CE 415: Design of Steel Structures

Course Teacher: Sinha Lamia Sultana (SLS)

Tension Members :
Residual Stress

RESIDUAL STRESS IN STEEL SECTIONS

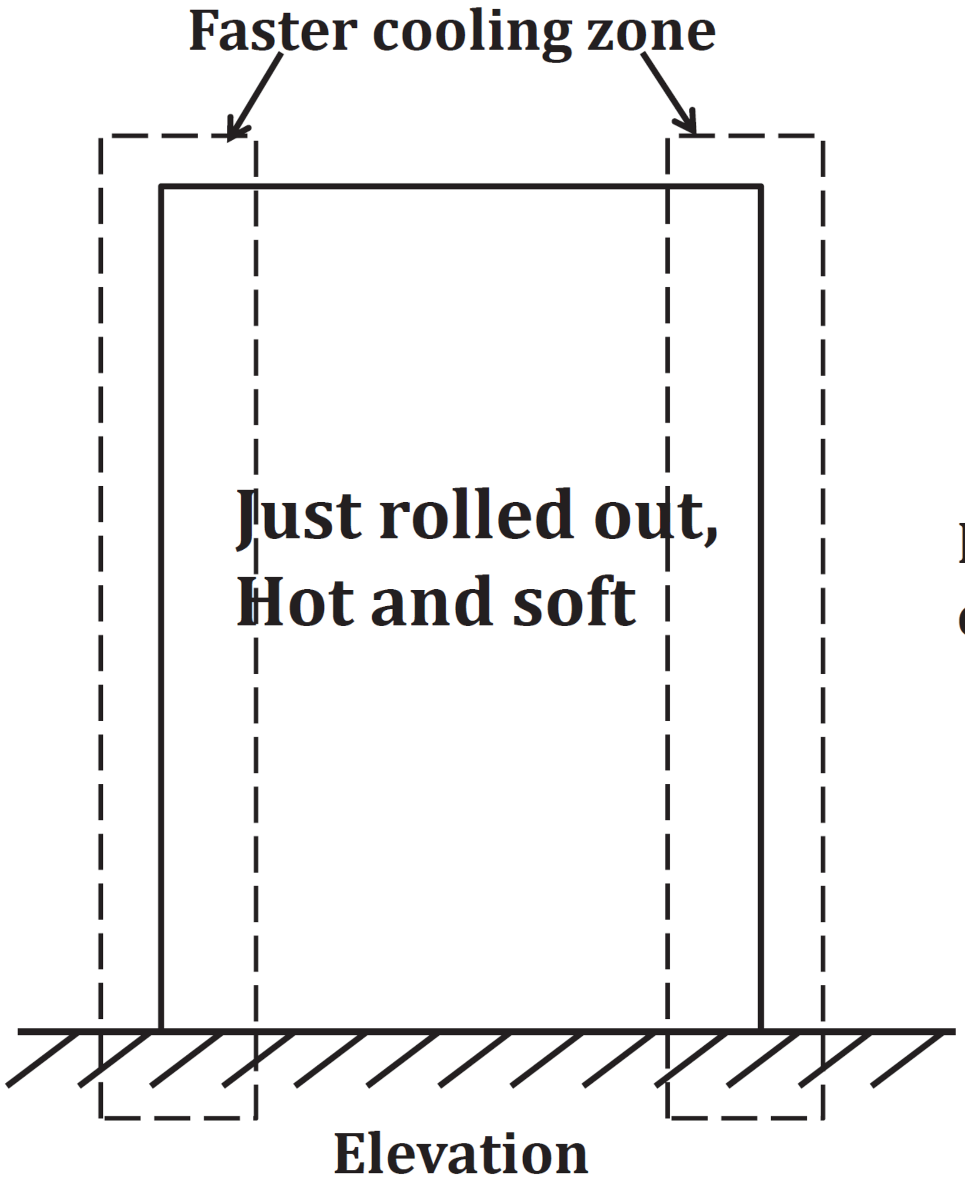
Residual stresses are self balancing stresses that remain in a member without application of load after it has been formed/rolled into a finished product.

