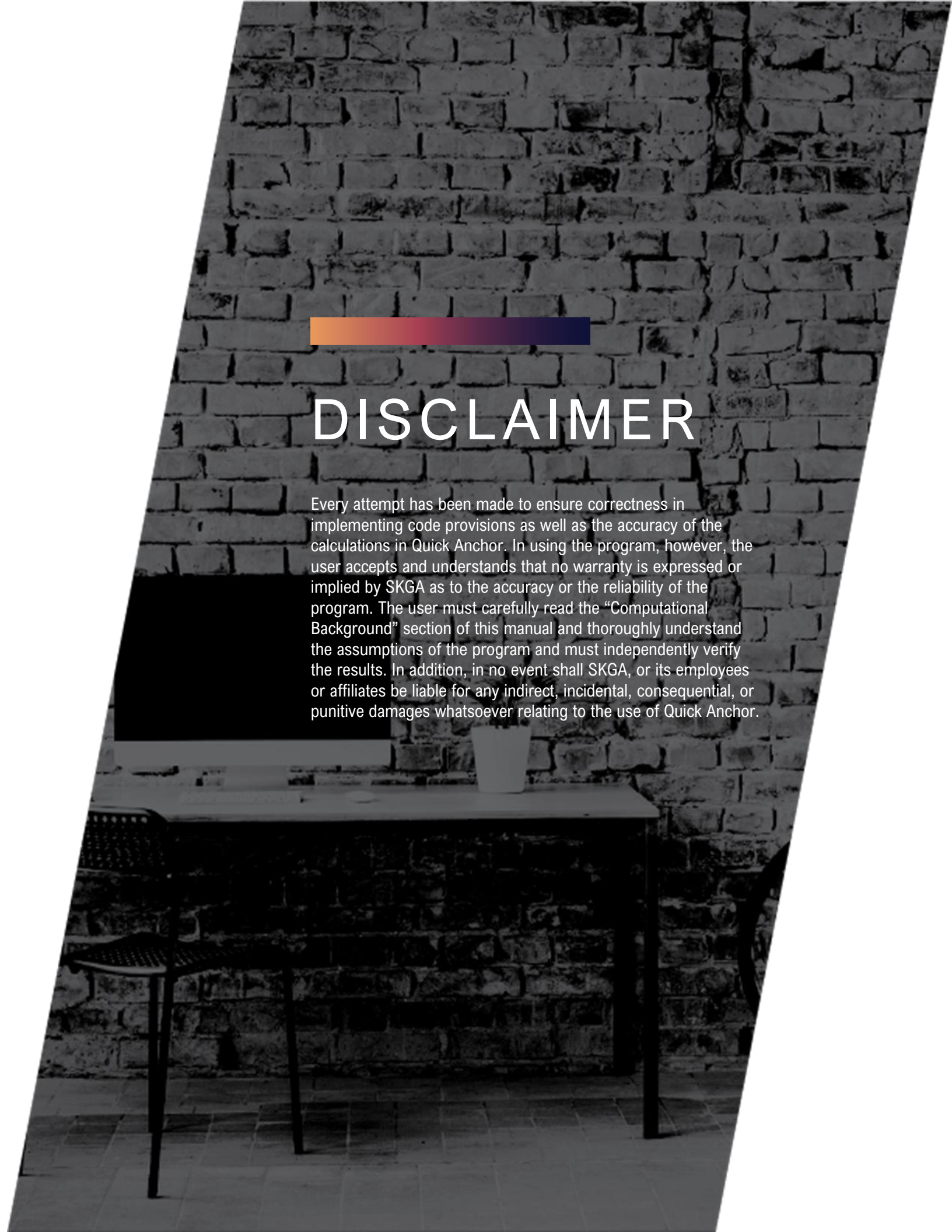


QUICK ANCHOR

VERSION 4.2.0

USER MANUAL

S. K. GHOSH ASSOCIATES LLC | www.skghoshassociates.com



DISCLAIMER

Every attempt has been made to ensure correctness in implementing code provisions as well as the accuracy of the calculations in Quick Anchor. In using the program, however, the user accepts and understands that no warranty is expressed or implied by SKGA as to the accuracy or the reliability of the program. The user must carefully read the “Computational Background” section of this manual and thoroughly understand the assumptions of the program and must independently verify the results. In addition, in no event shall SKGA, or its employees or affiliates be liable for any indirect, incidental, consequential, or punitive damages whatsoever relating to the use of Quick Anchor.

