In the name of God

Director of the course

Mohammad Javad Ashrafi

University of Golpayegan
Mechanical Engineering

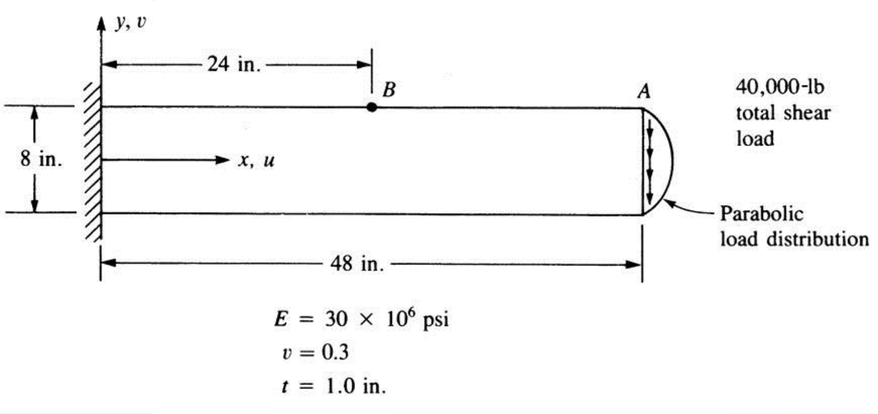
Practical considerations in FEM modeling

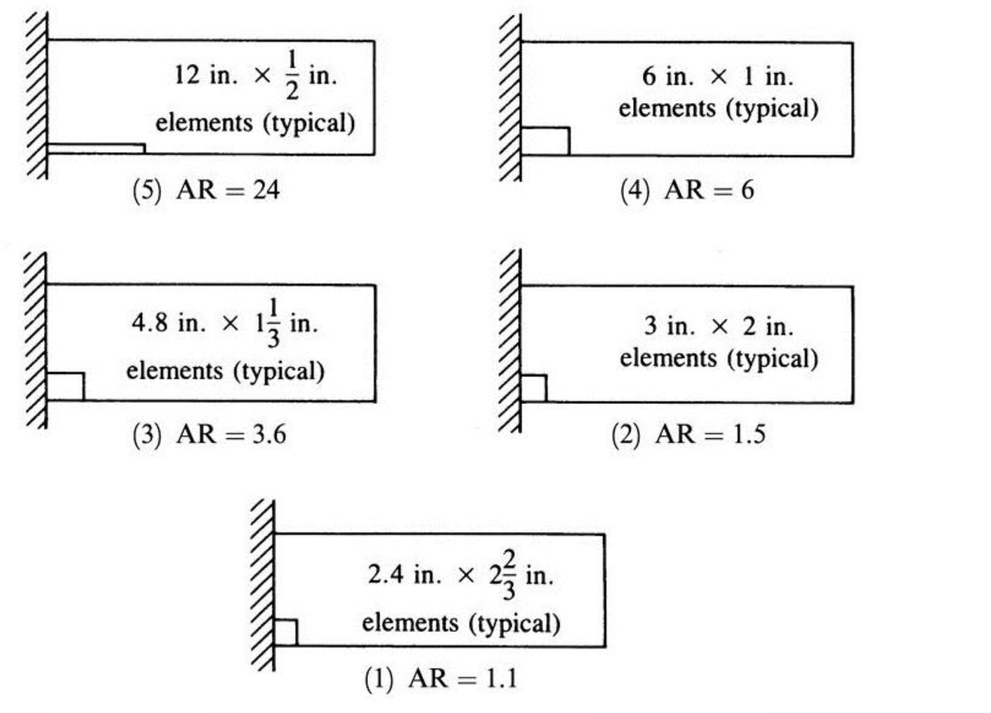
Outline

- Aspect ratio and element shapes
- Use of symmetry
- Natural subdivisions at discontinuities
- Stress equilibrium and compatibility in FEM solutions

