Fastenings with Bonded Anchors – Design Model –

Behavior of bonded anchors

Groups with 4 bonded anchors:
- 323
- 387

Groups with 2 bonded anchors:
- 84

Single bonded anchors at an edge:
- 146

Edge:
- 533

Numerical investigations:
Groups with 4 bonded anchors:
- 32

Single bonded anchors:
- 7

Database

Model for calculating average failure load of bonded anchors

\[ N_{\text{ave}} = N_{\text{ave}} A_{\text{ave}} \sigma \varepsilon_\psi \sigma \varepsilon_\psi \]

- Geometrical effect of axial spacing and edge distance:
  \[ A_{\text{ave}} = 25 \frac{d}{e_1/2} \]

- Geometrical effect of eccentricity of the load:
  \[ \varepsilon_\psi = \sqrt{\varepsilon_1^2 + \varepsilon_2^2} \]

- Effect of small spacing:
  \[ \varepsilon_2 = \frac{5}{4} \varepsilon_1 \]

- Effect of shell spalling:
  \[ \varepsilon_3 = \frac{5}{4} \varepsilon_1 \]
Numerical calculation

Part of numerical investigation

Concrete cone failure

False pull-out

Pull-out failure

Numerical calculation: Influence of bond strength on $\frac{N_{\text{group}}}{N_{\text{single}}}$

- $f_{\text{c}} = 30 \text{N/mm}^2$
- $h = 96 \text{mm}$

Characteristic spacing $s_{cr,h}$

First approach by evaluating test results:

$$I \leq \psi_{h,N} \leq \sqrt{n}$$

where:

- $\psi_{h,N} = \sqrt{\nu} + \frac{s}{s_{cr,h}} \left(1 - \sqrt{\nu}\right) \geq 1.0$
- $\psi_{h,N} = \frac{\nu}{s_{cr,h}} = 0$
- $\psi_{h,N} = \frac{\nu}{s_{cr,h}} = s_{cr,h}$
Failure load of fastenings with bonded anchors is limited by concrete cone failure of headed anchors

\[ N_u = \min \left( N_u, Bond; N_u, \text{headed anchors} \right) \]

More research is currently performed to confirm the validity of this assumption
Groups with bonded anchors

Evaluation of test results with

\[ N_{\text{comp}} = n_{\text{eff}} \left( \frac{f_{c}}{f_{c}} \right)^{\alpha} \]

Groups with 2 and 4 anchors

\[ N_{\text{comp}} = n_{\text{eff}} \left( \frac{f_{c}}{f_{c}} \right)^{\alpha} \]

Groups with bonded anchors

Evaluation of test results with

\[ N_{\text{comp}} = n_{\text{eff}} \left( \frac{f_{c}}{f_{c}} \right)^{\alpha} \]

Groups with 2 and 4 anchors

\[ N_{\text{comp}} = n_{\text{eff}} \left( \frac{f_{c}}{f_{c}} \right)^{\alpha} \]
Summary:

Proposed model for bonded anchors describes measured failure loads of groups and single anchors at an edge with reasonable accuracy. Some improvements are still possible.

Limitation of failure load by concrete cone failure load of headed anchors seems to be reasonable, but should be checked by further investigations.

It might be possible to incorporate this limit by limiting the maximum bond strength to be used in the bond model.