Y.S Factor in SS

For Structural Application

The Inventors

- ***Leonhard Euler*** : Buckling formula $\mathbf{F} = \mathbf{n}\pi^2 EI/L^2$
- ***Simeon Poisson*** : Poisson Ratio $v = -\frac{d\varepsilon_{trans}}{d\varepsilon_{axial}}$
- ***Thomas Young*** : Young's Modulus **Y = Stress/Strain** (in Elastic region)

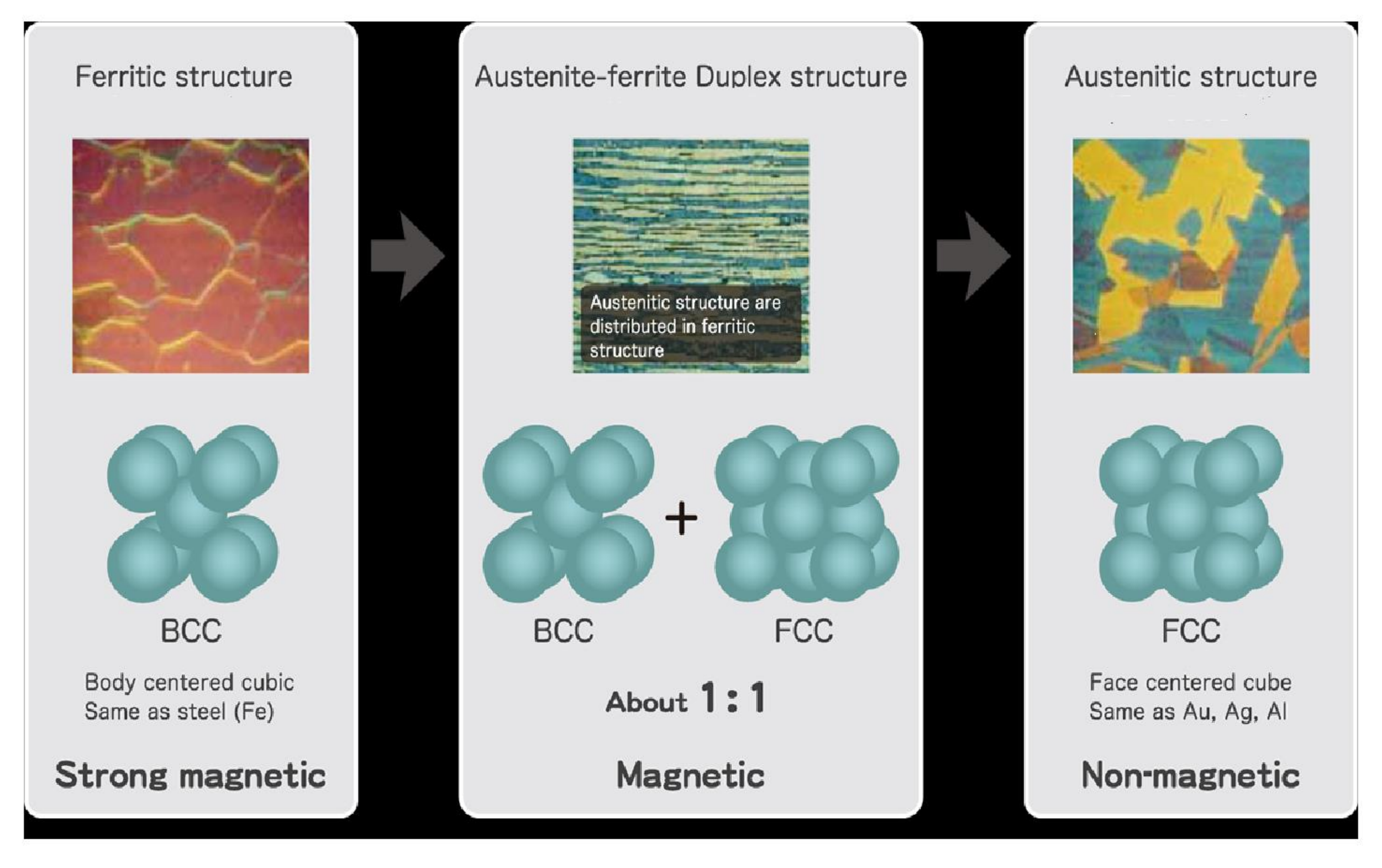
Their invention of formulae for structural design is invaluable

In a gist (keeping aside corrosion protection and welding)

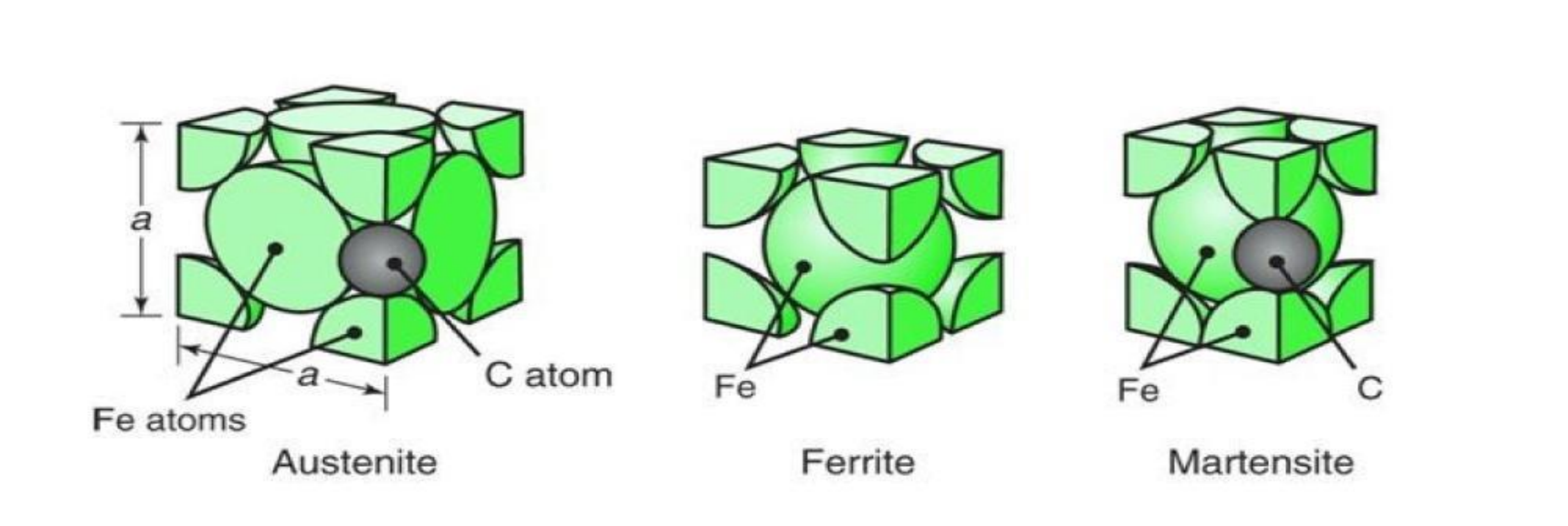
H
I
G
H
E
R

- Y.S, in annealed state lighter the structure (easier to compete with HSLA steel)
- Poisson Ratio, more rigid resistance to distortion
- Euler value, lesser the buckling

Overview of major SS groups



Overview of major SS groups



Carbon in between Iron atoms (interstitials)

