

Lecture 1: Introduction

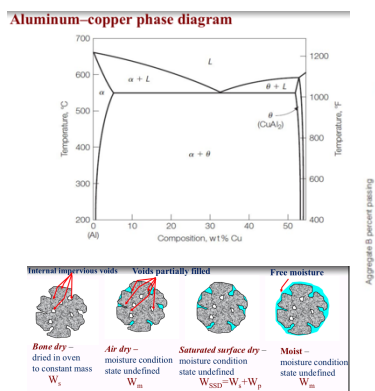
- Static (Dead) Loads: long term, due to gravity, members weight
- Dynamic (Live) Loads: short term, periodic, transient, random (earthquakes)
- The transition point is elastic limit
- Brittle Material: has little plastic deformation before failure (glass)
- Ductile Material: has lots of plastic deformation before failure (rubber, steel)
- Creep: long term deformation under constant load
- High Temp = ductile Low Temp= brittle
- Modulus of Resilience: energy required to reach yield point
- Toughness: energy required to fracture
- All materials expand and contract with temperature
- LEED Areas: water efficiency, materials, innovate design, sustainable site
- Procedural / Machine / Human Error

Lecture 2: Nature of Materials

- Atoms are the basic building blocks of all materials
- Proton (+) and Neutron (n) are at the centre, Electron (-) travels around nucleus in shells
- To be balanced and stable the number of electrons needs to be the same as protons
- Atomic number is number of protons in atom
- Mass Number is number of protons + neutrons
- Isotopes are atoms that have same # of protons and electrons but different # neutrons
- Crystal flaws have a major influence: impurities, voids
- Valence Electrons are in the outermost shell of an atom
- Primary Bonds: forms when atoms interchange electrons to fill outer shells
- Ionic Bond: transfer of electrons from one atom to another
- Covalent Bond: atoms share electrons with similar atoms to fill outer shells
- Metallic Bond: atoms share electrons with any surrounding atoms with valence
- Secondary Bond: forms when an imbalanced electric charge in atomic arrangements
- Alloys have one or more compounds dissolved in a metal
 - Rate of cooling of molten metal affects mechanical properties
 - Metals: metallic bonds between atoms with 1,2 or 3 valence electrons (steel, iron)
 - Inorganic Solids: covalent and ionic bonds between atoms with 5,6 or 7 valence electrons
 - Organic: long molecules of covalent H-C molecules with secondary bonds between chains

wrought Aluminum Alloys		Cast Aluminum Alloys	
Alloy Series	Description or Major Alloying Elements	Alloy Series	Description or Major Alloying Elements
1xxx	99.00% Minimum Aluminum	1xxx	99.00% Minimum Aluminum
2xxx	Copper	2xxx	Copper
3xxx	Manganese	3xxx	Silicon plus copper and/or magnesium
4xxx	Silicon	4xxx	Silicon
5xxx	Magnesium	5xxx	Magnesium
6xxx	Magnesium and silicon	6xxx	Unalloyed series
7xxx	Zinc	7xxx	Zinc
8xxx	Other element	8xxx	Tin
9xxx	Unalloyed series	9xxx	Other element

*worked by being forged or hammered
 †poured into a mold to give it its shape



Lecture 4: Portland Cement

- PC is named after the limestone & chalk cliffs on the side of Portland where it was first made in the early 1800's
- Cement Paste = cement + water || Mortar = cement paste + sand
- Production: crushing and grinding of raw materials, heat and mech in kiln at 1400°C which forms cement clinker, add gypsum to clinker
- Fineness controls the rate of hydration (heat & strength gain)
- Blaine Test: measures air permeability against known standard material
- Hydration: chemical reaction of cement with water
 - Voids in Hydrated Cement: interlayer hydrates squares, capillary voids (w/c ratio too high), trapped voids (large pockets and decrease strength), entrained air (increases durability)
 - Stiffening: change from plastic to solid (initial and final)
 - False Set: premature stiffening within a few minutes (due to humidity in cement during storage) (viral and filler-type tests)
 - W/C Ratio: the most important property of hydrating cement, extra water is needed for workability and drying
 - Sulphate Attack: ions penetrate concrete from surrounding and volume expansion takes place
 - Admixtures: air retainer; water reducer; retarder; hydration controller; accelerator; specialty admixtures
 - Air Retainers: produce tiny dispersed air bubbles into the concrete, recommended for all concrete exposed to freezing
 - Water Reducers: increases mobility of cement particles and workability
 - Retarders: delay initial set due to hot weather or long haul time
 - Hydration Controller: have the ability to stop and reactivate the hydration process of concrete (consists of stabilizer and activator)
 - Accelerator: speed up initial and final set (used for rate of strength gain)
 - Fly Ash: most common used pozzolan in CE structures | Silica Fume: by product of the production of silicon metal

