THE UNIVERISTY OF ZAMBIA

School of Engineering

Department of Civil and Environmental Engineering

CEE 3111 - CIVIL ENGINEERING MATERIALS AND CONSTRUCTION PRACTICES

2023 ACADEMIC YEAR

SEMESTER 1

TOPIC 2

Metals as construction materials

Steel

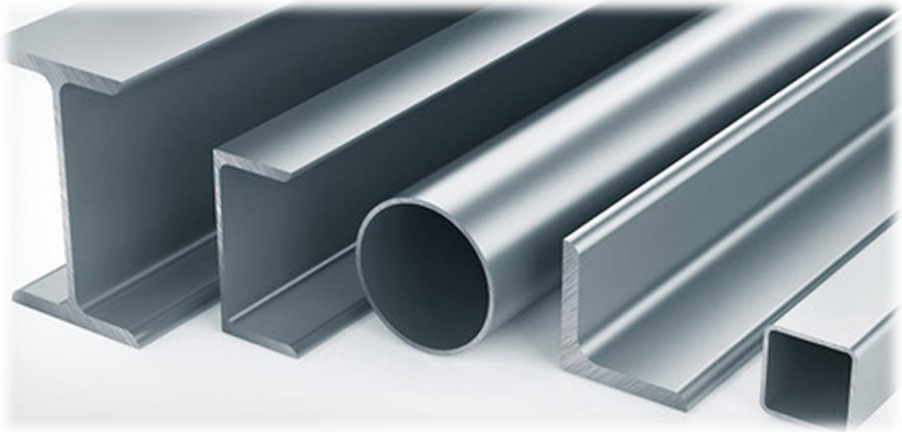
Background

- Use dates back to about 1500 B.C
- 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

3/13/2024

- 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:



✓ Structural steel
✓ Cold-formed steel
✓ Fastening products
✓ Reinforcing steel (rebars)

Steel

- Material engineers rarely involved in specifying properties of steel
- Usually select existing standard steel products
- However, bridges are a special case.

Steel

3/13/2024

Production of Steel

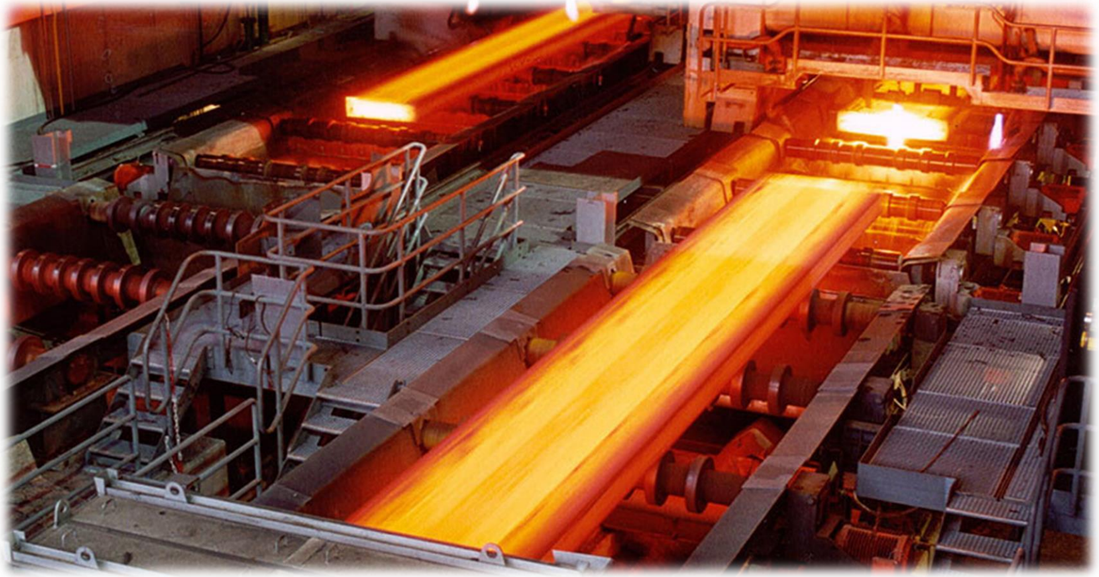
Phases in steel production:

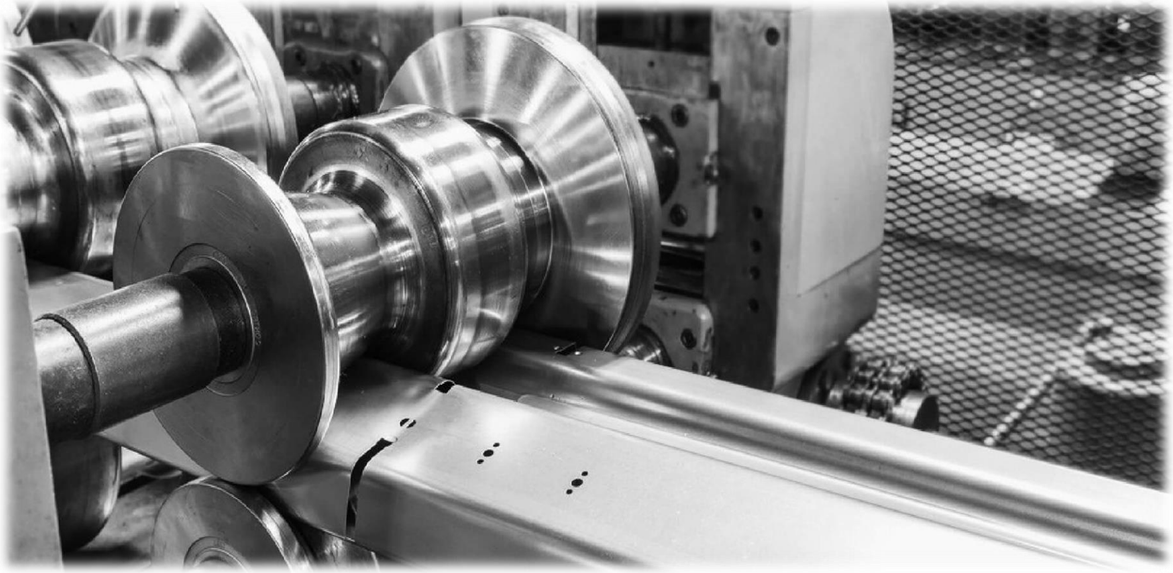
1. **Reducing iron ore to pig iron** - in a blast furnace

2. **Refining pig iron** (and scrap steel from recycling) to steel – in basic O2 or electric arc furnace
   - ✓ grade of steel depends on how much carbon dioxide is extracted from iron.

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 - more energy efficient
- Ingots - less energy efficient; must be reheated prior to shaping into the final product.
- Cold-formed steel - hot rolled steel rolled that has cooled, formed into sheets or coils, then re-rolled at room temperature to achieve more exact dimensions and better surface qualities.

DIFFERENCE BETWEEN COLD ROLLED & HOT ROLLED STEEL

Click here to see video

Steel

- Properties of hotrolled steel members:
  - ✓ Hot-rolled steel members (usually with rounded edges) are used when precise shapes and tolerances are not required
  - ✓ hot-rolled steel members shrink when cooled.
  - ✓ Thus, there is less control of the final shape and size of steel members produced.

- Properties of cold-formed steel members:
  - ✓ thinner, lighter, and easier to produce, and
  - ✓ typically cost less than their hot-rolled counterparts. Cold-formed steel members have an oily smooth surface Thus,

Classification of steel products

Structural Steel

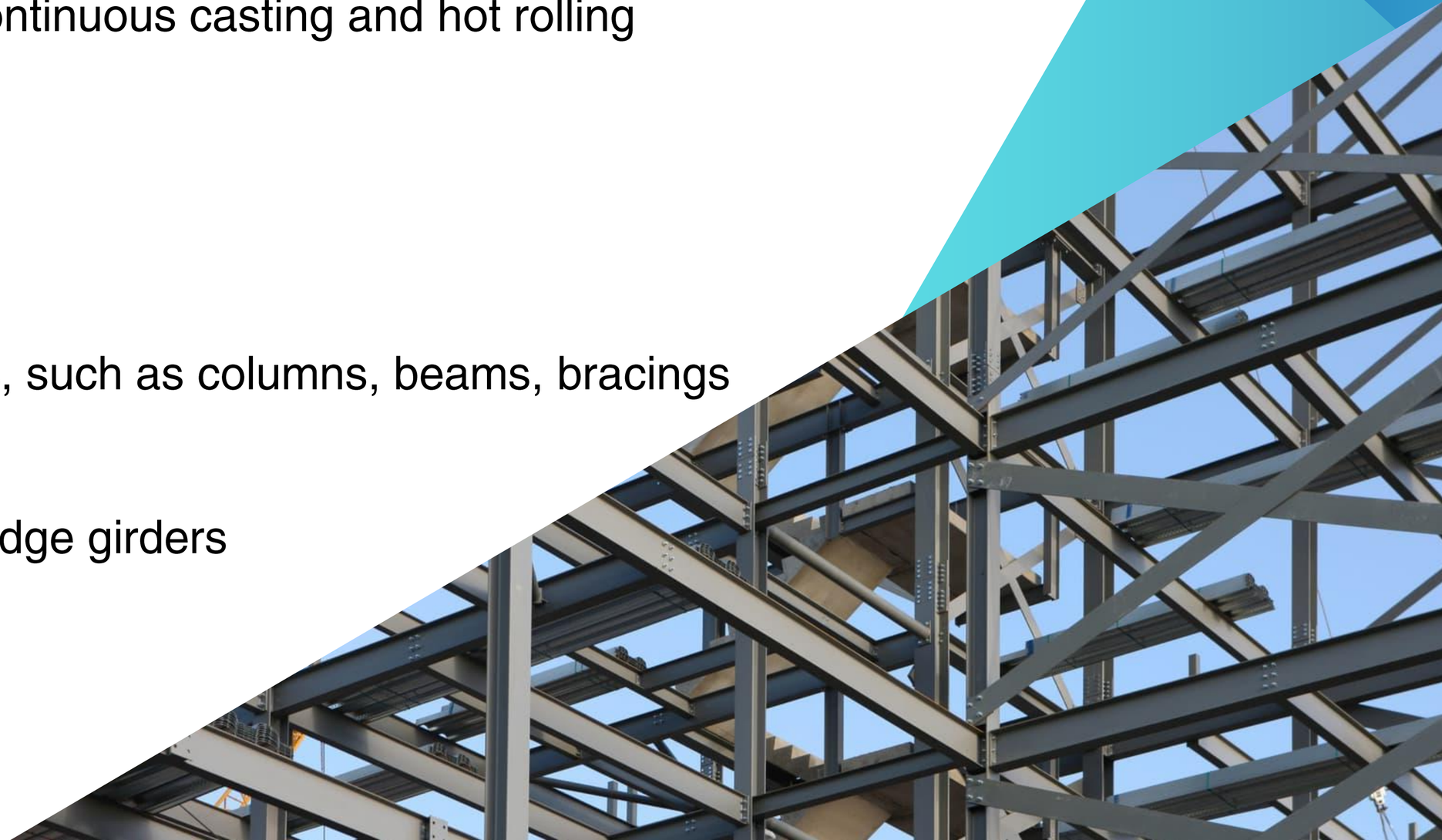
- produced by continuous casting and hot rolling