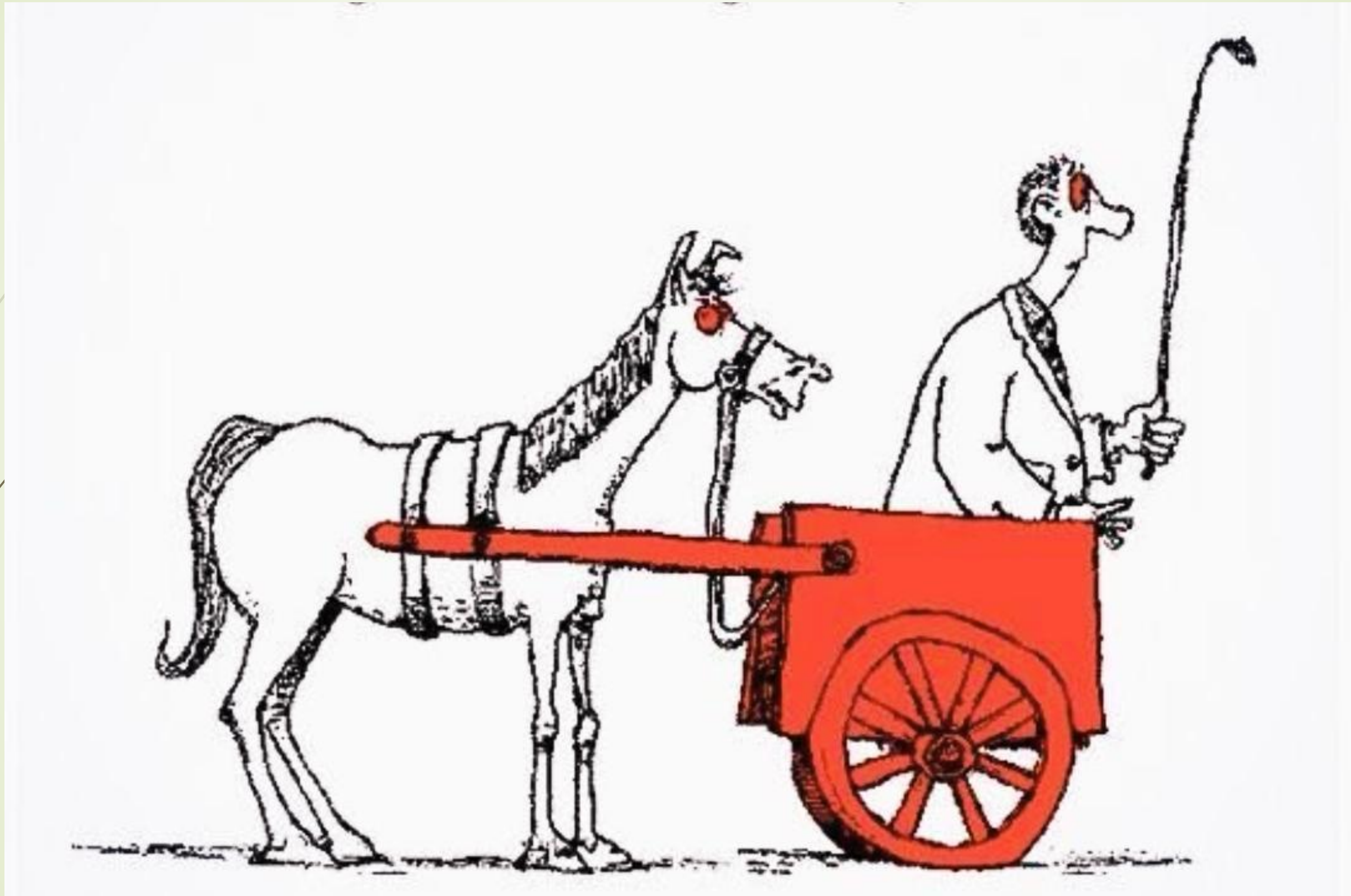
Higher Y.S by Cold Reduction

No room for Carbon atoms

Higher Y.S by process parameter

Carbon after heat treatment

Higher Y.S by quench hardening (brittle)



SS candidates for structural

Where they stand

Property	HSLA E450	Duplex 2101	Duplex 2205	Ferritic Cr +11	Ferritic Cr +16	Austenitic 301L	Austenitic 201L
Modulus of Elasticity (GPa)	200	205	200	200	200	193	193
Density (g/cc)	7.8	7.7	7.8	7.7	7.75	7.9	7.86
Poisson's ratio	0.26	0.3	0.3	0.32	0.3	0.27	0.27
Yield Stress (Mpa)	450	450	460	325/500	550	205/500	290/580
Elongation (%)	20	35	35	20	45	40/25	45/29

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Impact Strength (J)	20	60	80	40-50	150-200	150	150
Isotropy	Yes	Yes	Yes	Yes	Yes	No	No
Fabrication	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓✓	✓✓
Post Fabrication	Painting	Pickling passivation	Pickling passivation	Pickling, cursory painting	Pickling passivation	Pickling passivation	Pickling passivation

OUTLINE DESIGN SPECIFICATIONS
FOR
PHASE-IV

(MARCH 2019)

A. Young's Modulus

Clause-5.2.2.1 of IRS-CBC shall be followed.

Grade of Concrete (N/mm^2)	**Modulus of Elasticity (kN/mm^2)**
M10	18.0
M15	22.0
M20	25.0
M25	26.0
M30	28.0
M35	29.5
M40	31.0
M45	32.5
M50	34.0
M55	35.0
M60	36.0

REINFORCEMENT STEEL (REBARS)

High strength deformed (HYSD) reinforcement bars of Fe-500D grad IS 1786 and Clause 4.5 & 7.1.5 of IRS-CBC shall be used.

I. Young's Modulus: E= 200,000 Mpa

II. Yield Stress: f_y = 500 MPa.

III. Density: 78.5 kN/m^3

IV. Density

Density of concrete shall be 25 kN/m^3 for PSC and RCC, 23 kN/m^3 for Pla concrete and 26 kN/ m^3 for Wet concrete.

V. Poisson's Ratio

Poisson's ratio for all grades of concrete shall be 0.15.

