1.054/1.541 Mechanics and Design of Concrete Structures (3-0-9)

Outline 9

Beam Column Joints

- Importance of joint behavior
  - Weak link theory
  - Deterioration mechanisms
  - Detailing

- Monolithic beam-column joints
  - In the design with the philosophy of limit states it is seen that joints are often weakest links in a structural system.
  - The knowledge of joint behavior and of existing detailing practice is in need of much improvement.
  - Joint behavior is especially critical for structures subject to earthquake effects.
  - The shear forces developed as a result of such an excitation should be safely transferred through joints. The R/C system should be designed as a "ductile system".

- Design of joints
  - Joint types

    Type I – Static loading

    → strength important

    → ductility secondary

    Type II – Earthquake and blast loading

    → ductility + strength

    → inelastic range of deformation

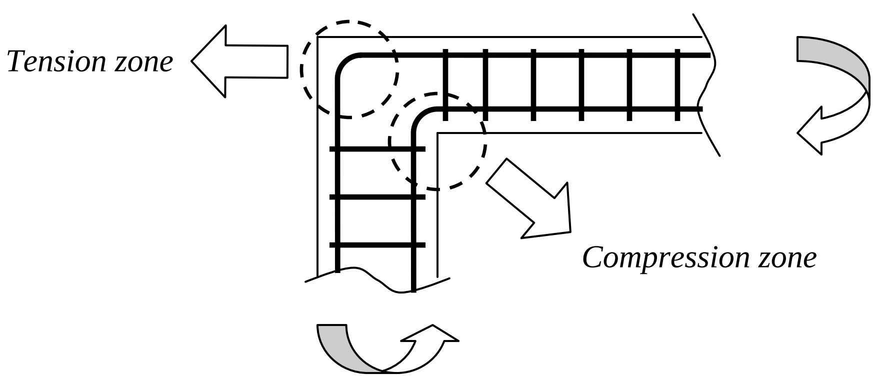
→ stress reversal

- Joints should exhibit a service load performance equal to that of the members it joins.
- Joints should possess strength at least equal to that of the members it joins (sometimes several times more).
- Philosophy: Members fail first, then joints.
  → The joint strength and behavior should not govern the strength of the structure.
- Detailing and constructability.