Lecture 8: PC Concrete 2

- Slump Test: measures workability
- Air Content Test: measures total air content (capillary and entrained)
- Vibration of Concrete: can do it manually or mechanically
- Finishing: must be completed before final set
- Curing: to maintain moisture and temperature in the concrete to promote continued hydration and strength gain
- Early Volume Shrinkage: cracking or swelling can occur
- Creep: long term or gradual deformation under sustained load, transfers load from concrete to steel in beams
- Increasing W/C ratio decreases both strength and stiffness, stronger concrete is more brittle
- Usually use chisel models for Ec
- Non-Destructive Tests: rebound hammer, penetration resistance, ultrasonic pulse velocity, maturity test

Lecture 3: Steel

- Iron: the basic constituent of steel with carbon, found in the form of ores
- Wrought: <0.1% carbon, can be moulded easily, good corrosion resistance
- Steel: 0.1-0.2% carbon - Cast iron: 5% carbon, strong/hard/brittle
- Steel Production: reduction of iron ore to pig iron, refining pig iron to steel, forming steel into products
- 1: blast furnace with carbon and limestone to remove impurities
- 2: remove excess carbon/impurities by oxidation in furnace
- 3: cast into ingots and continuous shapes
- Higher Carbon: steel is harder and more brittle, E is the same
- Strengthening Mechanisms: alloying, strain hardening, heat treatments
- Slow cooling: coarse grained steel -> Rapid Cooling: fine grained steel
- Annealing: heating metal to austenite and slowly cooling to room temp, improves ductility and toughness, relieves internal stresses and strains
- Normalizing: difference in temp and rate of cooling, heat well above crit temp and then cool slowly in still air, removes coarse grain struc/ does fine grain
- Quenching (Hardening): slowly heating metal to form austenite, hardens steel
- Tempering: uniform heating below critical temp followed by air cooling, increases ductility/toughness but reduces strength/hardness
- Corrosion Control: protective coatings, galvanic(Zn) protection, cathodic(water) protection, corrosion-resistant steel (combining alloys)
- Struc Steel Products: flat rolled, sections, bolts, welding electrodes

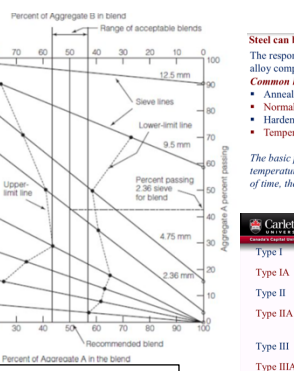
Lecture 4: Aluminum

- Primarily used for architectural/finishing elements like doors, not used for structure members because expense, strength/ductility and coefficient of thermal expans
- Advantages: most plentiful metal on earth, high strength-weight ratio, thermal conductivity, easy to recycle
- Aluminum Production: Bauxites are extracted from the ground, then processed into alumina/alum oxide (red muds are made), then pure aluminum is produced using electrolytic reduction in which aluminum oxide is broken into its components

