IDEA StatiCa®

Calculate yesterday's estimates

WHEN THE CONNECTION DOESN'T MATCH THE STRUCTURE: RETROFIT & MODIFICATION WORKFLOWS

SEPTEMBER 2026

AGENDA

IDEA StatiCa intro

Connection design for project modifications

1. Load increase in steel beam to concrete column connection
2. Base plate repairs due to misalignment of anchors
3. Retrofits

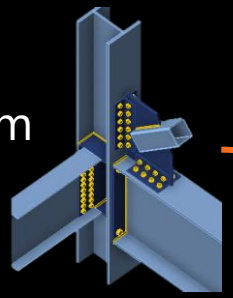
Anchor reinforcement design per ACI

Q&A Session

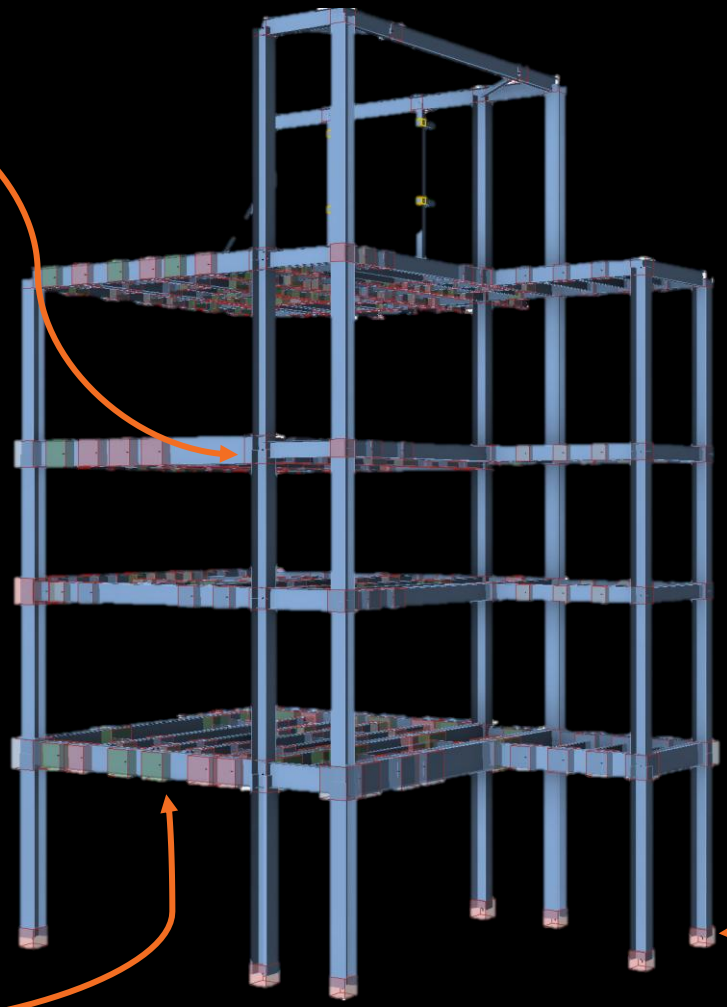


Connection

Design all steel connections from standard to complex joints

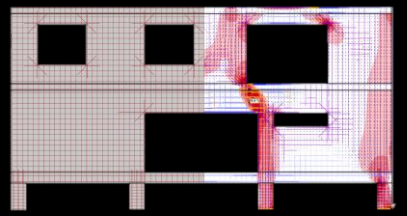


Checkbot



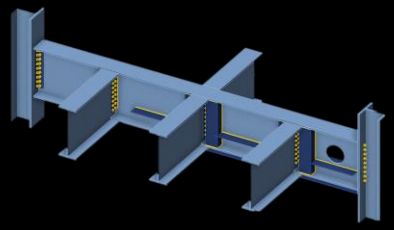
Detail

Strut and tie replacement for:
Transfer beams
Shear walls
Corbels
Walking columns

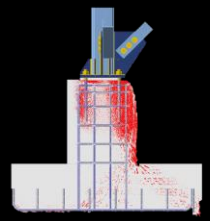


Member

Critical Beam and column design



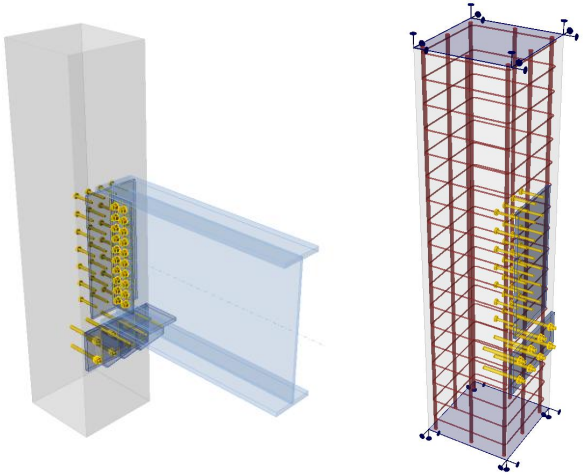
Connection + Detail



Complete base plate workflow including steel and concrete reinforcement design to avoid concrete breakout

RETROFIT AND CHANGES IN THE PROJECT

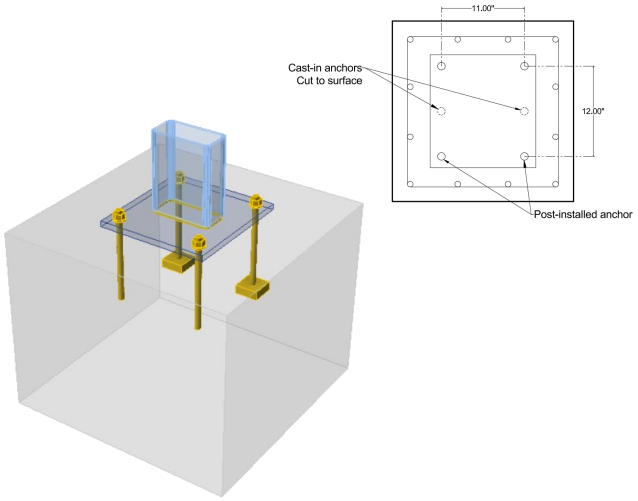
Challenges and solutions



1. Design revision: load increase

Add a seat angle

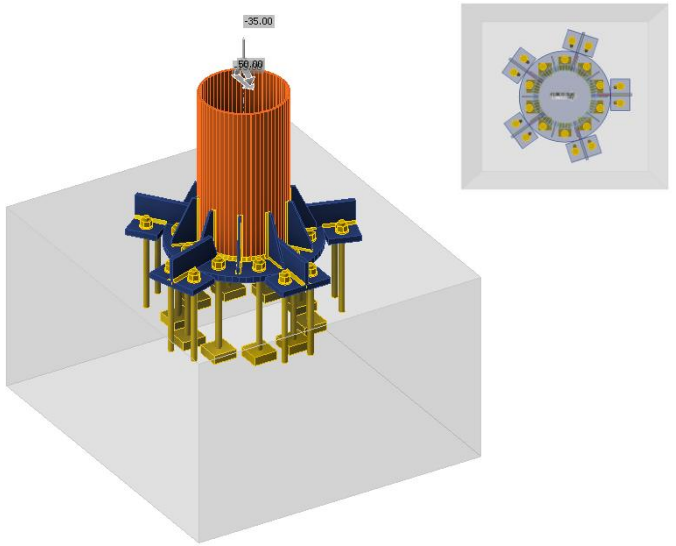
Anchor checks (embedded plate and post-installed anchors)



2. Misaligned anchors

Base plate modification

Add and check post-installed anchors



3. Base plate retrofits cases:

Reinforcement & Connection replacement w/post-installed anchors

LEARNING OBJECTIVES

Strategies from real cases for retrofit and design revisions of steel to concrete connections

Tools available in IDEA StatiCa to solve retrofit and changes

Analysis available

Post-processing results from the tools

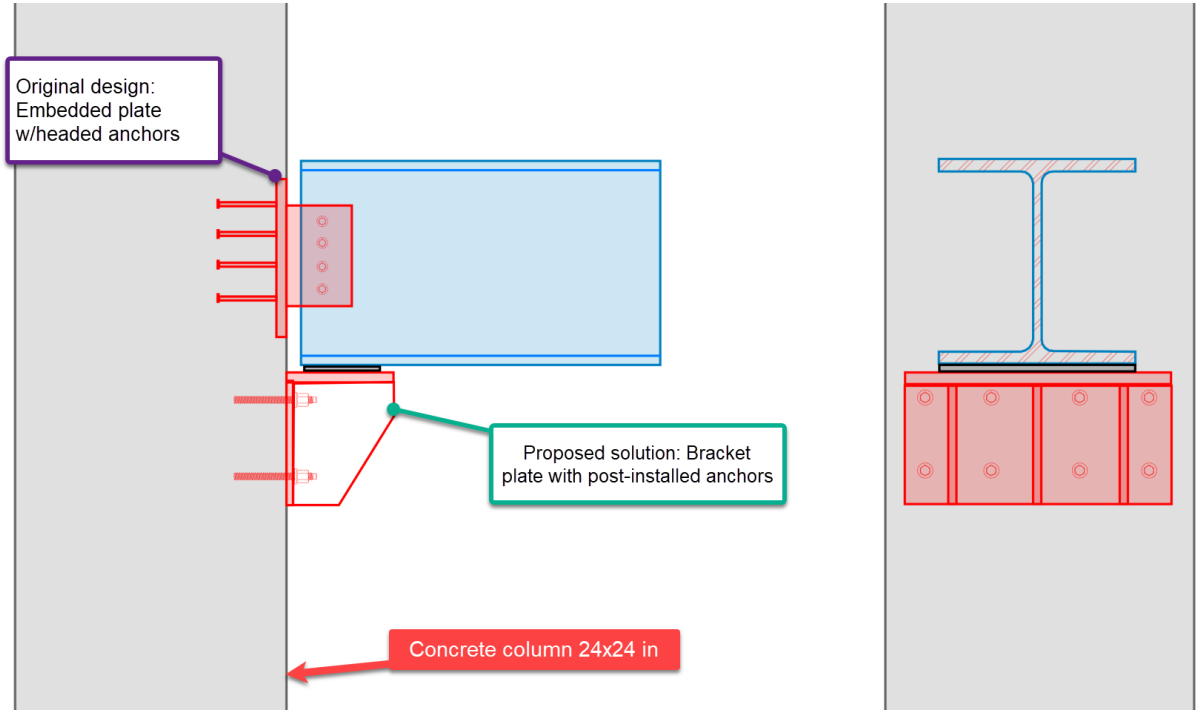
1. DESIGN REVISION: SHEAR FORCE INCREASE

Change: Shear load increase during a design revision in the construction phase

Proposed solution: Add a seat connection using a stiffened steel bracket

Anchor it using post installed anchors

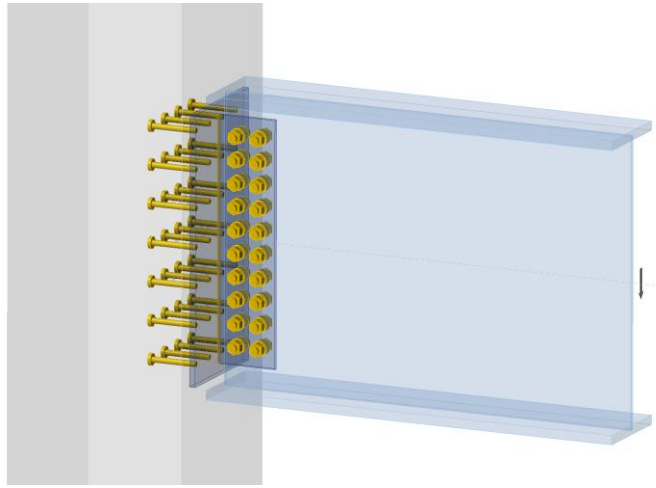
Verify the anchors, concrete breakout and interaction with the existing concrete reinforcement



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STEP BY STEP PROCESS

Watch the modeling video here

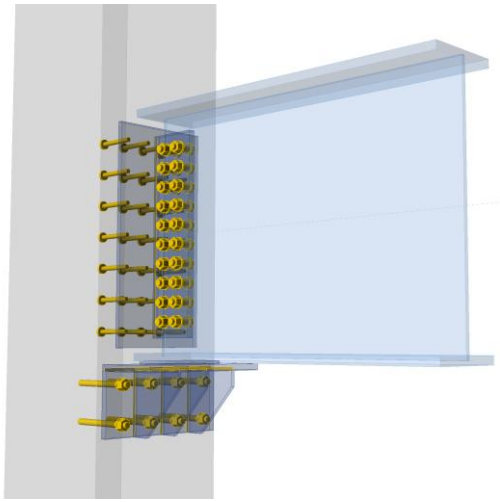


1. Connection app

Embedded plate model

Learn the capacity of the connection

Verify the old and new load

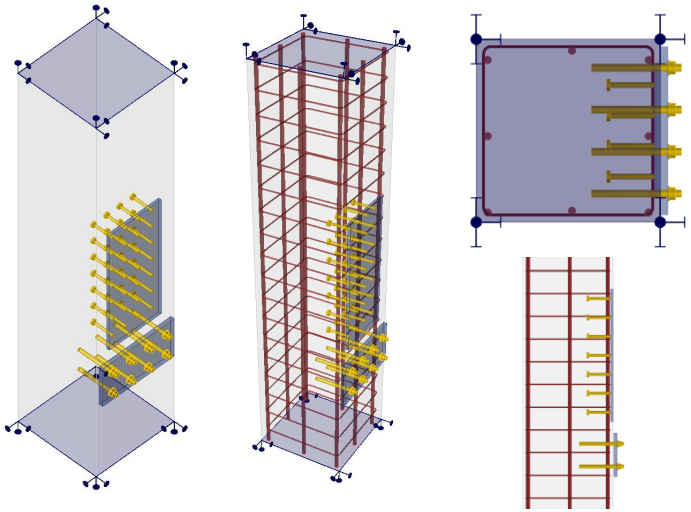


2. Connection app

Reinforced connection w/steel bracket

Learn the capacity of the combined connection

Verify the connection for new load



3. Detail app

Reinforced concrete design

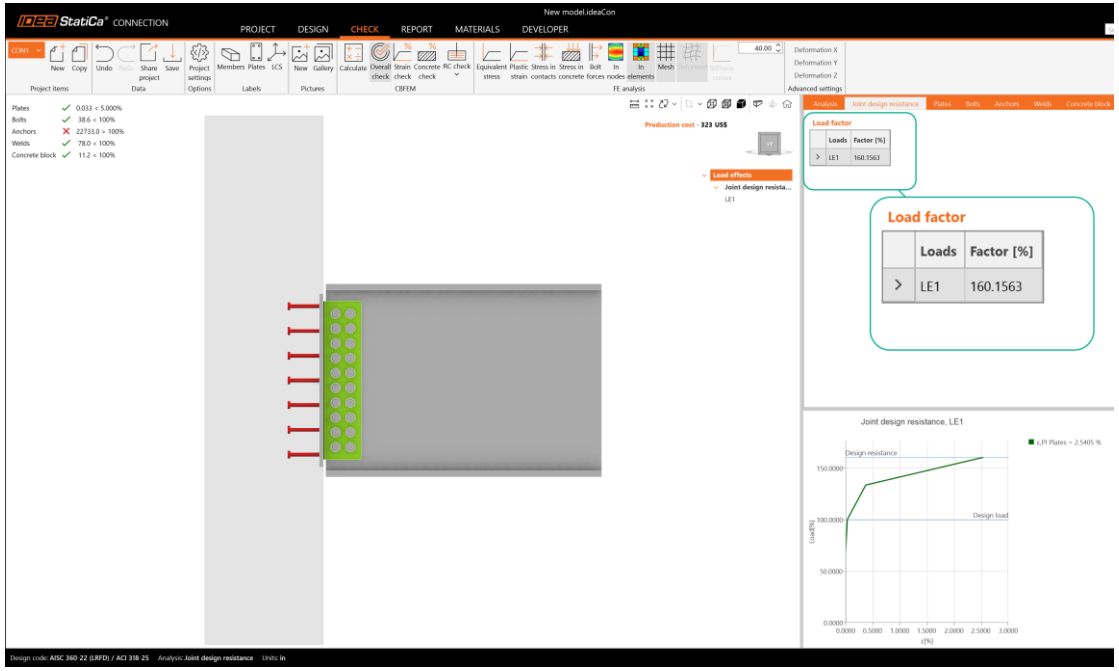
Concrete and reinforcement checks

Development length

JOINT DESIGN RESISTANCE

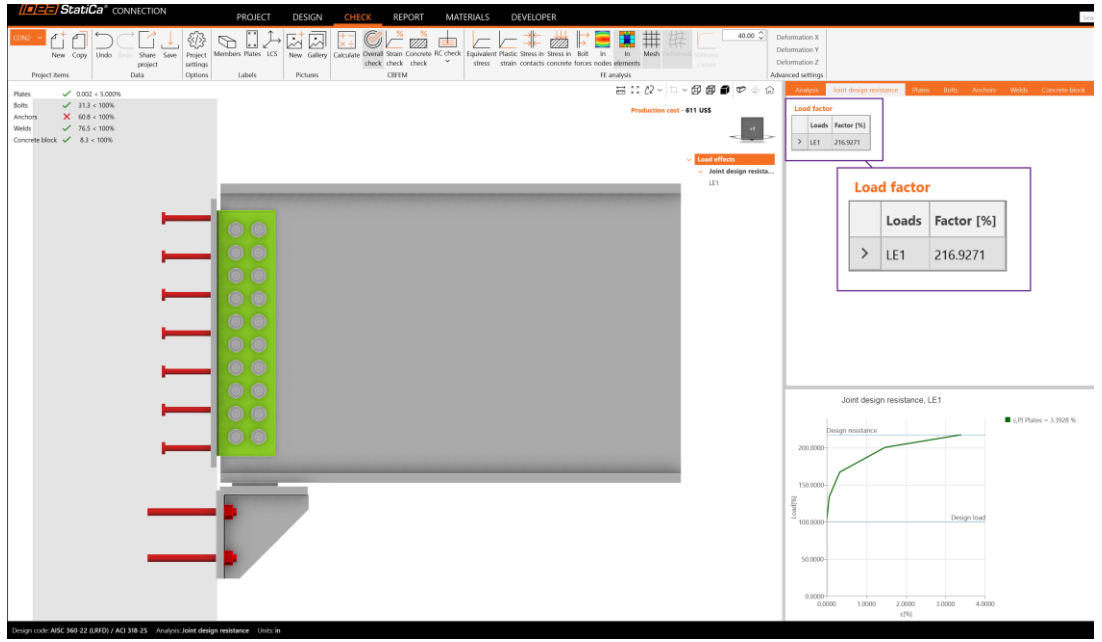
Vz=232 kips

Max cap= 232*1.60=371.2 kips

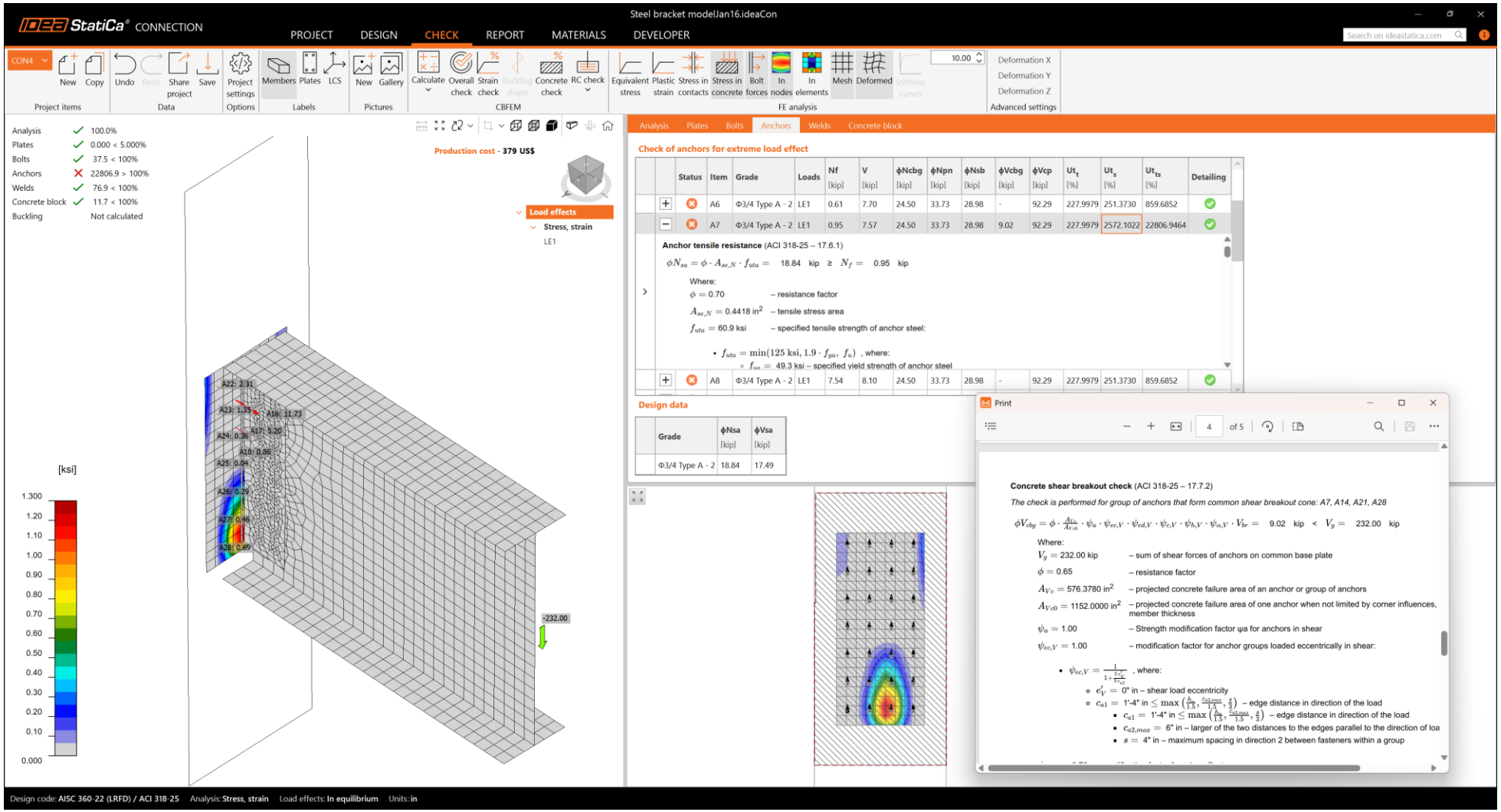


Vz=232 kips

Max cap= 232*2.169=503.20 kips



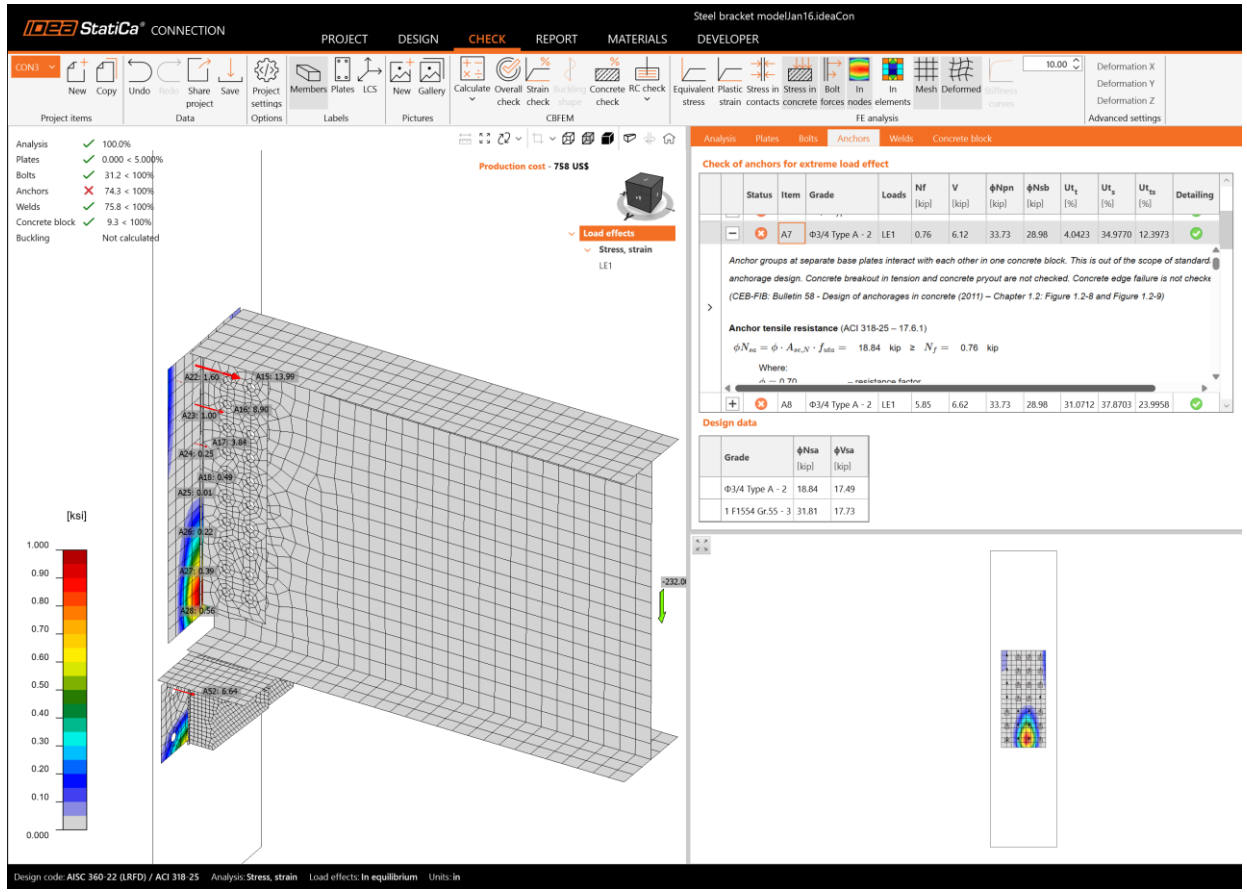
CONCRETE BREAKOUT FOR HEADED STUDS



EMBEDDED PLATE (HEADED STUDS)+POST-INSTALLED ANCHORS

Concrete breakout checks are not included when anchors in different plates and types.