Behavior of joints

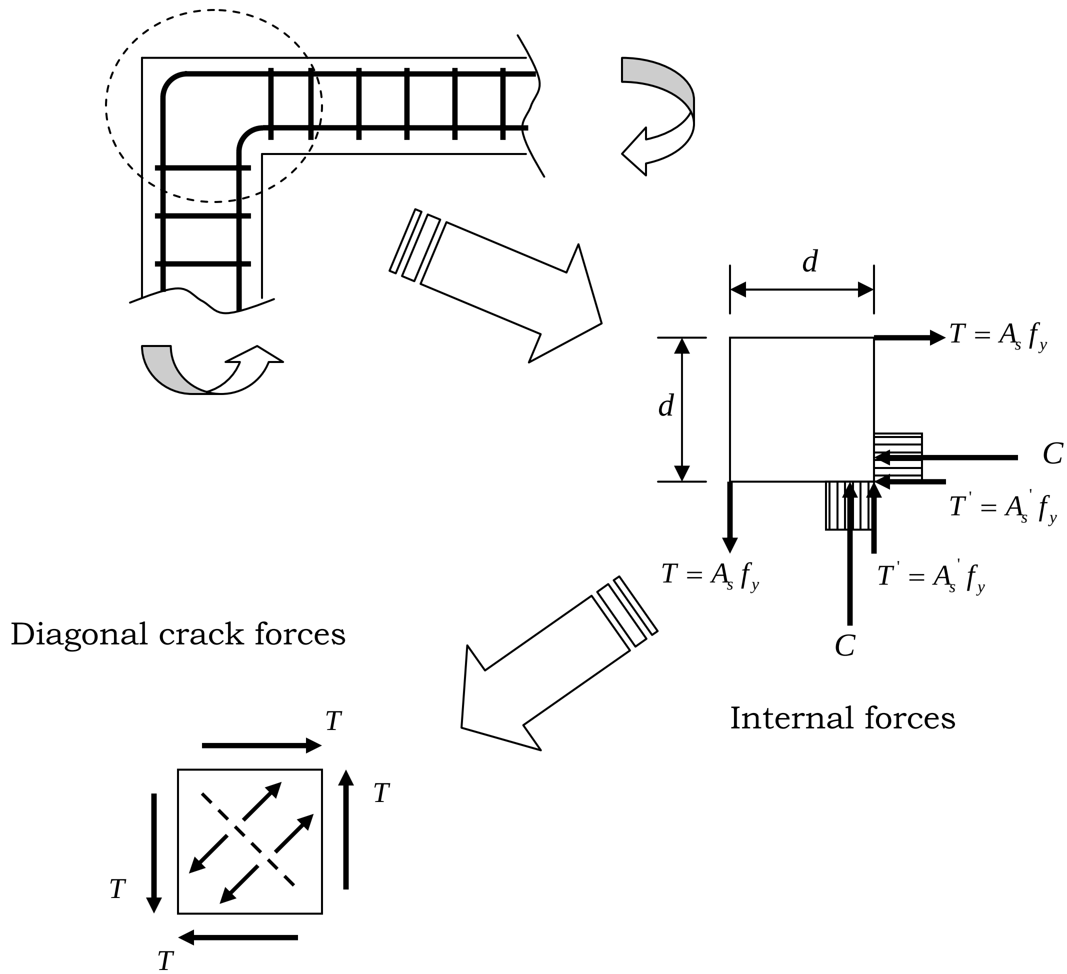
- Knee joint
  - Typical example of a portal frame. The internal forces generated at such a knee joint may cause failure with the joint before the strength of the beam or column.
  - Even if the members meet at an angle, continuity in behavior is necessary.

- Corner joints under closing loads
  - Biaxial compression: $\varepsilon_u > 0.003$



  - Full strength of the bars can be developed if there is no bond failure.

- Joint core



$$f_t' = \frac{T}{bd} = \frac{A_s f_y}{bd} = \rho f_y \cong 6\sqrt{f_c'}$$

The joint strength:

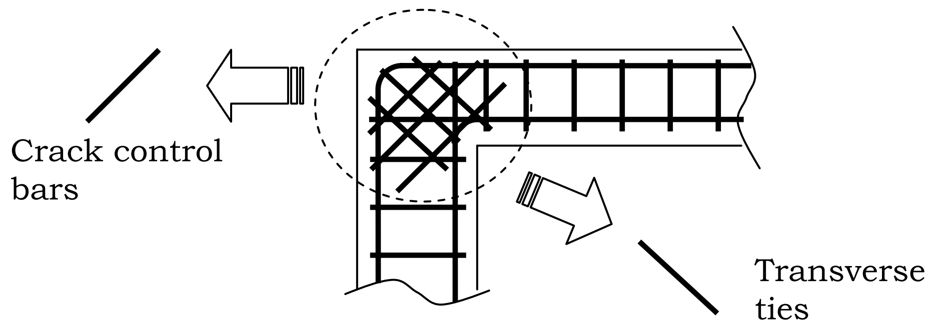
$$f_t' > \rho f_y \rightarrow \rho \le \frac{f_t'}{f_y} \cong \frac{6\sqrt{f_c'}}{f_y}$$

- Factors influencing joint strength
  1. Tension steel is continuous around the corner (i.e., not lapped within the joint).
  2. The tension bars are bent to a sufficient radius to prevent bearing or splitting failure under the bars.

