'c)
Shear strength	(12-13% f'c)
Flexural strength	(14% f'c)

Physical Properties (Cont'd)

How to increase Compressive Strength

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

Concrete Stress-Strain Diagram



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

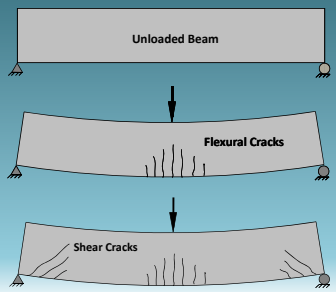
Concrete Damage & Deterioration

1. **CRACKS**

Crack is a linear fracture in concrete

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

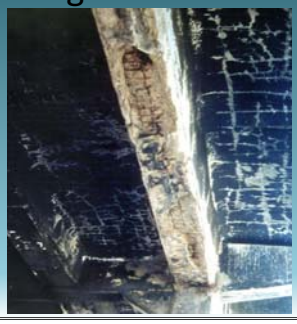
Structural Cracks



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

Shrinkage Cracks on Deck



Concrete Damage & Deterioration

2. SCALING

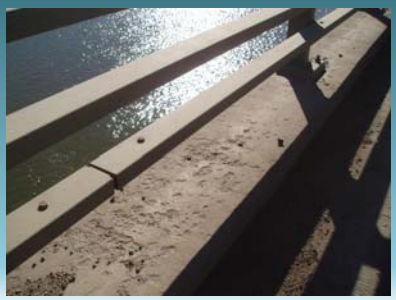
- Scaling is a gradual loss of mortar and aggregate
- Categories of Scaling
  - Light scaling — loss of surface mortar 6 mm deep
  - Medium Scaling — loss of surface mortar 6 to 13 mm deep
  - Heavy scaling — coarse aggregate exposed
  - Severe scaling — loss of coarse aggregate

Bridge Materials

Light Scaling

Bridge Materials

Medium Scaling



Bridge Materials

Heavy Scaling

Bridge Materials

Freeze/Thaw Deterioration of Deck

Concrete Damage & Deterioration

3. POP-OUTS

- Due to porous aggregate

4. ABRASION

- Due to wheel wear

5. SPALLING

- Expansion of corroding rebar and overstressing

Expansive Aggregate Pop-out

Abrasion Damaged Girders

Concrete Damage & Deterioration

6. DELAMINATION

- Bond failure between old and new concrete and expansion of corroding rebar

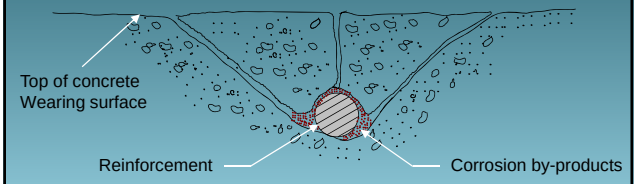
7. STAINING

- Rust stains leaching through cracks

8. ALKALAI AGGREGATE REACTION

9. CARBONATION (EFFLORESCENCE)

Delamination Mechanism



Delamination & Corroded Rebar

Longitudinal Crack & Corroding Rebar

Corrosion Spall

350

Calcium Carbonate Deposits

Concrete - Steel Combination

Reinforced Concrete
- Concrete has high compressive strength and low tensile strength
- Always cracks under tensile load
- Mild steel carries tensile load

Prestressed Concrete
- High strength steel strands
- Concrete is pre-compressed
- Carries load without cracking

STEEL

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%

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.

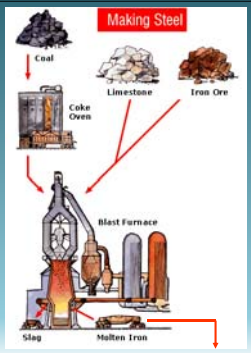
Steel Making Process

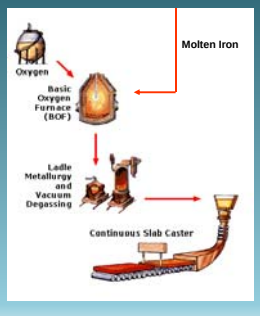
- Iron ore, coke and limestone are major raw materials.
- Raw material is charged into Blast furnace which has a temperature of 1600°C.
- Iron melts and settles at the bottom.
- Solidified iron is called “Pig Iron”

Steel Making Process

- 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.