No solution available in codes

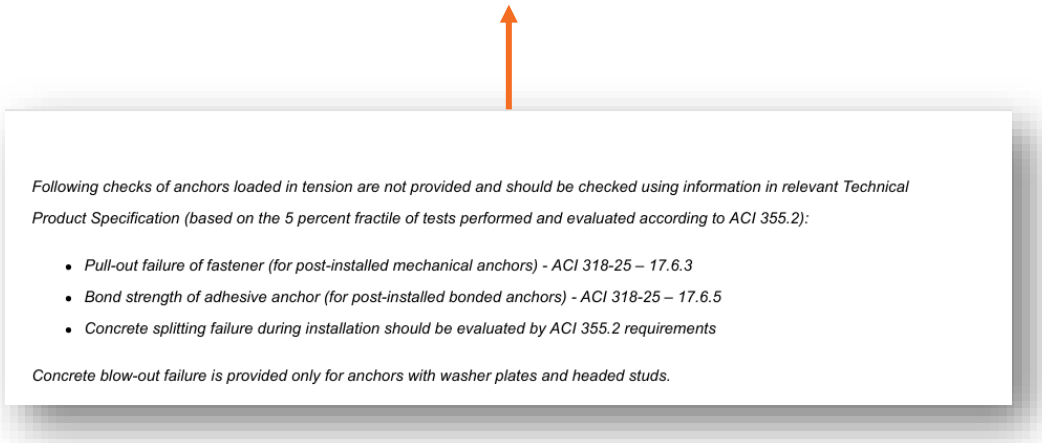


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WHAT CONNECTION DOES NOT CHECK

Post-installed anchors

Pull-out, mechanical anchors (17.6.3)
Bond strength, adhesive anchors (17.6.5)
Splitting during installation (ACI 355.2)



Following checks of anchors loaded in tension are not provided and should be checked using information in relevant Technical Product Specification (based on the 5 percent fractile of tests performed and evaluated according to ACI 355.2):

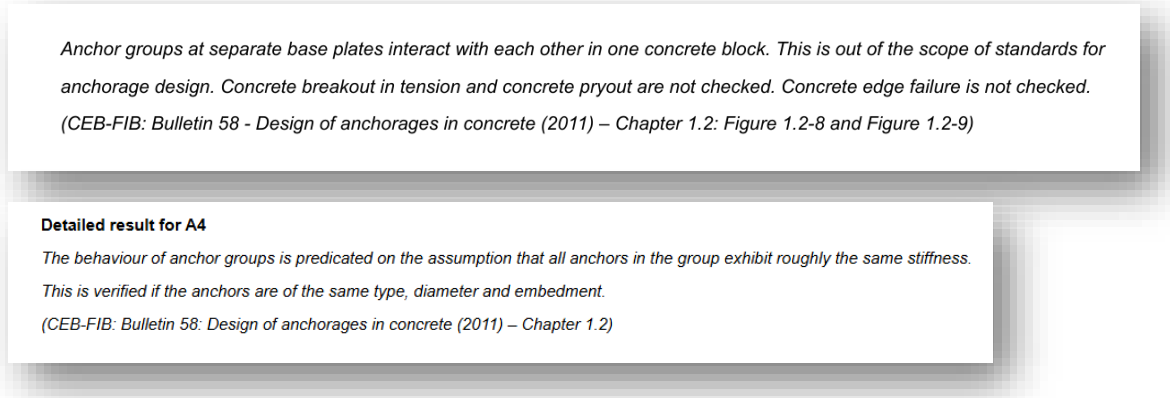
- *Pull-out failure of fastener (for post-installed mechanical anchors) - ACI 318-25 – 17.6.3*
- *Bond strength of adhesive anchor (for post-installed bonded anchors) - ACI 318-25 – 17.6.5*
- *Concrete splitting failure during installation should be evaluated by ACI 355.2 requirements*

Concrete blow-out failure is provided only for anchors with washer plates and headed studs.

*Note in the anchors report when checking Post-installed (adhesive) anchors

Combined anchors in different base plates, one block

Concrete breakout in tension (17.6.2)
Concrete pryout (17.7.3)
Concrete breakout in shear (17.7.2)



Anchor groups at separate base plates interact with each other in one concrete block. This is out of the scope of standards for anchorage design. Concrete breakout in tension and concrete pryout are not checked. Concrete edge failure is not checked. (CEB-FIB: Bulletin 58 - Design of anchorages in concrete (2011) – Chapter 1.2: Figure 1.2-8 and Figure 1.2-9)

Detailed result for A4

The behaviour of anchor groups is predicated on the assumption that all anchors in the group exhibit roughly the same stiffness. This is verified if the anchors are of the same type, diameter and embedment.
(CEB-FIB: Bulletin 58: Design of anchorages in concrete (2011) – Chapter 1.2)

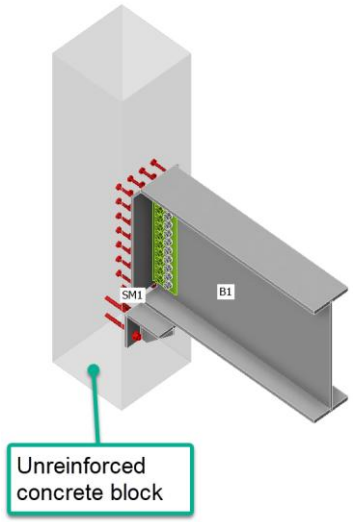
*Note in the anchors report when adding anchors in different plates same concrete block or different anchors in same concrete block

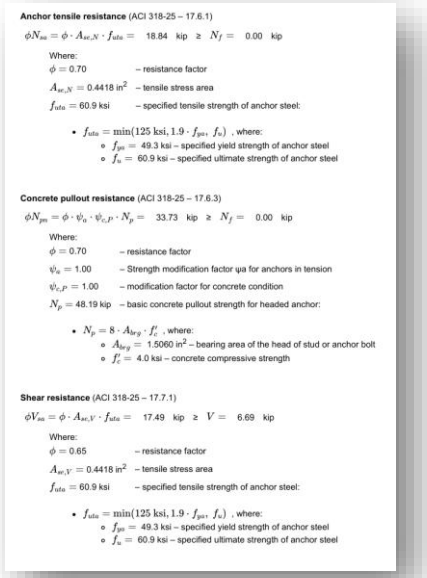
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TWO APPROACHES: CODE FORMULAS VS FEA

Connection

Empirical ACI 318 formulas – Chapter 17
Plain concrete only
Anchor steel checks in tension and shear





Anchor tensile resistance (ACI 318-25 – 17.6.1)

$\phi N_{sa} = \phi \cdot A_{se,N} \cdot f_{uta} =$ 18.84 kip ≥ $N_f =$ 0.00 kip

Where:
$\phi = 0.70$ – resistance factor
$A_{se,N} = 0.4418$ in² – tensile stress area
$f_{uta} = 60.9$ ksi – specified tensile strength of anchor steel:

- $f_{uta} = \min(125\text{ ksi}, 1.9 \cdot f_{ya}, f_u)$, where:
  - $f_{ya} =$ 49.3 ksi – specified yield strength of anchor steel
  - $f_u =$ 60.9 ksi – specified ultimate strength of anchor steel

Concrete pullout resistance (ACI 318-25 – 17.6.3)

$\phi N_{pn} = \phi \cdot \psi_a \cdot \psi_{c,P} \cdot N_p =$ 33.73 kip ≥ $N_f =$ 0.00 kip

Where:
$\phi = 0.70$ – resistance factor
$\psi_a = 1.00$ – Strength modification factor ψa for anchors in tension
$\psi_{c,P} = 1.00$ – modification factor for concrete condition
$N_p = 48.19$ kip – basic concrete pullout strength for headed anchor:

- $N_p = 8 \cdot A_{brg} \cdot f'_c$, where:
  - $A_{brg} =$ 1.5060 in² – bearing area of the head of stud or anchor bolt
  - $f'_c =$ 4.0 ksi – concrete compressive strength

Shear resistance (ACI 318-25 – 17.7.1)

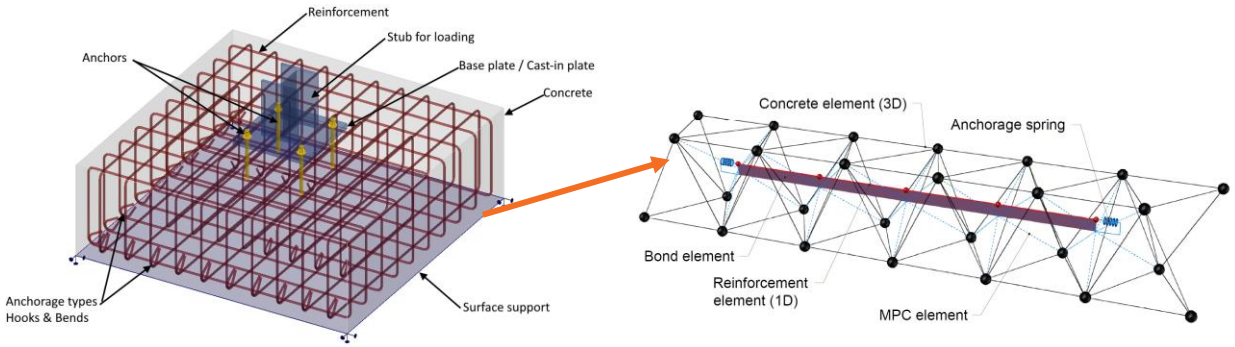
$\phi V_{sa} = \phi \cdot A_{se,V} \cdot f_{uta} =$ 17.49 kip ≥ $V =$ 6.69 kip

Where:
$\phi = 0.65$ – resistance factor
$A_{se,V} = 0.4418$ in² – tensile stress area
$f_{uta} = 60.9$ ksi – specified tensile strength of anchor steel:

- $f_{uta} = \min(125\text{ ksi}, 1.9 \cdot f_{ya}, f_u)$, where:
  - $f_{ya} =$ 49.3 ksi – specified yield strength of anchor steel
  - $f_u =$ 60.9 ksi – specified ultimate strength of anchor steel

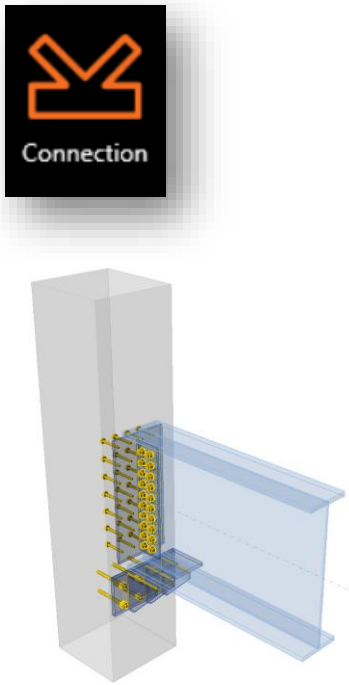
Detail 3D

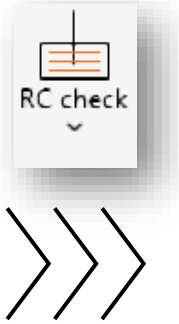
Nonlinear FEA of the whole block
Reinforced concrete
Concrete tensile strength neglected

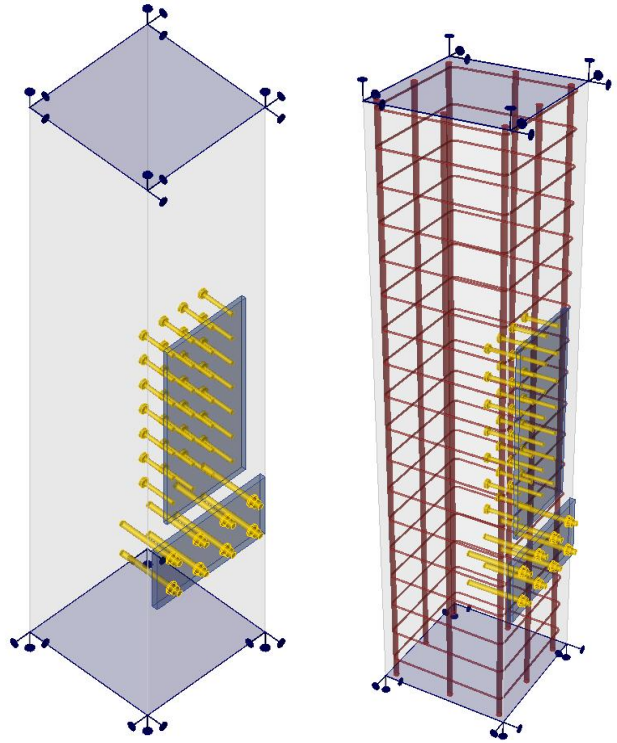


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EXPORT: CONNECTION TO DETAIL





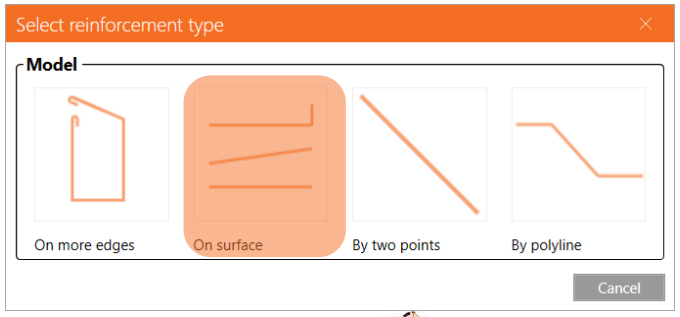


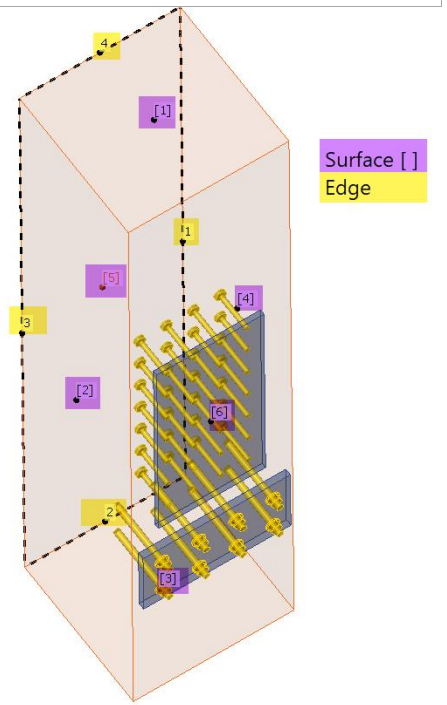


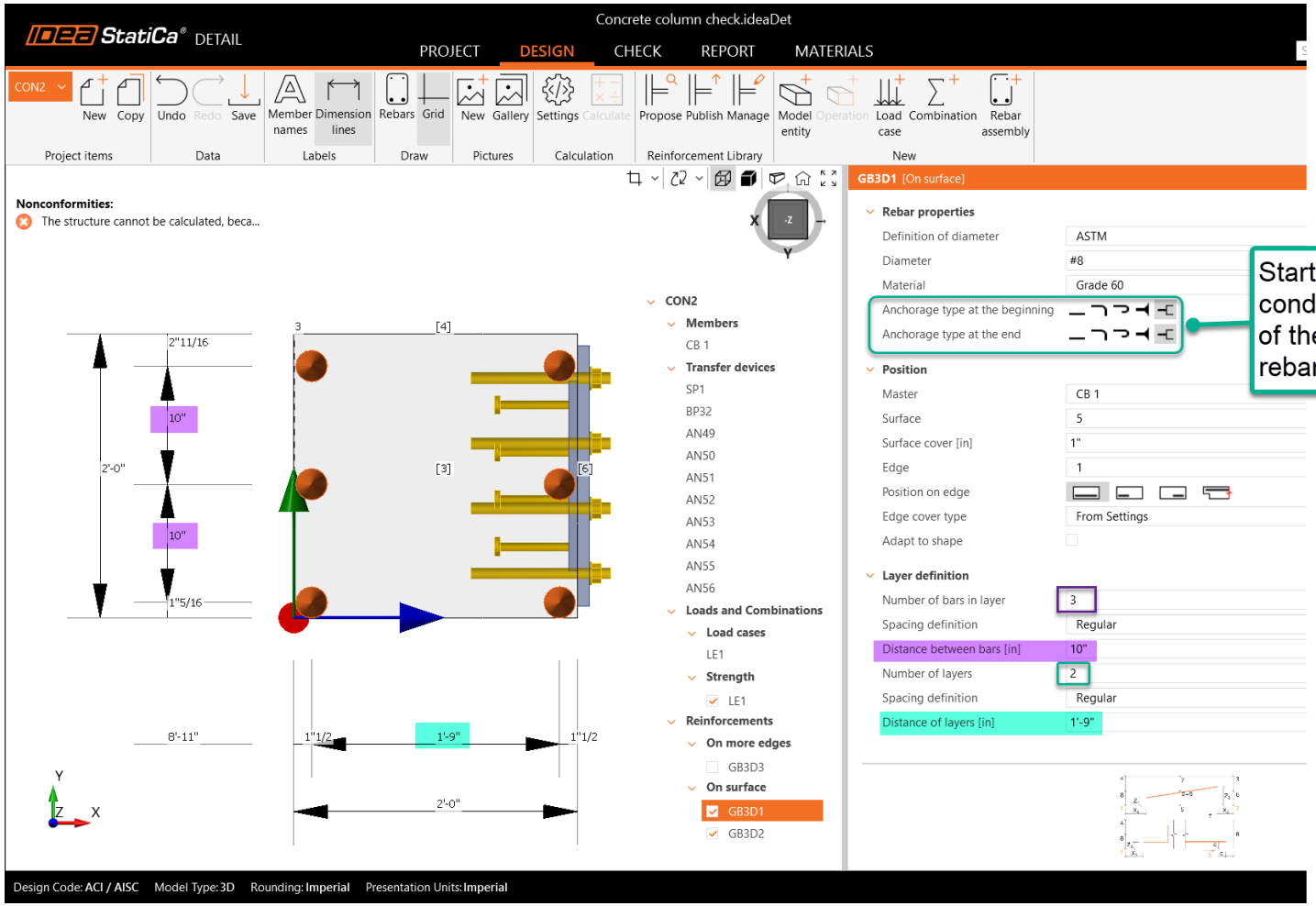
✓ Plates, anchors, concrete block, reactions on plates and anchors

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LONGITUDINAL REBAR MODELING







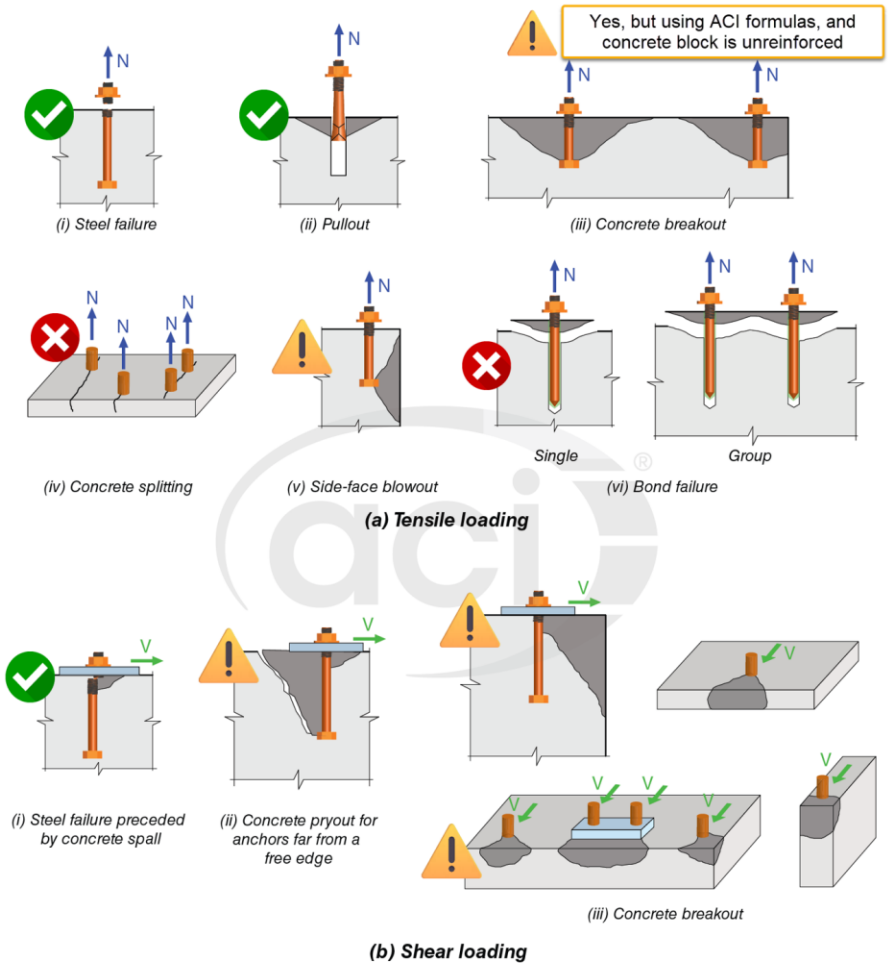
MISSING CHECK TO DETAIL 3D RESULT

ACI failure mode	Detail 3D result
Breakout, tension (17.6.2)	Strength, concrete + reinforcement
Pryout (17.7.3)	Strength, footing concrete
Breakout, shear (17.7.2)	Strength, concrete + reinforcement
Bond, adhesive (17.6.5)	Anchorage, bond stress ratio
Splitting	Strength, reinforcement + concrete
Pull-out, mechanical (17.6.3)	Not covered, use manufacturer data

