TOPIC 2

Metals as construction materials

Steel

Background

- The use of iron dates back to about 1500 B.C
- Ferrous metals were produced on a relatively small scale until the blast furnace was developed in the 18th century
- Steel production started in mid-1800s, when the Bessemer converter was invented
- More recently, computer-controlled manufacturing has increased the efficiency and reduced the cost of steel production.
- Steel and steel alloys are used widely in civil engineering applications.
- Wrought iron is used on a smaller scale for pipes, as well as for general blacksmith work.
- Cast iron is used for pipes, hardware, and machine parts not subjected to tensile or dynamic loading.

Steel

- Steel is an alloy of iron and carbon, and sometimes other elements
- Because of its high tensile strength and low cost, it is a major component used in various construction projects
- Steel products used in construction can be classified as follows:

1. **Structural steel** - produced by continuous casting and hot rolling (at high temperatures) for large structural shapes, plates, and sheet steel
2. **Cold-formed steel** - produced by cold-forming of sheet steel into desired shapes
3. **Fastening products** - used for structural connections, including bolts, nuts and washers
4. **Reinforcing steel (rebars)**- used in concrete reinforcement

Steel

- Material engineers rarely have the opportunity to formulate steel with specific properties
- They usually select existing products from suppliers
- Therefore, majority of civil engineering projects, with the exception of bridges, are designed using standard steel types and structural shapes
- Bridges are a special case. Majority of bridge structures are fabricated from plate steel rather than hot-rolled sections or hollow structural sections
- Even though civil and construction engineers are not responsible for formulating steel products, it is beneficial to understand how steel is manufactured and treated and how it responds to loads and environmental conditions.

Steel

Production of Steel

❖ This process of steel production consists of the following three phases:

1. **reducing iron ore to pig iron** - accomplished in a blast furnace
2. **refining pig iron** (and scrap steel from recycling) to steel – uses either basic oxygen furnace or electric arc furnace
   - Amount of carbon dioxide removed from the iron determines the quality or grade of steel produced
3. **forming the steel into products**

❖ Molten steel, with the desired chemical composition, is either cast into ingots (large blocks of steel) or cast continuously into a desired shape

Steel

Production of Steel

- Continuous casting with hot rolling is becoming the standard production method, since it is more energy efficient (It is also easier to shape and form the steel at high temperature)
- Ingots are less energy efficient because they must be reheated prior to shaping the steel into the final product.
- Cold-formed steel is produced from sheets or coils of hot rolled steel which is formed into shape either through press-braking blanks sheared from sheets or coils, or more commonly, by roll-forming the steel through a series of dies