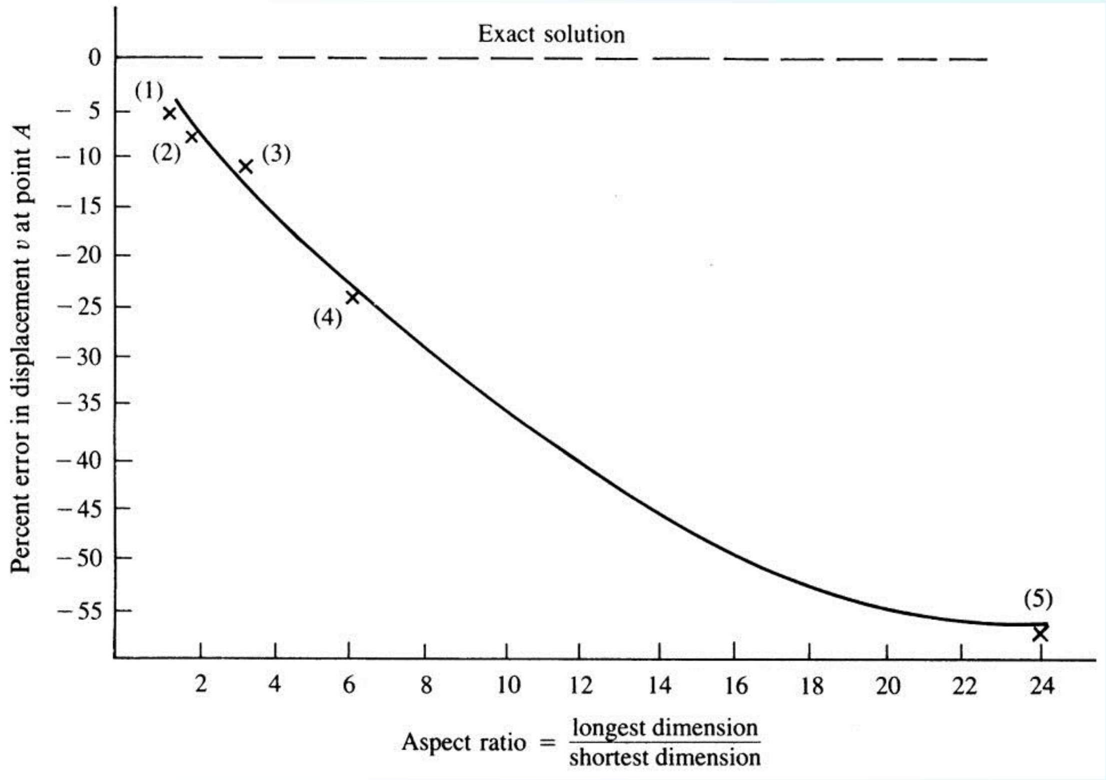
Aspect ratio and element shapes

- **Aspect ratio =** longest dimension/ shortest dimension
- **Beam with loading**: effects of the aspect ratio (AR) illustrated by the five cases with different aspect ratios