ANCHOR FAILURE MODES (ACI)

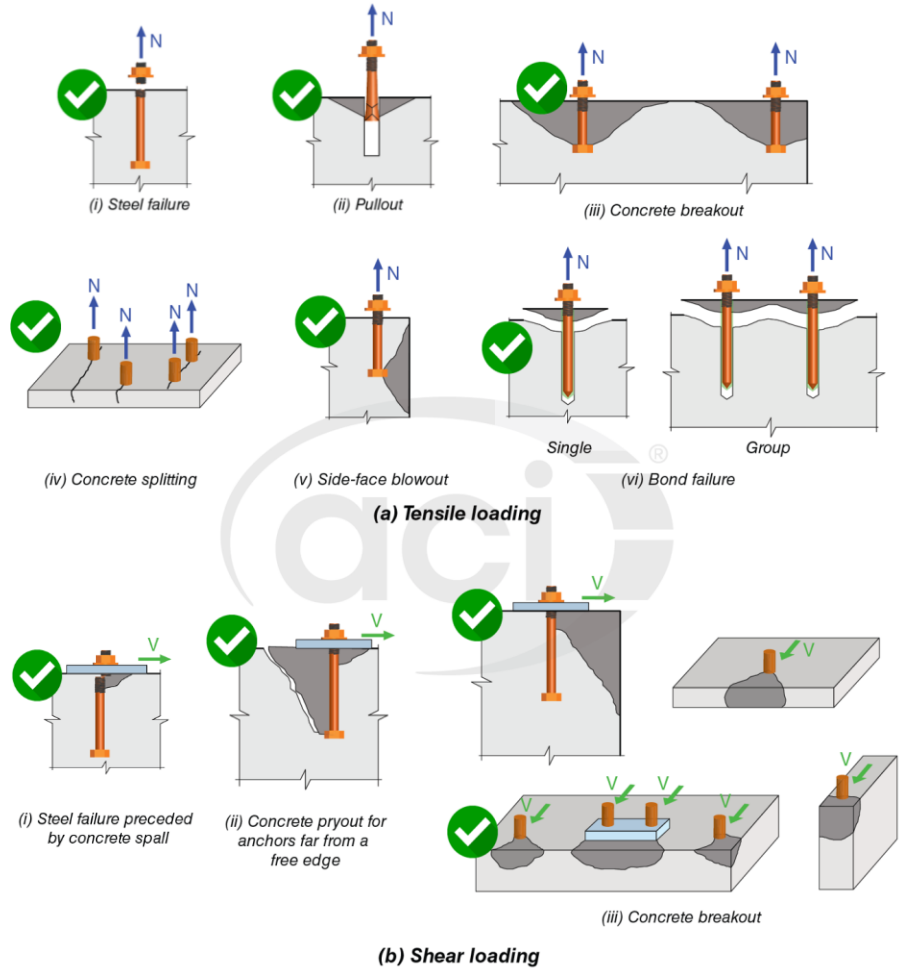
Connection

Steel



Detail

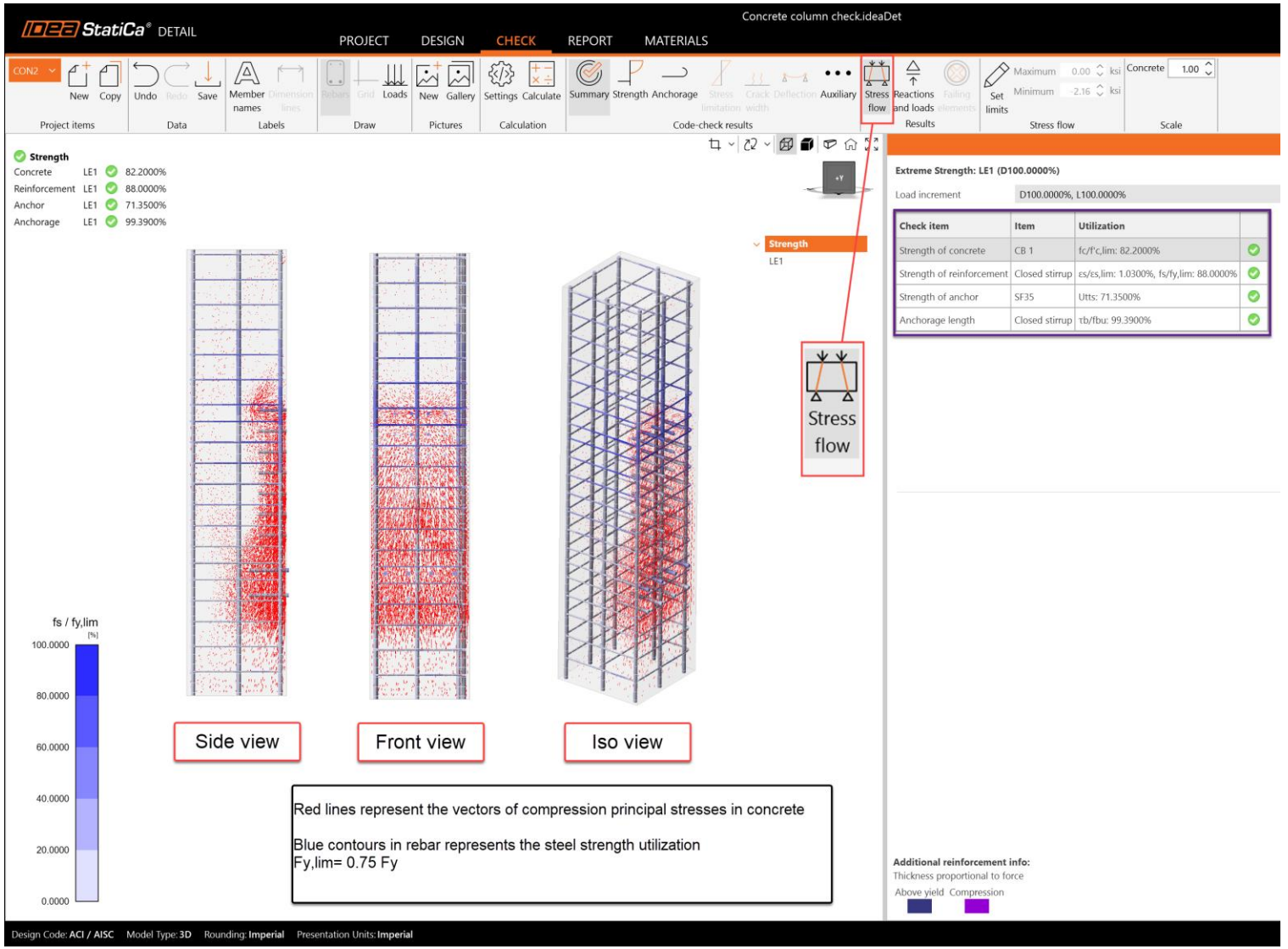
Concrete



START HERE: SUMMARY

Stress flow shows compression paths in concrete

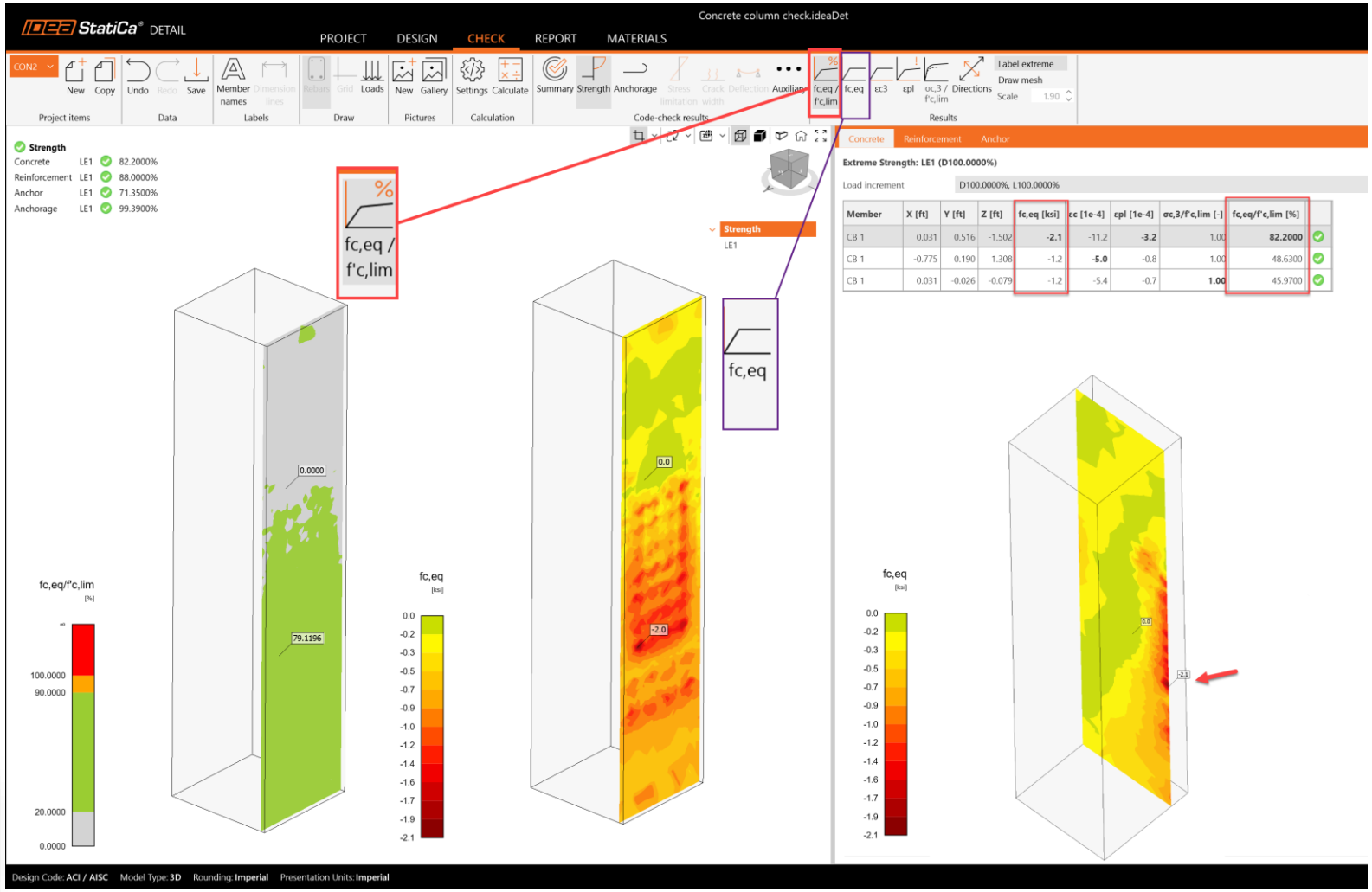
Plus utilization of reinforcement and anchors



CONCRETE BREAKOUT IN DETAIL

Principal stress directions show the cone

Fc,eq/fclim is checked against the factored strength



Concrete compressive strength is assumed as follows:

$$f'_{c,lim} = \alpha_1 \cdot \emptyset_c \cdot \eta_{fc} \cdot f'_c \qquad \left(\eta_{fc} = \left(\frac{30}{f'_c}\right)^{\frac{1}{3}} \leq 1\right)$$

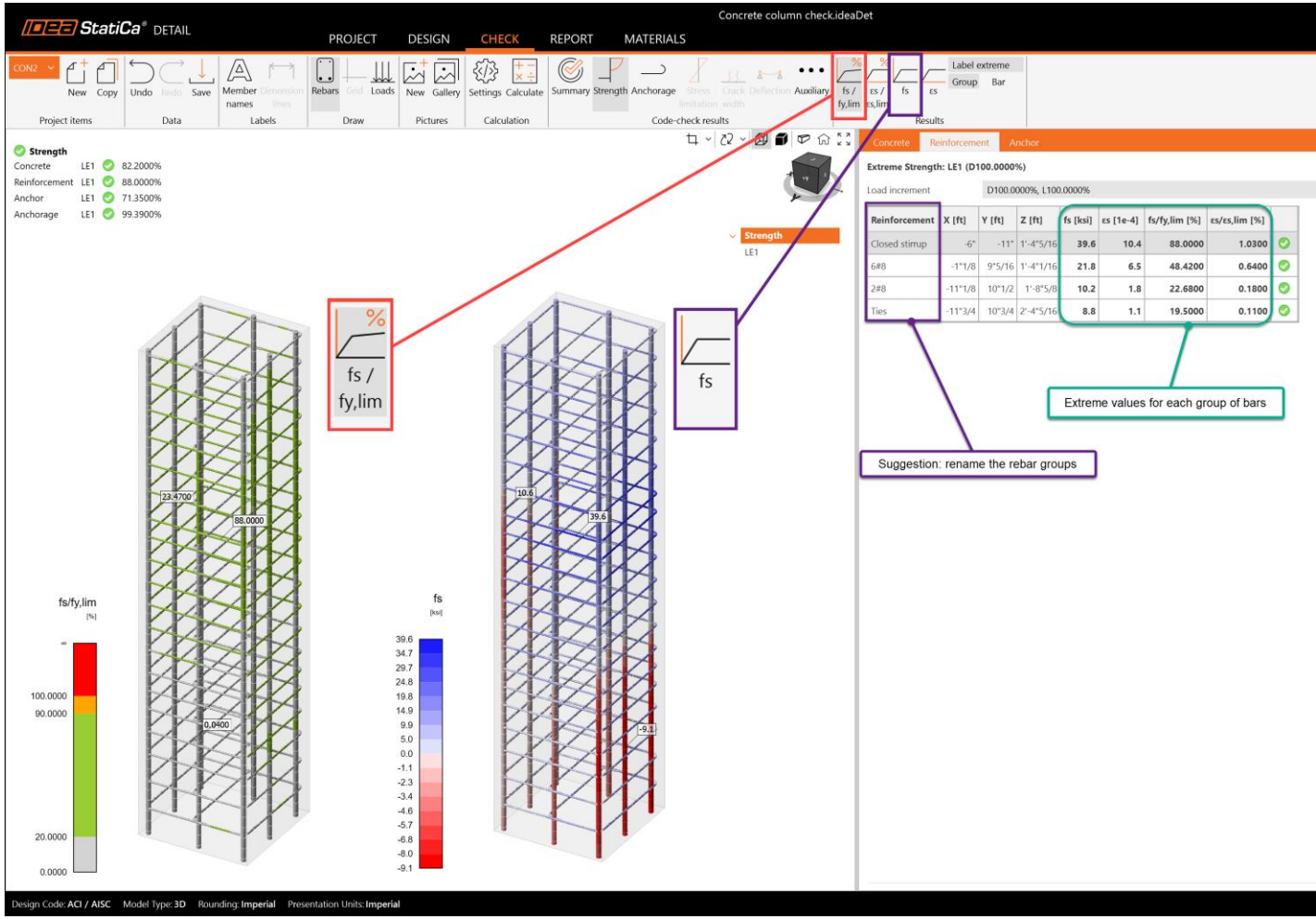
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REINFORCEMENT STRENGTH

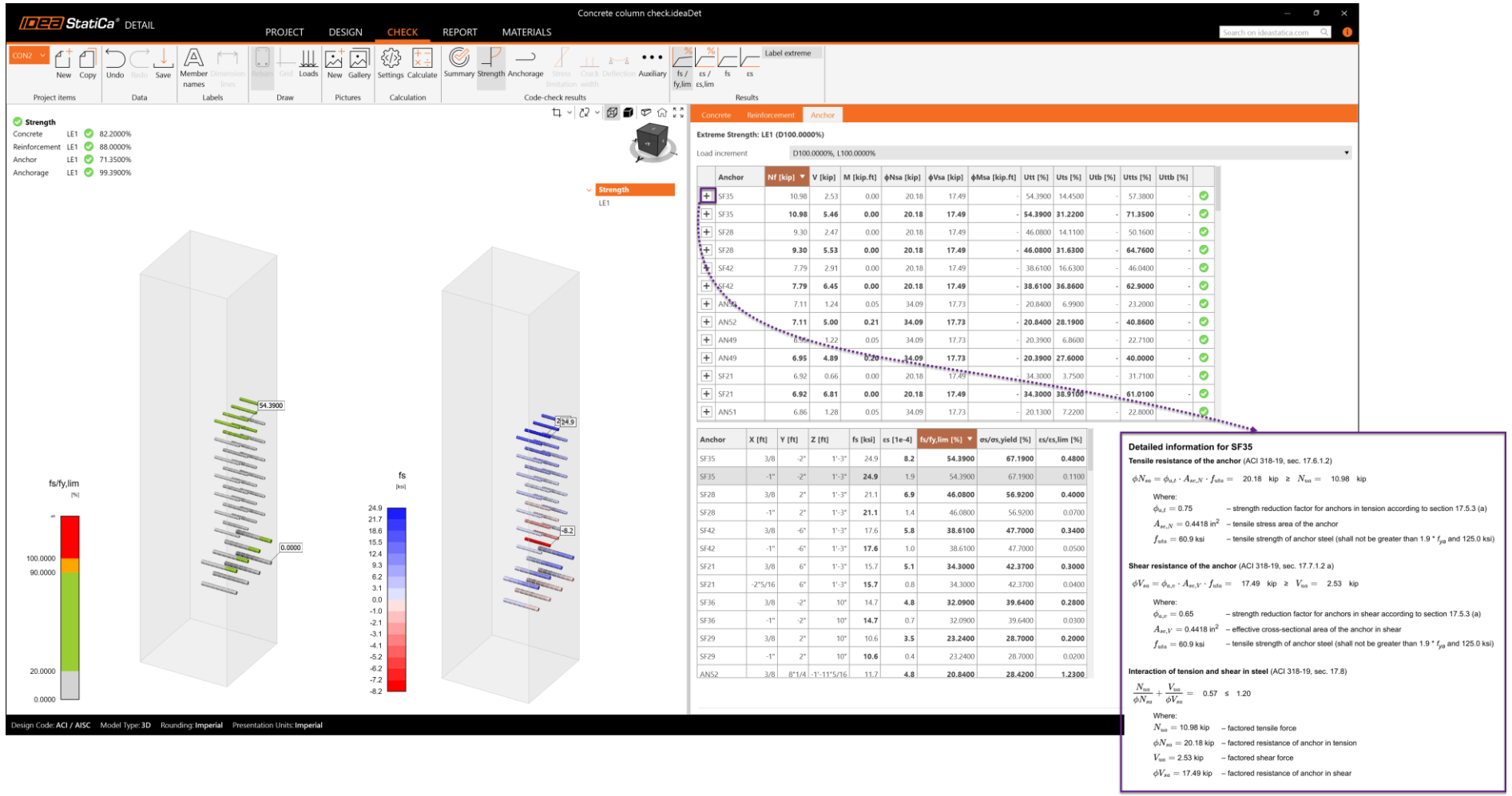
Material utilization: fs/fylim

Tension, compression stress in the bars

Rebar strains



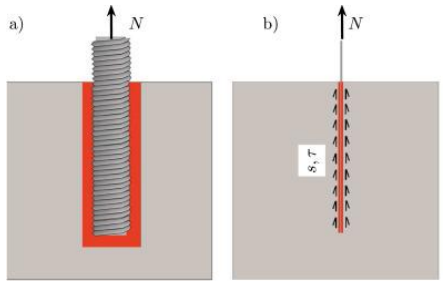
ANCHOR STRENGTH



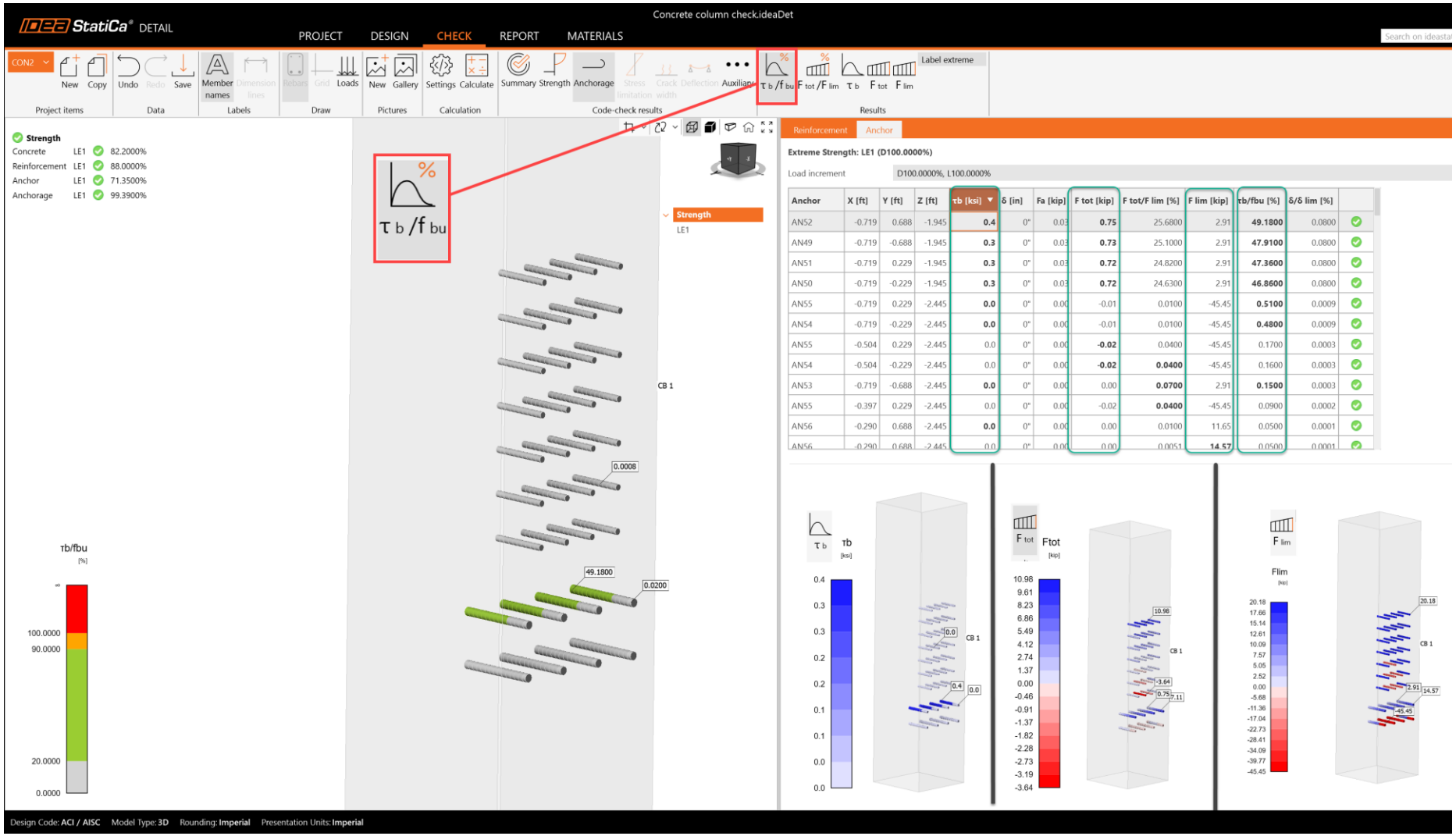
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ANCHORAGE: BOND FOR ADHESIVE ANCHORS

Tb=Bond stress
Ftot=Anchor area x fs (stress in the bar)
Flim= Maximum force that the anchor can develop