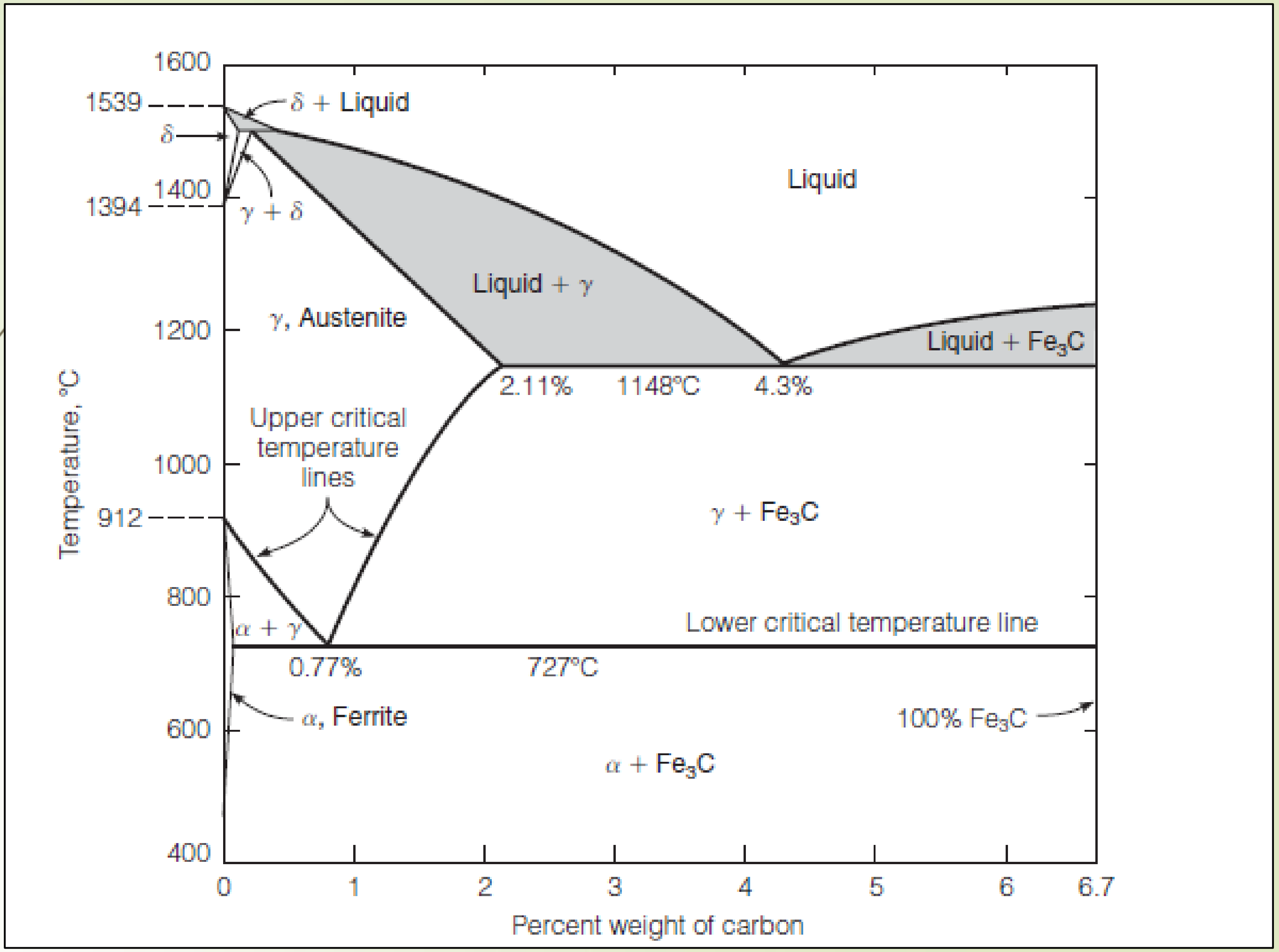
Steel

Production of Steel

- Cold-formed steel members are thinner, lighter, and easier to produce, and typically cost less than their hot-rolled counterparts. In addition, hot-rolled steel members shrink when cooled. Thus, there is less control of the final shape and size of steel members produced.
- Hot-rolled steel members (usually with rounded edges) are used when precise shapes and tolerances are not required
- Cold-formed steel is simply hot-rolled steel that has been processed further. In addition to the heating and cooling, cold-formed steel undergoes annealing (a process that refines the grain, soften the steel, remove internal stresses, remove gases, increase ductility and toughness, etc)
- Cold-formed steel members have an oily smooth surface.

Steel

Iron-Carbon Phase Diagram



Classification of steel products

Structural Steel

- produced by continuous casting and hot rolling

Uses

- Hot-formed steel is used for:
  - hot-rolled structural shapes, plates, and bars
  - structural members, such as columns, beams, bracings,
  - frames, trusses, bridge girders, and
  - other structural applications

Classification of steel products

Grades of Structural Steel

- Due to the widespread use of steel in many applications, there are a wide variety of systems for identifying or designating steel, based on grade, type and class.
- Virtually every country with an industrial capacity has specifications for steel.
- Examples of associations that write specifications for steel include:
  - Society of Automotive Engineers, SAE
  - the American Iron and Steel Institute, AISI,
  - the American Society for Testing and Materials, ASTM
- The most widely used designation system was developed cooperatively by SAE and AISI based on chemical composition

