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Advanced Structural Concrete

Information Sheet: Nodal Zone Verification[1]

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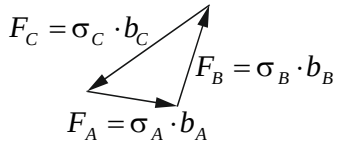
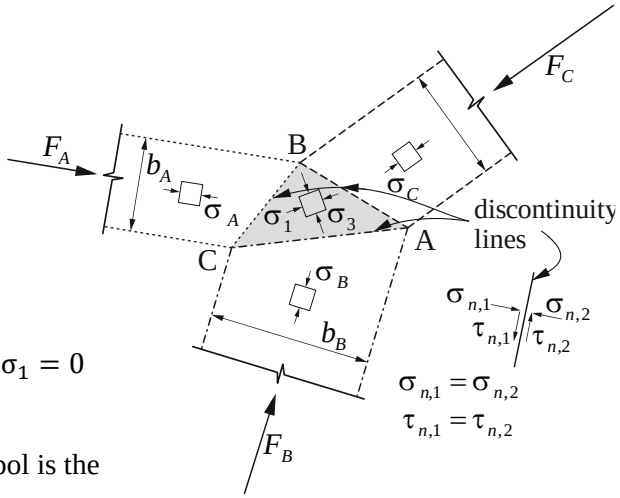
For practice, the stresses in the struts are usually assumed to be equal and the width is adapted accordingly. This leads to a biaxial uniform stress state[2]: $\sigma_1 = \sigma_2 = f_c$, which simplifies the verification.
For a general nodal zone ($\sigma_A \neq \sigma_B \neq \sigma_C$), there are two approaches for the verification, which are equivalent: (i) construction via pols in the Mohr's circles and (ii) by superimposing the stresses.

Construction via Pols

This approach is very practical in cases with three or more intersecting struts. First, the acting forces on the nodal zone need to be in equilibrium. At discontinuity lines, normal and shear stresses, σ_n and τ_n, need to be in equilibrium as well.





Approach:

1. Draw the Mohr's circles of each acting strut. Here $\sigma_1 = 0$ is assumed, but this does not need to be the case.
2. For each strut, find the corresponding pol Q_i. The pol is the intersection of the Mohr's circle and the principal direction 3 of each strut starting at σ_1 (if starting at σ_3 it would be principal direction 1). The pol Q_i is the point on the Mohr's circle, around which stresses rotate.
3. With the help of the pol, find the point S_i (σ_{ni}, τ_{ni}) which is the intersection of the Mohr's circle and the line L_i, parallel to the discontinuity line of the node boundaries, passing through the corresponding pol Q_i. The intersection of all L_i is the pol Q of the final Mohr's circle. All points S_i lie on the Mohr's circle of the nodal zone.
4. Finally, the Mohr's circle of the nodal zone can be drawn and the corresponding compressive stresses σ_1 and σ_3 can be read from the diagram.

[1] Presented in Lecture 2.1, Slide 39
[2] Often referred to as "hydrostatic" for simplicity although the stress state is not hydrostatic, because the stress perpendicular to the membrane plane is $\sigma_3 = 0$.

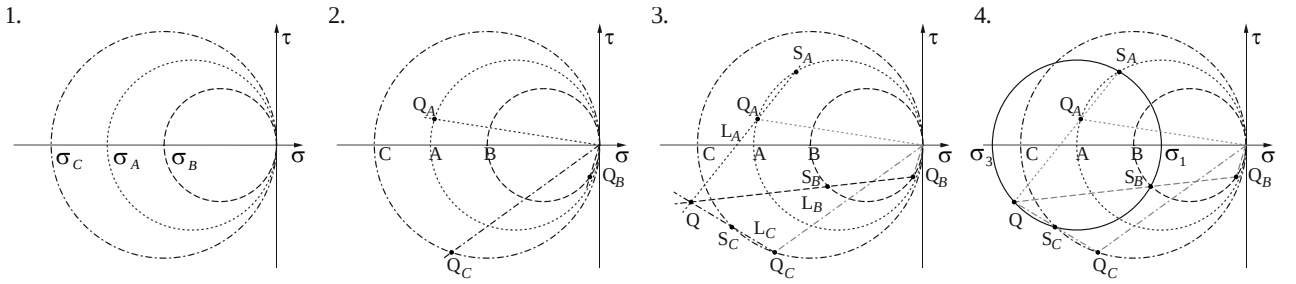
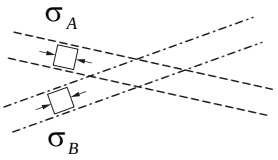


Figure 1: Construction via pols

Superimposing the stresses

In some situation, especially for overlapping struts in stress fields, this approach might be easier. The stress state in the nodal zone can be found with the following equivalent approach using Mohr's circles.



Approach:

1. Draw the Mohr's circles the two overlapping struts.
2. For each strut, find the corresponding pol Q_i and the corresponding stress states with respect to the coordinate directions X_i and Z_i.
3. Superimpose the two stress states (in Figure 2, stress state A onto the one of B). Thereby, the points X´ and Z´ are found.
4. Finally, the Mohr's circle of the node can be drawn through X´ and Z´ together with the corresponding pol Q´. The compressive stresses σ_2 and σ_3 can be read from the diagram.
5. Check that $\sigma_2, \sigma_3 \leq f_c$ (for $\sigma_1 = 0$).

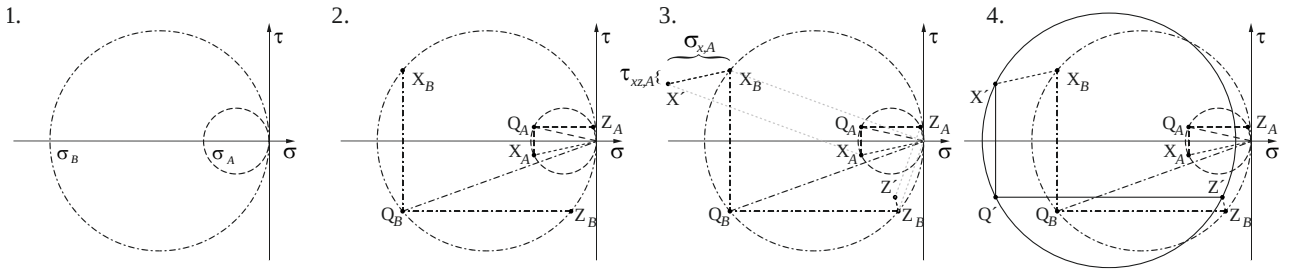


Figure 2: Superimposing the stresses