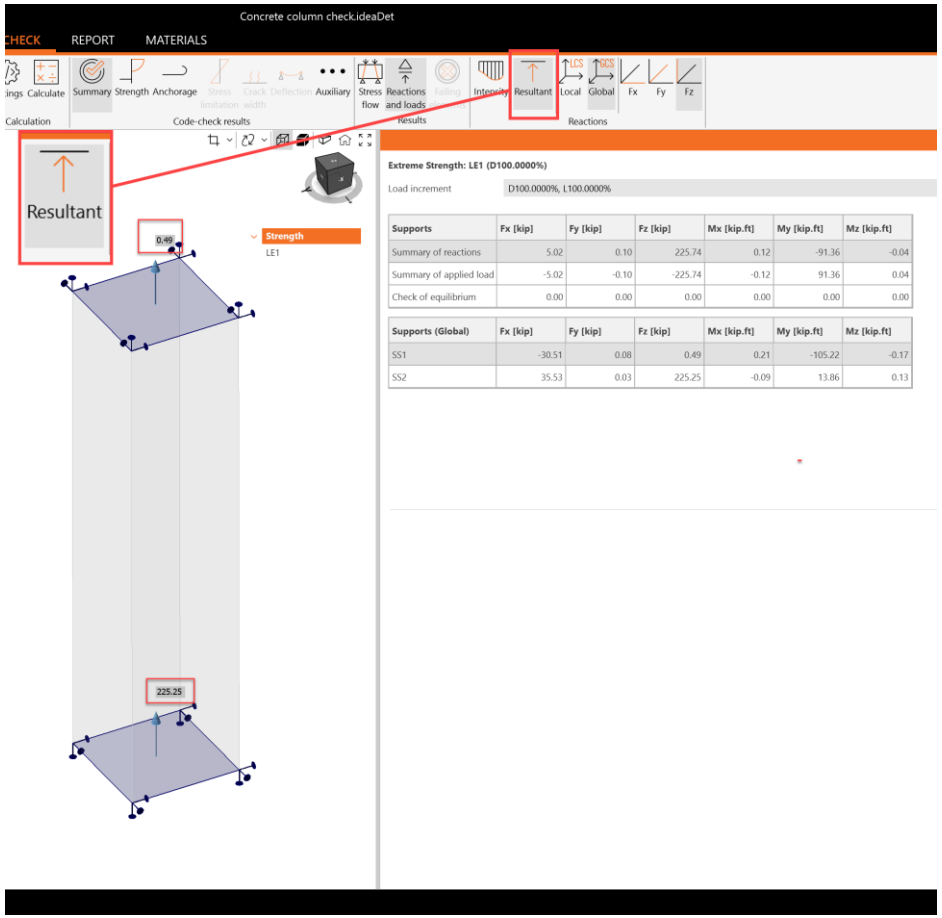


Bond stress representation in adhesive anchors



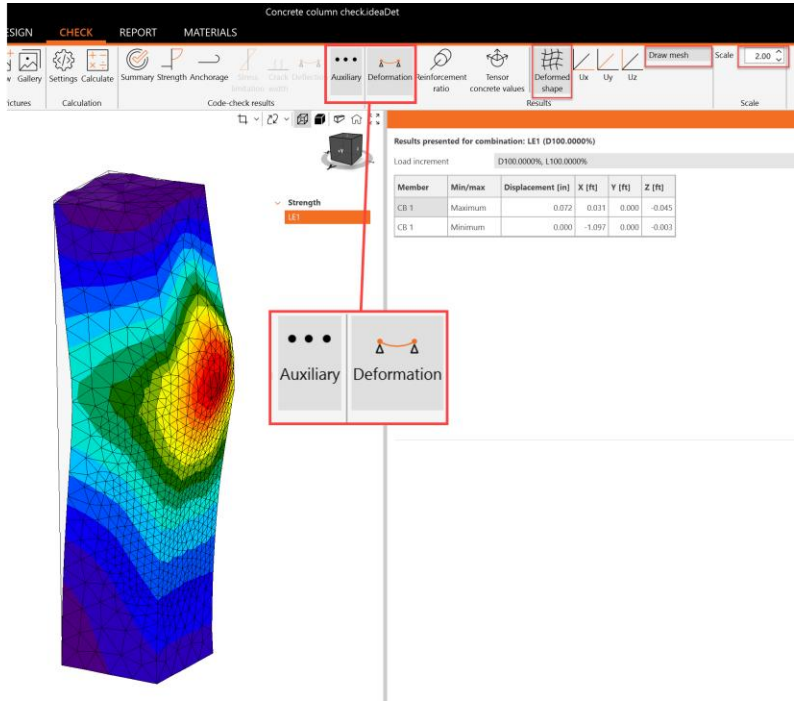
SANITY CHECKS BEFORE TRUSTING RESULTS

Reactions: intensity and resultant



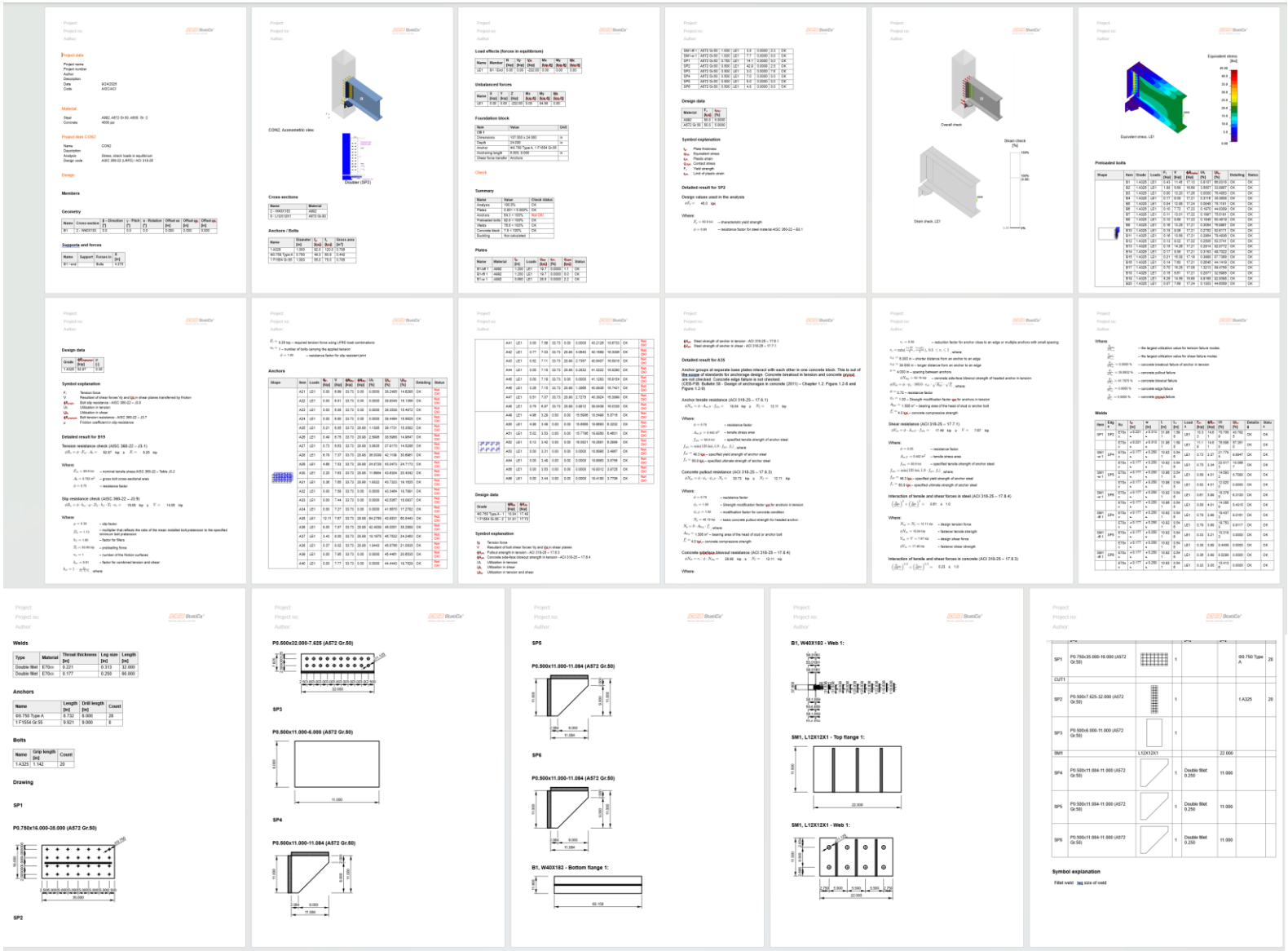
Auxiliary results

Deformation: no large rotations or damaged elements



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COMPLETE REPORT: STEEL CONNECTION+ CONCRETE REINFORCEMENT



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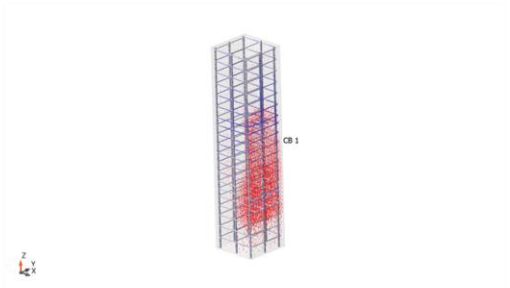
COMPLETE REPORT: STEEL CONNECTION+ CONCRETE REINFORCEMENT

Project:
Project no:
Author:

IDEA StatiCa

Strength - Summary

Stress flow



Summary of reactions and applied loads: LE1, Load increment: D100.0000%

Type	F_x [kip]	F_y [kip]	F_z [kip]	M_x [kip.ft]	M_y [kip.ft]	M_z [kip.ft]
Summary of reactions	5.02	0.10	225.74	0.12	-91.36	-0.04
Summary of applied load	-5.02	-0.10	-225.74	-0.12	91.36	0.04
Check of equilibrium	0.00	0.00	0.00	0.00	0.00	0.00

Strength

Detailed concrete strength results: LE1, Load increment: D100.0000%

Member	X [ft]	Y [ft]	Z [ft]	$f_{c,eq}$ [ksi]	$f_{c,eq}/f'_{c,lim}$ [-]	ε_c [1e-4]	ε_{pl} [1e-4]	$f_{c,eq}/f'_{c,lim}$ [%]	
CB 1	-0.584	-0.116	1.114	-1.8	100.0000	-9.2	-2.4	70.7900	OK
CB 1	-0.718	-0.080	1.416	-1.2	100.0000	-5.0	-0.9	48.8800	OK
CB 1	0.031	-0.026	-0.079	-0.9	100.0000	-3.7	0.0	37.2000	OK

Detailed reinforcement strength results: LE1, Load increment: D100.0000%

Member	X [ft]	Y [ft]	Z [ft]	f_s [ksi]	ε_s [1e-4]	$f_s/f_{y,lim}$ [%]	$\varepsilon_s/\varepsilon_{s,lim}$ [%]	
Closed stirrup	-0.502	-0.919	1.359	39.8	10.5	88.4000	1.0400	OK
6#8	-0.094	0.774	1.337	21.9	6.5	48.5600	0.6500	OK
2#8	-0.927	0.875	1.719	10.2	1.8	22.6500	0.1700	OK
Ties	-0.979	0.898	2.359	8.8	1.1	19.5000	0.1100	OK

Materials

Concrete

Name	f_c' [ksi]	E_c [ksi]	ν [-]
4000 psi	4.0	3605.0	0.15

Reinforcement

Name	f_y [ksi]	E_s [ksi]	Unit mass [lb/ft^3]	Surface
Grade 60	60.0	29000.0	490	Ribbed
	ε_{st} = 1000.0 1e-4, ε_{sc} = 1000.0 1e-4,			

Project:
Project no:
Author:

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$\phi P_n = \phi_{a,c} \cdot A_s \cdot F_n =$ 19.61 kip ≥ $N_{ua} =$ 3.65 kip

Where:

$\phi_{a,c} = 0.90$ – strength reduction factor for anchors in compression according to chapter E1

$A_s = 0.442$ in^2 – tensile stress area of the anchor

$F_n = 0.658^{\frac{F_y}{F_e}} \cdot F_y = 49.3$ ksi – nominal stress in compression

$F_y = 49.3$ ksi – yield strength of anchor steel

$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2} = \infty$ ksi – elastic buckling stress

$E = 30457.9$ ksi – modulus of elasticity of anchor steel

$L_c = 2 \cdot L = 0.000$ in – buckling length (it is assumed on a safe side that the bolt is fixed in the concrete and able to freely rotate at the base plate)

$L = 0.000$ in – laterally unbraced length of the member considered as the summation of half of the base plate thickness, gap, and half of the anchor diameter

$r = \sqrt{\frac{I}{A_s}} = 0.188$ in – radius of gyration of the anchor

$I = \frac{\pi d_s^4}{64} = 0.016$ in^4 – moment of inertia of the anchor

$d_s = 0.750$ in – anchor diameter reduced by threads (if exist)

Tensile resistance of the anchor SF21, SF22, SF23, SF24, SF25, SF26, SF27, SF28, SF29, SF30, SF31, SF32, SF35, SF36, SF37, SF38, SF42, SF43, SF44, SF45, SF46, SF47, SF48
(ACI 318-19, sec. 17.6.1.2)

$\phi N_{sa} = \phi_{a,t} \cdot A_{se,N} \cdot f_{uta} =$ 20.18 kip ≥ $N_{ua} =$ 10.98 kip

Where:

$\phi_{a,t} = 0.75$ – strength reduction factor for anchors in tension according to section 17.5.3 (a)

$A_{se,N} = 0.442$ in^2 – tensile stress area of the anchor

$f_{uta} = 60.9$ ksi – tensile strength of anchor steel (shall not be greater than 1.9 * f_{ya} and 125.0 ksi)

Shear resistance of the anchor SF21, SF22, SF23, SF24, SF25, SF26, SF27, SF28, SF29, SF30, SF31, SF32, SF33, SF34, SF35, SF36, SF37, SF38, SF39, SF40, SF41, SF42, SF43, SF44, SF45, SF46, SF47, SF48
(ACI 318-19, sec. 17.7.1.2 a)

$\phi V_{sa} = \phi_{a,v} \cdot A_{se,V} \cdot f_{uta} =$ 17.49 kip ≥ $V_{ua} =$ 8.52 kip

Where:

$\phi_{a,v} = 0.65$ – strength reduction factor for anchors in shear according to section 17.5.3 (a)

$A_{se,V} = 0.442$ in^2 – effective cross-sectional area of the anchor in shear

$f_{uta} = 60.9$ ksi – tensile strength of anchor steel (shall not be greater than 1.9 * f_{ya} and 125.0 ksi)

Interaction of tension and shear in steel SF35 (ACI 318-19, sec. 17.8)

$\frac{N_{ua}}{\phi N_{sa}} + \frac{V_{ua}}{\phi V_{sa}} =$ 0.72 ≤ 1.20

Where:

$N_{ua} = 10.98$ kip – factored tensile force

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CON2

Bill of material

Items numbering



Brief reinforcement bar table

Index	Φ [in]	Material	Items	Length [in]	Weight [lbm]	Total length [ft]
1	#8	Grade 60	8	107.000	24	71.333
2	#3	Grade 60	20	86.574	3	144.291
3	#3	Grade 60	20	36.882	1	61.470

Detailed reinforcement bar tables

Parameter	Value	Shape
Index	1	
Φ [in]	#8	
Material	Grade 60	
Number of items	8	107.000
Length [in]	107.000	
Weight [lbm]	24	
Total length [ft]	71.333	

Parameter	Value	Shape
Index	2	
Φ [in]	#3	
Material	Grade 60	20.175 20.175 20.175 20.175
Number of items	20	
Length [in]	86.574	
Weight [lbm]	3	
Total length [ft]	144.291	

Parameter	Value	Shape
Index	3	
Φ [in]	#3	
Material	Grade 60	1.125 4.500 19.750 4.500 1.125
Number of items	20	
Length [in]	36.882	
Weight [lbm]	1	
Total length [ft]	61.470	

Overview table

Φ [in]	#3	#8
Total length of Φ [ft]	205.761	71.333
Weight per meter of Φ [lbm/m]	1	9
Total weight of Φ [lbm]	77	191
Total weight of bars [lbm]	268	

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BILL OF MATERIALS

CAD Details

1 - Φ#8 - 107.000 - 8 Pieces

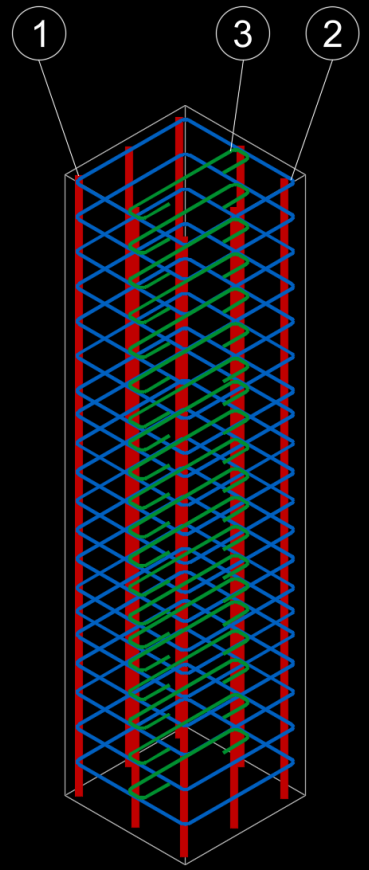


2 - Φ#3 - 86.574 - 20 Pieces

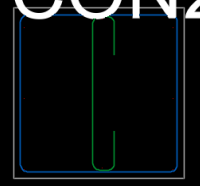


3 - Φ#3 - 36.882 - 20 Pieces





3D - CON2



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POLL

2. CASE: MISALIGNED ANCHORS

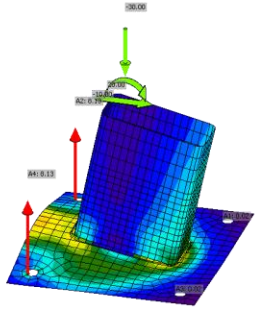
Change: Cast in place anchor position misaligned on site.

Anchors positioned 3” offset from original position

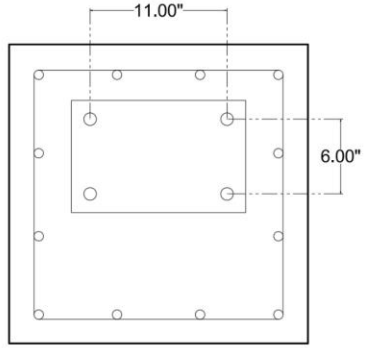
Proposed solution: Replace the existing plate

Keep outer cast-in anchor, cut remaining anchors & install additional post-installed anchors

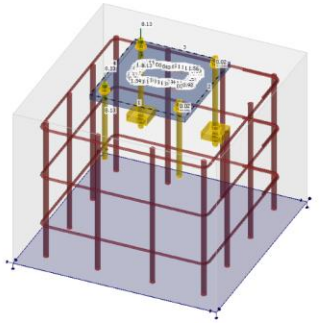
Verify adhesive anchor bond strength, interaction with existing concrete and anchors.



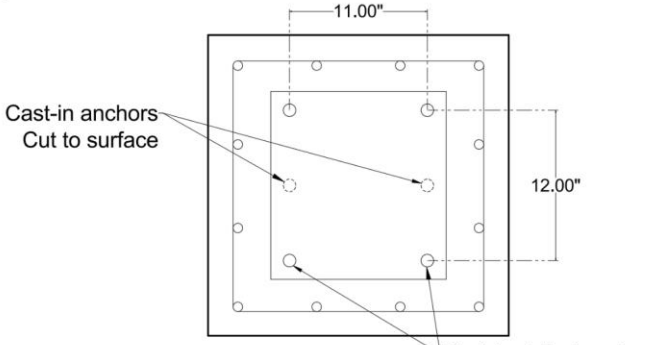
Stresses and anchor forces in Connection app