Uses

1. plates, and bars

2. structural members, such as columns, beams, bracings

3. frames, trusses, bridge girders

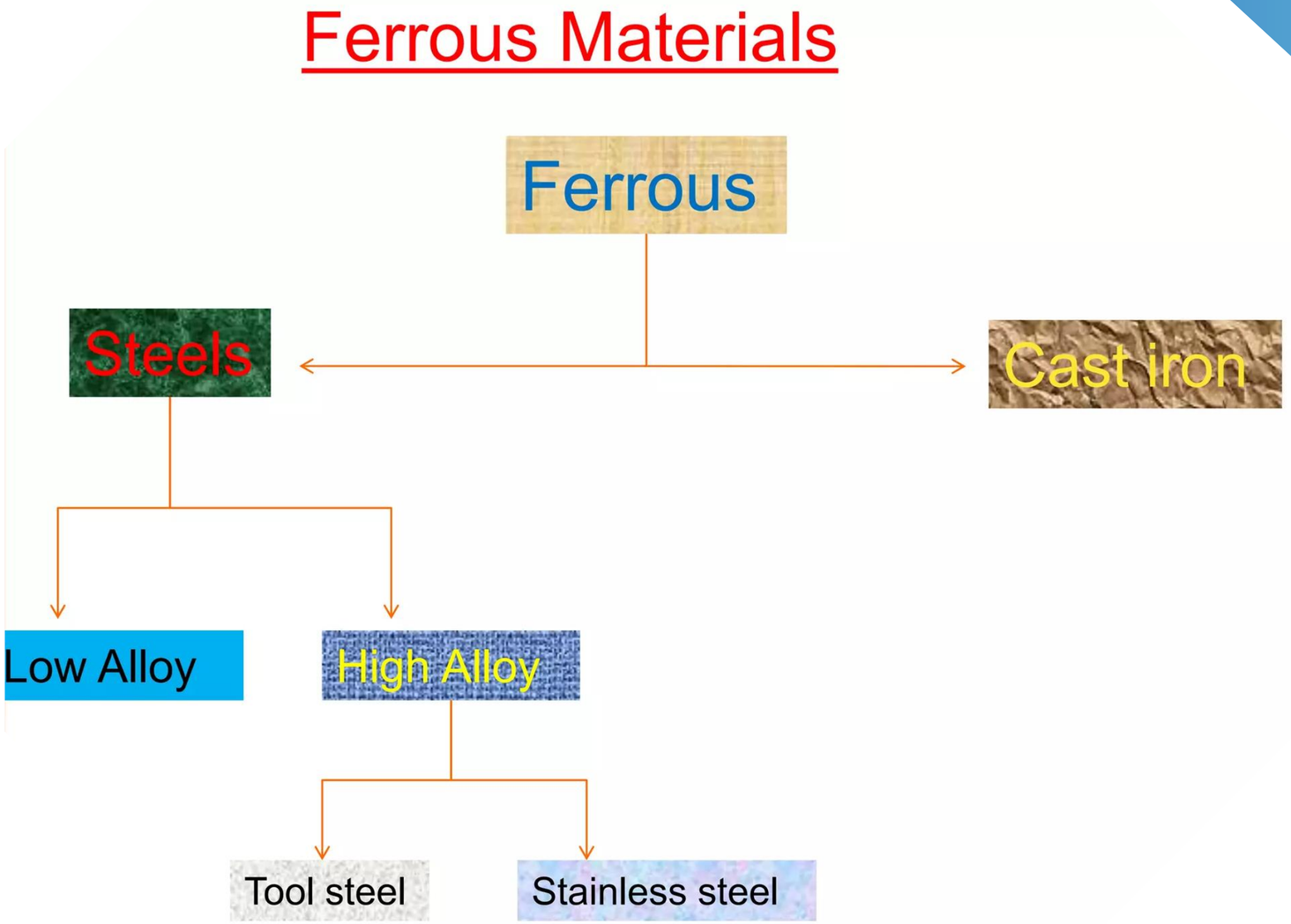


Classification of steel products

Grades of Structural Steel

- Wide variety of systems for identifying or designating steel
- Examples include:

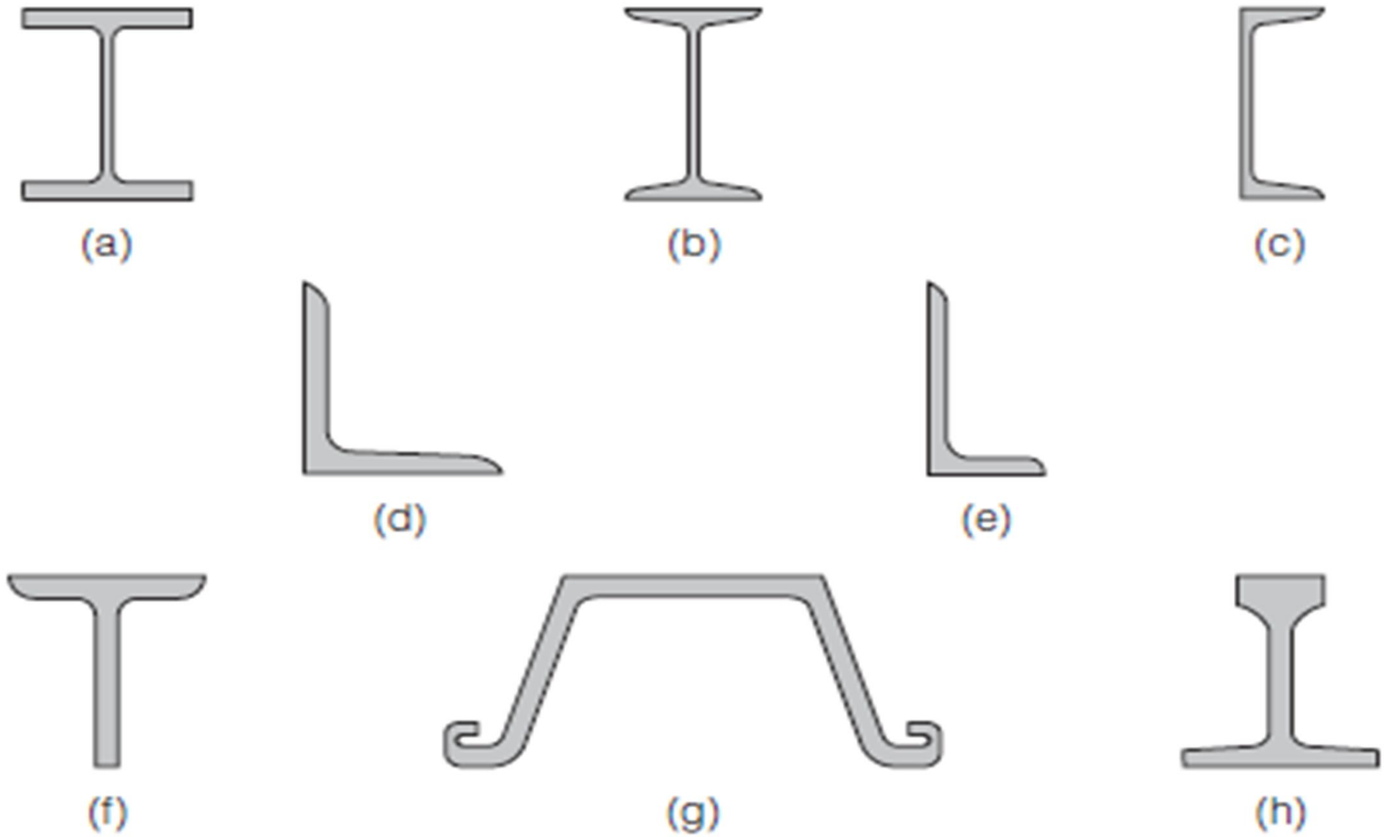
1. Society of Automotive Engineers, SAE
2. the American Iron and Steel Institute, AISI,
3. the American Society for Testing and Materials, ASTM
4. The most widely used designation system was developed cooperatively by SAE and AISI based on chemical composition



Classification of steel products - ASTM

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 - Shapes



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
- standards include:
  - ✓ the American Iron and Steel Institute's Specification for the Design of Cold-Formed Steel Framing Members (NASPEC) and
  - ✓ ASTM.

Uses

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

Classification of steel products

Reinforcing Steel

- Structural concrete members subjected to tensile and flexural stresses

- Since concrete has negligible tensile strength, must be reinforced ,
- Two types of reinforcing:

  ✓ **conventional reinforcing** - stresses fluctuate with loads on the structure.

  ✓ **prestressed reinforcing** - allows engineers apply predefined stresses to members to counterbalance loading strains. Needs strong and low relaxation steel cables, strands, or bars.