Lecture 5: Aggregates

- Can be defined as a combination of distinct parts gathered into a mass or a whole and is one of the most essential materials for construction
- Sources: Natural Aggregates, Crushed Stone, Slags, Recycled concrete
- Aggregate Uses: Portland Cement Concrete (60-75% volume, 80-85% weight) Hot Mix Asphalt (90-90% volume 90-90% weight)
- Coarse Aggregate: material retained on a sieve with 4.75 mm opening | Fine Aggregate: material passing a sieve with 4.75 mm openings
- Maximum Aggregate Size: smallest sieve opening through which entire passes
- Nominal Maximum Size: smallest sieve opening through which most (90-95%) passes
- The maximum aggregate size should be less than the narrowest dimension between reinforcement bars
- High Friction (angular, rough) for strength and stability of asphalt | Low Friction (rounded, smooth) for workability of concrete
- Properties: moisture content, specific gravity, bulk unit weight, gradation
- Absorption: the moisture content when the aggregates are in the SSD condition | Free Moisture is the moisture content in excess of SSD
- You want continuous gradation because it minimizes volume of voids
- The max aggregate size should be less than the narrowest dimension between forms & reinforcement bars or depth of slab

Type	Description	230, 350, 400
Type G	General construction steel	230, 350, 400
Type W	Weldable steel	260, 300, 350, 380, 400, 480
Type WT	Weldable notch tough steel	260, 300, 350, 380, 400, 480
Type R	Atmospheric Corrosion-Resistant Steel	350
Type A	Atmospheric Corrosion-Resistant Weldable Steel	350, 400, 480
Type AT	Atmospheric corrosion-resistant weldable notch tough steel	350, 400, 480
Type Q	Quenched and tempered low alloy steel plate	700
Type QT	Quenched and tempered low alloy notch tough steel plate	700



Steel can be hardened or softened by using heat treatment

The response of steel to heat treatment depends upon its alloy composition

Common heat treatments

- Annealing
- Normalizing
- Hardening
- Tempering

The basic process is to heat the steel to a specific temperature, hold the temperature for a specified period of time, then cool the material at a specified rate.

Types of PC in US

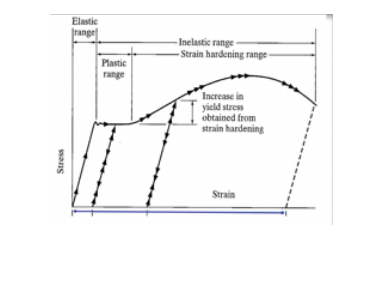
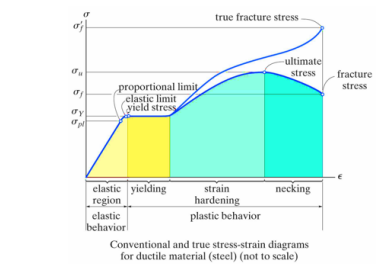
Type	Name	Formerly known as
Type I	Normal	
Type IA	Normal, air entraining	Type 10
Type II	Moderate sulphate resistant	Type 30
Type IIA	Moderate sulphate resistant, air entraining	Type 20
Type III	High early strength	Type 50
Type IIIA	High early strength, air entraining	
Type IV	Low heat of hydration	ASTM C150
Type V	High sulphate resistant	

Summary of Hydration of Cement Compounds

Compound	Reaction Rate	Strength	Setting	Heat Liberated
C ₃ S	Moderate	High	Low	High
C ₂ S	Slow	Low initially, high later	Low	Low
C ₄ A	Fast	Low	High	Very high
C ₃ A,F	Moderate	Low	Moderate	Moderate

Lecture 9: Wood

- Wood is the earliest construction material used by mankind because it is easy to use, durable, low cost, widely available
- Endogenous (intrinsic growth): very strong and lightweight, not generally used for engineering, eg. palm trees
- Exogenous (outward growth): fivers grow from the centre outward by adding concentric layers (rings), eg. most trees
- Deciduous: hardwood, expensive slow growing | Coniferous: softwood
- Tree Stem: From centre acts outward: Pith - center stem, Heartwood (darker) - provides structural support, Sapwood (lighter) - transports the sap, Cambium (very thin layer) - location of wood growth, Inner bark, Outer bark
- Wood is anisotropic: properties change with direction
- Moisture Content: shrinkage, strength, and weight depend on moisture content
- FSP: moisture content when cells are completely saturated with bound water but no free water inside cell services
- Shrinkage: largest shrinkage is in the tangential direction, smallest is in longitudinal direction
- Wood production: harvesting, sawing, seasoning, surfacing, grading, preservative treating