VI. Thermal Expansion Coefficient

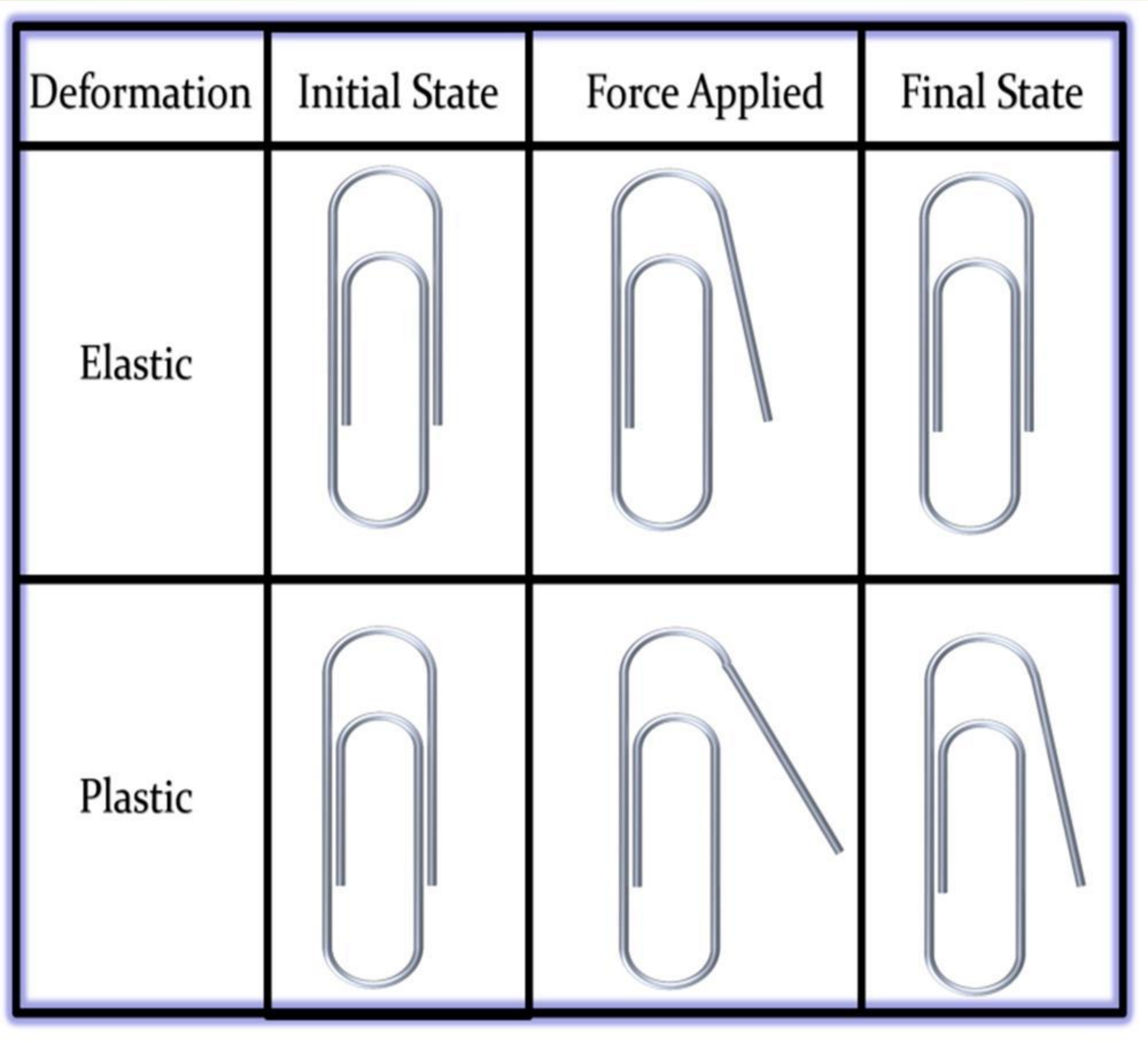
Coefficient of thermal expansion (a) has been considered as 11.7 x accordance with Clause-2.6.2 of IRS-Bridge Rules.

VII. Time-Dependent Characteristics of Materials

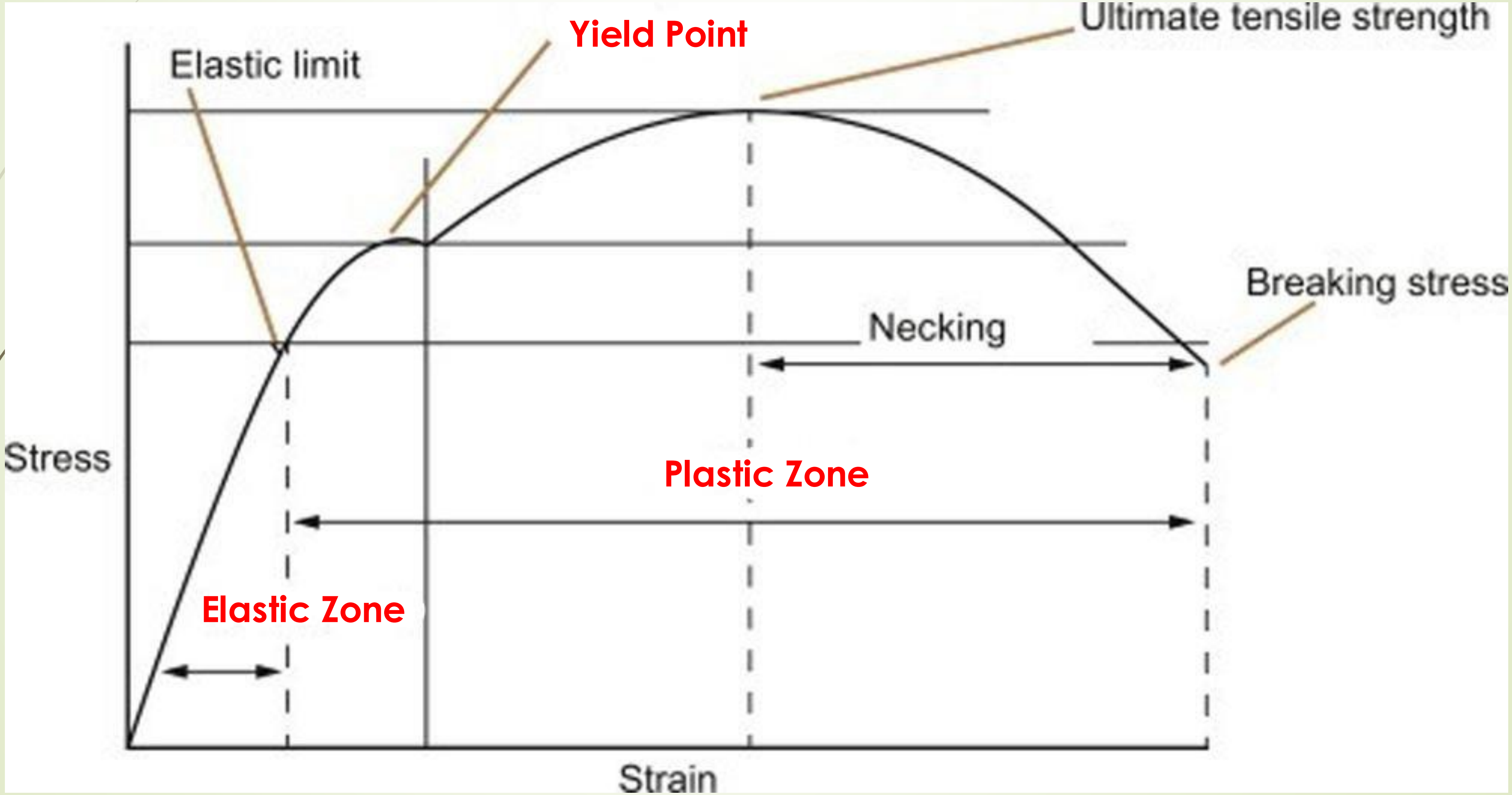
i) Long-term losses should be calculated in accordance with Clause-16.8 CBC.

ii) The design shall be done according to construction sequence to be a site.

