# CVL3211 : Civil Engineering Materials

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# Steel

This chapter will cover under given topics.

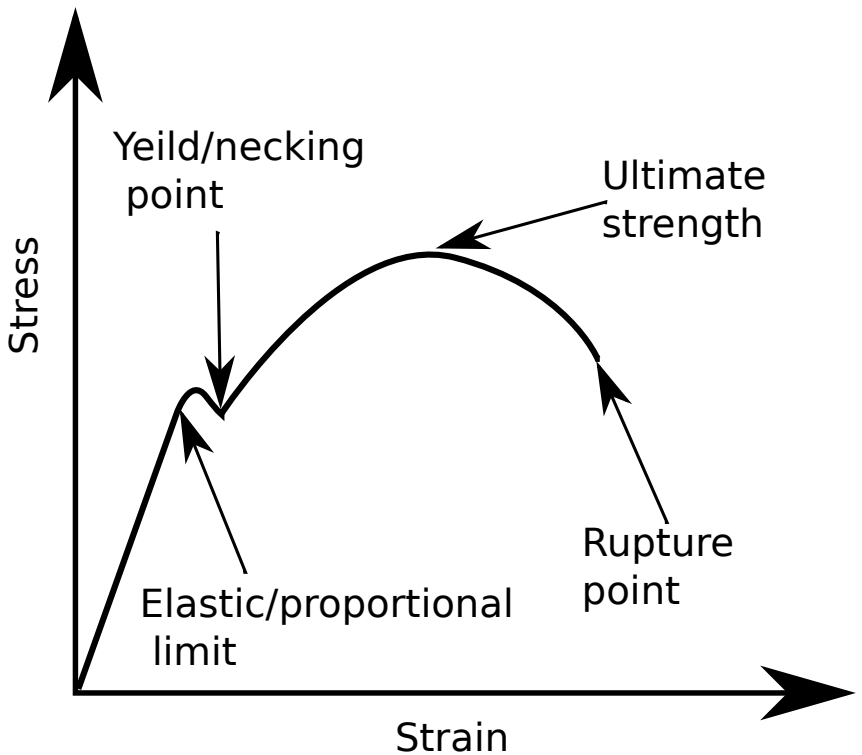
- Properties of steel
- Carbon equivalent
- Iron-Carbon Phase diagram
- Heat treatment

# Properties and application of steel

- Steel is an alloy of iron and carbon, where maximum carbon percentage is less than 2.
- Steel is manufactured by adding manganese or/and silicon to molten iron that reduce excess carbon as slag.
- Carbon content in steel is directly proportional to hardness, brittleness, melting point, corrosion resistance and inversely proportional to toughness, softness, ductility, weldability.
- Steel can be divided in three categories based on its carbon content:
  - Low carbon steel (0-0.4% carbon)
  - Medium carbon steel (0.4-0.8% carbon)
  - High carbon steel (0.8-1.2% carbon)
- Another form of iron-carbon alloy is cast iron (2-4% carbon). It is called so because it can be casted in any form easily but its brittleness induced due to high carbon content cause it difficult in cold forming.

# Physical behavior of steel

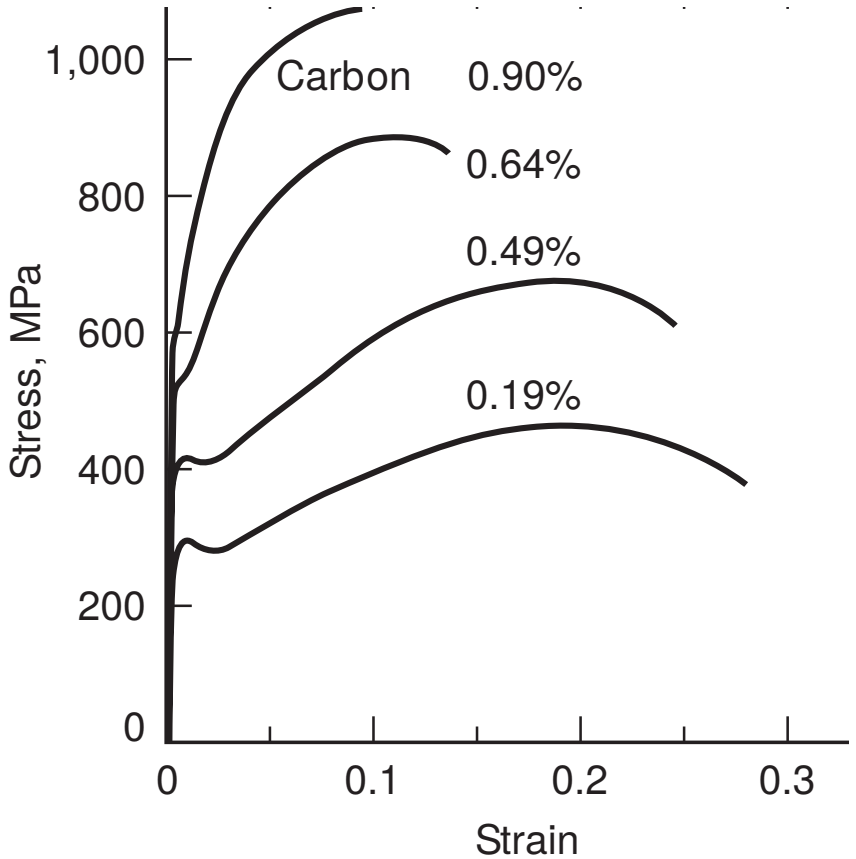
- Steel shows strain-hardening behavior.
- Stress-strain diagram of a cylindrical steel rod is given below based on its testing in universal testing machine (UTM).