Bridge Materials





Effects of Various Elements

Effects of Carbon in steel:
- Increases strength and hardness
- Reduces ductility, weldability, machinability and toughness

Effects of Phosphorus in steel:
- Increases strength and hardenability
- Reduces ductility and weldability

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

Effects of Various Elements

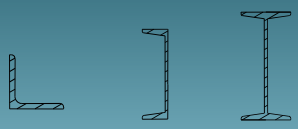
Silicon in steel:
- Increases strength, hardenability and notch toughness
- Reduces weldability
- Deoxidizer in steel making

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

Common Steel Shapes

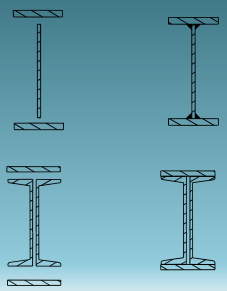
- Wires
- Cables
- Steel Plates
- Steel Bars
- Rolled Beams
- Built-up Shapes

Rolled Sections



Angle Channel Rolled I Beam

Built-up Sections

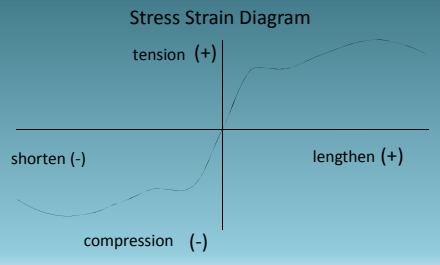


Bridge Materials

Important Physical Properties

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

Tension & Compression



Steel Damage and Deterioration

Corrosion
- Environmental corrosion
- Stray current corrosion
- Stress corrosion

Cracking
- Fatigue
- Impact
- Excessive loading

Note: Any crack in a steel member is serious

Steel Damage and Deterioration

Deformation
- Excessive loading
- Heat damage
- Impact

Corrosion Holes in Girder Web

Stains from Soil Side Corrosion

Crack initiated by Bolt Hole

Collision damaged steel girder.

Fire Damaged Truss.

Fire Damaged Truss.

UNCONTROLLED WELDING IS NOT ALLOWED ON BRIDGE STRUCTURES.

TIMBER

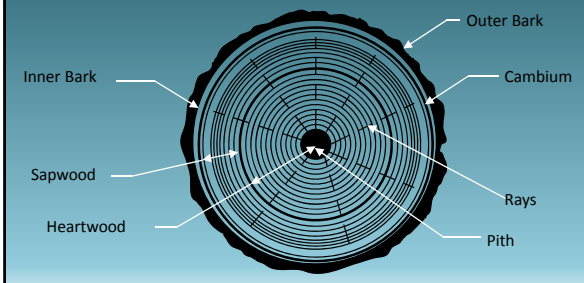
Wood

What is wood?
- A naturally occurring non- homogeneous material.

Composition of timber:
- Carbohydrate fibres
- Water

Classification of timber:
- Hardwood
- Softwood

Cross Section of Tree

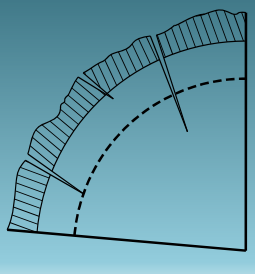


Growth Features

Growth features
- Knots
- Splits, Checks

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

Checks



Physical Properties

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

Timber Damage & Deterioration

- Abrasion
- Warping
- Checks & Splits
- Cracking
  - Flexural
  - Horizontal Shear
- Fire Damage
- Collision Damage
- Decay

Timber Damage & Deterioration

- Decay is caused by fungi
- To grow fungi need:
  - Oxygen
  - Temperature
  - Food
  - Moisture
- Insects or borers are not a problem in Alberta

Protective Systems

- Water repellents
- Preservatives
  - Creosote
  - Cromated Copper Arsenate (CCA)
  - Ammoniacal Copper Zinc Arsenate (ACZA)
- Paint

Warping due to Drying Shrinkage

Bridge Materials

Horizontal Shear Crack.

Bridge Materials

Checking & Start of Rot

Bridge Materials

Serious Rot in Stringer

Bridge Materials

Fire Damaged Timber

Questions??