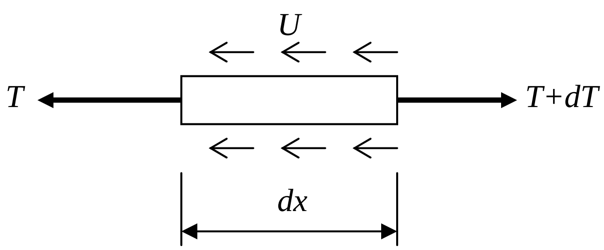
3. The amount of reinforcement is limited to

$$\rho \leq \frac{6\sqrt{f_c^{'}}}{f_y}$$

4. Relative size will affect strength and detailing for practical reasons.



5. Bond force

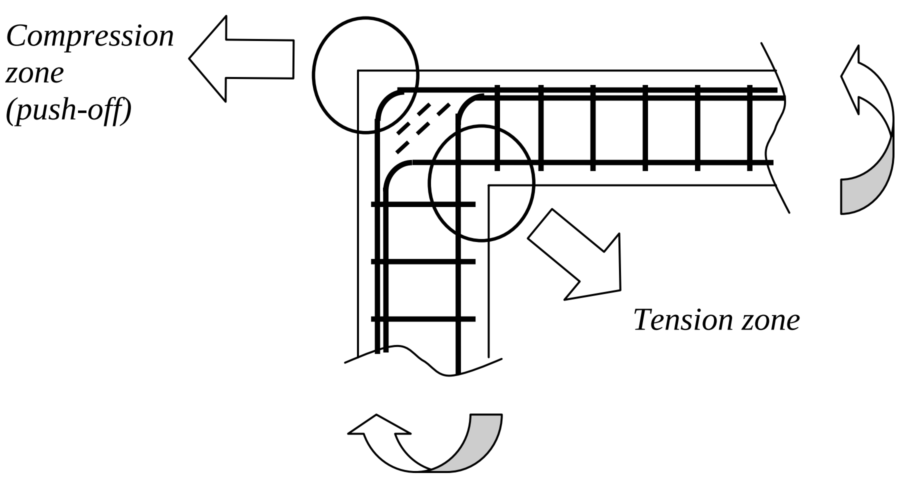


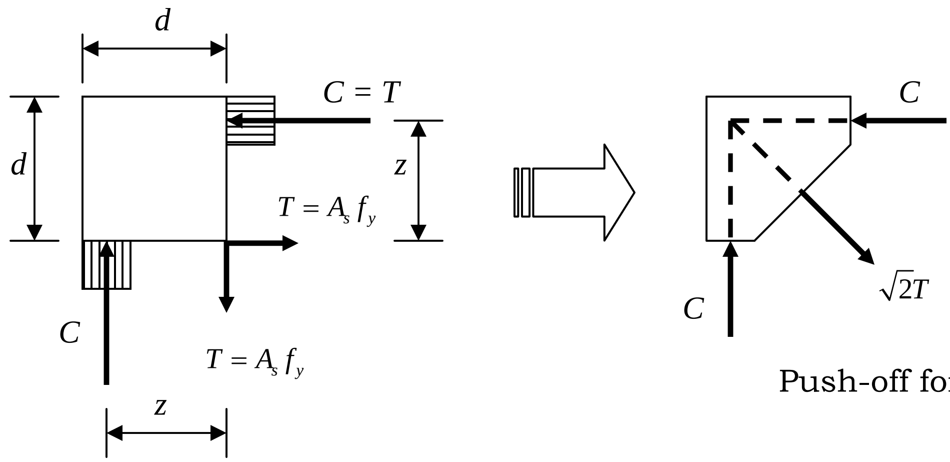
$$\Rightarrow U = \frac{dT}{dx}$$

6. Full bond strength needs to be developed to transfer shear forces into the concrete core.

- Corner joints under opening loads

  → When subjected to opening moments the joint effects are more severe.