Classification of steel products

Reinforcing Steel - Types of conventional reinforcing steel

1. Plain bars - round, without surface deformations.

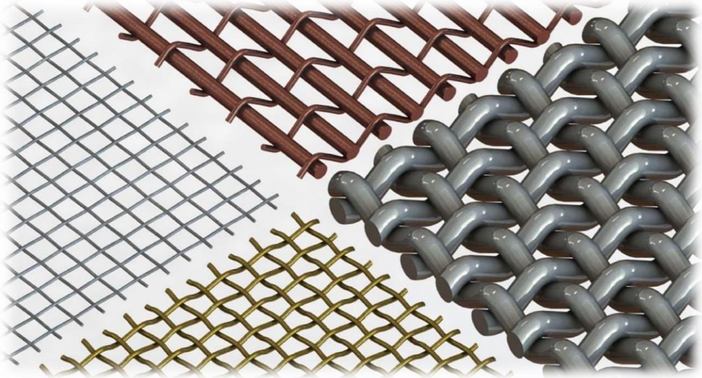
   ✓ provide limited bond with concrete, and

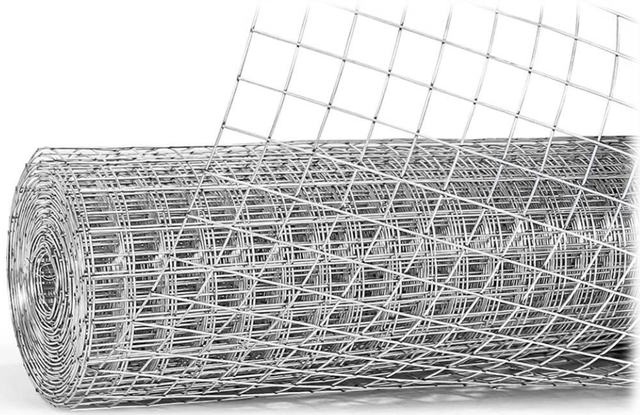
   ✓ not used in sections subjected to tension or bending.

2. Deformed bars - have protrusions (deformations) at the surface to ensure a good bond between the bar and the concrete.

   ✓ deformations prevent slipping, allowing the concrete and steel to work as one unit

3. Plain & deformed wire fabrics - Wire mesh





Tension Test of Steel

- Common lab tests used to determine properties required in steel include:

  ✓ tension test

  ✓ torsion test

  ✓ hardness test

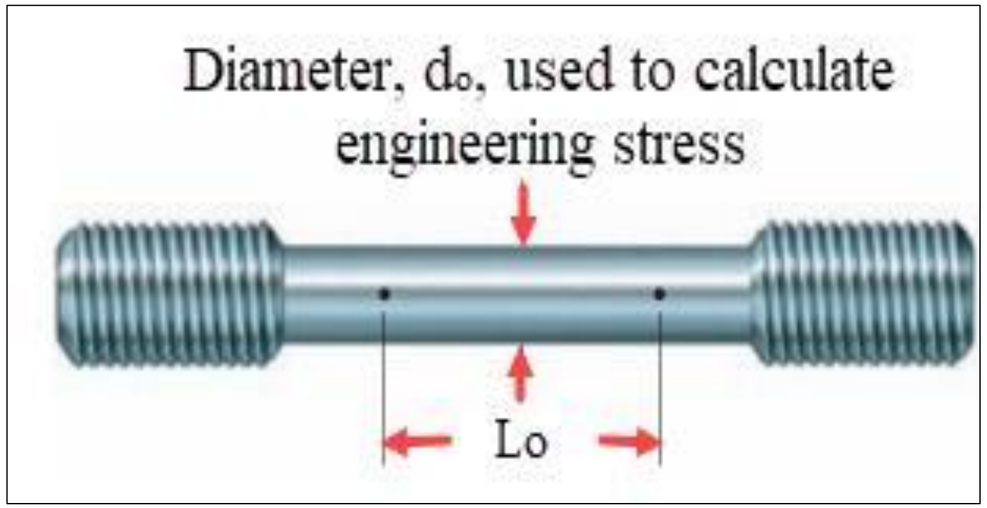
  ✓ ultrasonic test, etc

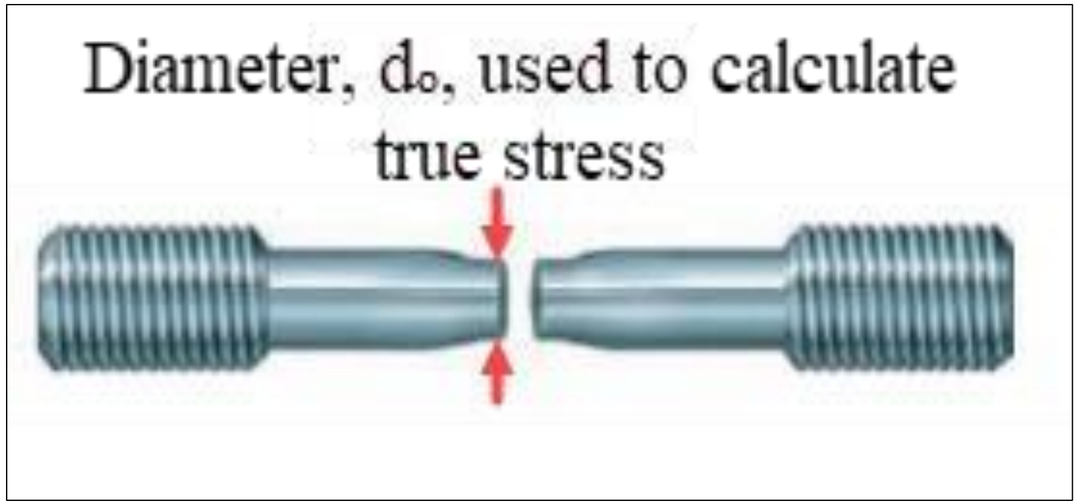
- Tension test (ASTM E8) is one of the most commonly performed tests to determine the yield strength, yield point, ultimate (tensile) strength, elongation, and reduction of area