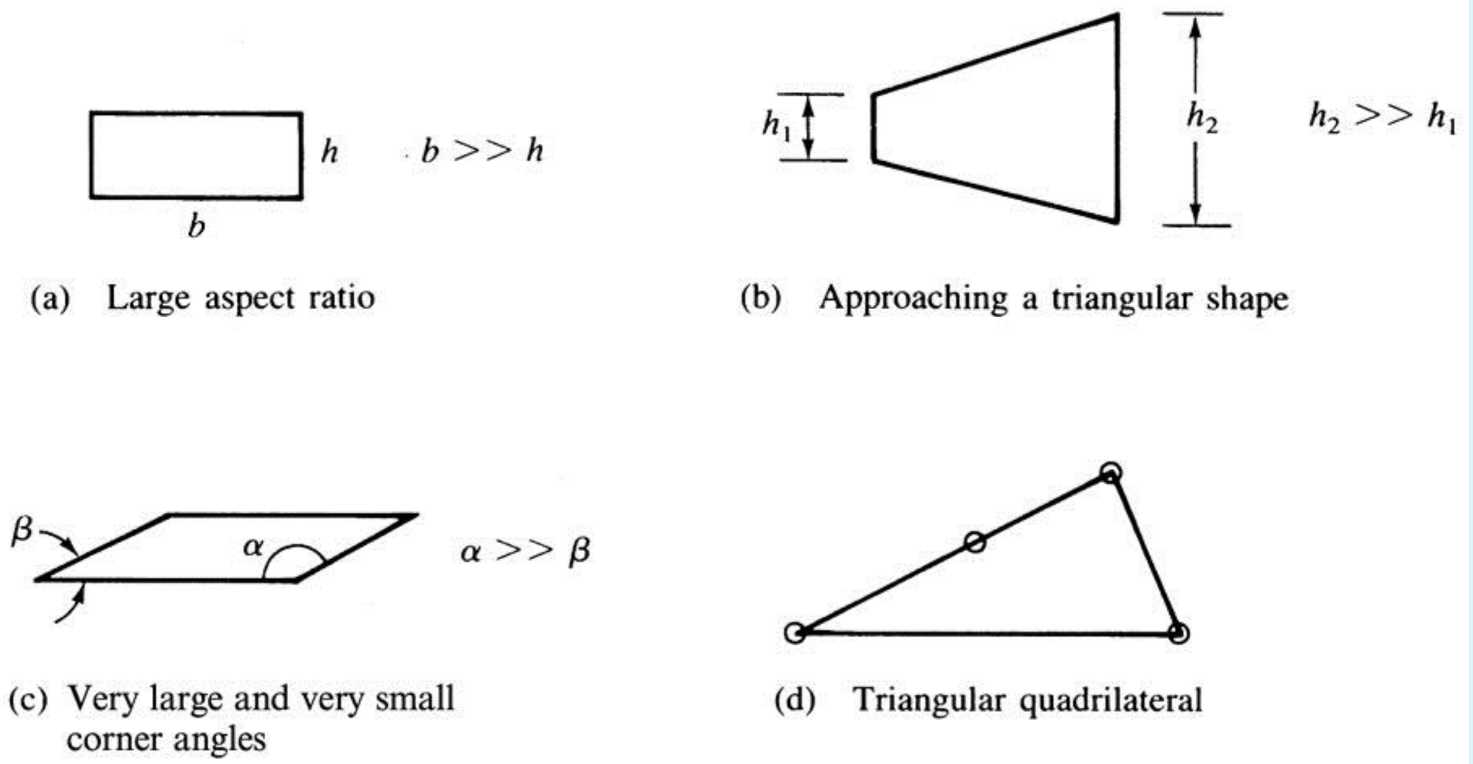
- Inaccuracy of solution as a function of the aspect ratio



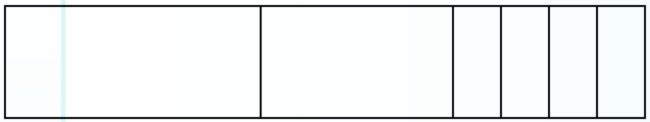
- Comparison of results for various aspect ratios

Case	Aspect Ratio	Number of Nodes	Number of Elements	Vertical Displacement, v (in.) Point A	Point B	Percent Error in Displacement at A
1	1.1	84	60	−1.093	−0.346	5.2
2	1.5	85	64	−1.078	−0.339	6.4
3	3.6	77	60	−1.014	−0.328	11.9
4	6.0	81	64	−0.886	−0.280	23.0
5	24.0	85	64	−0.500	−0.158	56.0
Exact solution [2]				−1.152	−0.360	