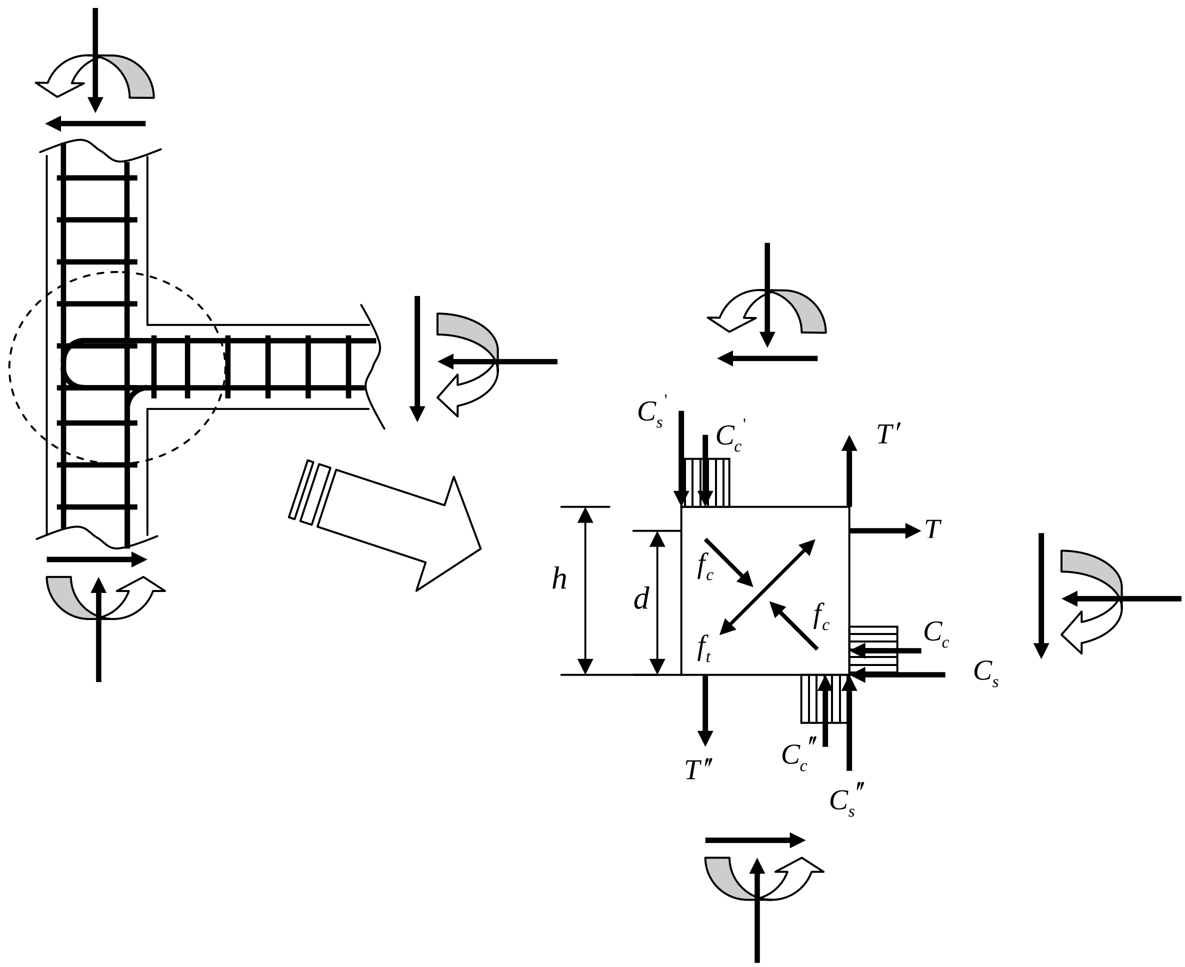
Internal forces

Push-off force

- Behavior under seismic loading
  → Concrete with joint cracks due to cycling.
  → Degradation of bond strength.
  → Flexural bars should be anchored carefully.
  → No benefit should be expected from axial loads.
  → Rely on ties within the joint.
  → Effects from both opening and closing should be considered.
  → An orthogonal mesh of reinforcing bars would be efficient.

o Corner joints under cyclic loads
  → When subjected to cyclic loading (opening moment), one should consider the interaction between tension and compression zones.

o Exterior joints
  - Exterior joints of multistory plane frames
    → Issues:
      a. Bond performance as affected by the state of the concrete around anchorage.
      b. Transmission of compression and shearing forces though the joint when the joint core cracks