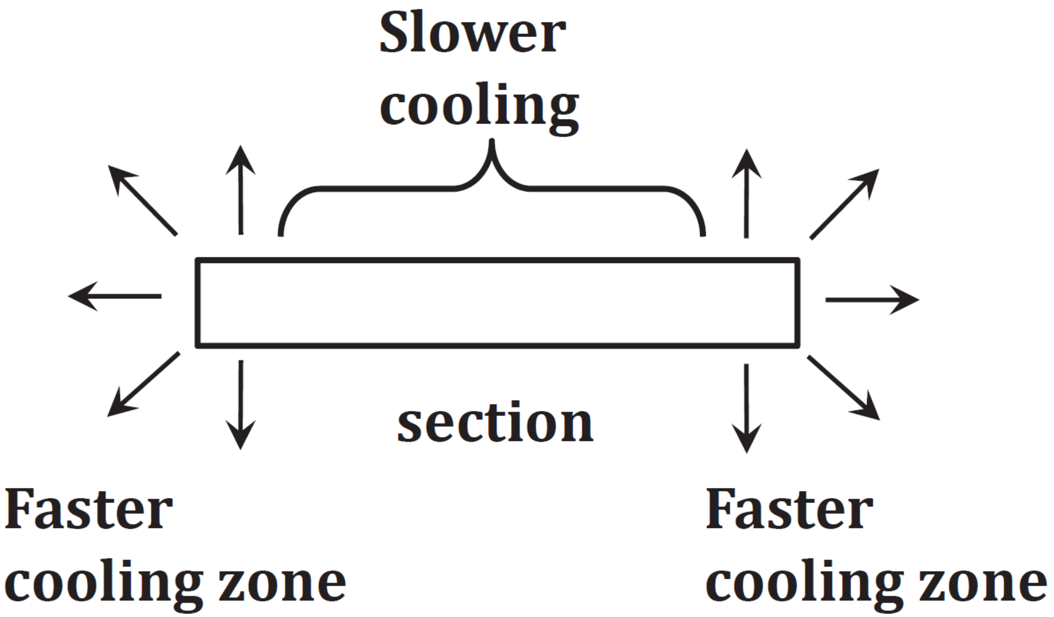
Sources of residual stresses:

- ❑ Uneven cooling which occurs after hot rolling of structural shapes
- ❑ Cold bending or cambering during fabrication
- ❑ Punching of holes and cutting operations during fabrication
- ❑ Welding

Under ordinary conditions those residual stresses resulting from uneven cooling and welding are the most important.
In wide-flange or H-shaped sections, after hot rolling, the flanges, being the thicker parts, cool more slowly than the web region. Furthermore, the flange tips having greater exposure to the air cool more rapidly than the region at the junction of flange to web. Consequently, compressive residual stress exists at flange tips and at mid-depth of the web (the regions that cool fastest), while tensile residual stress exists in the flange and the web at the regions where they join.