- Elements with poor shapes



- Avoid abrupt changes in element sizes

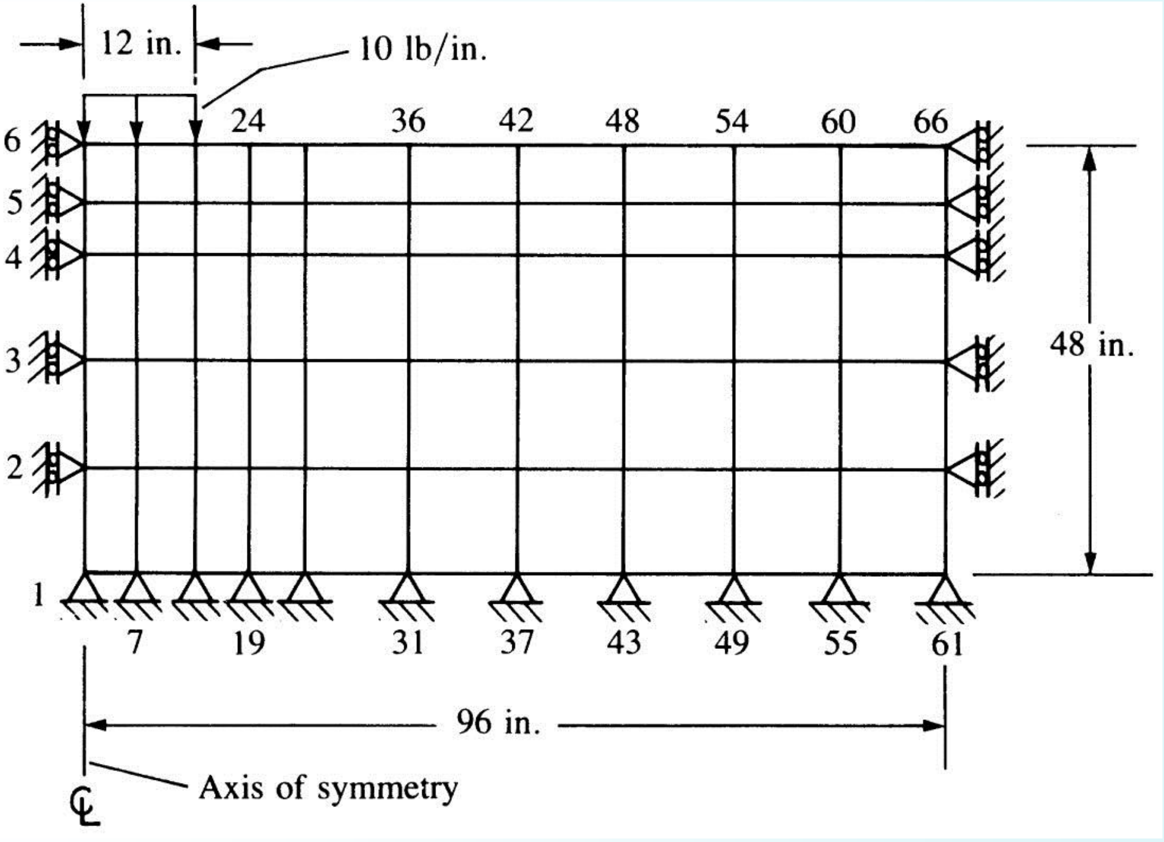


Abrupt change in element size

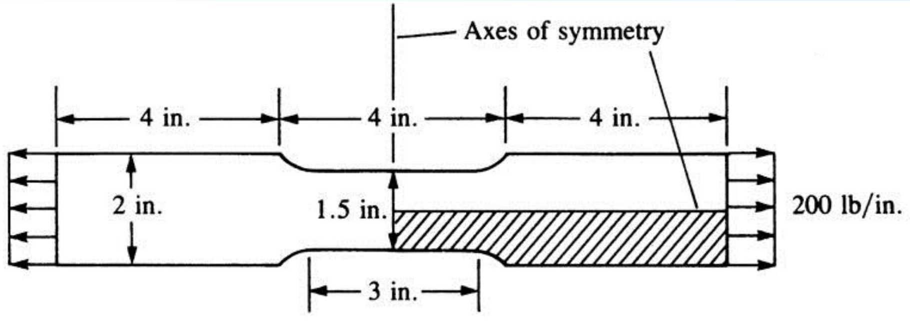
Gradual change in element size

Use of symmetry in modeling

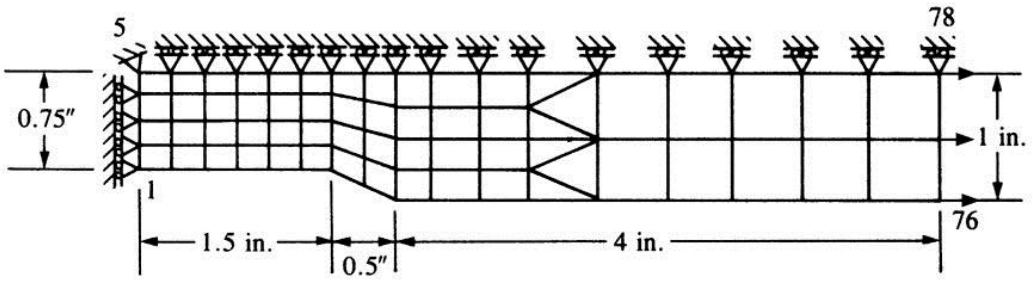
- A soil mass subjected to foundation loading