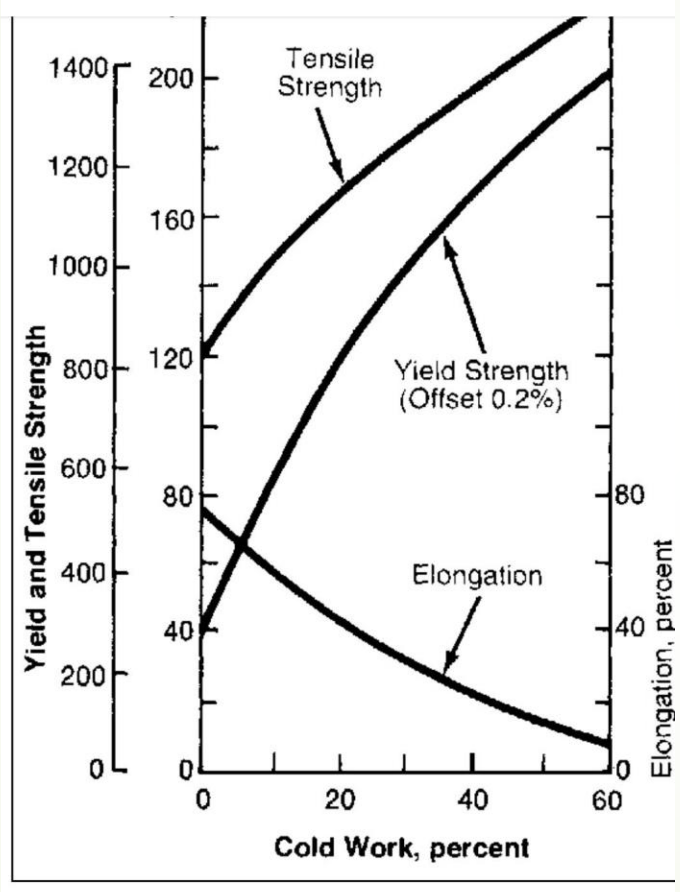
Elasticity and Plasticity



Stress and Strain curve



Cold Work Hardening Curve (Austenitic)