Classification of steel products

Structural Steel Grades

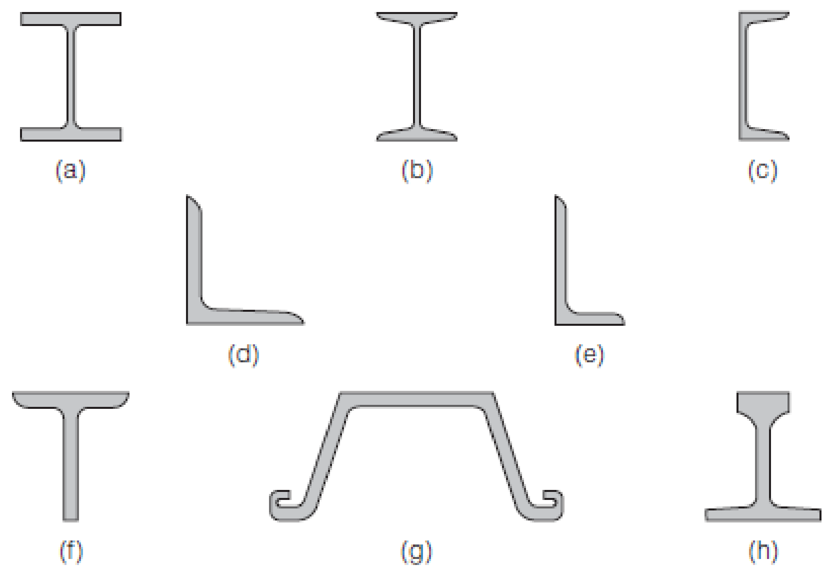
- ASTM specification names consist of a letter, generally an A for ferrous materials, followed by an arbitrary, serially assigned number. For example, ASTM A7 was a specification for structural steel

Steel Type	ASTM Designation		F_y[1] (ksi)	F_u[1] (ksi)	Minimum Elongation[2] (%)	Typical Chemical Composition[3] (%)									
						C	Cu[5]	Mn	P	S	Ni	Cr	Si	Mo	V
Carbon	A36		36	58–80	23	0.26	0.2	0.8–1.2[6]	0.04	0.05					
	A53 Gr. B		35	60		0.25	0.4	0.95	0.05	0.045	0.4	0.4		0.15	0.08
	A500	Gr. B	42	58	23	0.3	0.18		0.045	0..045					
			46	58											
		Gr. C	46	62	21	0.27	0.18	1.4	0.045	0.045					
			50	62											
	A501		36	58	23	0.3	0.18		0.045	0.045					
	A529	Gr.50	50	65–100	19	0.27	0.2	1.35	0.04	0.05					
		Gr.55	55	70–100											
High-strength Low-alloy	A572	Gr. 42	42	60	24	0.21	-	1.35	0.04	0.05			0.15–0.4		
		Gr. 50	50	65	21	0.23	-	1.35	0.04	0.05			0.15–0.4		
		Gr. 55	55	70		0.25	-	1.35	0.04	0.05			0.15–0.5		
		Gr. 60	60	75	18	0.26	-	1.35	0.04	0.05			0.4		
		Gr. 65	65	80	17	0.23	-	1.65	0.04	0.05			0.4		
	A618	Gr. I&II	50	70	22	0.2	0.2	1.35	0.04	0.05					
		Gr. III	46	67	22	0.23	-	1.35	0.04	0.05			0.3		
	A913	50	50	65	21	0.12	0.45	1.6	0.04	0.03	0.25	0.25	0.4	0.07	0.06
		65	65	80	17	0.16	0.35	1.6	0.03	0.03	0.25	0.25	0.4	0.07	0.06
	A992[4]		50–65	65	18	0.23	0.6	0.5–1.5	0.04	0.05			0.4	0.15	0.11
Corrosion resistant High-strength low-alloy	A242	50	50	70	21	0.15	0.2	1	0.15	0.05					
	A588		50	70	21	0.19	0.25–0.4	0.8–1.25	0.04	0.05	0.4	0.4–0.65		0.02–0.1	

Classification of steel products

Sectional Shapes

- Figure below illustrates structural cross-sectional shapes commonly used in structural applications



Important : Shapes commonly used in structural applications: (a) wide-flange (W, HP, and M shapes), (b) I-beam (S shape), (c) channel (C and MC shapes), (d) equal-legs angle (L shape), (e) unequal-legs angle (L shape), (f) tee, (g) sheet piling, and (h) rail.

Classification of steel products

Cold-formed steel

- produced by cold-forming of sheet steel into desired shapes
- Fabrication of cold-formed steel construction materials is governed by industry standards including:
  - the American Iron and Steel Institute's Specification for the Design of Cold-Formed Steel Framing Members (NASPEC) and
  - ASTM.

Uses

- used for:
  - structural framing of floors, walls and roofs as well as interior partitions and exterior curtain wall applications.

Classification of steel products

Reinforcing Steel

- Since concrete has negligible tensile strength, structural concrete members subjected to tensile and flexural stresses must be reinforced
- Two types of reinforcing:
  - **conventional reinforcing** - stresses fluctuate with loads on the structure. This does not place any special requirements on the steel
  - **prestressed reinforcing** - allows for predetermined engineering stresses to be placed in members to counteract the stresses that occur when they are subject to loading
- Conventional reinforcing is manufactured in three forms:
  - **plain bars** - round, without surface deformations. They provide limited bond with the concrete, and therefore are not typically used in sections subjected to tension or bending.