- A uniaxially loaded member with a fillet

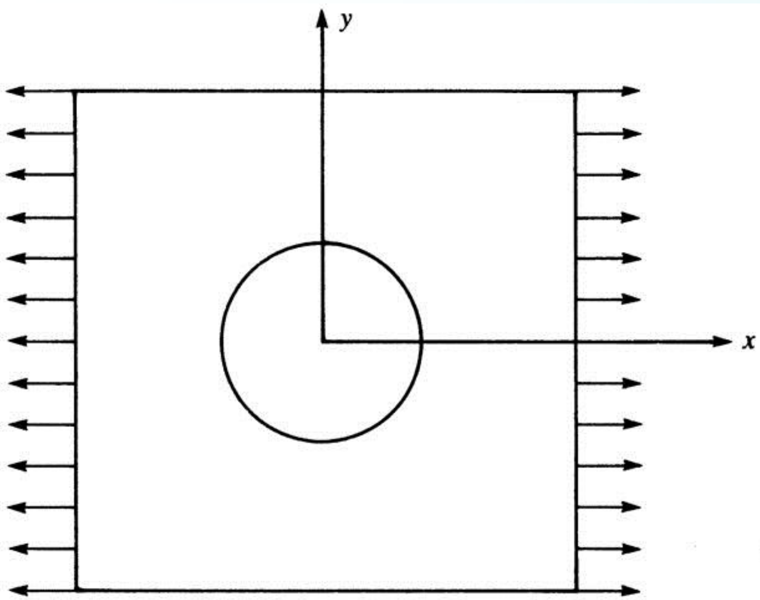


(a) Plane stress uniaxially loaded member with fillet

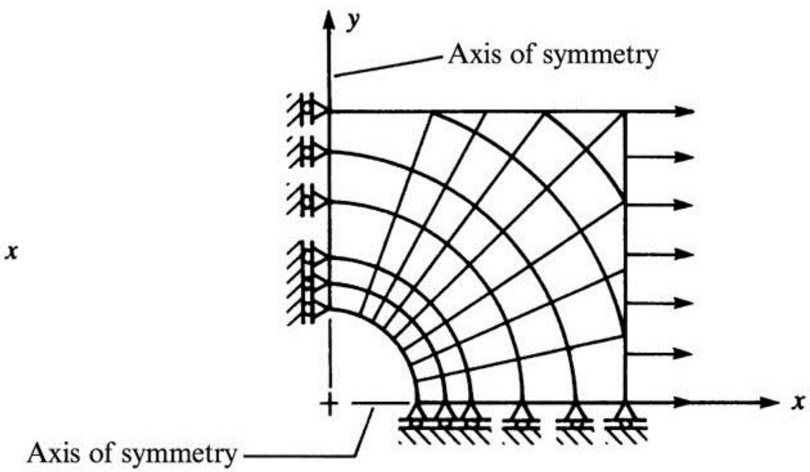


(b) Enlarged finite element model of the cross-hatched quarter of the member (number of nodes = 78, number of elements = 60) (2.54 cm = 1 in.)