Strength ↑

Springback ↑

Stress Corrosion Failure ↑

Residual Stress ↑

Ductility ↓

Due to their structure, ferritic cold work-harden the least

Young's Modulus

Stiffness is resistance to elastic deformation

Young's modulus Y=stress/strain

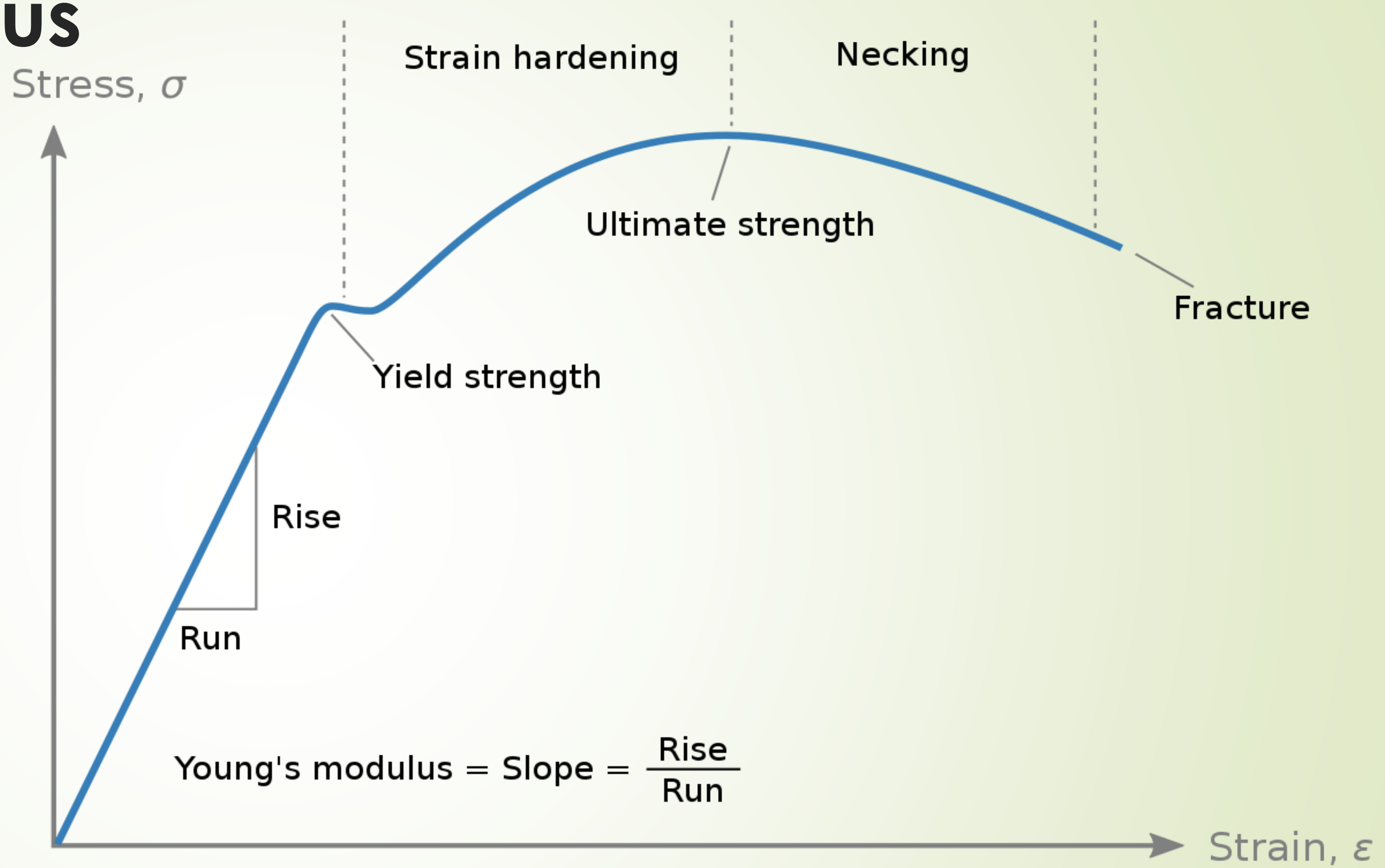
Y⬆ means ⬇elastic deformation

Stiffness α Y

Most important factor in Structural Design

SS with high Young's modulus is better suited for structural application

Young's Modulus

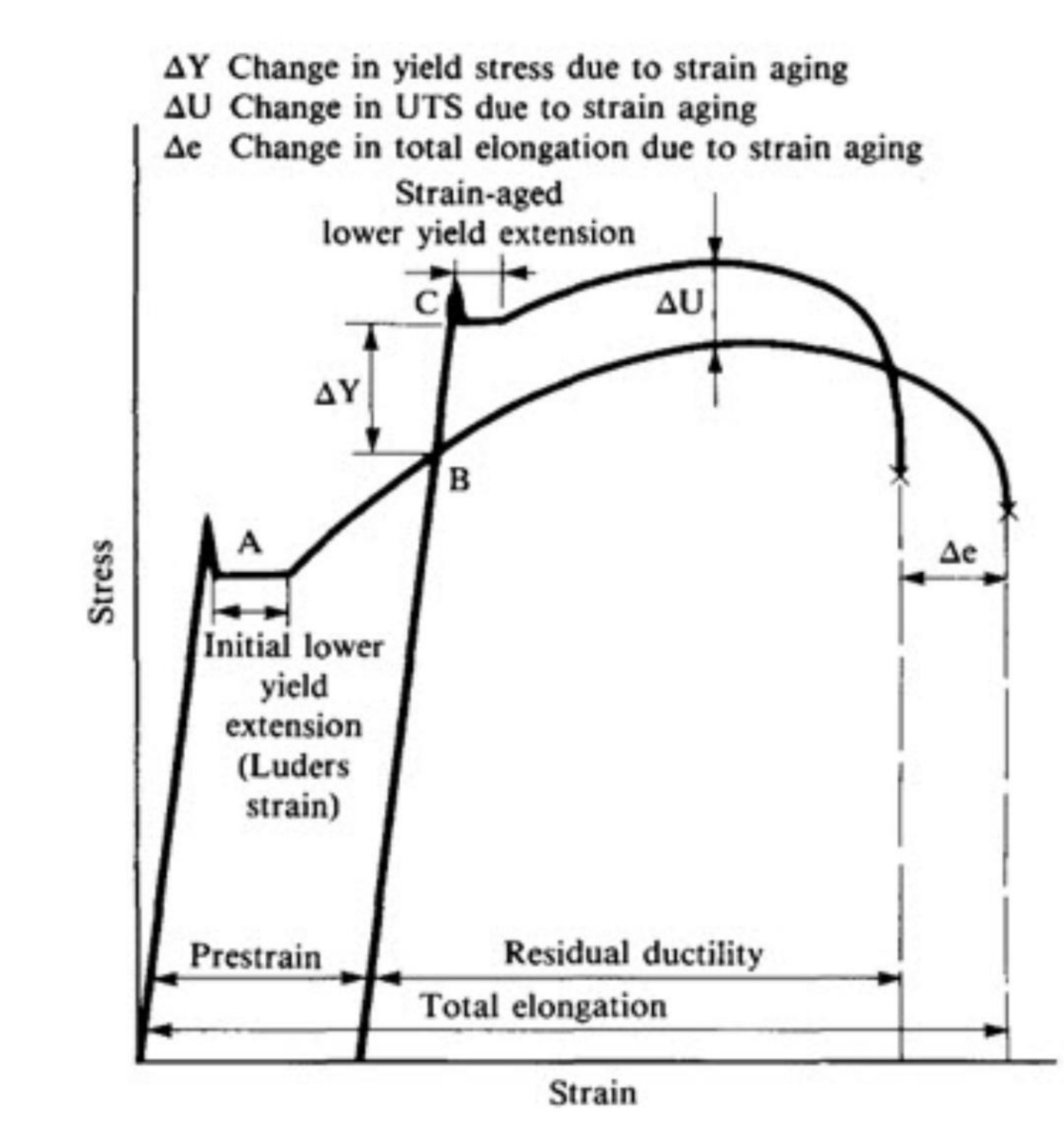


Young's modulus of

- Austenitic – 193 GPa
- Ferritic – 200 GPa
- Duplex – 205 GPa
- HSLA – 200 GPa

Young’s Modulus (Hard and Annealed material)

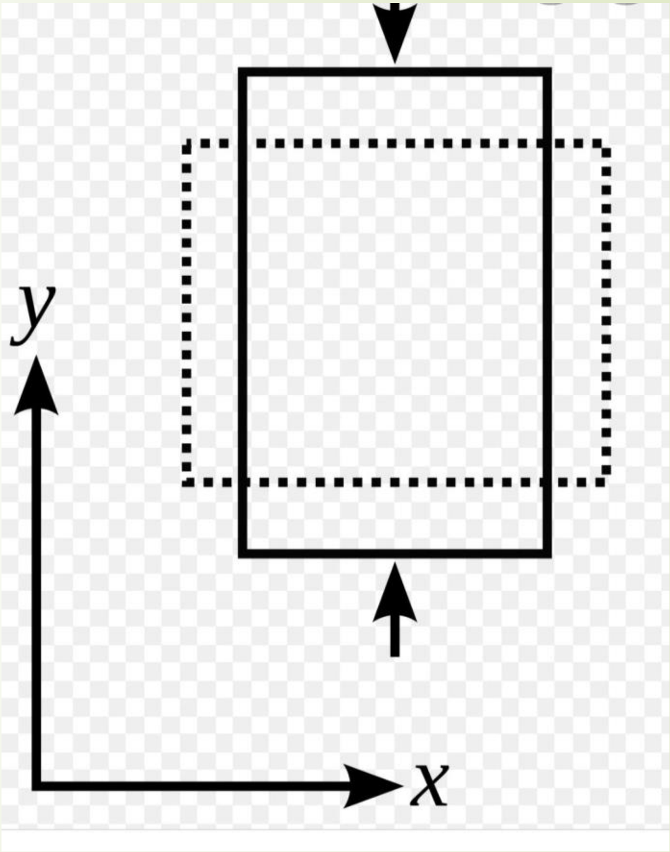
- Young’s modulus is a physical property which doesn’t change between annealed and strain-hardened condition of SS



Role of Poisson's Ratio

Higher Poisson's ratio, more rigid the plate

Poisson's ratio = change in lateral width per unit width to change in axial length per unit length during axial stretching or stressing of material



Poisson's ratio of

- Austenitic – 0.27
- Ferritic – 0.32/0.3
- Duplex – 0.3
- HSLA – 0.26

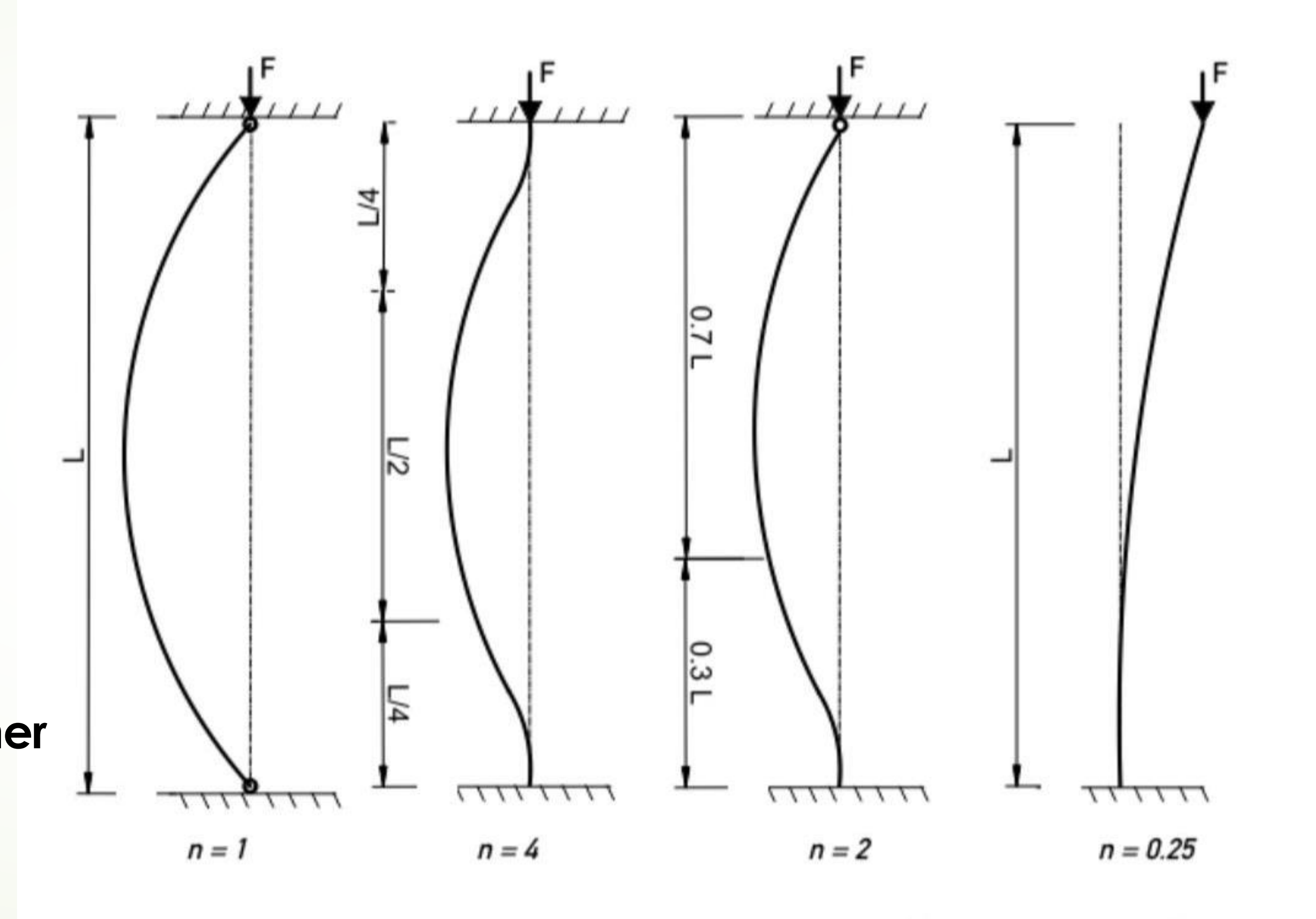
Structural SS should have higher Poisson's ratio