REVISION HISTORY

CURRENT VERSION (4.2.0)

- The program is made part of Quick Anchor Pro.
- Correction made in torsion analysis.
- Correction made in how the program handles user generated adhesive anchors.

VERSION (4.1.0)

- Post-installed screw anchors are now supported, and a comprehensive screw anchor database has been added to the program.
- The program now supports user-defined post-installed anchors.
- A bug regarding centering of the base plate with respect to the anchors has been fixed.
- Some ACI 318-19 section numbers have been corrected.

VERSION (4.0.2)

- A bug in negative values for eccentricities and loads has been corrected.

VERSION (4.0.1)

- A bug in determining φ-factor for ductile anchors has been corrected.
- An issue with saving the values in “Anchor Properties” form has been addressed.
- An extra explanation for some of the shear factors has been added to the report.
- An issue with reading the inserted loads has been addressed.

VERSION 4.0.0

- An updated user-friendly interface.
- An updated database for adhesive, undercut and expansion anchors according to the latest manufacturers’ report.
- Allow the user to input seismic and non-seismic loads.
- Allow the user to define maximum short-term temperature and maximum long-term temperature as a criterion for anchors choice.
- Display the applicable anchor list based on the user input criteria.
- A web-based license activation.
- Up-to-date of ACI 318-19 and IBC 2021.

VERSION 3.6.0

- An error in determining φ-factor for pry out failure in post-installed anchors has been corrected.
- An option has been provided for users to specify λa for light-weight concrete from test reports for post-installed anchors.
- An issue with saving and reading “default input” has been rectified.

VERSION 3.5.0

- An issue has been resolved where the program was not able to converge in determining anchor forces for certain anchor formations.

VERSION 3.4.1

- An error has been rectified where the program was printing the left and right edge distances of the base plate incorrectly on the detailed output.

VERSION 3.4.0

- A new approach is employed to produce the output in order to mitigate conflicts with MS Office applications.

VERSION 3.3.1

- A display issue has been resolved where one of the objects on the “Check for Splitting” window was not shown completely for post-installed anchors.
- An error has been rectified where the program was not using the absolute eccentricity values in determining the concrete pry-out strength of adhesive anchors in shear.

VERSION 3.3.0

- An error has been rectified where the program was mistakenly applying the 0.75 seismic design factor to the concrete pry-out strength of anchors in shear when using ACI 318-11.

VERSION 3.2.2

- An error has been rectified where the program was not determining the concrete breakout strength of headed studs in shear correctly.

VERSION 3.2.1

- An error has been rectified where the program was skipping the shear strength calculations where there was no shear force applied.

VERSION 3.2.0

- An error has been rectified where the program was not initializing the N_{sb}/N_{sbg} value in consecutive runs.

VERSION 3.1.0

- An error has been rectified where the program was not determining the concrete pryout strength of adhesive anchors in shear correctly.
- A new web-based temporary license feature has been added which enables the users to start using the full features of the program right after the purchase/upgrade for 14 days while they are waiting to receive/upgrade their USB license key.

VERSION 3.0.1

- A display issue has been fixed where the program was not scaling properly when viewed on a high DPI monitor.

VERSION 3.0.0

- Added a new option for a “Perimeter” arrangement of anchors.
- Added input options for applied moments and torsion. The program will determine the anchors that are to be included in tension and shear analyses based on all applied loads.
- Re-designed and improved program interface.

INPUT INTERFACE

The input fields in the Quick Anchor interface are mostly self-explanatory. However, a short description of each input field is provided below for better clarity. Different input fields are marked by item definition, as shown below. Units used in this program are as follows:

- Quantities related to length (spacing, edge distance, diameter, etc.): inches
- Material strength: psi
- Applied load: kips or kip-ft