Classification of steel products

- **deformed bars** – have protrusions (deformations) at the surface to ensure a good bond between the bar and the concrete. The deformed surface of the bar prevents slipping, allowing the concrete and steel to work as one unit.
- **plain and deformed wire fabrics** – Wire mesh

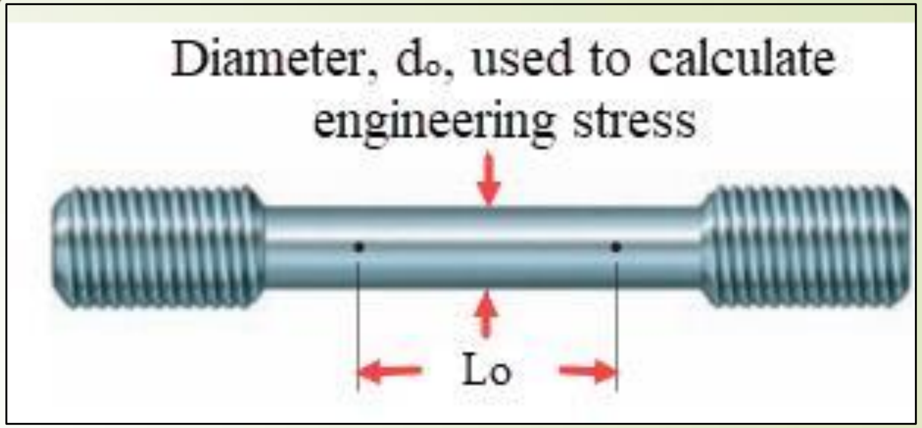
- Prestressed concrete requires special wires, strands, cables, and bars
- Steel for prestressed concrete reinforcement must have high strength and low relaxation properties

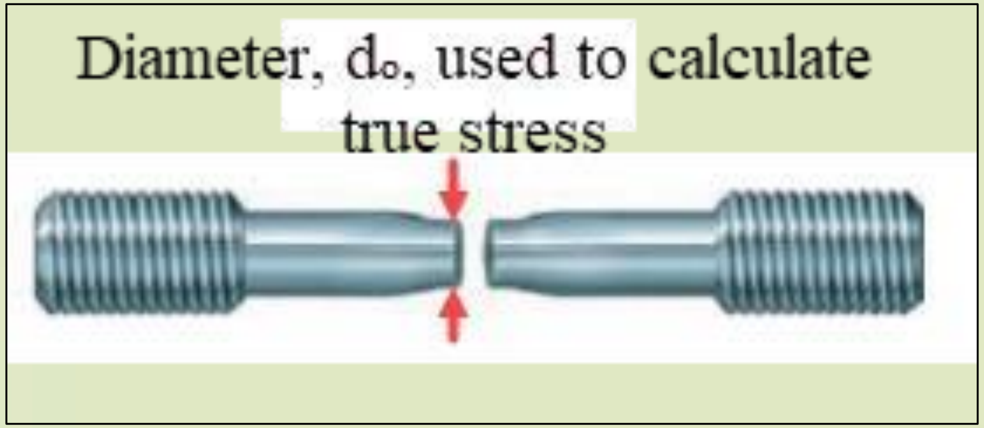
Tension Test of Steel

- Some of the laboratory tests commonly used to determine properties required in steel include tension test, torsion test, hardness test, ultrasonic test, etc
- Tension test (ASTM E8) is one of the most commonly performed tests
- It is performed to determine the yield strength, yield point, ultimate (tensile) strength, elongation, and reduction of area
- Typically, the test is performed at temperatures between 10°C and 35°C (50°F to 95°F)
- Various types of gripping devices may be used to hold the specimen, depending on its shape. In all cases, the axis of the test specimen should be placed at the center of the testing machine head to ensure axial tensile stresses within the gauge length without bending.