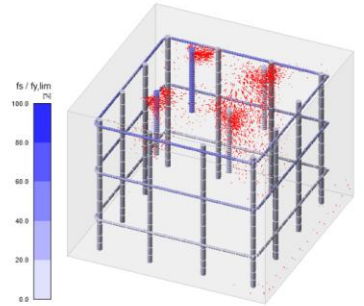
Field placement



Base plate design and forces in Detail 3D app

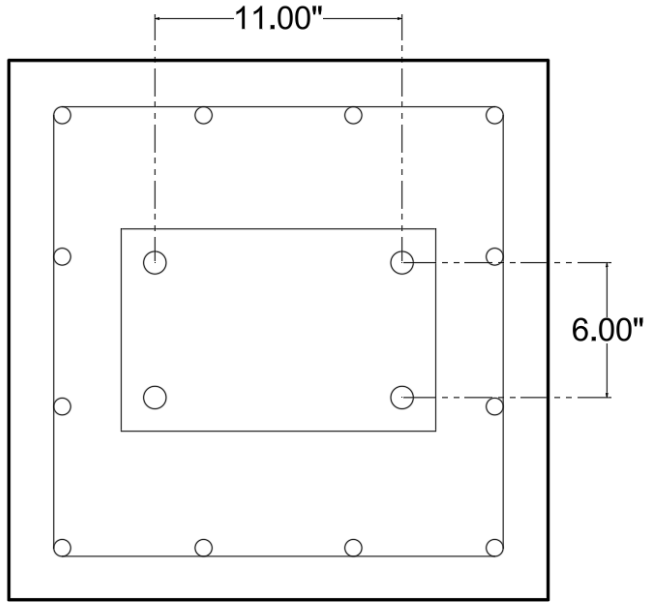


Base plate repair

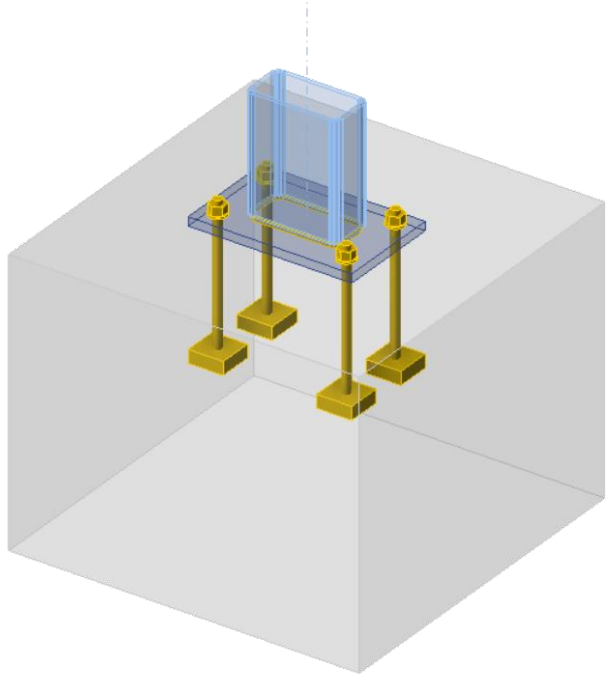


Stress flow in concrete, reinforcement and anchors

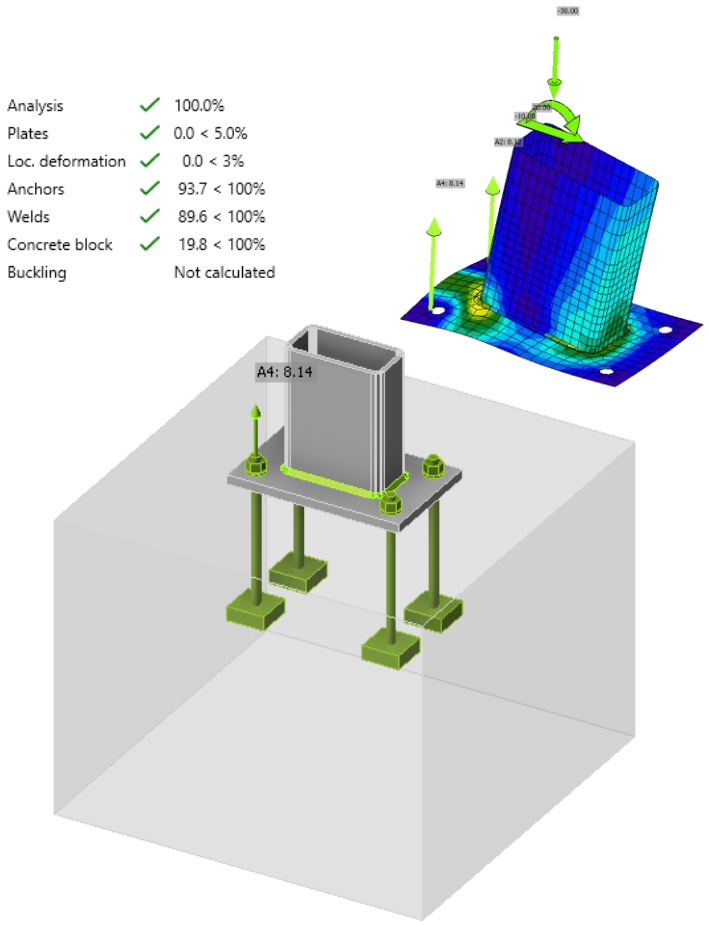
ORIGINAL DESIGN



Original base plate design drawing



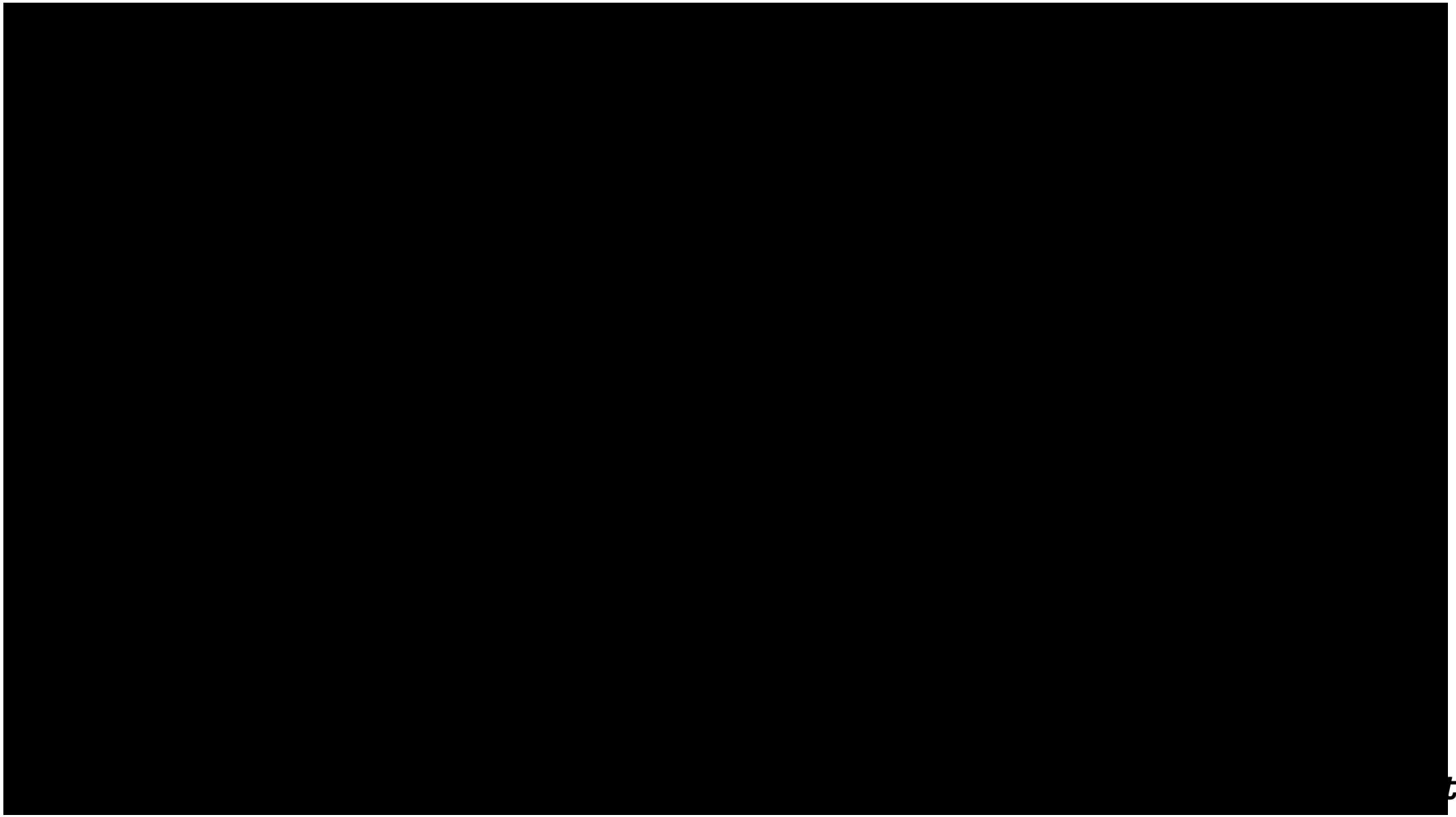
Base plate model in Connection app



Base plate connection design results

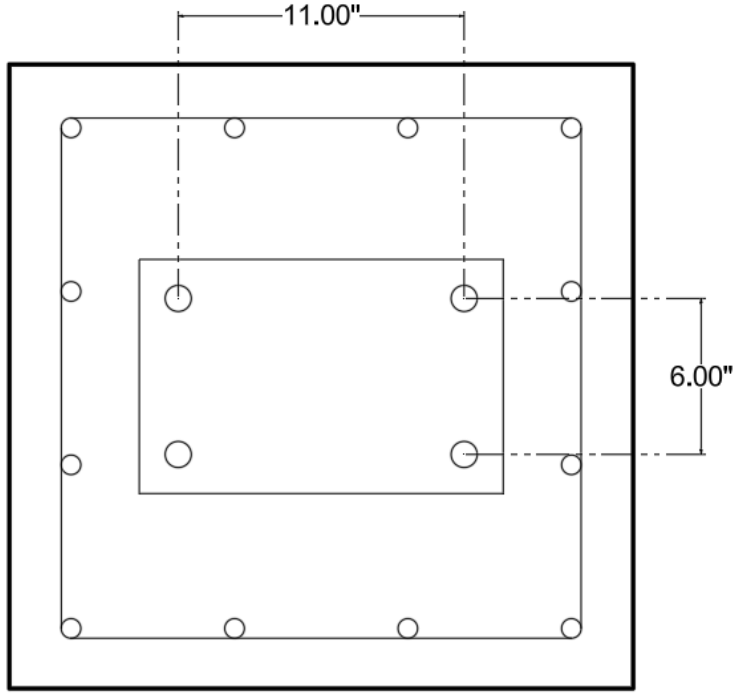
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Link to YT

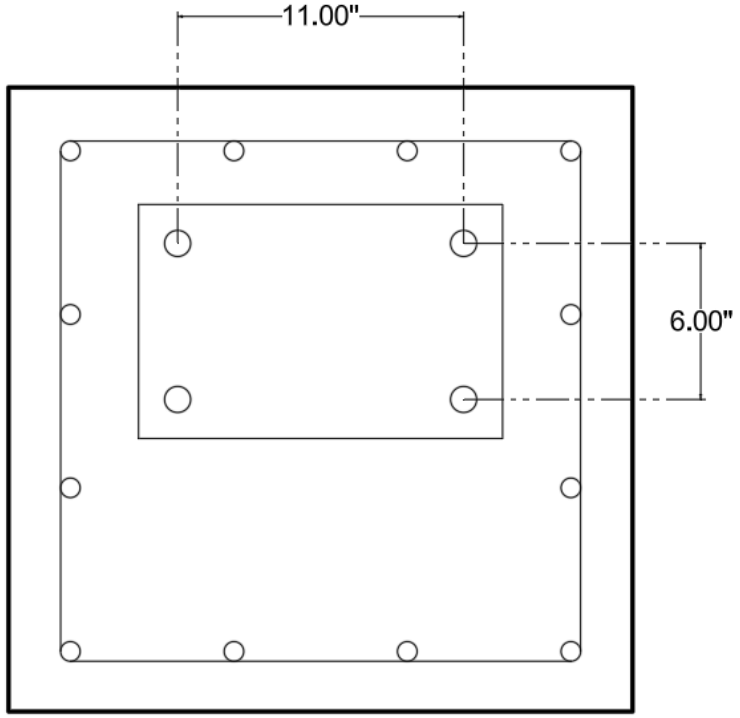


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RFI – MISALIGNED ANCHORS



Original base plate design



Field placement base plate

Cast-in place 3” offset from original position

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AISC DESIGN GUIDE 1 – BASE PLATE AND ANCHOR ROD DESIGN

AISC Design guide 1, chapter 2.11 provides guidance on anchor rod repairs



signed, and placed in a proper and timely manner.

Grout should have a design compressive strength at least twice the strength of the foundation concrete. This will be adequate to transfer the maximum steel bearing pressure to the foundation. The design thickness of the grout space will

2.11.1 Anchor Rods in the Wrong Position

For anchor rods in the wrong position, the repair method depends on the nature of the problem and when in the construction process it is first noted. Is the repair required for

only one rod, or for the entire pattern of rods? How far out of position is the rod or pattern, and what are the required strengths of the rods?

If the error is discovered before the column base plate has been fabricated, it might be possible to use a different pattern or even a different base plate. If the rod positions interfere with the column shaft, it may be necessary to modify the column shaft by cutting and reinforcing sections of the flange or web.

If one or two rods in a pattern are misplaced after the column has been fabricated and shipped, the most common repair is to slot the base plate, and use a plate washer to span the slot. If the entire pattern is off uniformly, it might be possible to cut the base plate off and offset the base plate to accommodate the out of tolerance. It is necessary to check the base plate design for this eccentricity. When removing the base plate, it may be required to turn the plate over to have a clean surface on which to weld the column shaft.

If the anchor rod or rods are more than a couple of inches out of position, the best solution may be to cut off the existing rods and install new drilled-in epoxy-type anchor rods. When using such rods, carefully follow the manufacturer's recommendations, and provide inspection as required in the applicable building code. Locate the holes to avoid reinforcing steel in the foundation. If any reinforcing steel is cut, a check of the effect on foundation strength should be made.

removal. Anchor rod locations should be clearly flagged so that they are visible to equipment operators working in the area. The anchor rods shown in Figure 2.3 were damaged because they were covered with snow and the crane operator could not see them.

ASTM F1554 permits both cold and hot bending of anchor rods to form hooks; however, bending in the threaded area can be a problem. It is recommended that only Grade 36 rods be bent in the field and the bend limited to 45° or less. Rods up to about 1 in. in diameter can be cold bent. Rods over 1 in. can be heated up to 1,200 °F to make bending easier. It is recommended that bending be done using a rod bending device called a hickey. After bending, the rods should be visually inspected for cracks. If there is concern about the tensile strength of the anchor rod, the rod can be load tested.

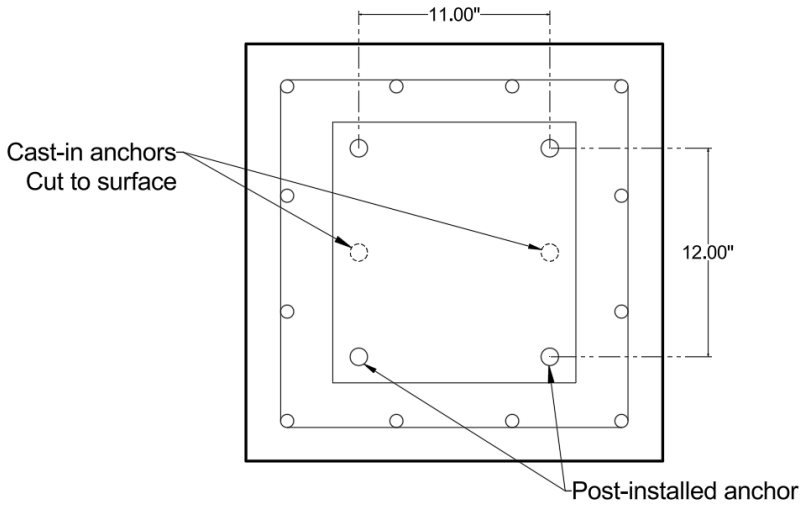
2.11.3 Anchor Rod Projection Too Long or Too Short

Anchor rod projections that are too short or too long must be investigated to determine if the correct anchor rods were installed. If the anchor rod is too short, the anchor rod may be projecting below the foundation. If the rod projection is too long, the embedment may not be adequate to develop the required tensile strength.

Often, when the anchor rod is short, it may be possible to partially engage the nut. A conservative estimate of the

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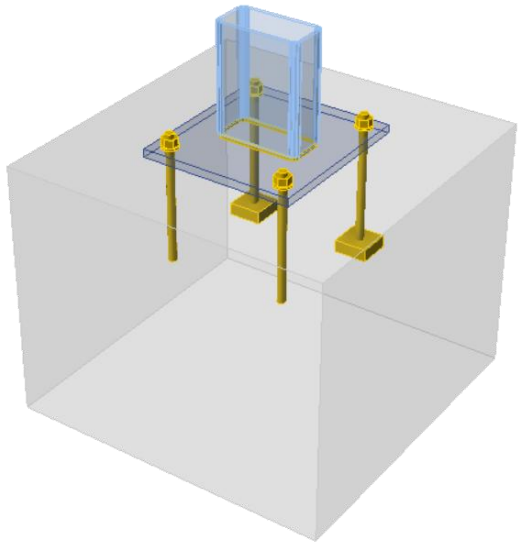
POST-INSTALLED ANCHORS – PROPOSED SOLUTION



Proposed connection design solution

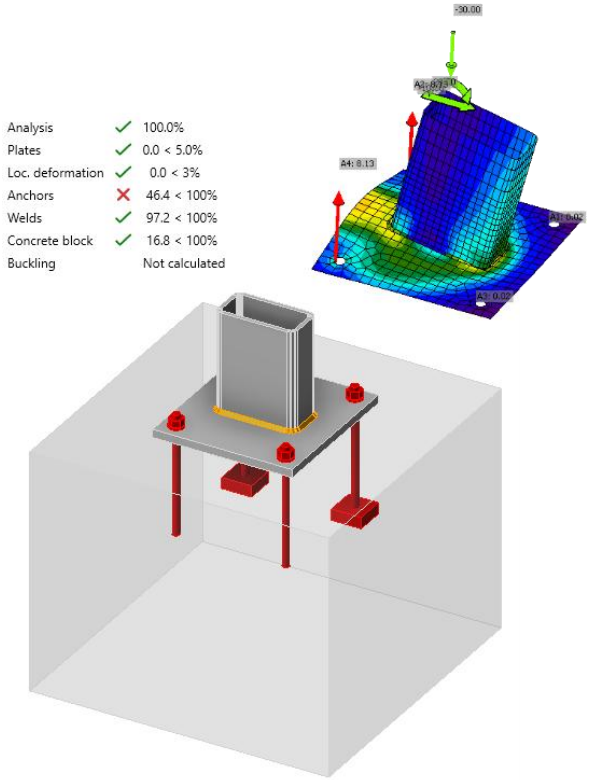
Cut existing central anchors

Add post-installed anchors



Proposed connection model in Connection app

Cast-in place and post-installed anchors modeled



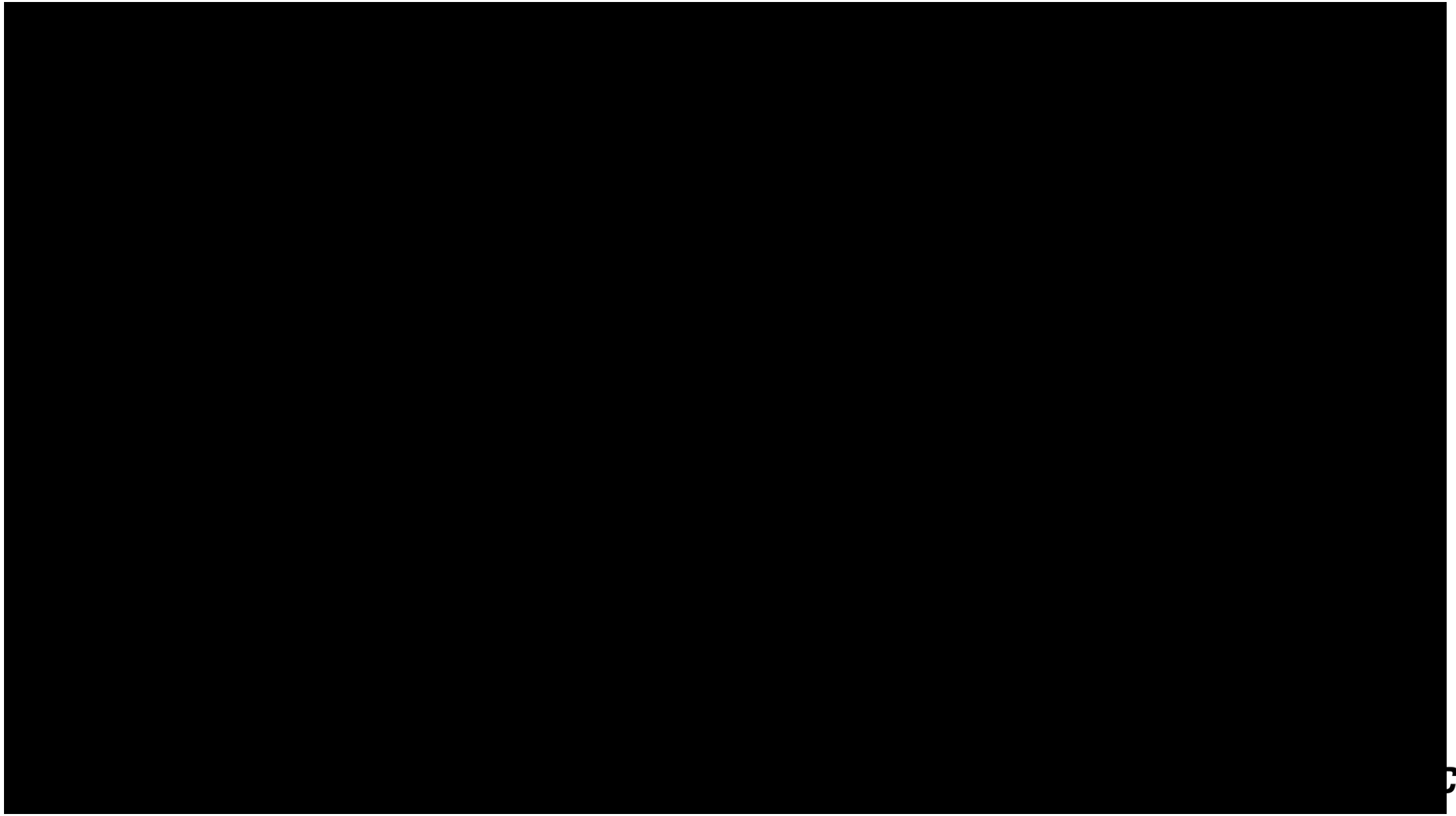
Proposed connection design results

Modified base plate verified

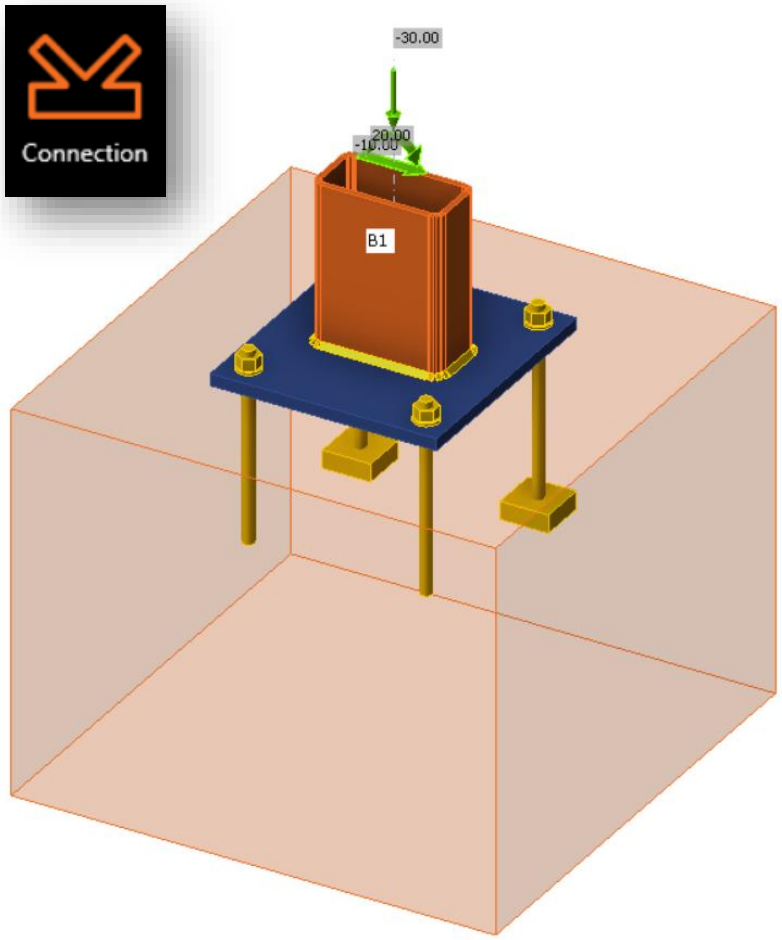
Interaction of different anchor types

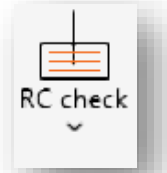
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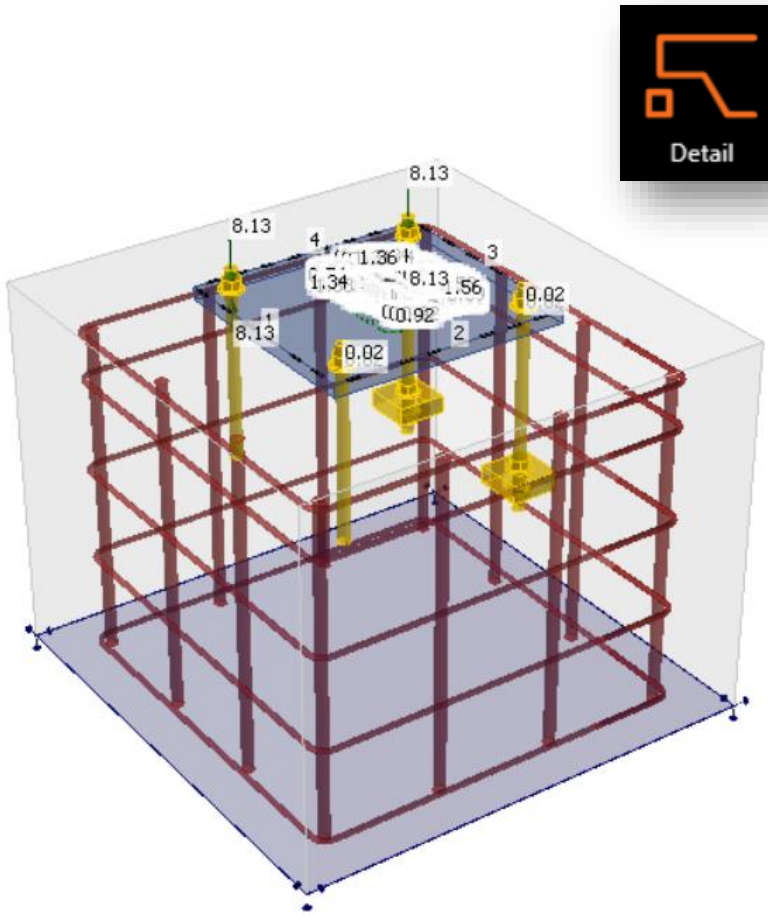
Link to YouTube



POST-INSTALLED ANCHOR VERIFICATION – WHAT TO DO?