RESIDUAL STRESS IN ROLLED FLAT BAR

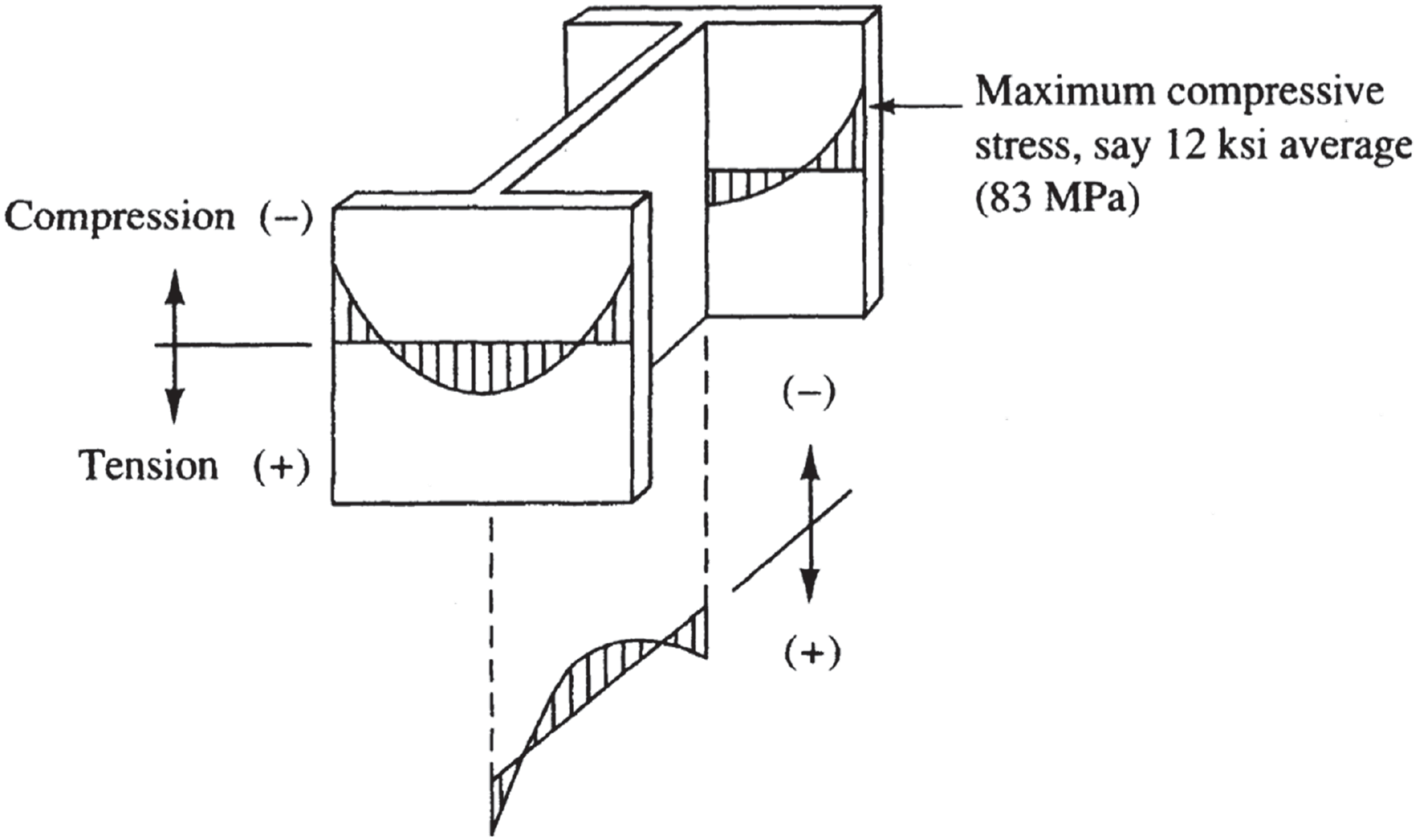




Two edges of the flat bar shall cool down faster due to radiation of heat in three directions. The middle part shall cool slower due to radiation in two direction only.

