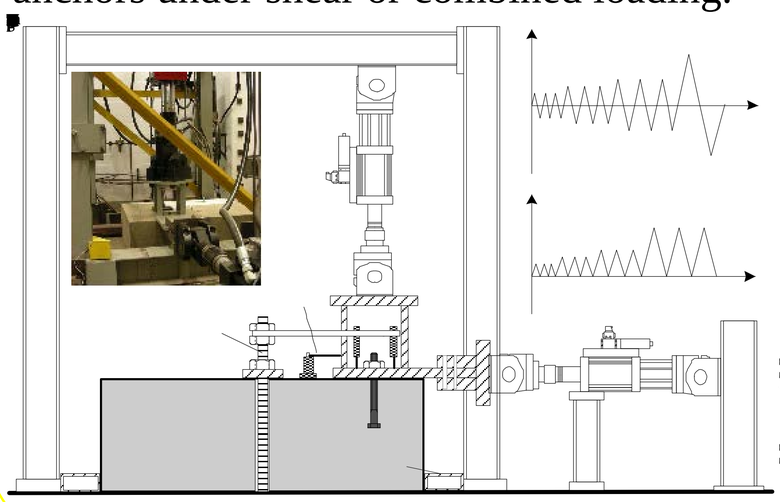
Behavior and Design of Cast-in-Place Anchors under Simulated Seismic Loading (NEES-Anchor)

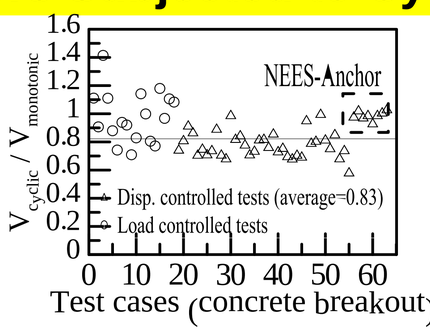
Jian Zhao, *University of Wisconsin, Milwaukee* (UWM) **Bahram Shahrooz,** *University of Cincinnati* (UC) **Xiangdong Tong,** *Jinhuan Manufacturing Group*
Derek Petersen (UWM *graduate student*); **Zhibin Lin** (UWM *Post-doc*); **Luke Butler** (UC *graduate student*)

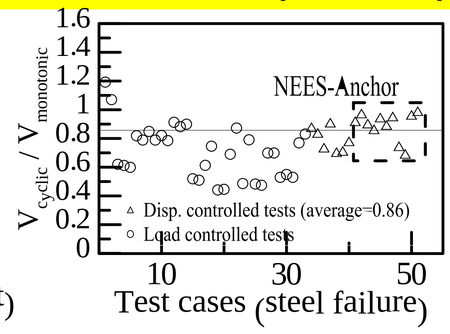
Unreinforced Single Anchors Subjected to Cyclic Tension, Shear, and Combined Loading

Sufficient data is not available for anchors under cyclic loading. Consequently, ACI 318-11 recommends a capacity reduction factor for tension anchors with concrete breakout failure. No factor is stipulated for anchors under shear or combined loading.

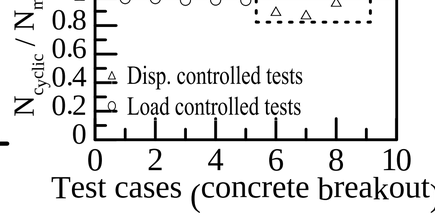


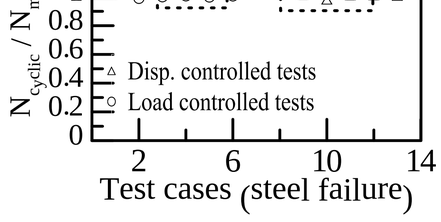
Quasi-static cycle tests were conducted.





The observed anchor capacities under cyclic loads were lower than that of anchors subjected to monotonic loads, mostly due to accumulative/progressive damage in concrete.





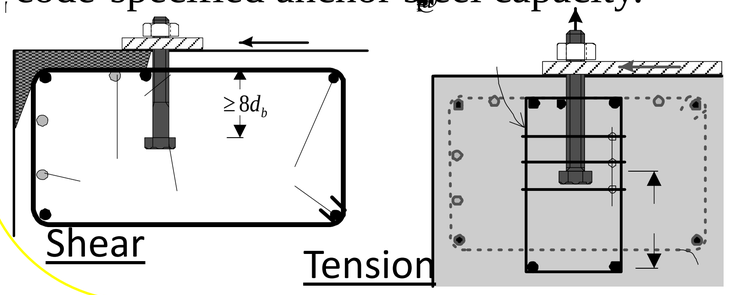
Concrete around an anchor bolt subjected to cyclic shear crushed, causing the top portion of the anchor shaft unsupported, and bending moment. → reduced anchor shear capacity.