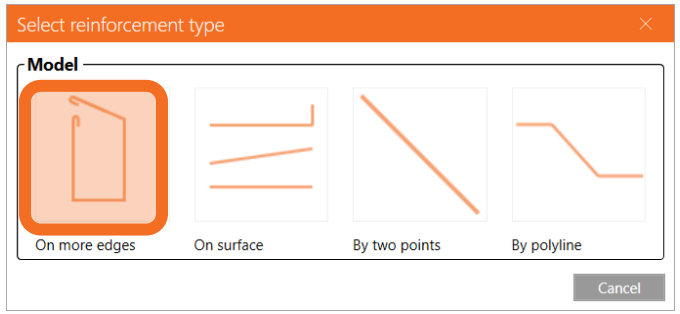


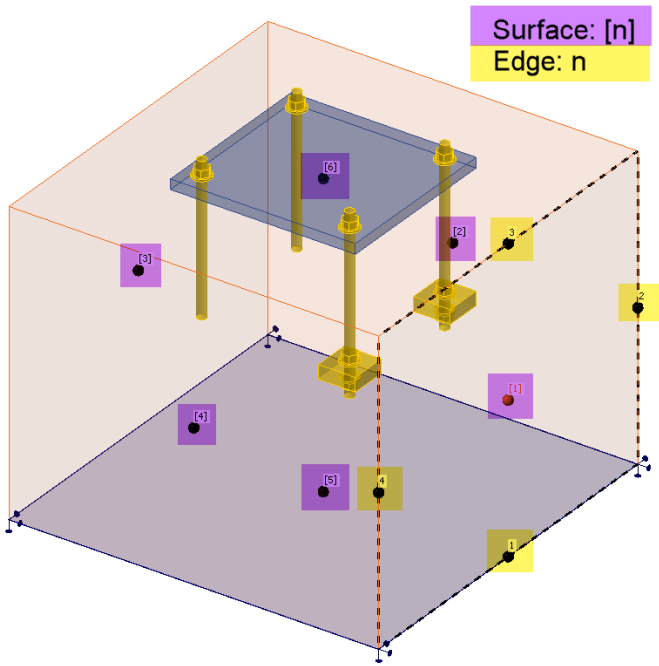


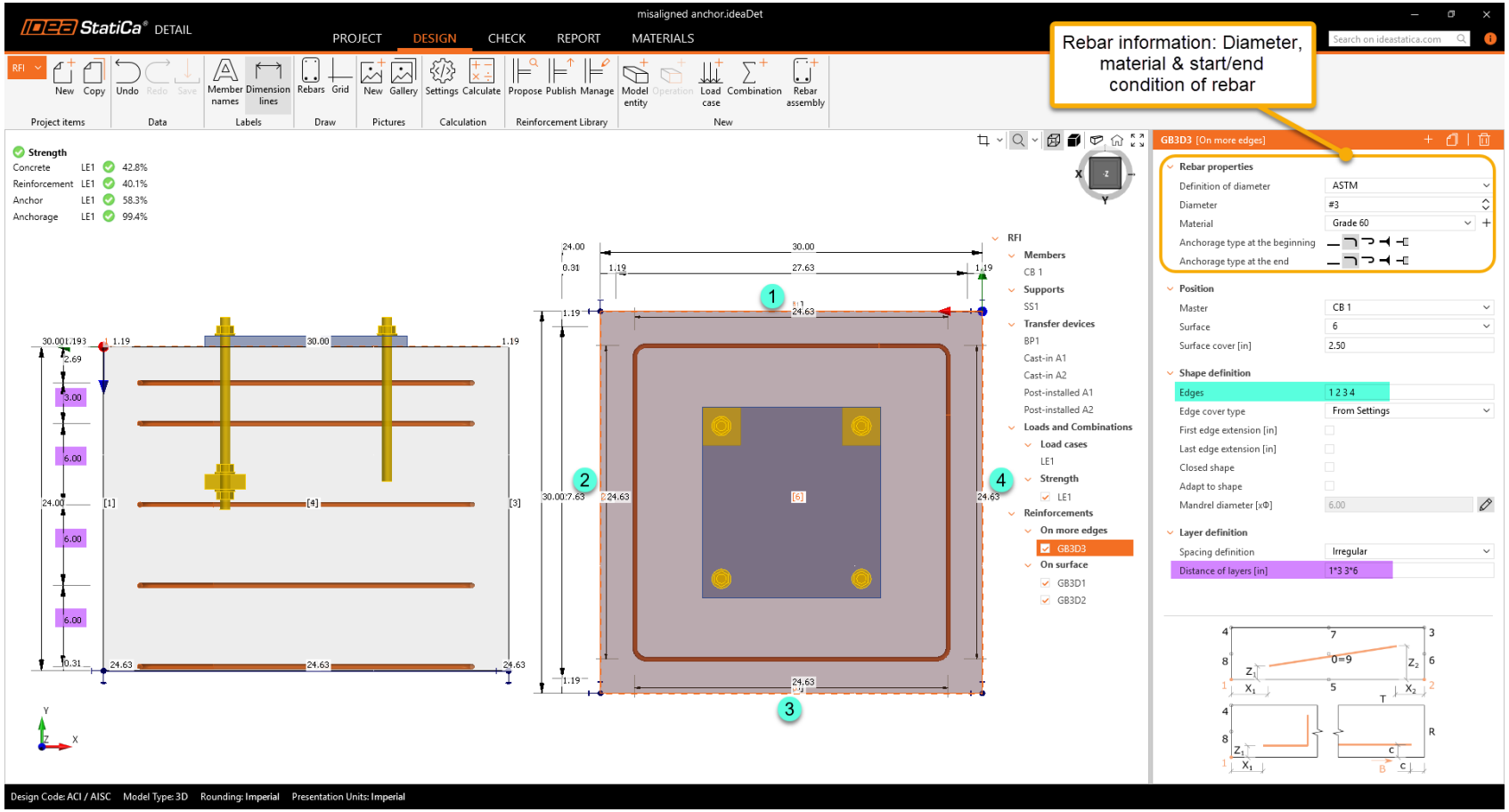


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TIE REBAR MODELING

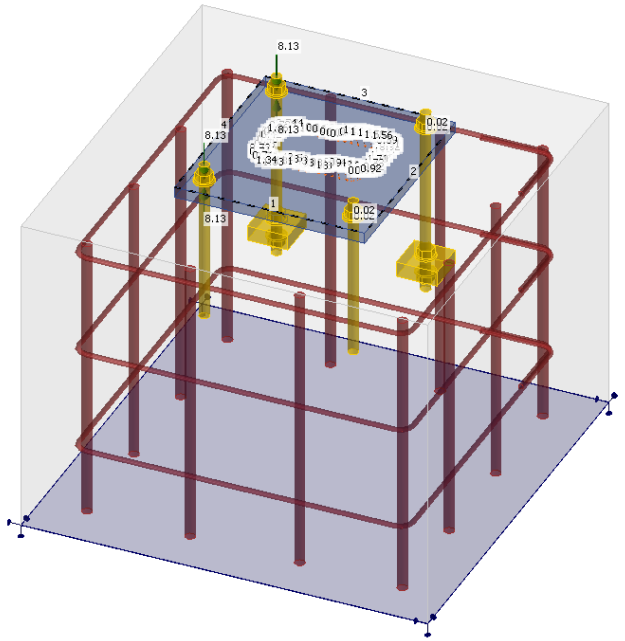


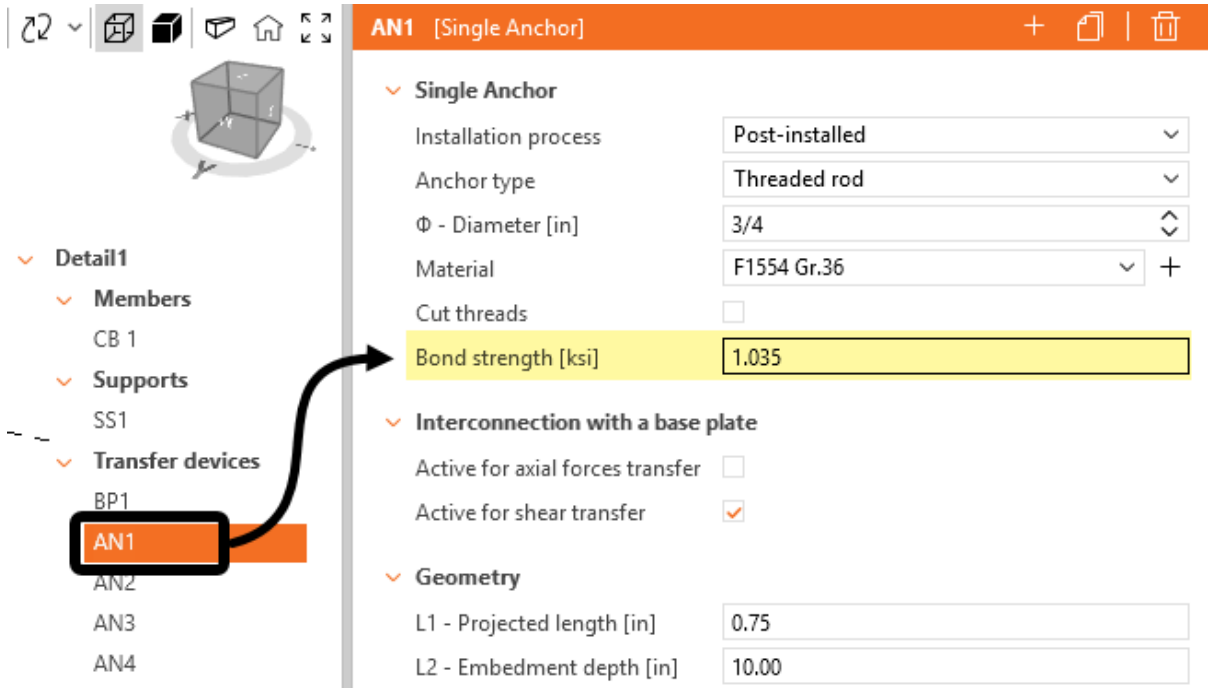




BOND STRENGTH IN DETAIL 3D

- Export base plate with RC Check
- Apply bond strength to post installed anchors
- Add reinforcement to concrete

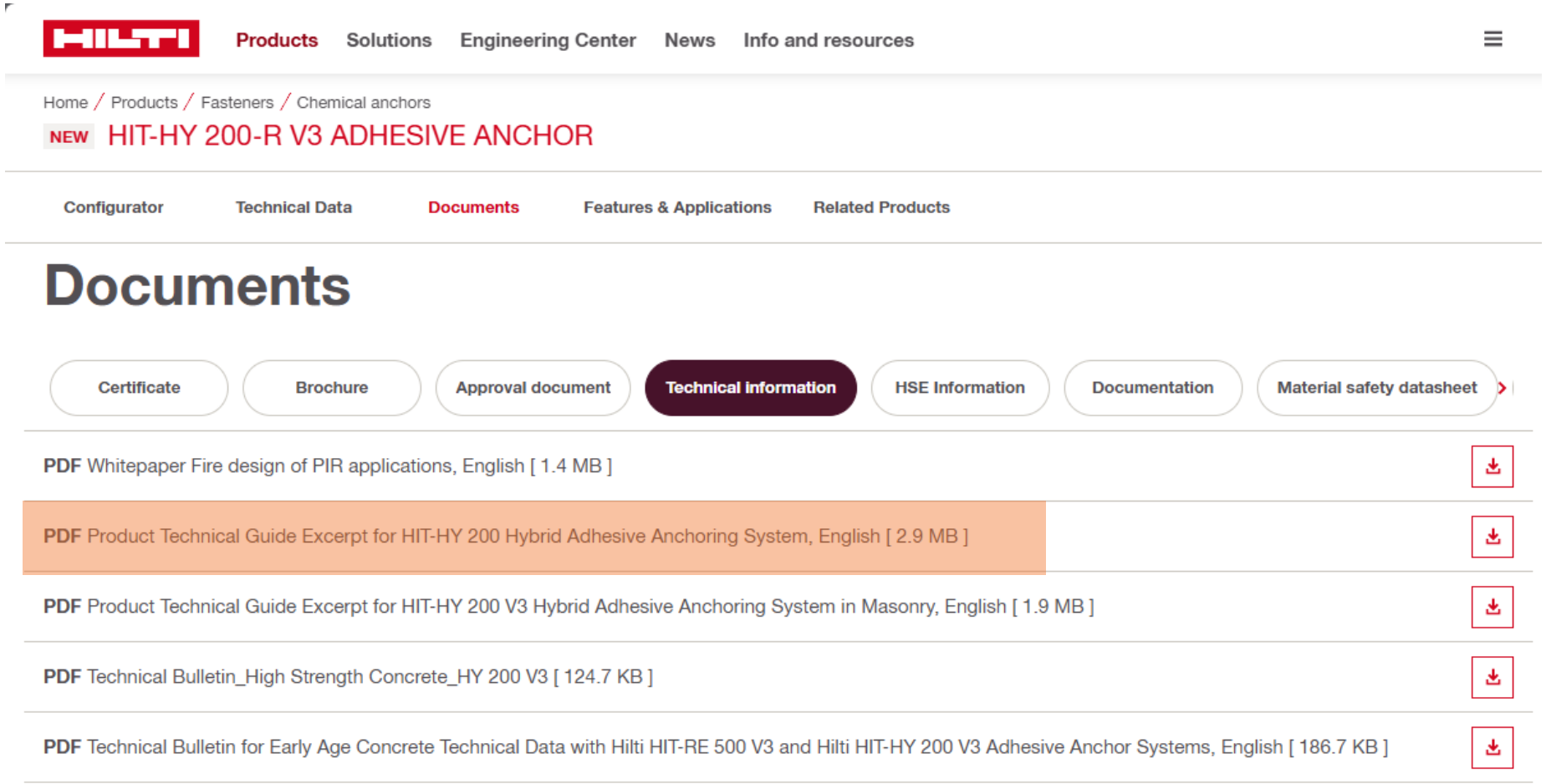




Bond strength for anchors in Detail 3D

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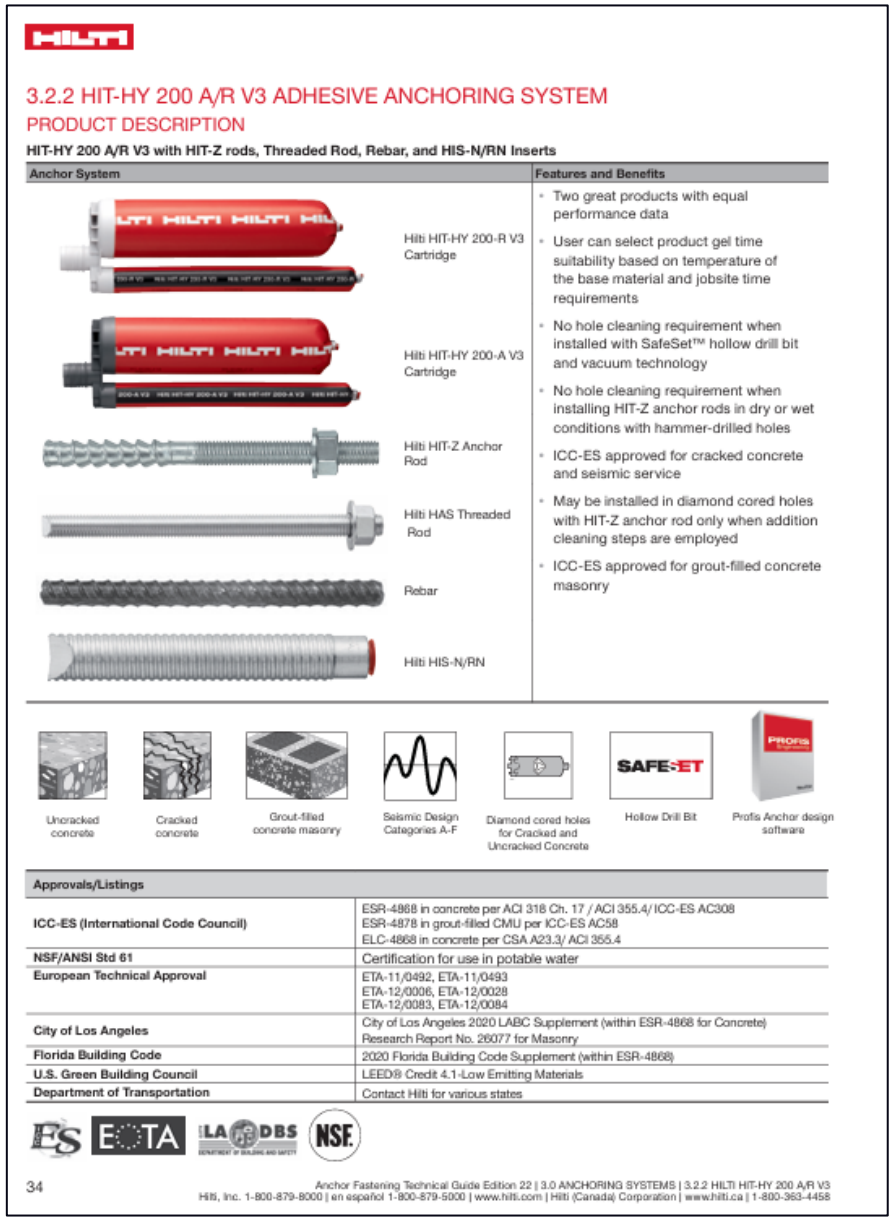
MANUFACTURER TECHNICAL GUIDE



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PRODUCT APPROVALS TABLE

Approvals/Listings	
ICC-ES (International Code Council)	ESR-4868 in concrete per ACI 318 Ch. 17 / ACI 355.4/ ICC-ES AC308 ESR-4878 in grout-filled CMU per ICC-ES AC58 ELC-4868 in concrete per CSA A23.3/ ACI 355.4
NSF/ANSI Std 61	Certification for use in potable water
European Technical Approval	ETA-11/0492, ETA-11/0493 ETA-12/0006, ETA-12/0028 ETA-12/0083, ETA-12/0084
City of Los Angeles	City of Los Angeles 2020 LABC Supplement (within ESR-4868 for Concrete) Research Report No. 26077 for Masonry
Florida Building Code	2020 Florida Building Code Supplement (within ESR-4868)
U.S. Green Building Council	LEED® Credit 4.1-Low Emitting Materials
Department of Transportation	Contact Hilti for various states



HILTI

3.2.2 HIT-HY 200 A/R V3 ADHESIVE ANCHORING SYSTEM

PRODUCT DESCRIPTION

HIT-HY 200 A/R V3 with HIT-Z rods, Threaded Rod, Rebar, and HIS-N/RN Inserts

Anchor System	Features and Benefits
Hilti HIT-HY 200-R V3 Cartridge Hilti HIT-HY 200-A V3 Cartridge Hilti HIT-Z Anchor Rod Hilti HAS Threaded Rod Rebar Hilti HIS-N/RN	• Two great products with equal performance data • User can select product gel time suitability based on temperature of the base material and jobsite time requirements • No hole cleaning requirement when installed with SafeSet™ hollow drill bit and vacuum technology • No hole cleaning requirement when installing HIT-Z anchor rods in dry or wet conditions with hammer-drilled holes • ICC-ES approved for cracked concrete and seismic service • May be installed in diamond cored holes with HIT-Z anchor rod only when addition cleaning steps are employed • ICC-ES approved for grout-filled concrete masonry

Uncracked concrete | Cracked concrete | Grout-filled concrete masonry | Seismic Design Categories A-F | Diamond cored holes for Cracked and Uncracked Concrete | Hollow Drill Bit | Profis Anchor design software

Approvals/Listings	
ICC-ES (International Code Council)	ESR-4868 in concrete per ACI 318 Ch. 17 / ACI 355.4/ ICC-ES AC308 ESR-4878 in grout-filled CMU per ICC-ES AC58 ELC-4868 in concrete per CSA A23.3/ ACI 355.4
NSF/ANSI Std 61	Certification for use in potable water
European Technical Approval	ETA-11/0492, ETA-11/0493 ETA-12/0006, ETA-12/0028 ETA-12/0083, ETA-12/0084
City of Los Angeles	City of Los Angeles 2020 LABC Supplement (within ESR-4868 for Concrete) Research Report No. 26077 for Masonry
Florida Building Code	2020 Florida Building Code Supplement (within ESR-4868)
U.S. Green Building Council	LEED® Credit 4.1-Low Emitting Materials
Department of Transportation	Contact Hilti for various states

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Anchor Fastening Technical Guide Edition 22 | 3.0 ANCHORING SYSTEMS | 3.2.2 HILTI HIT-HY 200 A/R V3
Hilti, Inc. 1-800-879-8000 | en español 1-800-879-5000 | www.hilti.com | Hilti (Canada) Corporation | www.hilti.ca | 1-800-363-4458

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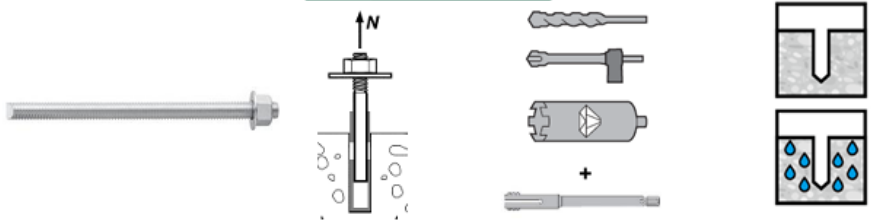
OBTAIN BOND STRENGTH OF ANCHOR

ICC EVALUATION SERVICE®

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ESR-4868



Fractional Threaded Rod | Bond Strength | Carbide Bit or Hilti Hollow Carbide Bit or Diamond Core Bit with Roughening Tool | Dry and Water Saturated Concrete



Fractional Threaded Rod | Bond Strength | Carbide Bit or Hilti Hollow Carbide Bit or Diamond Core Bit with Roughening Tool

TABLE 15—BOND STRENGTH DESIGN INFORMATION FOR FRACTIONAL THREADED ROD
IN HOLES DRILLED WITH A HAMMER DRILL AND CARBIDE BIT (OR HILTI HOLLOW CARBIDE DRILL BIT) OR CORE DRILLED WITH A DIAMOND CORE BIT AND ROUGHENED WITH A HILTI ROUGHENING TOOL[1]

DESIGN INFORMATION		Symbol	Units	Nominal rod diameter (in.)						
				3/8	1/2	5/8	3/4	7/8	1	1 1/4
Minimum Embedment		$h_{ef,min}$	in. (mm)	2 3/8 (60)	2 3/4 (70)	3 1/8 (79)	3 1/2 (89)	3 1/2 (89)	4 (102)	5 (127)
Maximum Embedment		$h_{ef,max}$	in. (mm)	7 1/2 (191)	10 (254)	12 1/2 (318)	15 (381)	17 1/2 (445)	20 (508)	25 (635)
Temperature range A[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range B[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	1,045 (7.2)	1,135 (7.8)	1,170 (8.1)	1,260 (8.7)	1,290 (8.9)	1,325 (9.1)	1,380 (9.5)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)	2,220 (15.3)
Temperature range C[2]	Characteristic bond strength in cracked concrete	$\tau_{k,cr}$	psi (MPa)	855 (5.9)	930 (6.4)	960 (6.6)	1,035 (7.1)	1,055 (7.3)	1,085 (7.5)	1,130 (7.8)
	Characteristic bond strength in uncracked concrete	$\tau_{k,uncr}$	psi (MPa)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)	1,820 (12.6)
Permissible installation conditions	Dry and water saturated concrete	Anchor Category	-	1						
		ϕ_{d}, ϕ_{ws}	-	0.65						
Reduction for seismic tension	Hammer drilled	$\alpha_{N,seis}$	-	0.88	0.99	0.99	1.0	1.0	0.95	0.99
	Core drilled + roughening	$\alpha_{N,seis}$	-	N/A		0.88	0.96	0.96	1.0	0.82