- A plate with a hole subjected to tensile force

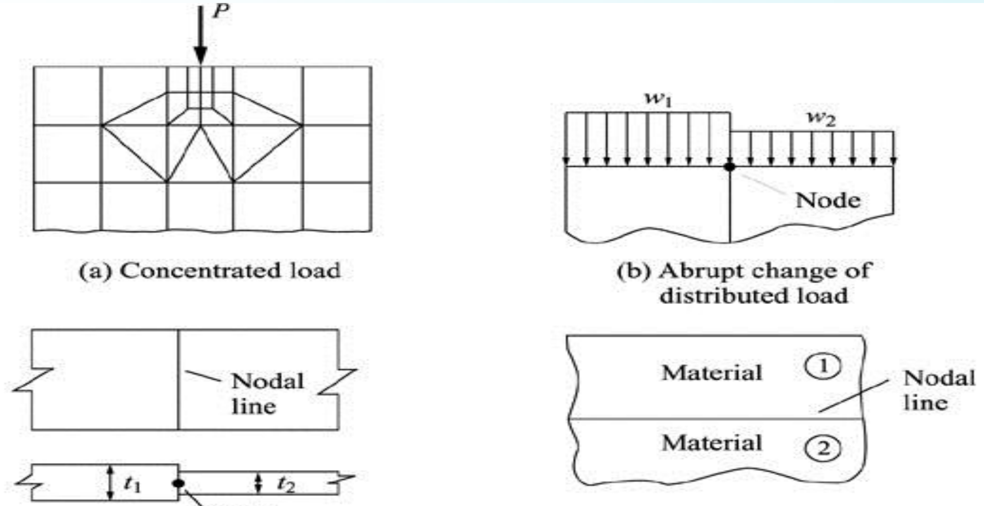


(a) Plate with hole under plane stress



(b) Finite element model of one-quarter of the plate

Natural subdivisions at discontinuities



(a) Concentrated load

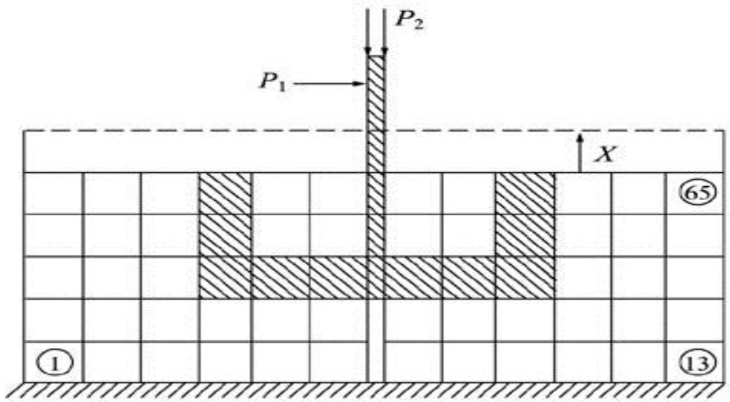
(b) Abrupt change of distributed load

(c) Abrupt change of plate thickness

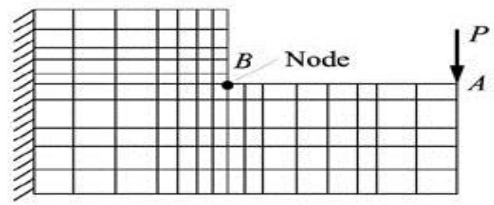
(d) Abrupt change of material properties