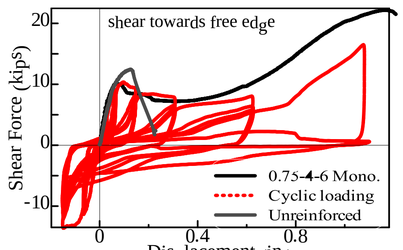
A database of about 130 tests was assembled for cast-in-place anchors and headed studs subjected to stepwise increasing cyclic loading. Data analysis indicated a seismic reduction factor of 0.80 for anchors with concrete breakout failure. A reduction factor of 0.80 was recommended for steel fracture in shear. No reduction is needed for tension anchors failed by steel fracture.

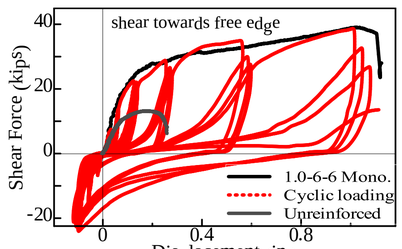
Effects of Anchor Reinforcement on Headed Anchors under Cyclic Loading

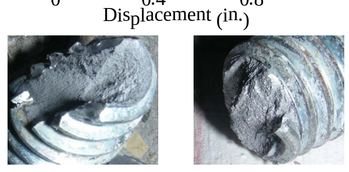
ACI 318-11 recommends hairpins and surface reinforcement consisting of hooked bars encasing an edge reinforcement for anchors in shear, and hairpins placed close to anchors in tension. Concrete breakout occurs before reinforcement takes effect.

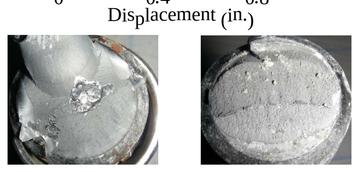
We proposed alternative designs and detailing for anchor reinforcement. The new reinforcement consists of a group of closed stirrups proportioned to resist the code-specified anchor steel capacity.



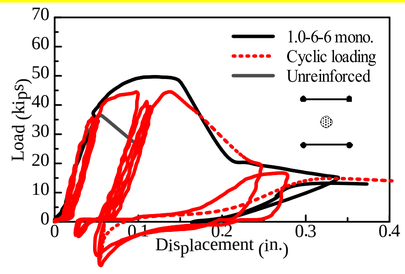






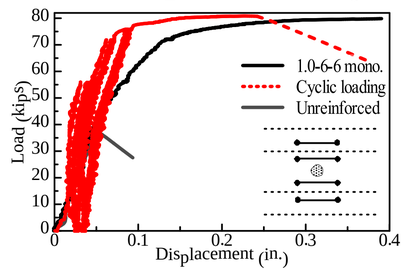


Steel fracture was achieved in all shear tests of 1.0 in. dia. reinforced anchors. Meanwhile, the observed anchor capacities were smaller than the code-specified anchor values because concrete spalling caused combined bending and shear action. Use a 0.75 factor, or $V_{se} = f_{ya} A_{se,v} \sin\beta + \dfrac{f_{ya} \cos\beta}{\dfrac{1}{0.9 A_{se,v}} + \dfrac{l}{3.45}}$



Code-complying reinf.

The expected steel tension fracture was not achieved mainly because the anchor reinforcement did not effectively prevent splitting cracks. Concrete around the anchor head thus lost its confinement and crushed prematurely. → Anchor pullout.



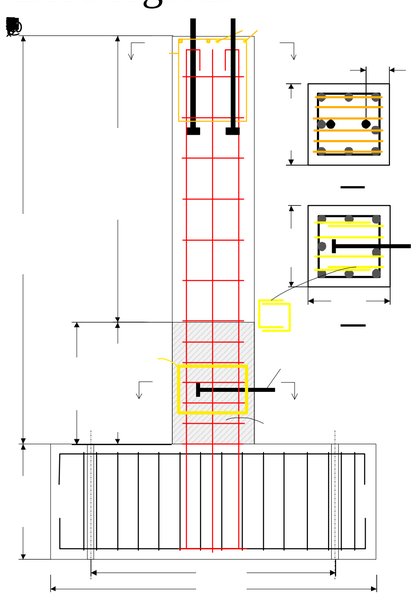
Proposed anchor reinf.