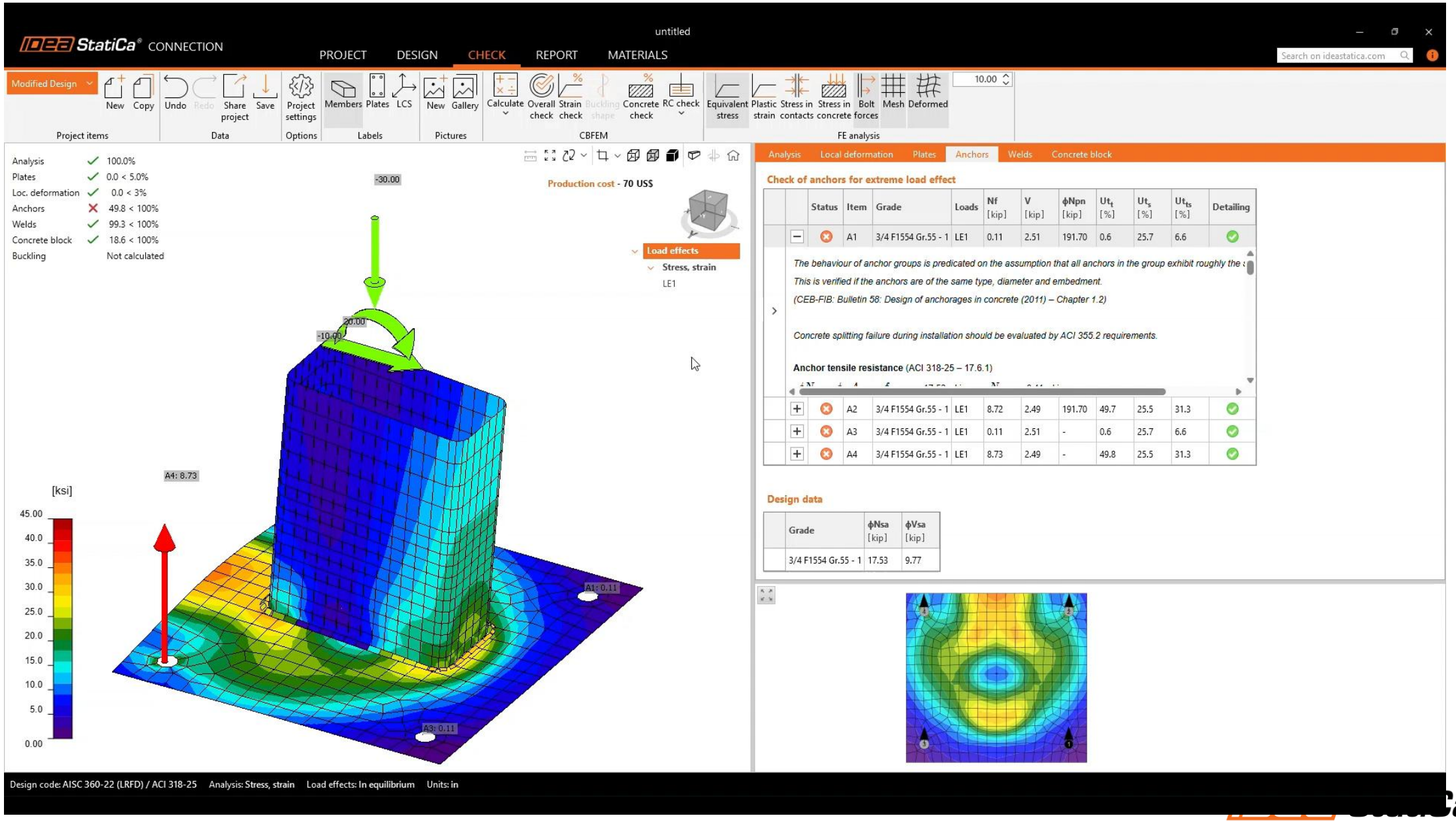
For **SI**: 1 inch ≡ 25.4 mm, 1 lbf = 4.448 N, 1 psi = 0.006897 MPa.
For pound-inch units: 1 mm = 0.03937 inches, 1 N = 0.2248 lbf, 1 MPa = 145.0 psi

[1] Bond strength values correspond to concrete compressive strength f'_c = 2,500 psi (17.2 MPa). For concrete compressive strength, f'_c, between 2,500 psi (17.2 MPa) and 8,000 psi (55.2 MPa), the tabulated characteristic bond strength may be increased by a factor of $(f'_c / 2{,}500)^{0.1}$ [For SI: $(f'_c / 17.2)^{0.1}$]. See Section 4.1.4 of this report for bond strength determination.

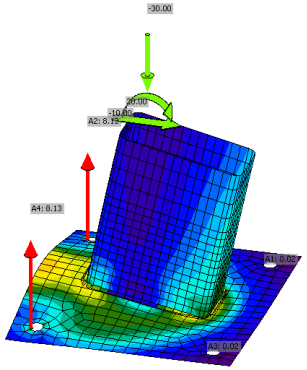
[2] Temperature range A: Maximum short term temperature = 130°F (55°C), Maximum long term temperature = 110°F (43°C).
Temperature range B: Maximum short term temperature = 176°F (80°C), Maximum long term temperature = 110°F (43°C).
Temperature range C: Maximum short term temperature = 248°F (120°C), Maximum long term temperature = 162°F (72°C).
Short term elevated concrete temperatures are those that occur over brief intervals, e.g., as a result of diurnal cycling. Long term concrete temperatures are roughly constant over significant periods of time.

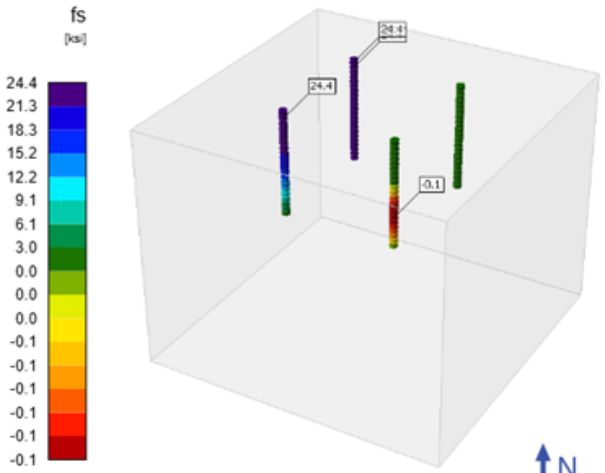
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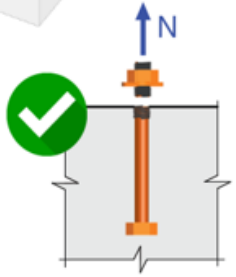
Link to YouTube video



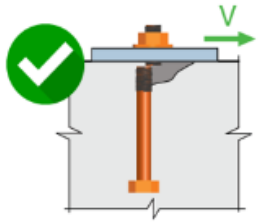
VERIFY ANCHOR STRENGTH FROM RESULTS







(i) Steel failure



(i) Steel failure preceded by concrete spall

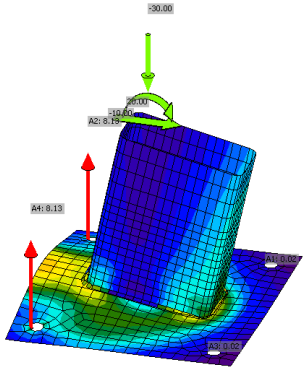
Load increment D100.0%, L100.0%

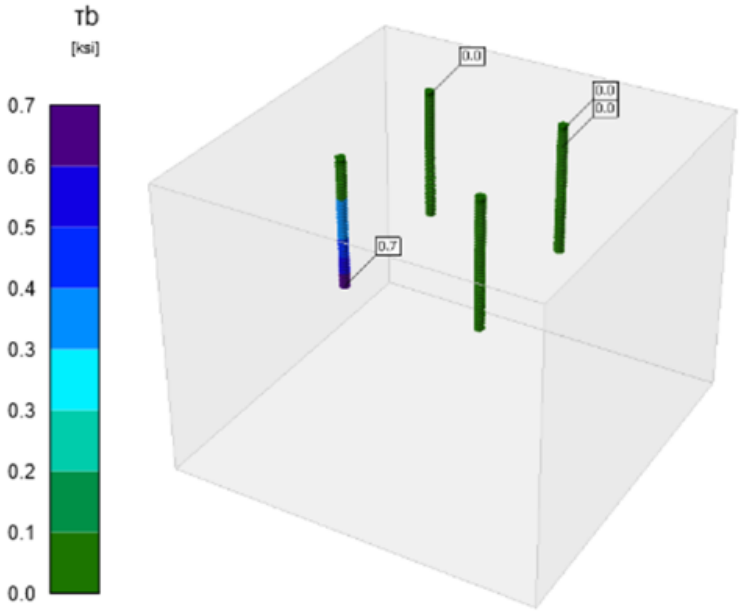
Steel anchor tension and shear check

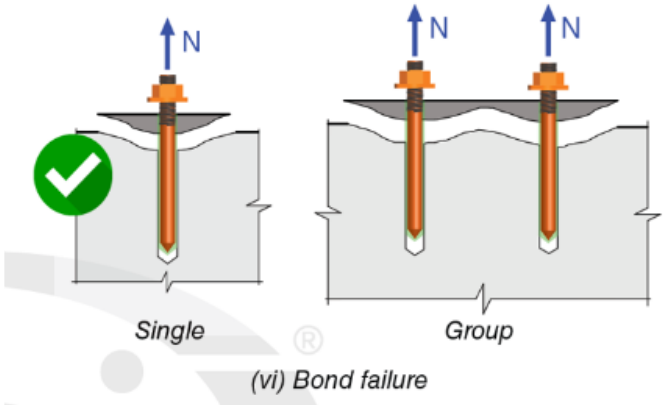
	Anchor	Nf [kip]	V [kip]	M [kip.ft]	ϕNsa [kip]	ϕVsa [kip]	ϕMsa [kip.ft]	Utt [%]	Uts [%]	Utb [%]	Utts [%]	Uttb [%]	
+	Cast-in A2	8.13	2.65	0.09	18.75	9.75	-	43.3	27.2	-	58.8	-	✓
+	Post-installed A2	8.13	2.55	0.08	18.75	9.75	-	43.4	26.1	-	57.9	-	✓
+	Cast-in A2	8.13	1.99	0.06	18.75	9.75	-	43.3	20.4	-	53.1	-	✓
+	Post-installed A1	0.02	2.45	0.08	18.75	9.75	-	0.1	25.2	-	21.1	-	✓
+	Cast-in A1	0.02	2.37	0.08	18.75	9.75	-	0.1	24.3	-	20.3	-	✓
+	Post-installed A1	0.33	0.65	0.02	18.75	9.75	-	1.8	6.7	-	7.0	-	✓
+	Cast-in A1	0.02	0.65	0.02	18.75	9.75	-	0.1	6.7	-	5.7	-	✓

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VERIFY BOND STRENGTH FROM RESULTS







(vi) Bond failure

Extreme Strength: LE1 (D100.0%)

Load increment D100.0%

Bond stress

Bond strength

Anchor	X [ft]	Y [ft]	[ft]	τb [ksi]	δ [in]	Fa [kip]	F tot [kip]	F tot/F lim [%]	[kip]	τb/fbu [%]	δ/δ lim [%]	
Post-installed A2	-0.46	-0.50	-0.90	**0.7**	0"	0.02	**0.27**	36.4	0.74	**68.5**	0.3	✓
Post-installed A2	-0.46	-0.50	-0.80	0.6	0"	0.02	2.12	**27.3**	3.69	58.7	0.2	✓
Post-installed A1	0.46	-0.50	-0.07	**0.1**	0"	0.00	0.06	0.3	18.75	**12.1**	0.0	✓
Post-installed A1	0.46	-0.50	-0.35	0.0	0"	0.00	0.32	**1.9**	16.99	1.7	0.0	✓
Post-installed A1	0.46	-0.50	-0.90	0.0	0"	0.00	**0.00**	0.5	0.74	0.6	0.0	✓
Post-installed A1	0.46	-0.50	-0.29	0.0	0"	0.00	**0.3**	1.8	18.47	0.3	0.0	✓
Cast-in A2	-0.46	0.50	-0.07	**0.0**	0"	0.00	**8.13**	43.3	18.75	**0.0**	0.0	✓
Cast-in A1	-0.46	0.50	-0.07	**0.0**	0"	0.00	0.02	0.1	18.75	**0.0**	0.0	✓
Cast-in A2	-0.46	0.50	-0.09	0.0	0"	0.00	**8.13**	43.3	18.75	0.0	0.0	✓

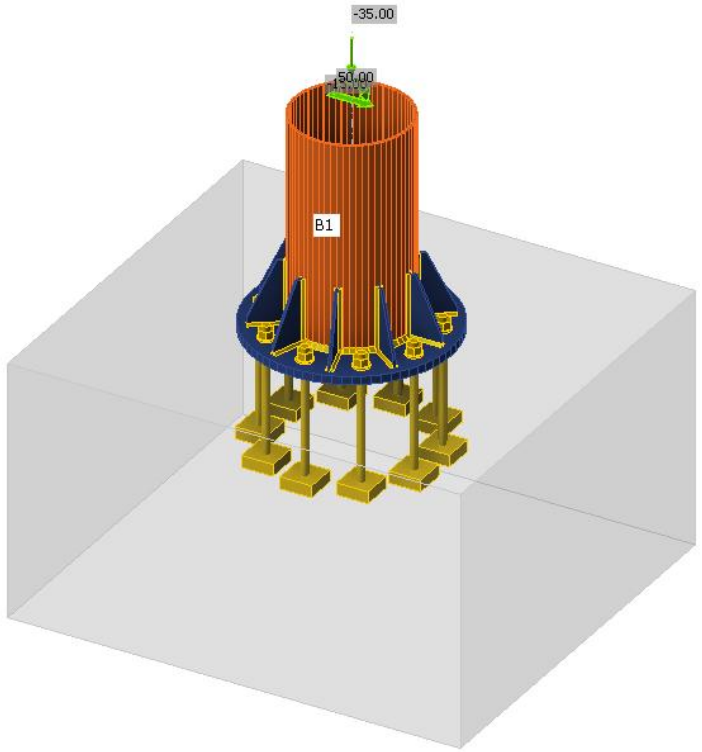
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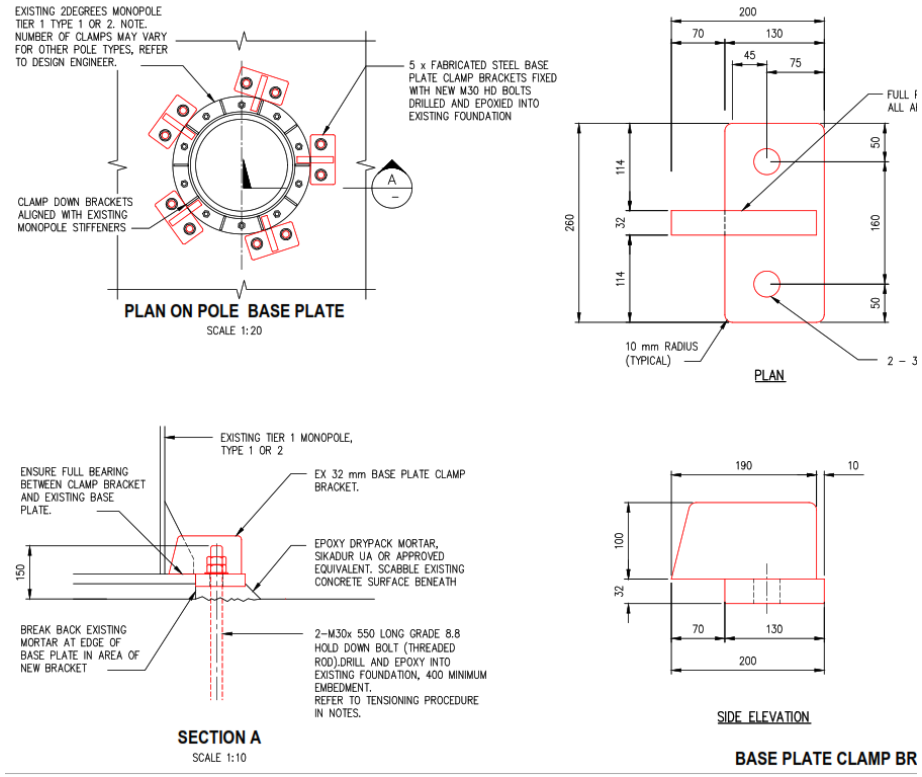
3. RETROFITS

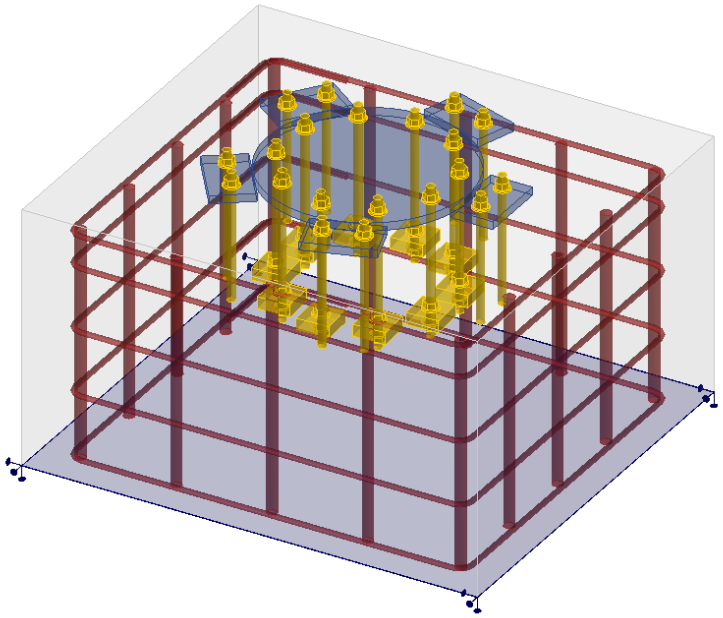
Adapting a joint to a new layout



CASE: POLE BASE PLATE RETROFIT

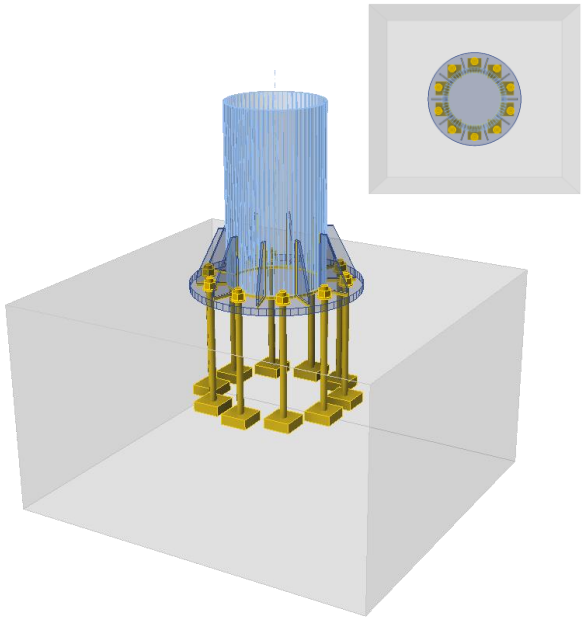






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CASE: POLE BASE PLATE RETROFIT

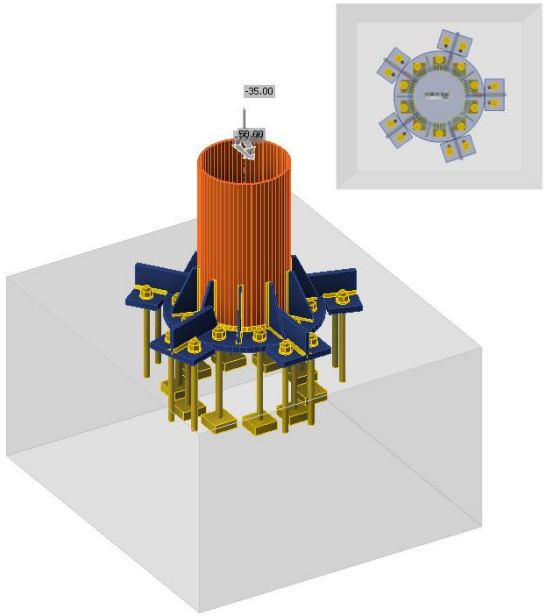


1. Connection app

Base plate model

Learn the capacity of the connection

Verify the old and new load

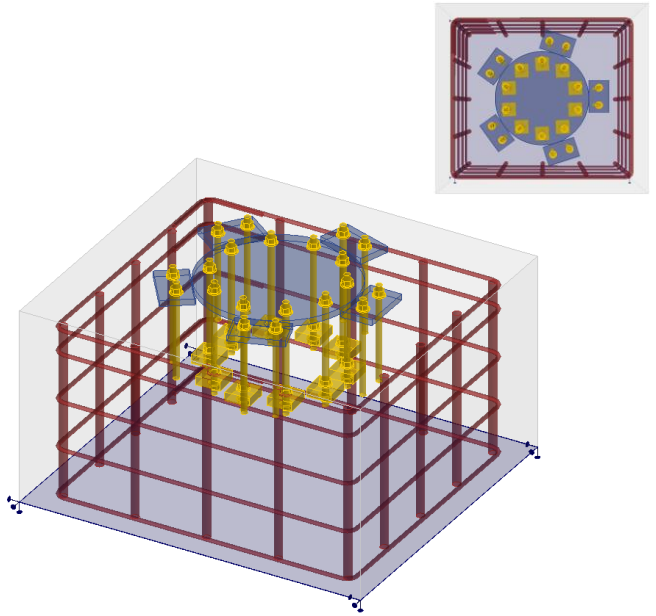


2. Connection app

Reinforced connection w/stiffeners & anchors

Learn the capacity of the combined connection

Verify the connection for the new load



3. Detail app

Reinforced concrete design & post-installed anchor verification

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RETROFIT CASE: LOAD INCREASE ON EXISTING STRUCTURE

AISC Design guide 15 Rehabilitation and Retrofit

$R_a' = 75.0$ kips	$R_a' = 50.0$ kips

Chemical composition and field testing finds that the existing ASTM A9 steel ($F_y = 33$ ksi) is weldable. [See Ricker (1988) and Design Guide 21, Section 4.4.3, for additional information about welding to historic steels.] For the new seated connection, use ASTM A36 steel and fillet welds with 70-ksi electrodes.

Solution:

From Table 5-3.1, the geometric properties of the historic structural steel beam are as follows:

S20×85
$d = 20$ in. $t_w = 0.653$ in. $t_f = 0.917$ in. $k = 1.831$ in.

From AISC *Specification* Section J1.9, existing rivets are permitted to be utilized for resisting loads present at the time of alteration, and the welded seated connection need only provide the additional required strength. However, many designers have expressed concerns about the deformation capability of a bolted/riveted connection acting in tandem with a seated connection. Therefore, this example will conservatively design the stiffened seat to take the full required strength of:

LRFD	ASD
$R_u = R_{u,final}$ = 165 kips	$R_a = R_{a,final}$ = 110 kips

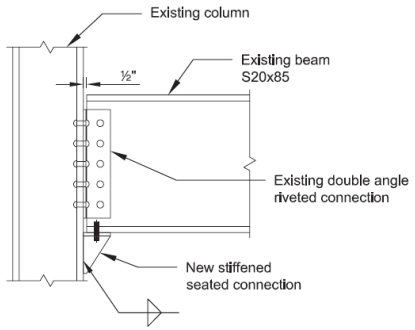
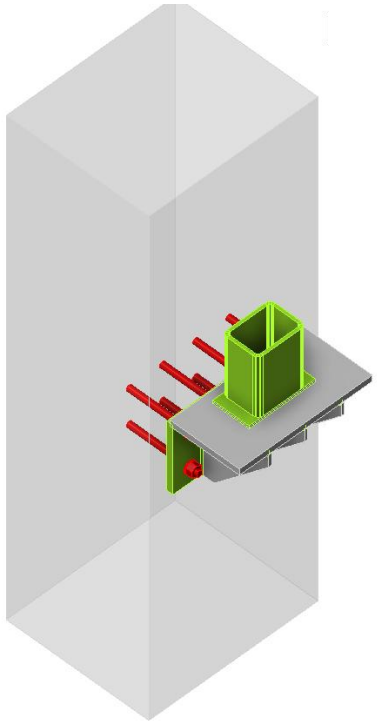
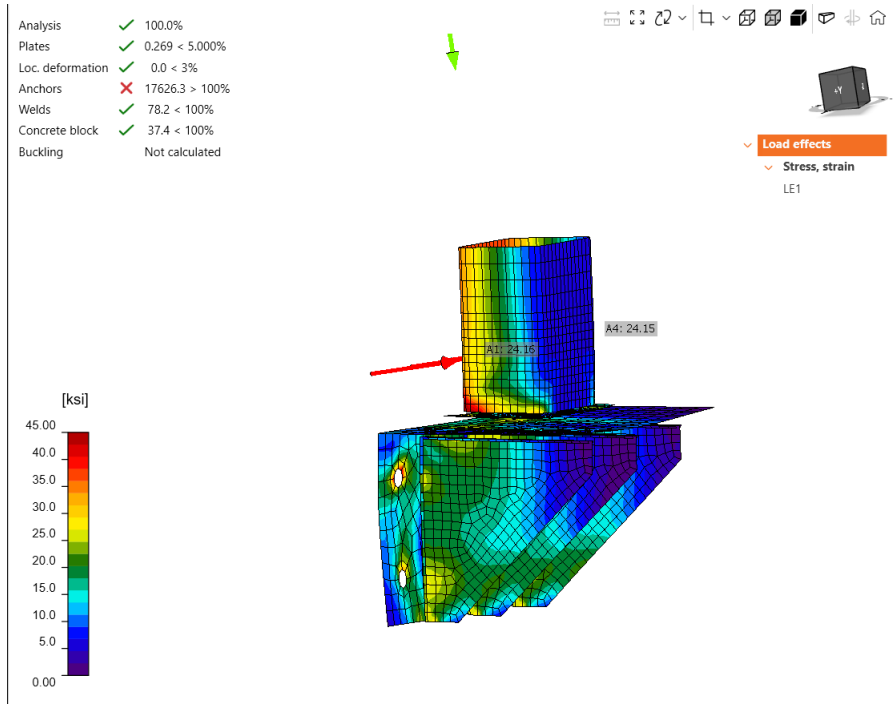


Fig. 6-38. Added seat for strengthening of existing connection.