Euler's Formula

Higher column buckling force, better the structure

Euler's formula F = $n\pi^2 EI/L^2$

Higher the E (Elastic modulus) and I (moment of inertia) higher the buckling force



Structural SS should have higher buckling force

Moment of Inertia (I)

- ✓ Measure of object's resistance to changes to its rotation
- ✓ Capacity of cross-section to resist bending
- ✓ Specified with respect to chosen axis of rotation
- ✓ Quantified in kgm^2

SS structure should have high moment of Inertia

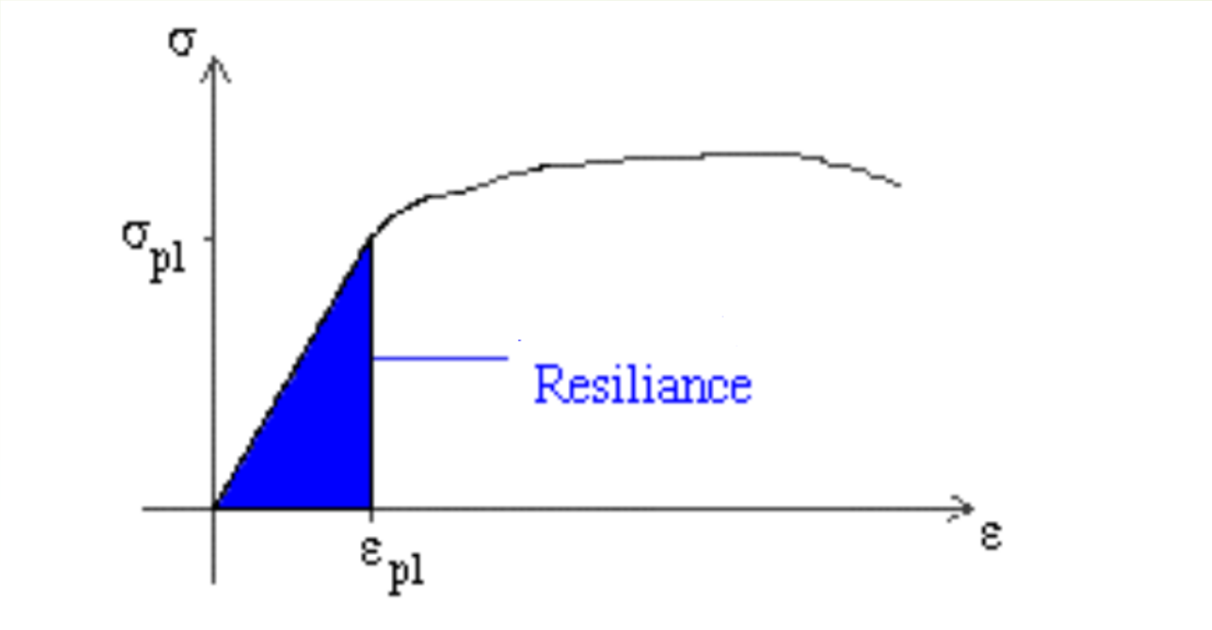
Relationship between Young's modulus and Poisson's ratio

$$\varepsilon_x = \sigma_x / E$$

A material subjected to a uniaxial stress σ_x in x direction will experience a resulting strain ε_x in same direction

Higher the Young's modulus, lesser the strain

Resilience

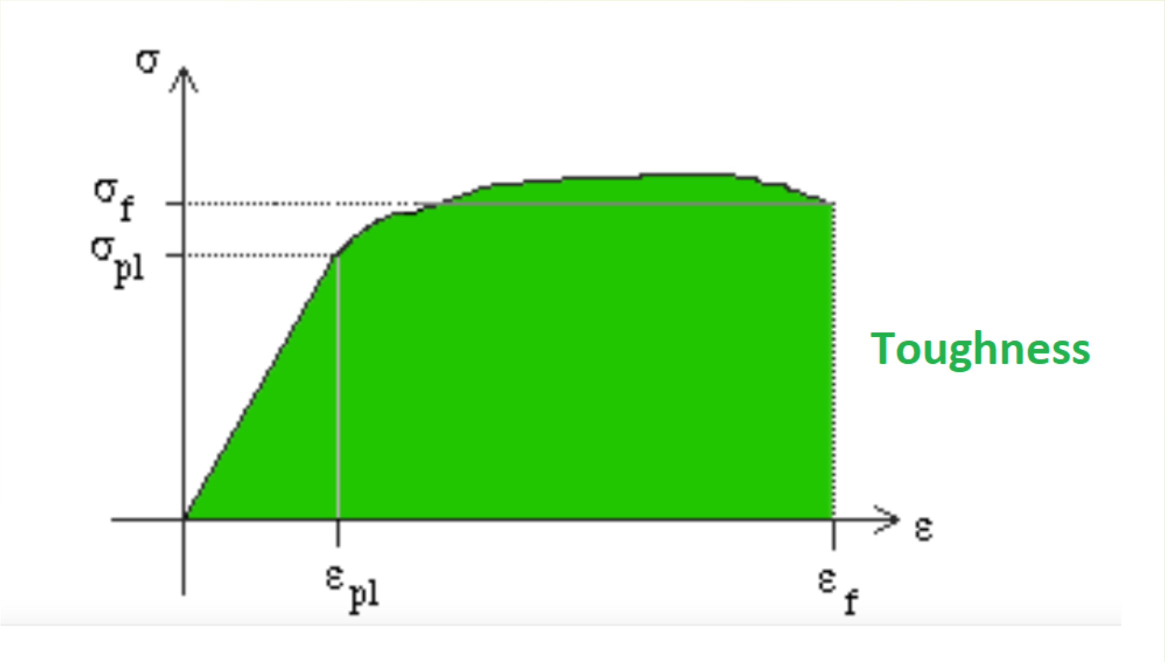


Resilience is the ability to absorb energy when elastically deformed and is released on unloading

Resilience is represented by the area in the stress/strain curve below yield point

Higher the area(YS) better the resilience for given load

Toughness



Toughness is the ability to absorb energy up to point of fracture

Toughness is the area in stress/strain curve below UTS

Higher toughness withstands unforeseen load for longer time
Gap between YS and UTS is proportional to safety

Lean Ferritic SS

	Specified Chemistry %									
	C	Mn	P	S	Si	Cr	Ni	N	Mo	Others
ASTM 1010 UNS S41003	0.03	1.50	0.040	0.030	1.00	10.5-12.5	1.5	0.03	-	-
Durracor (Arcelor)	0.025	1.50	0.040	0.015	0.70	11.0-12.5	1.00	0.03	0.20-0.30	-
Cr^{11+}	?	?	?	?	?	?	?	?	???	???
Cr^{16+}	?	?	?	?	?	?	?	?	???	???