- Ultrasonic testing is performed on welds to check their uniformity.
- Other tests like torsion and V-notch tests are also performed to find out shear and hardness of steel.

# Carbon equivalent and weldability

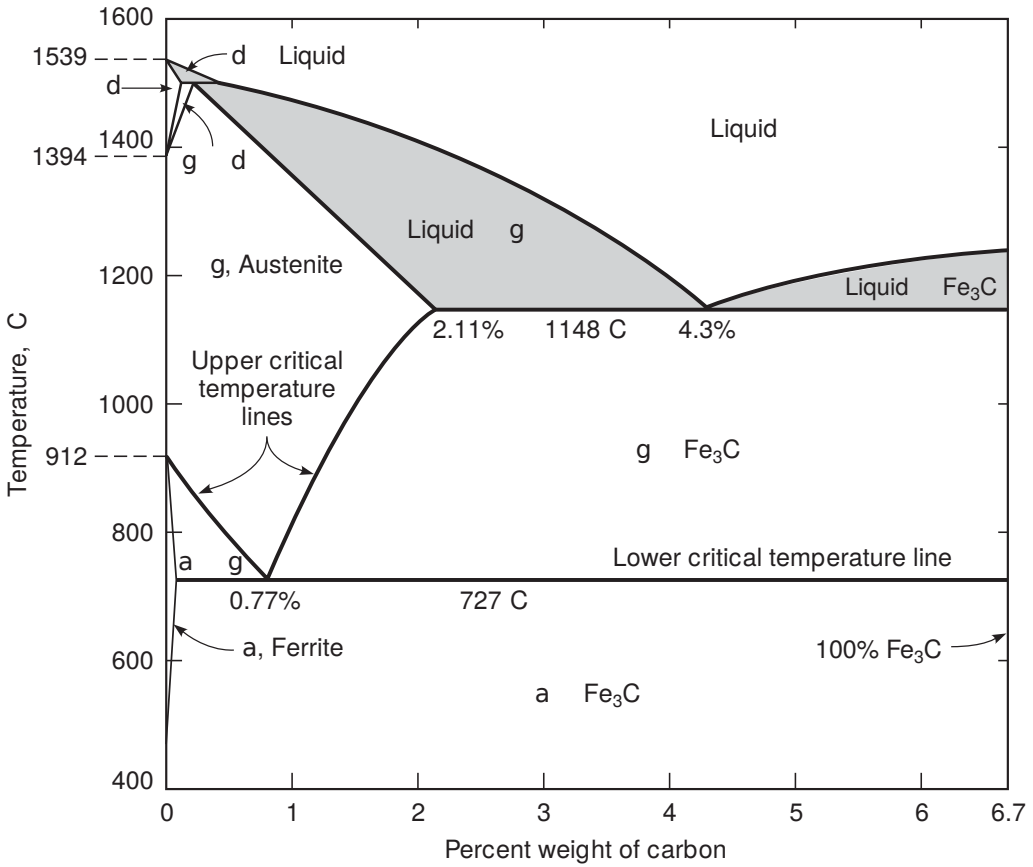
Effect of varying carbon content in steel effects its strength as shown in figure below. It was also mentioned previously.




- Carbon equivalent is percentage of alloyed metals equivalent to the percent of carbon.
- $C_{eq} = \%C + \%Mn/6 + (\%Cr + \%Mo + \%V)/5 + (\%Ni + \%Cu)/15$
- $C_{eq}$ is inversely proportional to weldability of steel. As higher carbon cause more hardness and that affect ability to melt when being welded.

# Iron-Carbon phase diagram

Its study is useful for treatment of steel and to metallurgy of steel. **It critical to look and understand all transitions in this diagrams.**




- Maximum carbon content here is 6.7%, at this point pure cementite ($Fe_3C$) exists in mix.
- Critical temperature lines are defined for transition from phases of iron ($\alpha(BCC), \gamma(FCC)$ and $\delta(BCC)$)
- Maximum carbon content for pure $\alpha$ is 0.022% and for pure $\gamma$ is 2.11%.

# Heat treatment and cold formed shapes

Four basic heat operation are used on steel to reform it for various applications:

- Annealing: Heating $50^0C$ above austenite line and cooling at $20^0C/hour$ till $680^0C$ then air cooling/natural convection.
- Normalizing: Heating $60^0C$ above austenite line and cooling by natural convection.
- Hardening/Quenching: Heating $50^0C$ above austenite line and rapid cooling by quenching in water.
- Tempering: Cooling hardened steel to $40^0C$ then reheating it by immersion in oil. Natural air convection is used to cool later.

Controlled heating or cooling require more industrious setup and hence all processes but annealing can be used by simple blacksmith.