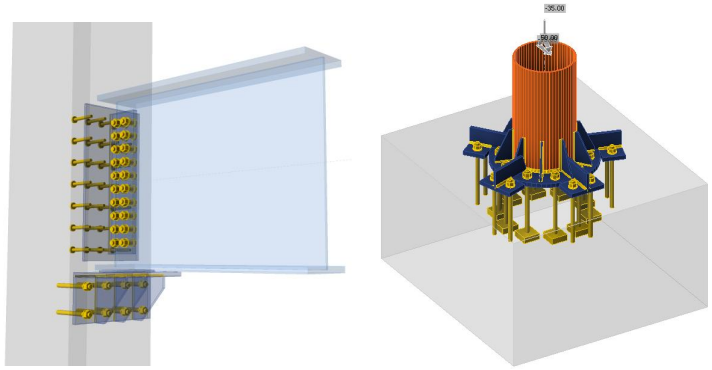
Similar approach for a bracket plate to concrete column



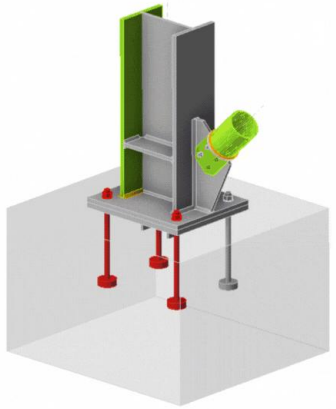


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KEY TAKEAWAYS



Retrofit, revisions and changes



Integrated Workflows



Results & Documentation

ANCHORING WATCHLIST:

Articles

Retrofitting existing steel connections

Misaligned anchors and notches in base plates

On site interferences - Change assessment

Revising a bolted shear tab to a welded shear tab

Office-to-residential conversions structural engineering deep dive

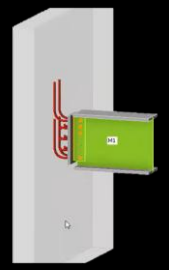
Tutorial: Embedded plate with mixed anchors

Detail 3D – Theoretical background

Webinars

Solve design RFIs and Retrofit challenges quicker than ever

Cast-in Plate Design in IDEA StatiCa



Headed studs + Welded reinforcement

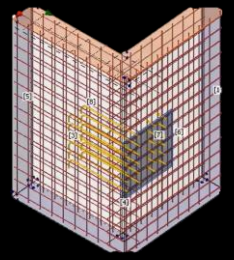


Plate in the corner

Today Webinar videos:

Embedded plate+bracket plate

Base plate

Misaligned anchors

Concrete pedestal

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ADDITIONAL RESOURCES

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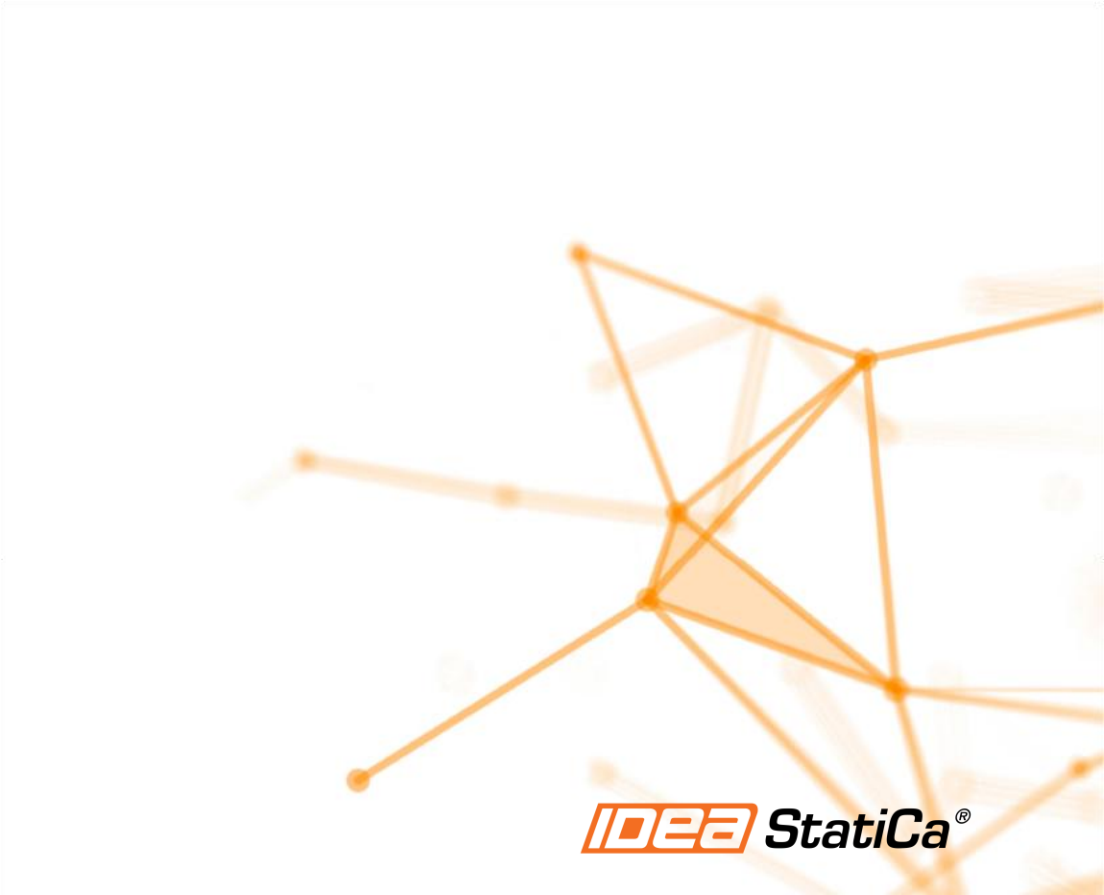
Calculate yesterday's estimates

Q&A

More questions? office@ideastatica.com

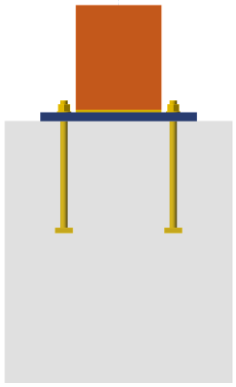


APPENDIX SLIDES

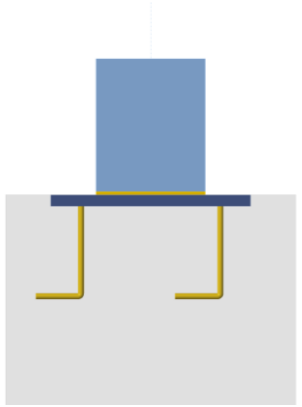


ANCHOR DESIGN

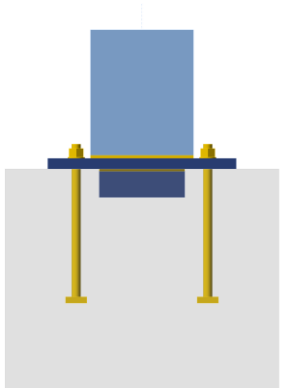
Cast in place



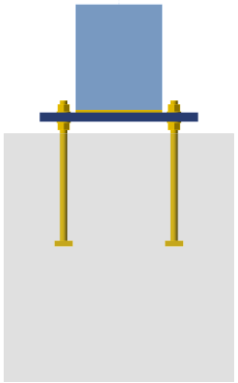
Anchors with washer plates



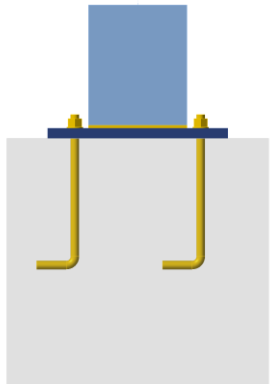
Embedded plate with welded reinforcement



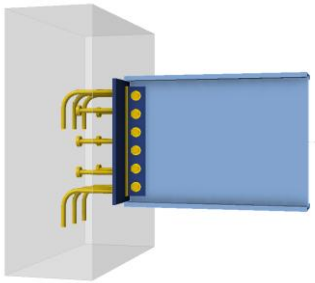
Shear lug



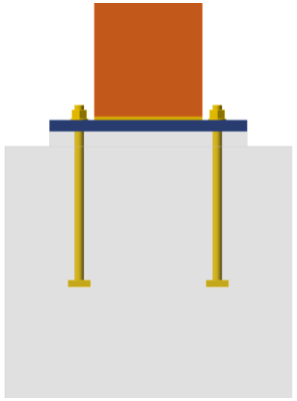
Gap



Hooked anchors

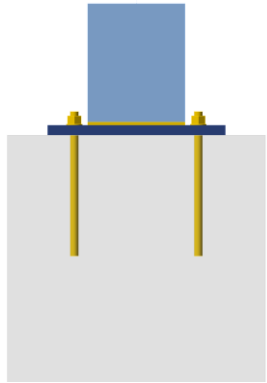


Embedded plate w/headed studs and welded rebar



Mortar joint/grout

Post installed



Adhesive anchors

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ANCHOR REINFORCEMENT FOR TENSION

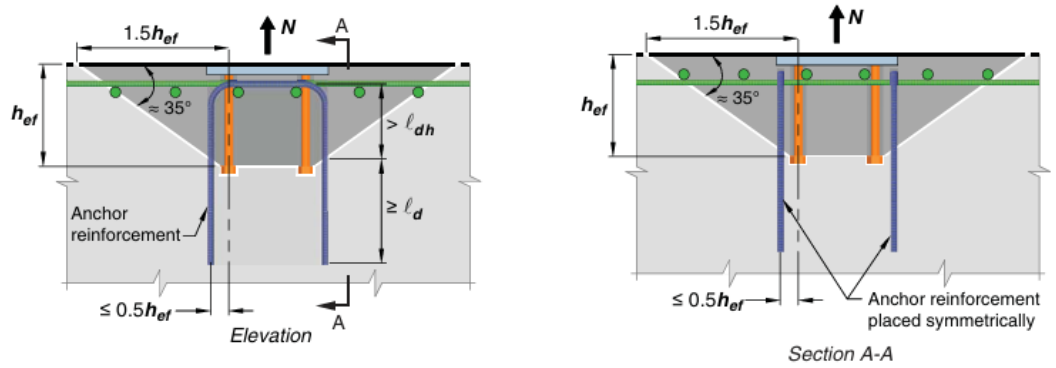
ACI 318-19, commentary R17.5.2.1

Practical use is cast-in anchors

Stirrups, ties or hairpins as close to the anchor as practicable

Bars within 0.5hef of the anchor centerline may count as effective

Supporting research covered bars no larger than No. 5



ANCHOR REINFORCEMENT FOR SHEAR

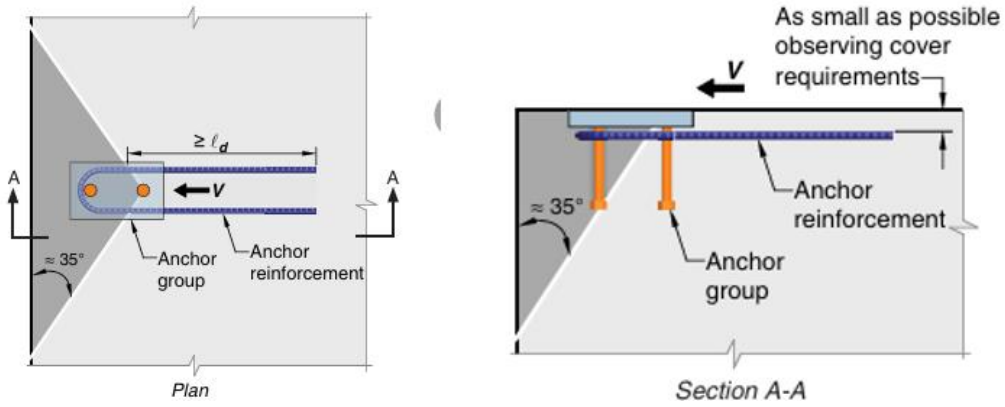
Enclosing bars contact the anchor, close to the surface

Bars larger than No. 6 are not recommended

Full fy development, both sides of the breakout surface

Extra bars cannot shorten development length

Alternative: bars enclosing the edge reinforcement



CONFINING REINFORCEMENT AND PULLOUT

ACI 318, R17.6.3.2.2

- Spirals through the head region can raise pullout strength

Cast-in headed studs and headed bolts only

COMMENTARY

R17.6.3.2.2 The pullout strength equations given in 17.6.3.2.2(a) and 17.6.3.2.2(b) are only applicable to cast-in headed and hooked anchors (Kuhn and Shaikh 1996; *fib* 2011); they are not applicable to post-installed expansion, screw, and undercut anchors that use various mechanisms for end anchorage unless the validity of the pullout strength equations is verified by tests.

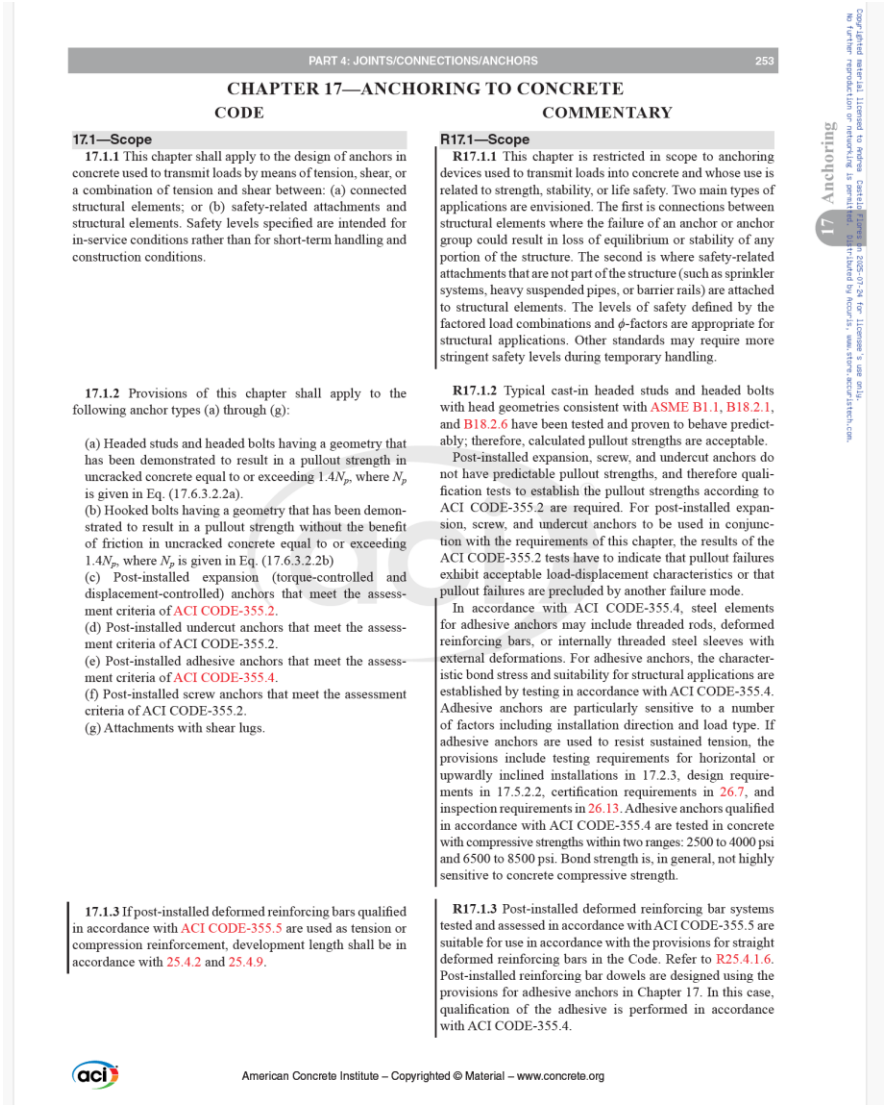
The value calculated from Eq. (17.6.3.2.2a) corresponds to the force at which crushing of the concrete occurs due to bearing of the anchor head (*fib* 2011; ACI CODE-349). It is not the force required to pull the anchor completely out of the concrete; therefore, the equation does not contain a term relating to embedment depth. Local crushing of the concrete greatly reduces the stiffness of the connection, and generally will be the beginning of a pullout failure. The pullout strength in tension of headed studs or headed bolts can be increased by providing reinforcement, such as closely spaced spirals, throughout the head region. This increase can be demonstrated by tests, as required by the Licensed Design Professional for the specific application.

Equation (17.6.3.2.2b) for hooked bolts was developed by Lutz (1995) based on the results of Kuhn and Shaikh (1996). Reliance is placed on the bearing component only, neglecting any frictional component, because crushing inside the hook will greatly reduce the stiffness of the connection and generally will be the beginning of a pullout failure. The limits on e_h are based on the range of variables used in the three test

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ACI 318 – CHAPTER 17 ANCHORING TO CONCRETE

ACI 318, Chapter 17 is the governing code for headed stud anchors welded to embed plates



CHAPTER 17—ANCHORING TO CONCRETE

CODE

17.1—Scope

17.1.1 This chapter shall apply to the design of anchors in concrete used to transmit loads by means of tension, shear, or a combination of tension and shear between: (a) connected structural elements; or (b) safety-related attachments and structural elements. Safety levels specified are intended for in-service conditions rather than for short-term handling and construction conditions.

17.1.2 Provisions of this chapter shall apply to the following anchor types (a) through (g):

(a) Headed studs and headed bolts having a geometry that has been demonstrated to result in a pullout strength in uncracked concrete equal to or exceeding $1.4N_p$, where N_p is given in Eq. (17.6.3.2.2a).
(b) Hooked bolts having a geometry that has been demonstrated to result in a pullout strength without the benefit of friction in uncracked concrete equal to or exceeding $1.4N_p$, where N_p is given in Eq. (17.6.3.2.2b)
(c) Post-installed expansion (torque-controlled and displacement-controlled) anchors that meet the assessment criteria of ACI CODE-355.2.
(d) Post-installed undercut anchors that meet the assessment criteria of ACI CODE-355.2.
(e) Post-installed adhesive anchors that meet the assessment criteria of ACI CODE-355.4.
(f) Post-installed screw anchors that meet the assessment criteria of ACI CODE-355.2.
(g) Attachments with shear lugs.

17.1.3 If post-installed deformed reinforcing bars qualified in accordance with ACI CODE-355.5 are used as tension or compression reinforcement, development length shall be in accordance with 25.4.2 and 25.4.9.

COMMENTARY

R17.1—Scope

R17.1.1 This chapter is restricted in scope to anchoring devices used to transmit loads into concrete and whose use is related to strength, stability, or life safety. Two main types of applications are envisioned. The first is connections between structural elements where the failure of an anchor or anchor group could result in loss of equilibrium or stability of any portion of the structure. The second is where safety-related attachments that are not part of the structure (such as sprinkler systems, heavy suspended pipes, or barrier rails) are attached to structural elements. The levels of safety defined by the factored load combinations and ϕ-factors are appropriate for structural applications. Other standards may require more stringent safety levels during temporary handling.

R17.1.2 Typical cast-in headed studs and headed bolts with head geometries consistent with ASME B1.1, B18.2.1, and B18.2.6 have been tested and proven to behave predictably; therefore, calculated pullout strengths are acceptable.

Post-installed expansion, screw, and undercut anchors do not have predictable pullout strengths, and therefore qualification tests to establish the pullout strengths according to ACI CODE-355.2 are required. For post-installed expansion, screw, and undercut anchors to be used in conjunction with the requirements of this chapter, the results of the ACI CODE-355.2 tests have to indicate that pullout failures exhibit acceptable load-displacement characteristics or that pullout failures are precluded by another failure mode.

In accordance with ACI CODE-355.4, steel elements for adhesive anchors may include threaded rods, deformed reinforcing bars, or internally threaded steel sleeves with external deformations. For adhesive anchors, the characteristic bond stress and suitability for structural applications are established by testing in accordance with ACI CODE-355.4. Adhesive anchors are particularly sensitive to a number of factors including installation direction and load type. If adhesive anchors are used to resist sustained tension, the provisions include testing requirements for horizontal or upwardly inclined installations in 17.2.3, design requirements in 17.5.2.2, certification requirements in 26.7, and inspection requirements in 26.13. Adhesive anchors qualified in accordance with ACI CODE-355.4 are tested in concrete with compressive strengths within two ranges: 2500 to 4000 psi and 6500 to 8500 psi. Bond strength is, in general, not highly sensitive to concrete compressive strength.

R17.1.3 Post-installed deformed reinforcing bar systems tested and assessed in accordance with ACI CODE-355.5 are suitable for use in accordance with the provisions for straight deformed reinforcing bars in the Code. Refer to R25.4.1.6. Post-installed reinforcing bar dowels are designed using the provisions for adhesive anchors in Chapter 17. In this case, qualification of the adhesive is performed in accordance with ACI CODE-355.4.

17 Anchoring
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AISC 360-22 CHAPTER I – SECTION I8.3

I8 Steel anchors section **not applicable** for headed studs for embedded plates

used and 10 in. (250 mm) if lightweight concrete is used. The provisions of ACI 318, Chapter 17, are permitted to be used in lieu of these values.

(d) Minimum center-to-center spacing of steel headed stud anchors shall be four diameters in any direction. For composite beams that do not contain anchors located within formed steel deck oriented perpendicular to the beam span, an additional minimum spacing limit of six diameters along the longitudinal axis of the beam shall apply.

(e) The maximum center-to-center spacing of steel anchors shall not exceed eight times the total slab thickness or 36 in. (900 mm).

3. Steel Anchors in Composite Components

This section shall apply to the design of cast-in-place steel headed stud anchors and steel channel anchors in composite components.

The provisions of the applicable building code or ACI 318, Chapter 17, are permitted to be used in lieu of the provisions in this section.

User Note: The steel headed stud anchor strength provisions in this section are applicable to anchors located primarily in the load transfer (connection) region of composite columns and beam-columns, concrete-encased and filled composite beams, composite coupling beams, and composite walls, where the steel and concrete are working compositely within a member. They are not intended for hybrid construction where the steel and concrete are not working compositely, such as with embed plates.

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