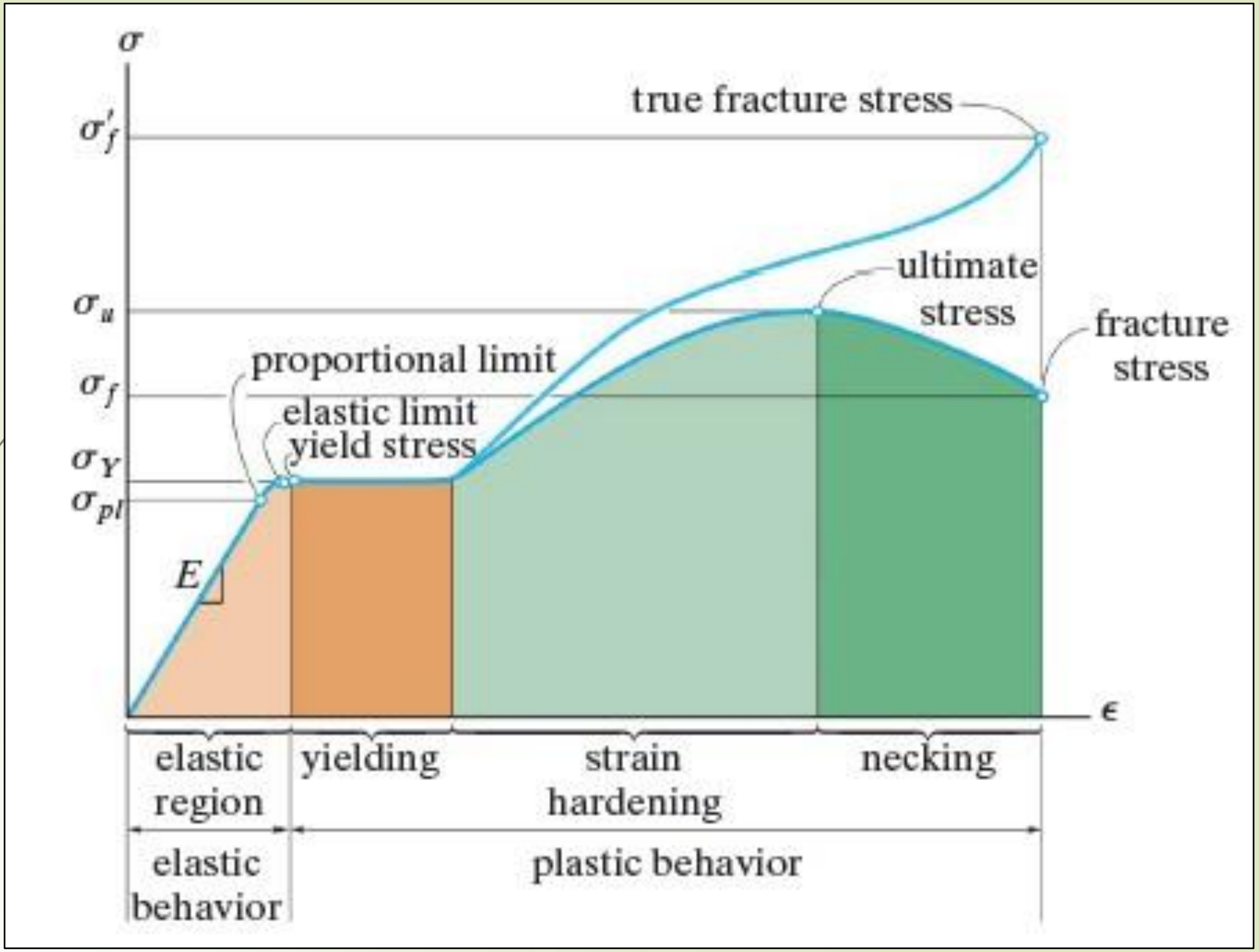
Tension Test of Steel

- The traditional, or engineering, way of calculating the stress and strain uses the original cross-sectional area and gauge length.
- If the stress and stains are calculated based on the instantaneous cross-sectional area and gauge length, a true stress–strain curve is obtained, which is different than the engineering stress–strain curve