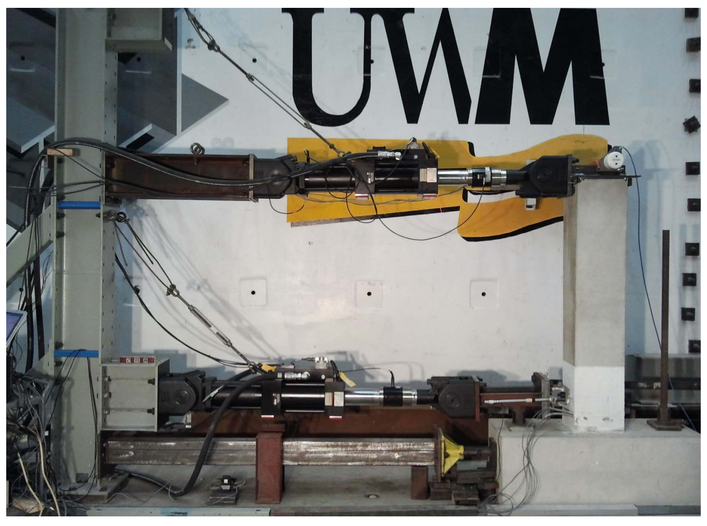
Headed anchors in Plastic Hinge Zone of RC Columns

Anchors are currently not allowed in plastic hinge zones in ACI 318-11 if concrete failure modes likely control the behavior; and anchor reinforcement is needed. Extensive concrete damage is expected in these regions.

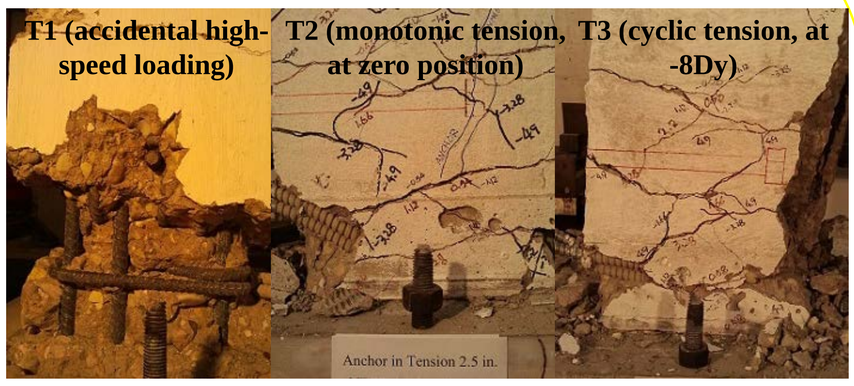
This group of tests was to investigate the feasibility of installing headed anchors in plastic hinge zones.

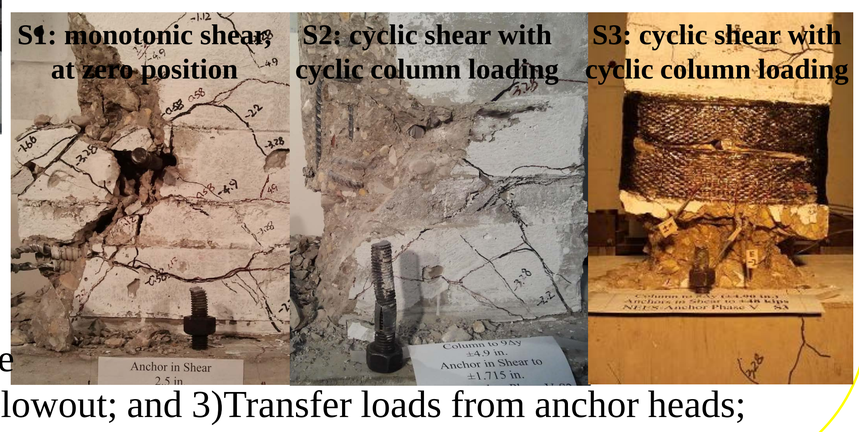
- 3 specimens w/ one anchor in tension
- 3 specimens w/ two anchors in shear





Well-confined core concrete can support headed anchors installed in plastic hinge zones of RC columns





Anchor reinforcement should 1) Confine core concrete; 2) Restrain concrete splitting and blowout; and 3)Transfer loads from anchor heads; Cover spalling leads to exposed anchor shaft. Estimation of exposed length is key for capacity.

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