Tension Test of Steel

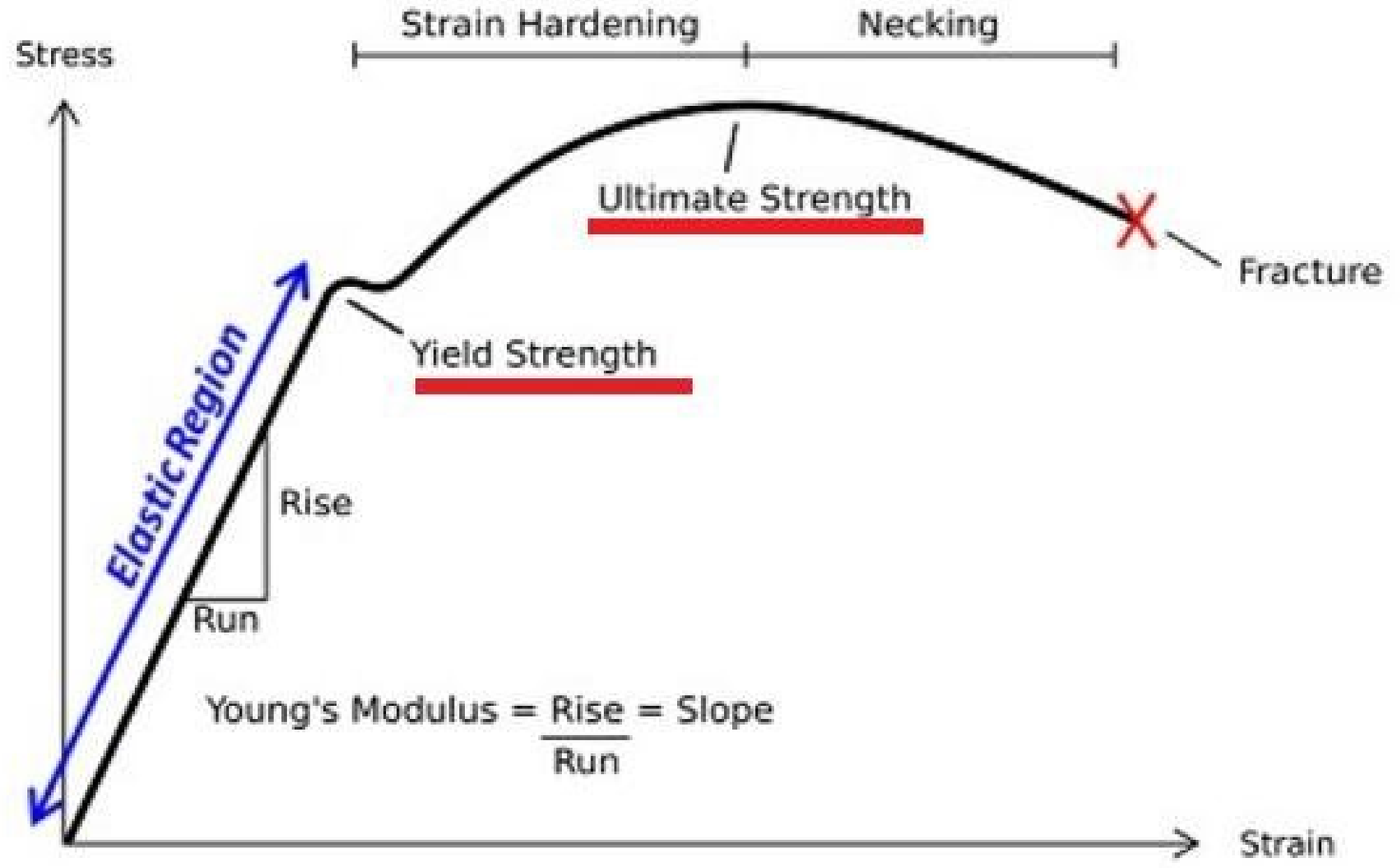
- Traditional, or engineering, way of calculating the stress and strain uses the original cross-sectional area and gauge length.