Natural subdivisions at discontinuities

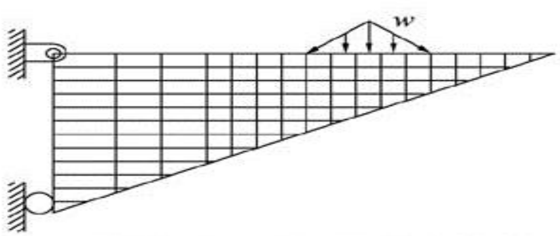
University of Golpayegan
Mechanical Engineering



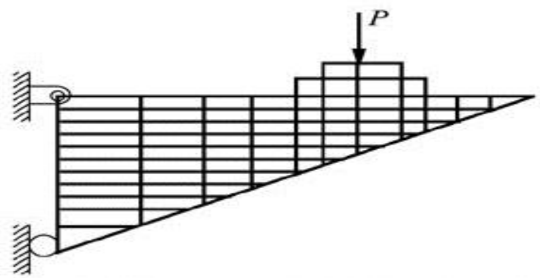
(e) Basic model of an implant (cross-hatched) in bone, located at various depths X beneath the bony surface, using rectangular elements



(f) Re-entrant corner, B



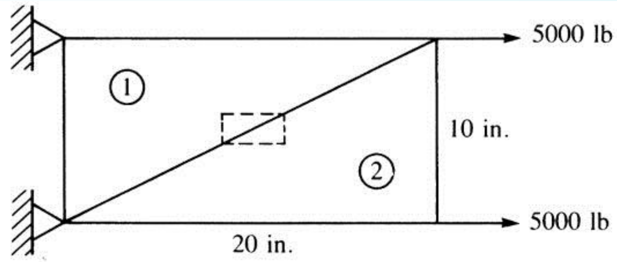
(g) Structure with a distributed load



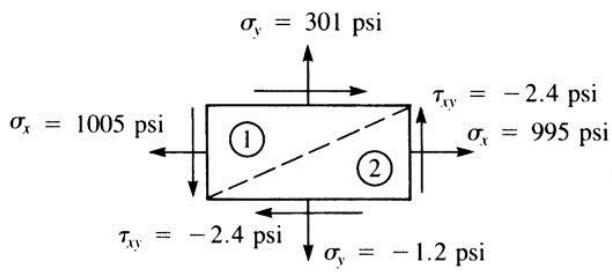
(h) Using elements to distribute the loading and spread the concentrated load

Equilibrium and Compatibility

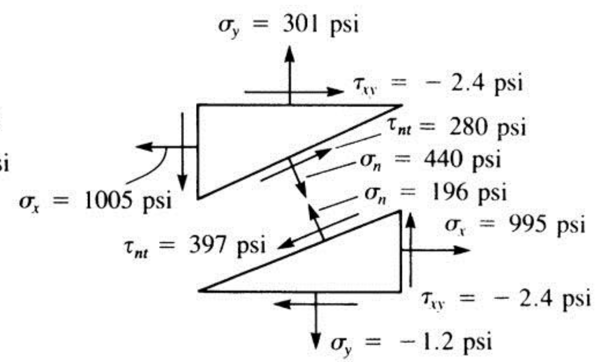
- Equilibrium of nodal forces and moments is satisfied.
- Equilibrium within an element is not always satisfied.
  - For CSB and CST and Beam elements is satisfied.
  - For LST, Rectangular and Axisymmetric elements is not satisfied.
- Equilibrium is not usually satisfied between elements.