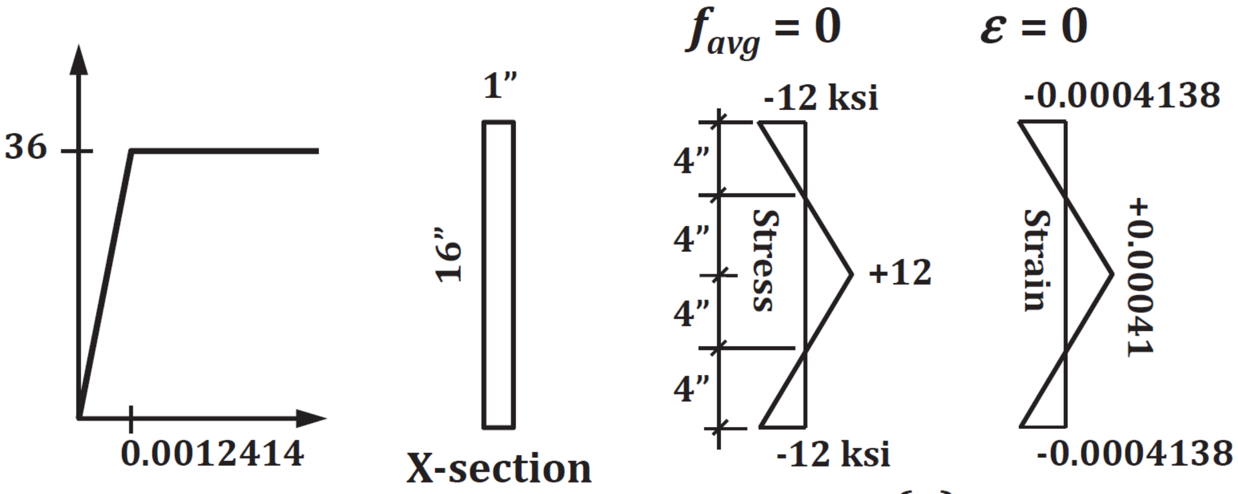
RESIDUAL STRESS IN ROLLED SECTIONS

Typical residual stress distribution in rolled shapes

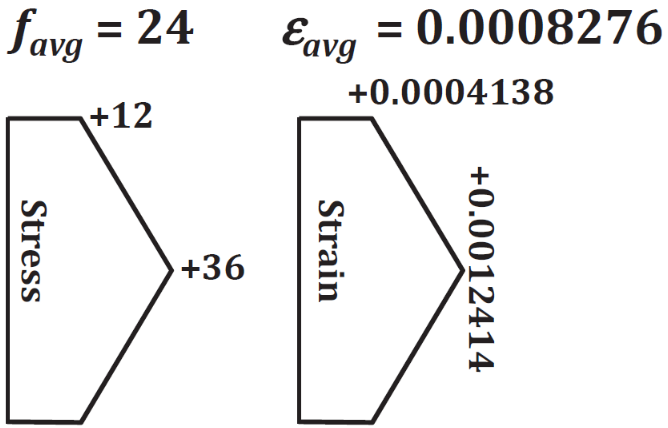


Average tensile stress-strain relation of a 16"x1" x-section flat bar having residual stress.

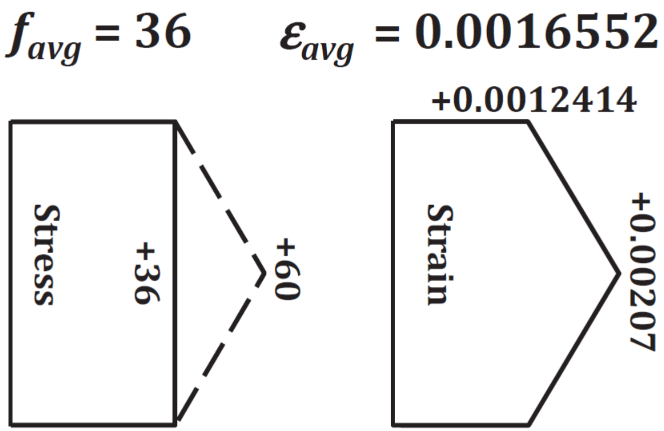
Distribution of residual stress and stain are shown in Fig. (A) when no external force acts. The bar is then gradually pulled.



(a)