- If stresses 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



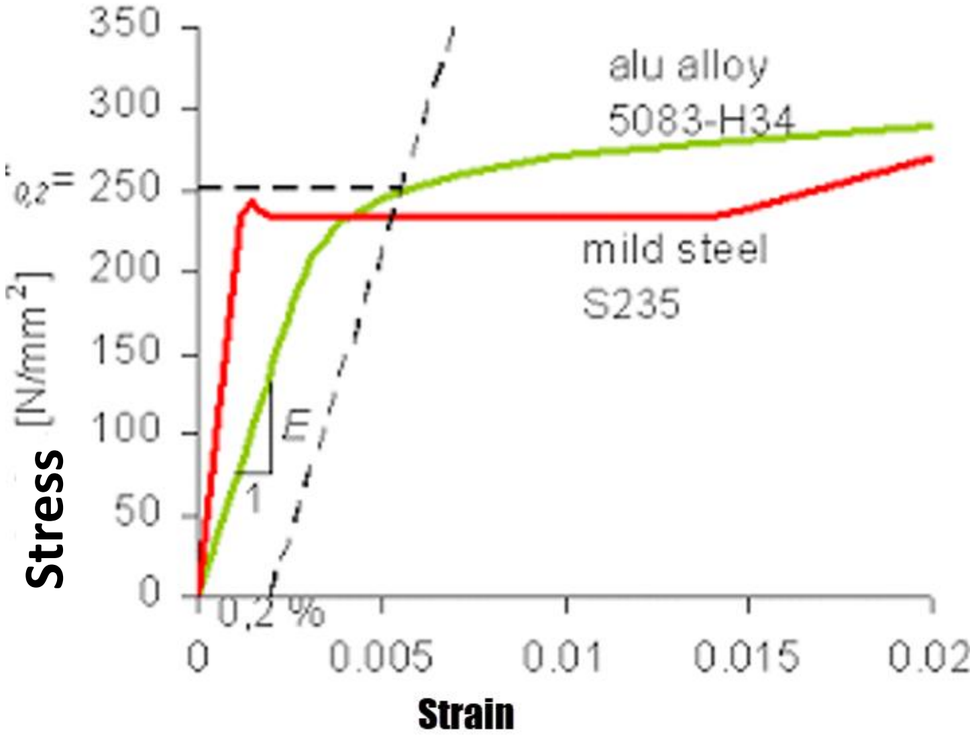
Aluminum

- Common uses of Aluminum in construction include:
  - ✓ Windows, door frames, roofing & cladding
  - ✓ Curtain walls – outer non-structural walls
  - ✓ Structural components in buildings and bridges where weight reduction is required

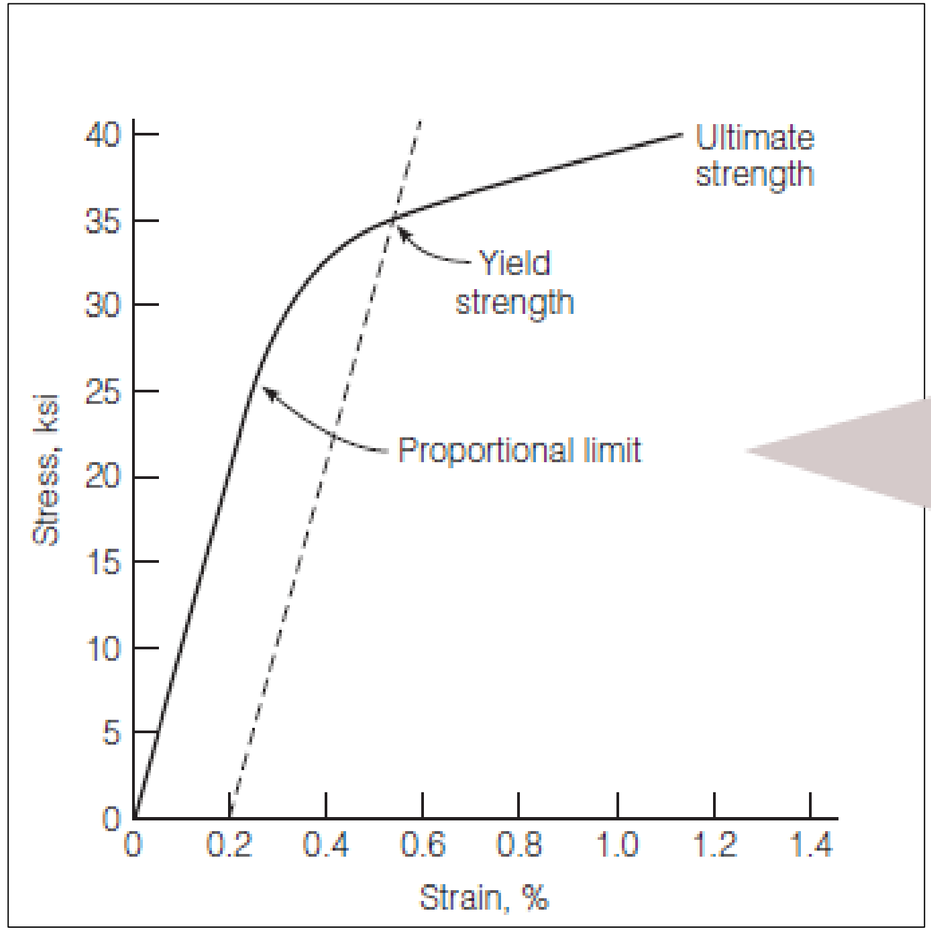
- Tests similar to those described for steel.

- Aluminum alloys do not display an upper and lower yield point

- Yield strength is defined based on the 0.20% strain offset method



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.