Example 6.2



Stresses on a differential element common to both finite elements, illustrating violation of equilibrium



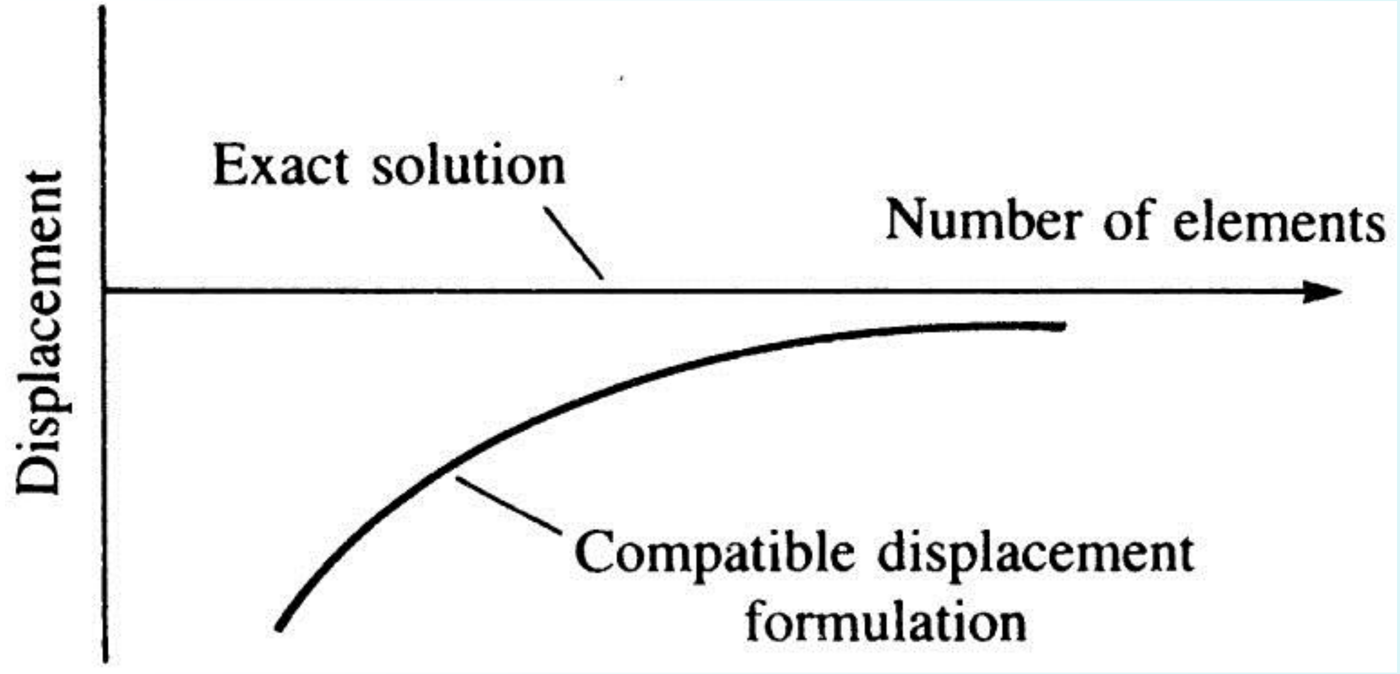
Stress along the diagonal between elements, showing normal and shear stresses, σ_n and τ_{nt}. *Note:* σ_n and τ_{nt} are not equal in magnitude but are opposite in sign for the two elements, and so interelement equilibrium is not satisfied

illustrating violation of equilibrium of a differential element and along the diagonal edge between two elements

Equilibrium and Compatibility

- Compatibility is satisfied within an element as long as the element displacement field is continuous
- Compatibility may or may not be satisfied along interelement boundaries.
  - For line elements such as bars and beams, interelement boundaries are merely nodes.
  - CST and Rectangular elements remain straight-sided an are compatible at the boundary.

Convergence of solution



Convergence of a finite element solution based on the compatible displacement formulation

Convergence of solution

Case	Number of Nodes	Number of Elements	Aspect Ratio	Vertical Displacement, v (in.) Point A
1	21	12	2	−0.740
2	39	24	1	−0.980
3	45	32	3	−0.875
4	85	64	1.5	−1.078
5	105	80	1.2	−1.100
Exact solution [2]				−1.152

Excercise

- 7.1
- 7.7