Ferrite Factor – lean ferritic structural SS

$$FF = \%Cr + 6 \times \%Si + 8 \times \%Ti + 4 \times \%Mo + 2 \times \%Al - 2 \times \%Mn - 4 \times \%Ni - 40 \times (\%C + \%N)$$

Ferrite factor should be within 8-13, preferred range being 8-11

Lower limit has small amount of ferrite and is beneficial for easy weldability

Upper limit could be detrimental to strength

Specs for other structural SS

- HSLA

IS 2062-E450

- Duplex

2101 and 2205

IS 6911-2017

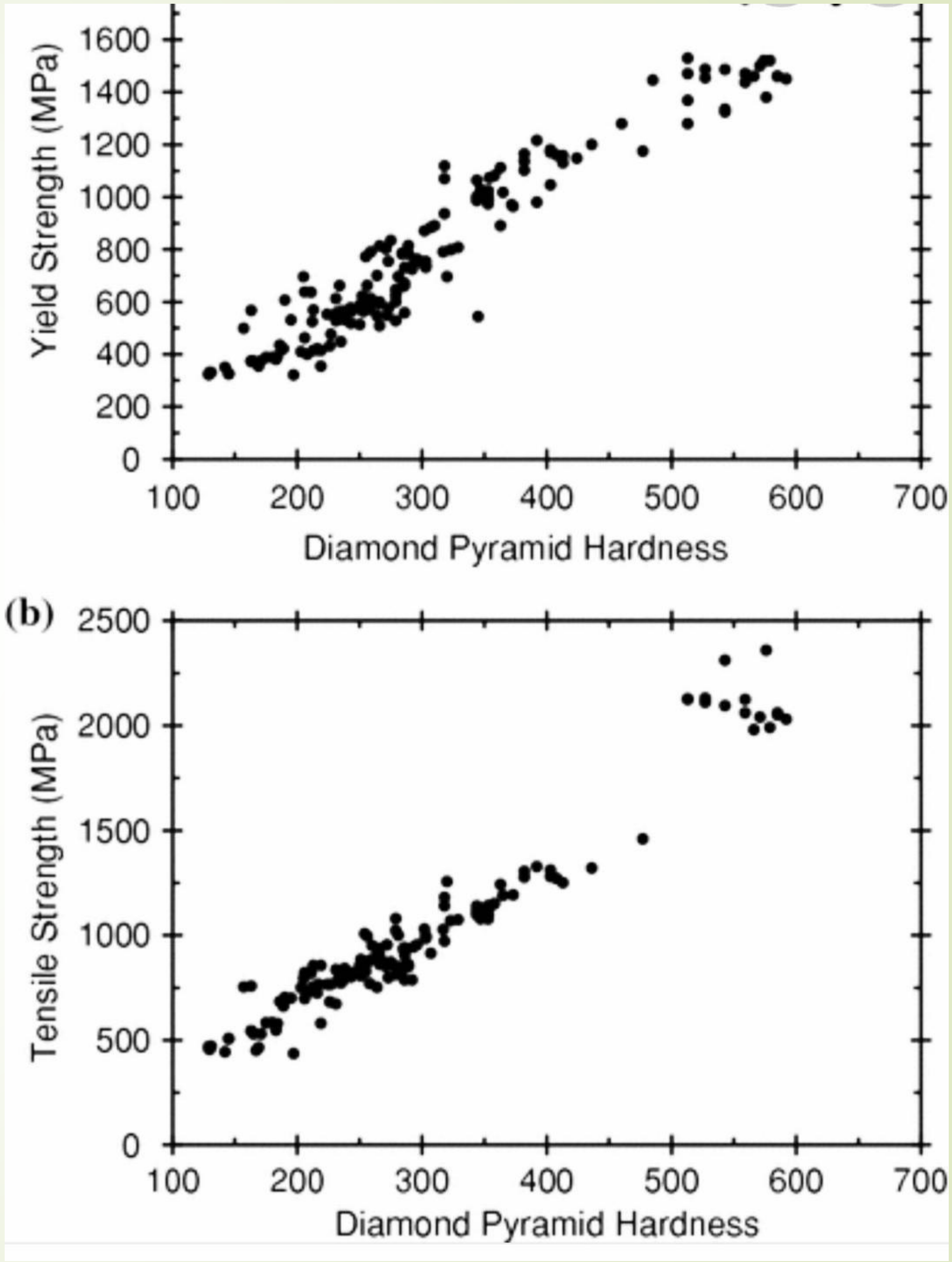
- Austenitic

201L and 301L

IS 6911-2017

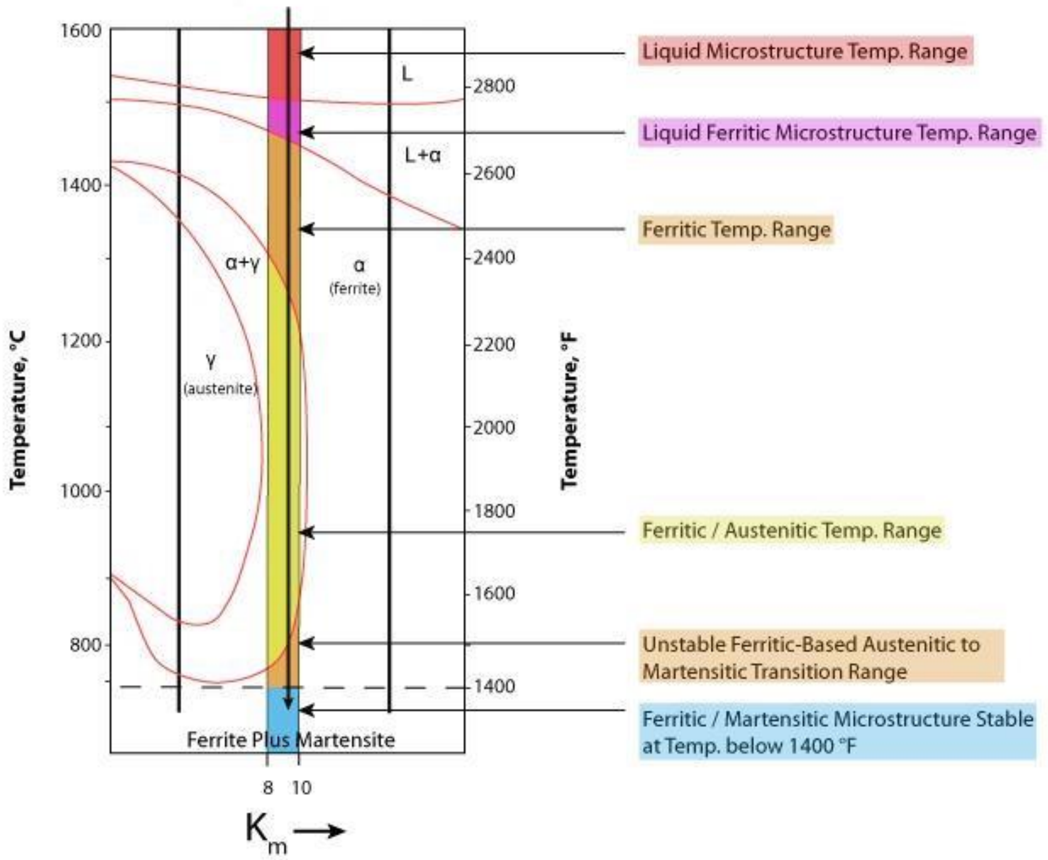
Relation between YS, UTS and Hardness

As strength increases hardness increases



Lean Ferritic SS Processing Guidance

Temperature – Phase diagram



Chemical Balance For Dual Phase Microstructure

For Structural Applications

Cr^{11+} and Cr^{16+} SS grades with high YS are best competitor to HSLA (High strength low alloy Carbon Steel) in terms of cost analysis