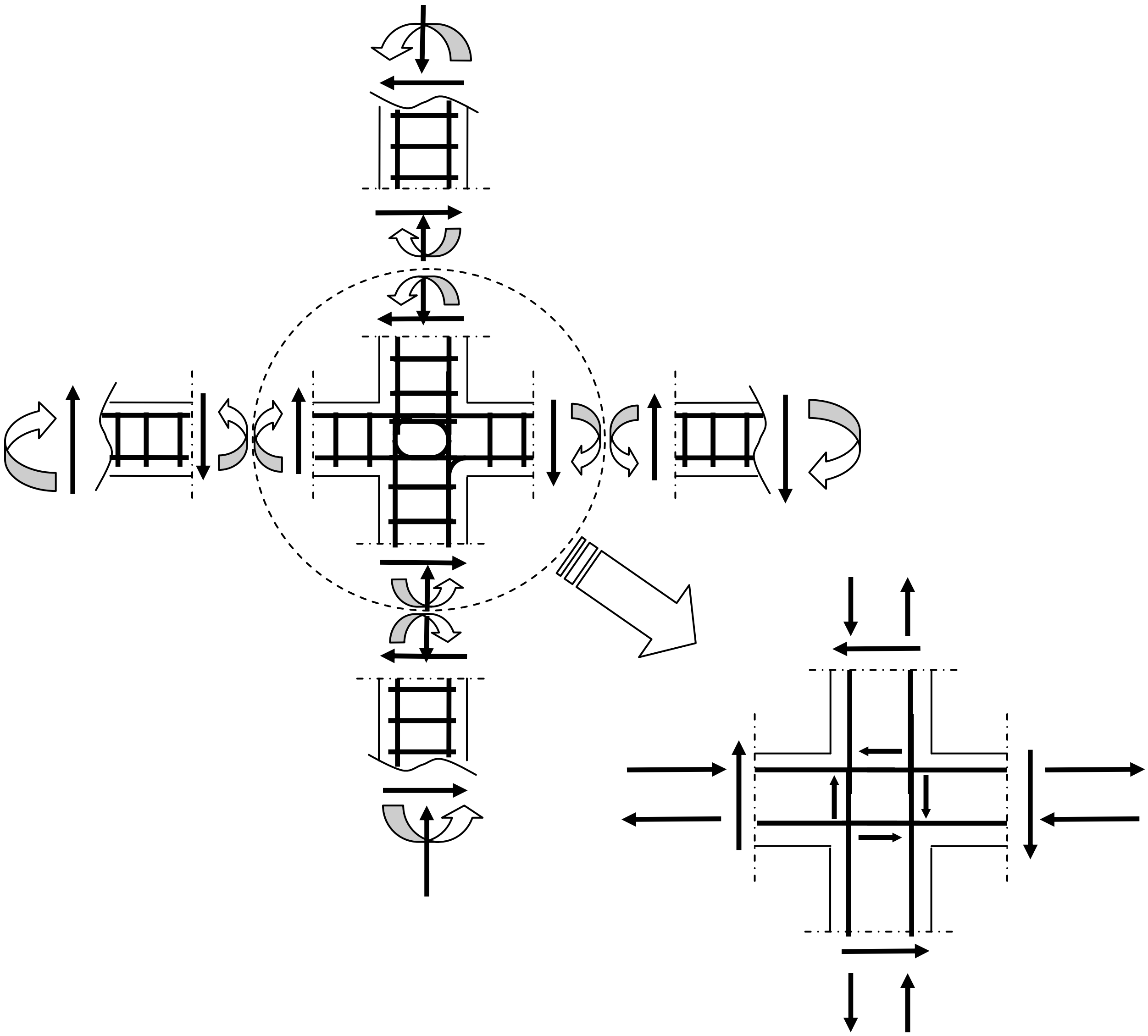
- Also consider load reversals. This is critical for seismic effects.
- Top beam bars

