Steel-Concrete Connections in High-Rise Buildings

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https://nees-anchor.ceas.uwm.edu
https://nees.org/warehouse/project/725
Steel-Concrete Connections
Connections can be the **weak link**
NEES-Anchor Project

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NEES-Anchor Project

- Phase I: Unreinforced single anchors subjected to cyclic loading (UWM)
- Phase II: Reinforced single anchors subjected to shear (UWM)
- Phase III: Reinforced single anchors subjected to tension (UWM)
- Phase IV: Anchor groups in plastic hinge zones of a concrete wall (NEES-UIUC, UC)
- Phase V: Reinforced single anchors in plastic hinge zones of columns (UWM)
Typical Tension Failure Modes

$152 \text{ mm} [6 \text{ in.}]$ - $406 \text{ mm} [16 \text{ in.}]$

$h_{ef} = 6 \text{ in.} [152 \text{ mm}]$

Idealized breakout cone

$35^\circ$
Anchor Reinforcement

Diagram showing anchor reinforcement details, including dimensions and recommended practices for placement and orientation of reinforcement elements.
Summary of Phase III Tests

a) A1-unreinforced
b) B1-2#6 stirrups
c) D1-4#6’s
d) B3-6#4’s+2#3’s
e) D3-6#4’s+2#3’s
f) F1-8#4’s
Proposed Anchor Reinforcement

- Stirrups @ 2~3in
- Surface bars

- 3~4 hoops @ 3 in.
- Less than \( h_{ef} \)

- Stirrups @ 2~3in
- More stirrups for tension if needed

- Reinforcement cage encasing anchor bolt

- Free surface

- 3~4 hoops if close to an edge

- \( > 8d_b \)
Design of Anchor Reinforcement

STMs for load transfer from anchor to reinforcement

STMs for load transfer from reinforcement to structure
Anchor reinforcement in tension should include

1) load-carrying reinforcement in the direction of the anchors;
2) crack-controlling reinforcement in all directions that has a limited edge distance; and
3) local confining reinforcement near the anchor head to avoid side-face blowout.
Plastic Hinge Zones

peer.berkeley.edu

Wenchuan, China (2008) earthquake
Anchors needed in Plastic Hinge Zones

Olive View Hospital, 1971

www.world-housing.net
Laboratory tests
Test Setup and Instrumentations
Summary of Phase V Tension Test Results

Typically:
Anchors in Plastic Hinge Zones
Summary of Tension Tests

T1: high-speed loading at zero position

T2: monotonic tension, 8Dy, at zero position

T3: cyclic tension, anchor broke at -8Dy
Proposal for ACI 381 Adoption

17.4.2.9 — Anchor tension reinforcement

17.4.2.9.1 Anchor tension reinforcement shall be designed either by 17.4.2.9.2 for anchors and anchor groups in mass concrete, or 17.4.2.9.3 for anchors and anchor groups close to concrete edges.

17.4.2.9.2 Where anchor reinforcement is developed in accordance with 25.4 on both sides of the breakout surface, the design strength of the anchor reinforcement shall be permitted to be used instead of the concrete breakout strength in determining $f_{ce}$. A strength reduction factor of 0.75 shall be used in the design of the anchor reinforcement.

17.4.2.9.3 Anchor tension reinforcement shall include 1) load-carrying reinforcement in the direction of the anchors; 2) crack-controlling reinforcement in all directions that has a limited edge distance; and 3) local confining reinforcement near the anchor head if side-face blowout may control the failure. The area of load-carrying reinforcement shall be determined by

$$A_{eq} = \frac{f_{eq}}{f_{y}}$$  \hspace{1cm} (17.4.2.9.3)

where the limitation of $1.9f_{cm}$ on $f_{eq}$ shall not be applied. The value of $f_{eq}$ shall satisfy 20.2.2.4.

The design of the crack-controlling reinforcement can use two strut-and-tie models: one describing the load transfer from the anchor head to the load-carrying reinforcement, and the other describing the load transfer from the load-carrying reinforcement to the rest of the structure.
Connection Hardware Proposal

Anchor reinforcement

RC wall W/ reinforcement
Acknowledgements

ACI Committee 355 - Anchorage to Concrete

fib SAG 4 ‘fastenings to structural concrete & masonry’
Thanks for your attention!

In a few years...
Additional Slides

Anchor Reinforcement in Shear
What is anchor reinforcement

- Two types of hairpins

- $c_{al}$

- $35^\circ$

- $l_d$

- $l_{dh}$

- $c_{a2}$

- $0.3c_{a2}$

- $0.5c_{a1}$

- Concrete cover

- Breakout cone

- Section A-A

- Section B-B
anchor reinforcement (Shear)

Section A-A

Section B-B
Confining reinforcement
Summary of Phase V shear Tests

S1: monotonic shear, at zero position
03/10/2012

S2: cyclic shear along with cyclic column deformation
03/15/2012

S3: cyclic shear along with cyclic column deformation
05/02/2012