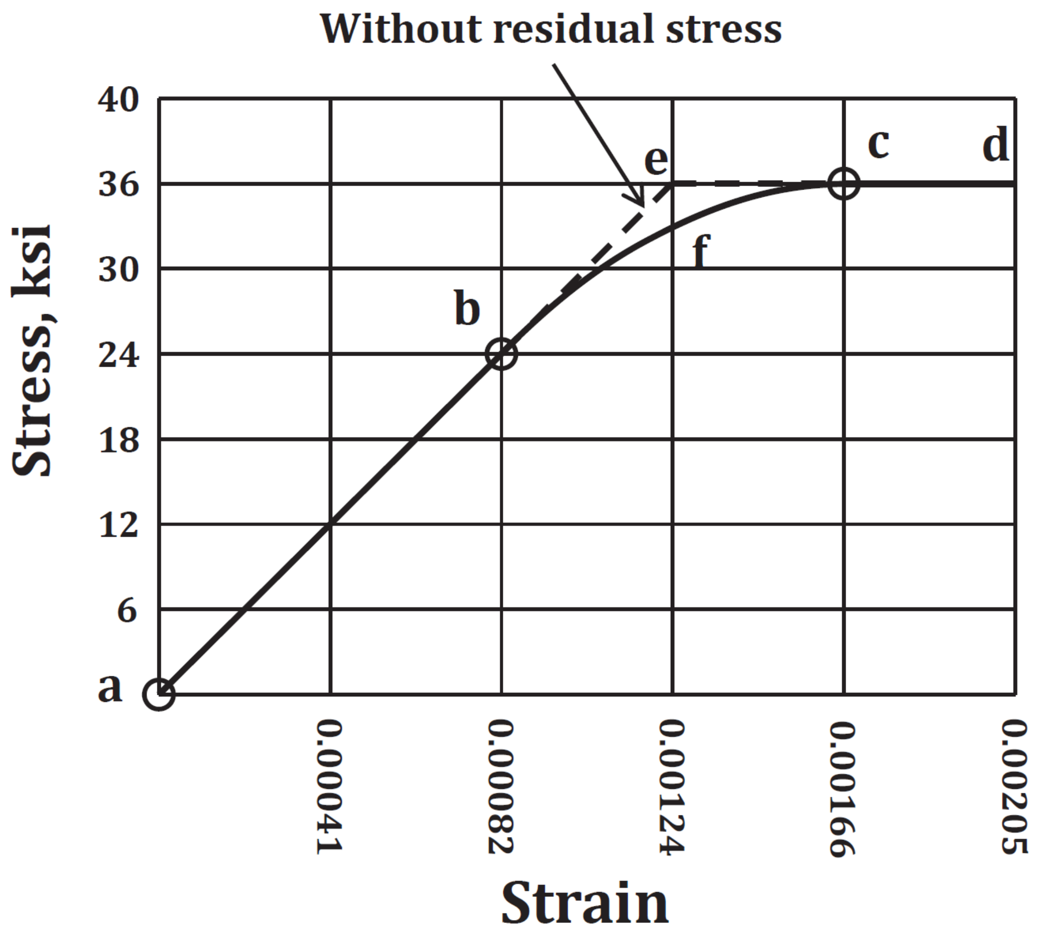
(b)



(c)

RESIDUAL STRESS IN STEEL SECTIONS

Average tensile stress-strain relation of a 16”x1” x-section flat bar having residual stress.



Due to presence of residual stress/strain the average stress-strain behavior follows path a-b-f-c-d

If there was no residual stress then the path would be a-b-e-c-d

Equation of Stress-Strain Curve:

Up to point b, the stress-strain relation is linear. After c, the curve is flat. The transition from b to c can be covered by one parabolic curve as follows:

$f = k_1\varepsilon^2 + k_2\varepsilon + k_3$ Here, f is stress and ε is strain.

The constants k_1, k_2 and k_3 can be found from three conditions:

1) At b, $df/d\varepsilon = E = 29000$, when $\varepsilon = 0.0008276$ where E is the Young's modulus.
2) At b, $f = 24$ when $\varepsilon = 0.0008276$
3) At c, $f = 36$ when $\varepsilon = 0.0016552$

Now, $df/d\varepsilon = 2k_1\varepsilon + k_2$, ∴ from (1), $2k_1(0.0008276) + k_2 = 29000$ ----(1)

From (2), $k_1(0.0008276)^2 + k_2(0.0008276) + k_3 = 24.0$ -----(2)

From (3), $k_1(0.0016552)^2 + k_2(0.0016552) + k_3 = 36.0$ ------(3)

Solving the above three,

$k_1 = -17520833.3$, $k_2 = +58000.48$, $k_3 = -12$

Therefore,

$f = +29000\varepsilon$ for $0 \le \varepsilon \le 0.008276$ [portion a-b]

$f = -17520833.3\varepsilon^2 + 58000.48\varepsilon - 12$ for $0.008276 \le \varepsilon \le 0.0016552$ [portion b-f-c]

$f = +36$ for $\varepsilon \ge 0.0016552$

Check: ideally at c, $df/d\varepsilon = 0$

Check at e, $df/d\varepsilon = 2(-17520833.3)(0.0016552) + 58000.48$

$= -0.49 \rightarrow$ very small compared to $E = 29000 \rightarrow$ OK.