Aluminum

- Aluminum and Steel pieces can be joined either by:
  - ✓ welding
  - ✓ using fasteners,
  - ✓ bolts or rivets
- Common types of welding for steel are arc welding (AW) and gas welding
- Common types of welding for Aluminum Gas Metal AW & Gas Tungsten AW
- Steel corrodes but its harder than aluminum and less likely to warp, deform or bend under weight, force or heat.
- Steel is typically 2.5 times denser than aluminum.

Aluminum Vs Steel - Properties

Aluminum	Steel
1. More Malleable	1. Stronger but cannot be pushed to the same dimentional limits
2. Naturally corossion resistant	2. Must be treated or painted to protect it in rugged conditions
3. Reduces the overall weight of a piece of equipment	3. Very strong and less likely to warp under, deform, or bend under weight
4. More Expensive	4. Less Expensive

Aluminum vs Steel – Properties

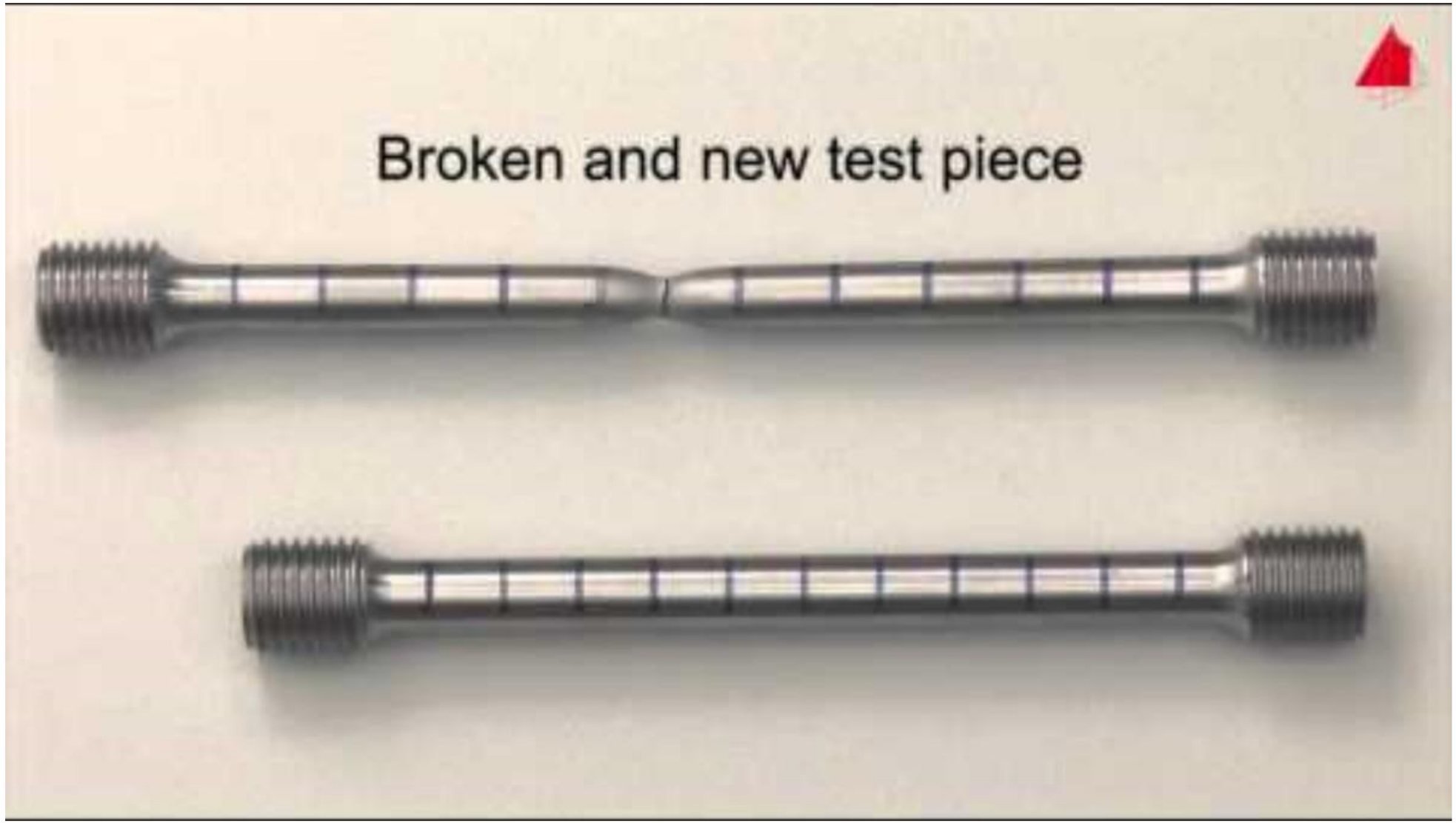
- Steel, with its high tensile, compressive, and yield strengths, is often the material of choice for applications that require a high degree of durability and resilience

- Aluminum's adequate strength, lower density, and superior strength-to-weight ratio make it a good choice for applications that benefit from lighter weight

- The choice often comes down to the specific requirements of the project.

QUIZ 2:

Lab: Tension Test of Steel and Aluminum



Click here to watch video

Thank You!!!