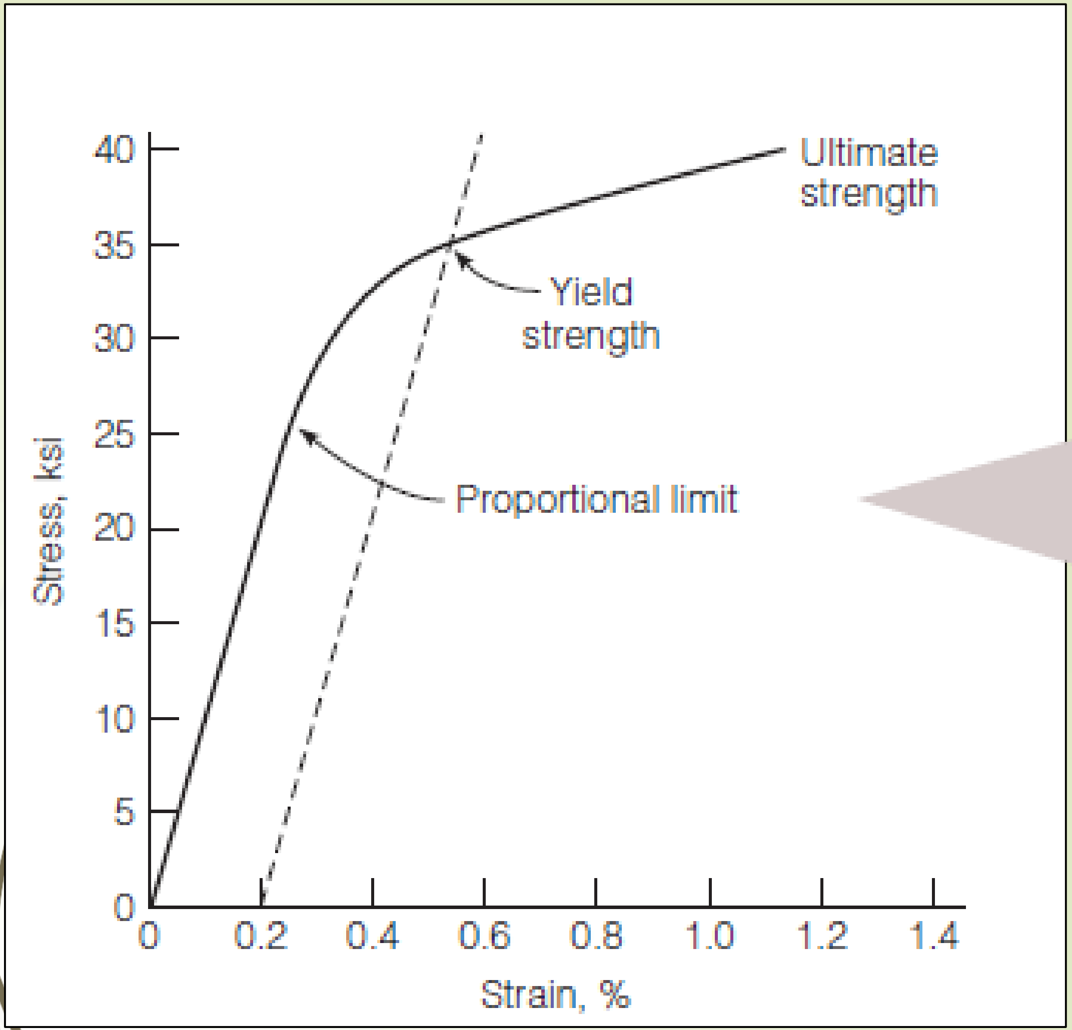
Tension Test of Steel



Aluminum

- Aluminum production uses processes that were developed in the 1880s
- Tests performed on aluminum are similar to those described for steel.
- These typically include stress–strain tensile tests to determine elastic modulus, yield strength, ultimate strength, and percent elongation.
- In contrast to steel, aluminum alloys do not display an upper and lower yield point. Instead, the stress–strain curve is linear up to the proportional limit, and then is a smooth curve up to the ultimate strength.
- Yield strength is defined based on the 0.20% strain offset method (When a yield point is not easily defined based on the shape of the stress–strain curve, an offset yield point is arbitrarily defined. The value for this is commonly set at 0.1 or 0.2% plastic strain)

Aluminum



Aluminum's coefficient of thermal expansion is 0.000023/°C (0.000013/°F),

about twice as large as that of steel and concrete. Thus, joints between aluminum

and steel or concrete must be designed to accommodate the differential movement.

Steel and Aluminum Compared

- Aluminum and Steel pieces can be joined either by welding using fasteners, bolts or rivets
- For Aluminum, welding requires that the tough oxide coating on aluminum be broken and kept from reforming during welding, so arc welding is generally performed in the presence of an inert gas that shields the weld from oxygen in the atmosphere.
- The two common processes by which aluminum is welded are:
  - gas metal arc welding (GMAW,) and
  - gas tungsten arc welding, GTAW
- Steel corrodes but its harder than aluminum and less likely to warp, deform or bend under weight, force or heat.
- Common types of welding for steel are are arc welding and gas welding
- Steel is typically 2.5 times denser than aluminum.

Lab:
Tension Test of Steel and Aluminum

Thank You!!!