Duplex SS and Austenitic SS also offer higher corrosion resistance but at a cost

Developments in Structural Carbon steel

- YS 200 MPa (Carbon steel)
- YS 350 MPa (Copper tensile weather resistant steel)
- YS 400, 500 MPa (High strength, low alloy steel)

High YS ferritic, duplex, austenitic SS have potential in replacing HSLA in many structural applications

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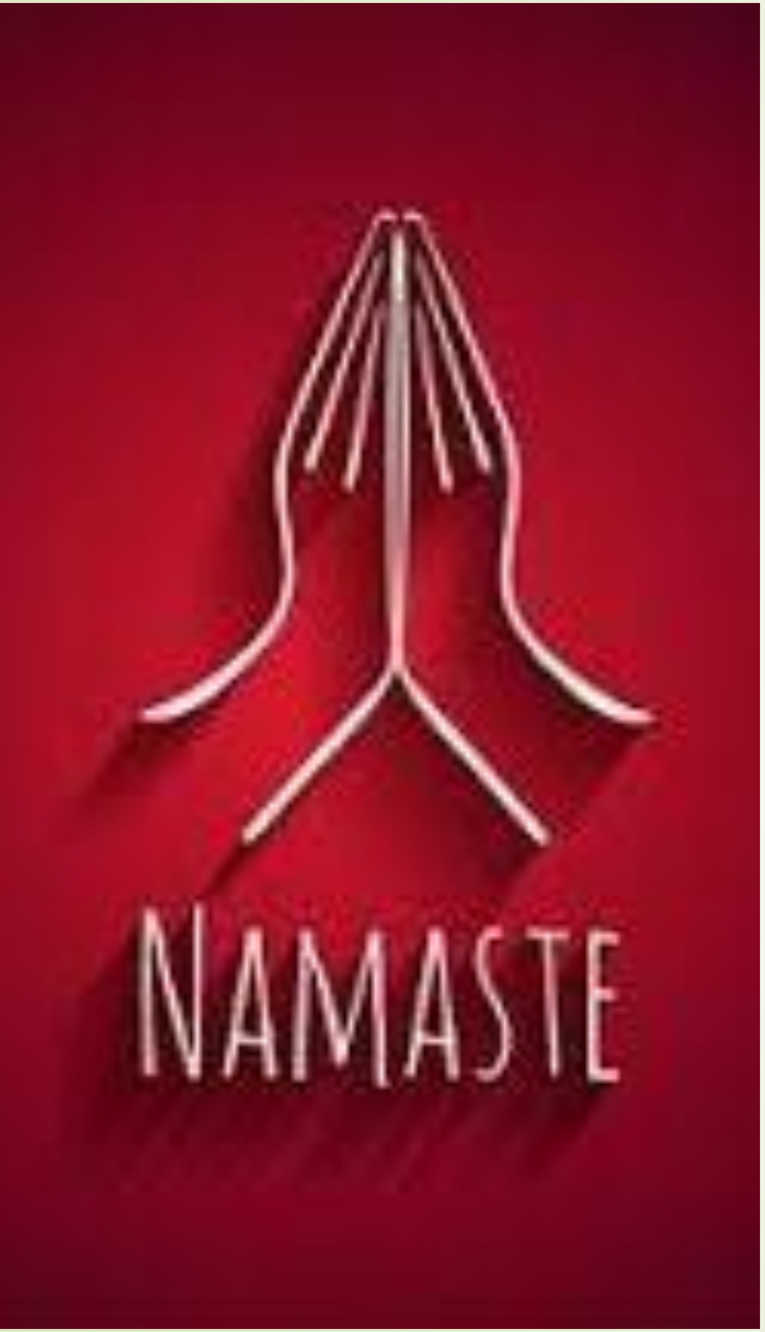
“

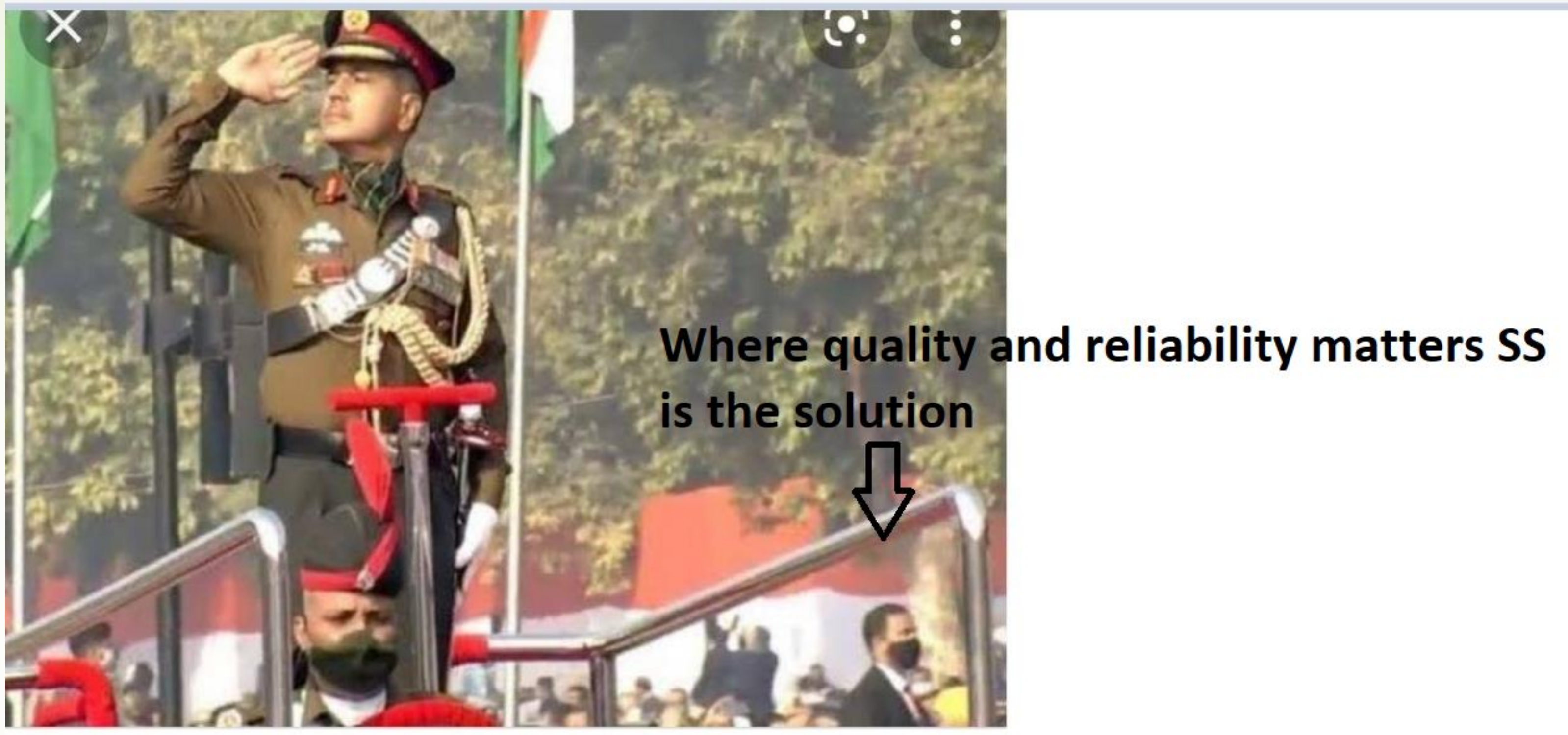
Every accomplishment starts with decision to **TRY**

”

Never Give up

Be a lion – kill and eat; Not a vulture – eating the dead





Thank you for being with me