Material	Modulus (Gpa)	Poisson's Ratio
Aluminum	69-75	0.33
Brick	10-17	0.23-0.40
Concrete	14-40	0.11-0.21
Limestone	58	0.2-0.3
Steel	200	0.27
Wood	6-15	0.29-0.45

Alloy metals can be used to alter the characteristics of steel

The use and control of alloying agents is one of the most significant factors in the development of steels with better performance characteristics.

- 1. Low alloy**
- Low carbon
 - ✓ Plain
 - ✓ High strength-low alloy
 - Medium carbon
 - ✓ Plain
 - ✓ Heat treatable
 - High carbon
 - ✓ Plain
 - ✓ Tool
- 2. High Alloy**
- ✓ Tool
 - ✓ Stainless

Alloying Element	Typical Ranges in Alloy Steels (%)	Principal Effects
Aluminum	<2	Aids nitriding, Refines grain, Removes oxygen in steel melting
Sulfur	<0.05	Aids machinability, Reduces weldability and ductility
Chromium	0.3 to 4	Increases resistance to corrosion and oxidation, Increases hardenability, Increases high-temperature strength, Can combine with carbon to form hard, wear-resistant microconstituents
Nickel	0.3 to 5	Promotes an austenitic structure, Increases toughness
Copper	0.2 to 0.5	Promotes an austenitic structure, Increases corrosion resistance
Manganese	0.3 to 2	Increases hardenability, Improves toughness, Promotes an austenitic structure, Combines with sulfur to reduce its adverse effects
Silicon	0.2 to 2.5	Removes oxygen in steel making, Improves toughness, Increases hardenability
Molybdenum	0.1 to 0.5	Promotes grain refinement, Increases hardenability
Vanadium	0.1 to 0.3	Improves high-temperature strength, Promotes grain refinement, Increases hardenability, Will combine with carbon to form wear-resistant microconstituents

Types of Hydraulic Cement in Canada

Type	Name	Formerly known as
GU	General use	Type 10
HE	High-early strength	Type 30
MS	Moderate sulphate-resistant	Type 20
HS	High sulphate-resistant	Type 50
MH	Moderate heat of hydration	
LH	Low heat of hydration	Type 40

Grade refers to the strength of the steel

CSA G40.21-M

- chemical composition
- strength level
- methods of manufacture
- methods of identification

Each grade identified by a number and a letter

- Number -> yield point in MPa
- Letter -> characteristics of the 6 types of steel available

For example, 350W -> yield point of 350 MPa, weldable steel

Cement Composition

Chemical Name	Chemical Formula	Industry Notation	Weight %
Tricalcium silicate	3CaO·SiO ₂	C ₃ S	45-60
Dicalcium silicate	2CaO·SiO ₂	C ₂ S	15-30
Tricalcium aluminate	3CaO·Al ₂ O ₃	C ₃ A	6-12
Tetracalcium aluminoferrite	4CaO·Al ₂ O ₃ ·Fe ₂ O ₃	C ₄ AF	6-8
Calcium sulfate dihydrate (gypsum)	CaSO ₄ ·2H ₂ O	CSH ₂	2-5

A glulam beam with a depth of 18 in. at moisture content of 38%
 Compute the new depth if moisture content is decreased to 12%

Solution

Assume a 30% FSP
 Decreasing mc from 38% to 30% does not cause shrinkage. Decreasing mc from 30% to 12% causes shrinkage.
 Assume a 1% shrinkage (relative to the green dimensions) per 5% decrease in mc below FSP.
 Assume $X_{g,0}$ = green dimension, and $X_{g,12}$ = dimension at 12% below the FSP
 $X_{g,12} = X_{g,0}(1 - 0.01(30 - 12))$
 New depth = $X_{g,12} = 17.35$ in