  → Subject to transverse tension

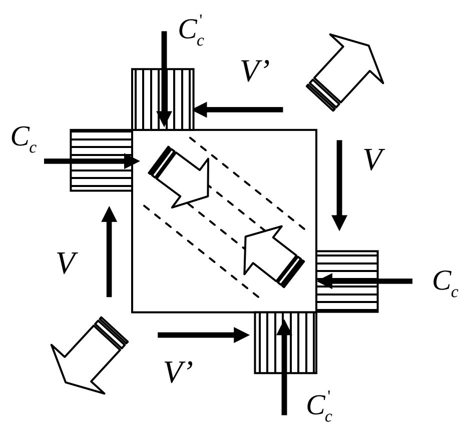
  → The anchorage condition of the reinforcement steel
- Bottom beam bars

  → Subject to transverse compression
- Outer column bars are subjected to severe stress conditions.
- Transmission of shearing and compression forces by diagonal strut across the joint

- Interior joints

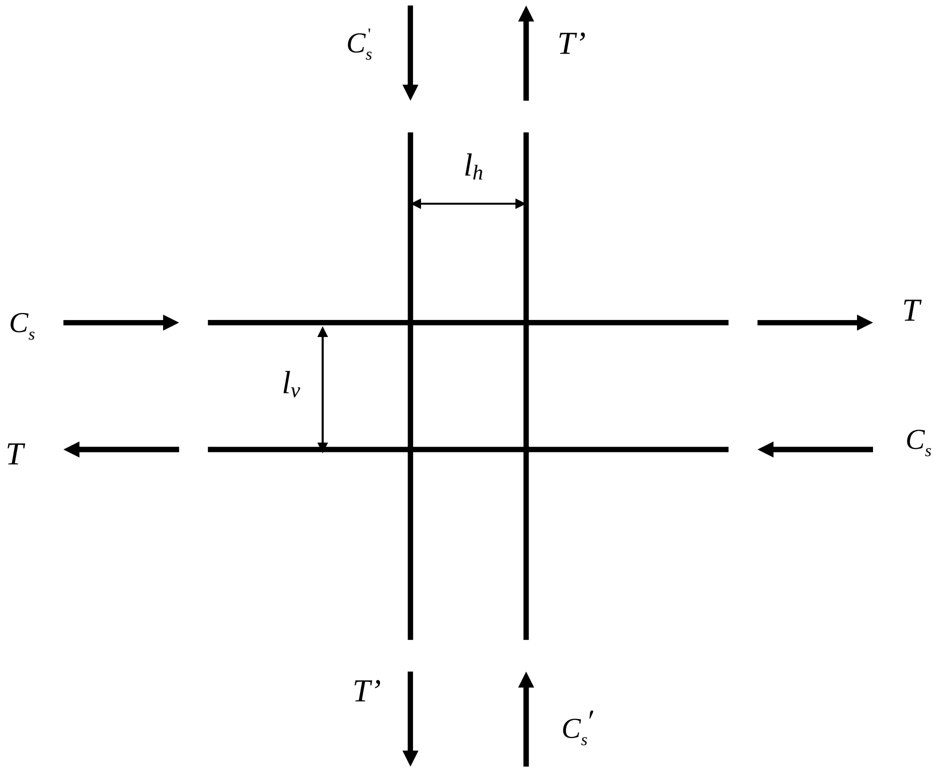


- Concrete



→ $V_c = C_c - V'$ = shear force transferred through concrete

- Steel



→ $V_s = C_s + T$ = shear force transferred through steel

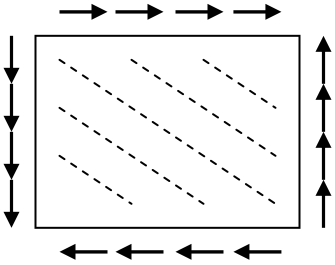
→ $u_0 = \dfrac{C_s + T}{l_h}$ and $v_0 = \dfrac{C_s' + T'}{l_v}$

- Combined behavior:

Shear transfer by bond

$$u_0 = \frac{C_s + T}{l_h}$$

$$v_0 = \frac{C_s' + T'}{l_v}$$



$V_j = V_c + V_s$

- Reduction in compressive strength due to biaxiality in concrete and deterioration of bond due to load cycling are of importance in joint integrity.
- Effect of axial force
- Effect of confinement