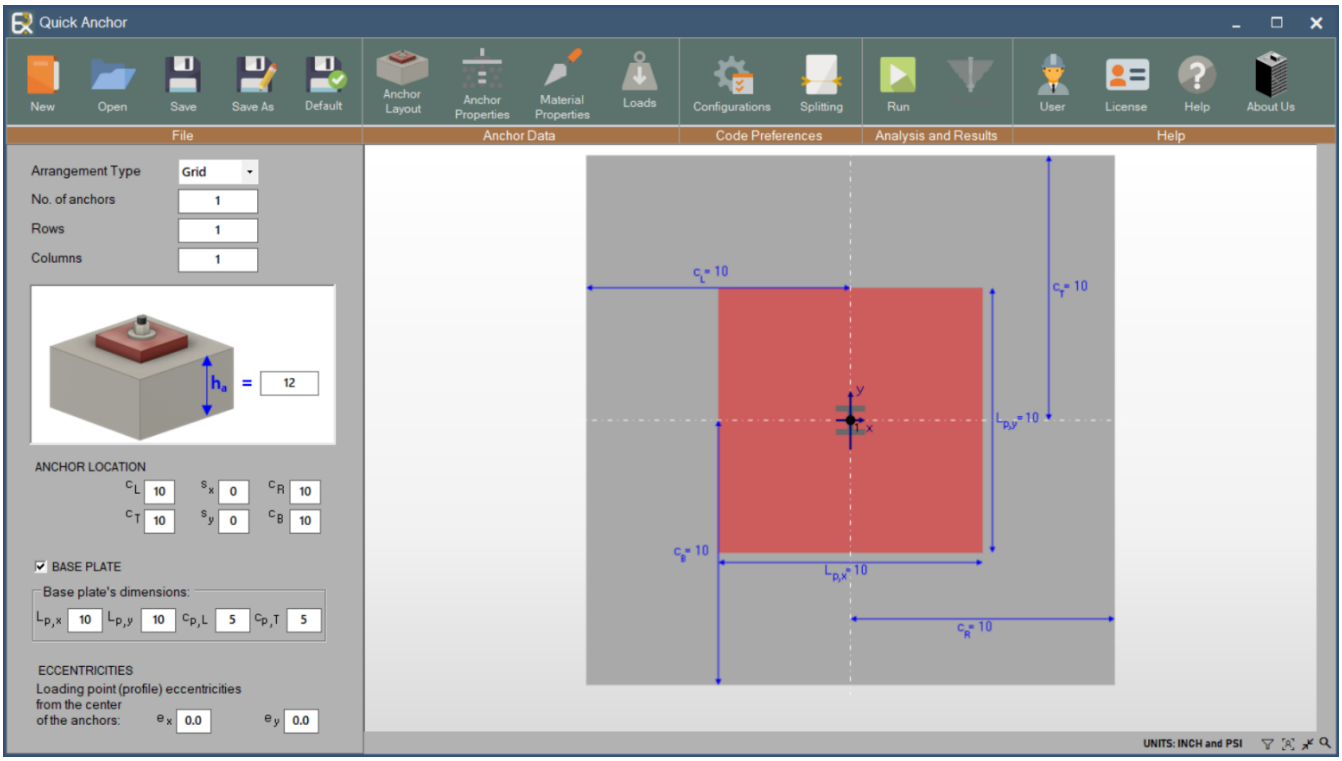


Figure 1 – Anchor Layout Input of Quick Anchor

Arrangement Type: Select the type of arrangement – grid (rectangular w/ middle anchors) or perimeter (rectangular w/o middle anchors).

No. of anchors: Total number of anchors, *n*, must be greater than or equal to one.

Rows: Number of rows in which the anchors are arranged.

Columns: Number of columns in which the anchors are arranged.

h_a: Enter depth of the concrete block.

s_x: Spacing of anchor columns, s_x.
This is automatically set as 0 when there is only one column of anchors.

For a *perimeter* arrangement, these values show the spacing of gridlines.

s_y: Spacing of anchor rows, s_y.
This is automatically set as 0 when there is only one column of anchors.

c_L, c_R, c_T, and c_B: Edge distances, in inches, on all four sides of the anchor or the anchor group.

Base Plate: Select if there is a base plate. Specifying base plate parameters is required only when there are applied moments (including eccentrically applied tension) on a group of anchors, so that the program can determine the distribution of tension forces on the anchors. The baseplate itself is not designed by the program.

$L_{P,x}$ and $L_{P,y}$: Lengths of the base plate in x- and y-direction, respectively.

$c_{P,L}$ and $c_{P,T}$: Edge distances on left and top side of base plate. The other distances will be calculated automatically. Base plate must extend at least half an inch beyond the center of the edge anchors.

e_x and e_y: Eccentricities of the applied load in x- and y-direction with respect to the center of a group of anchors.

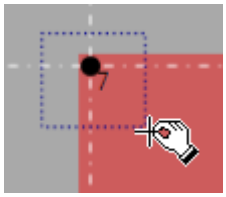


Quick Anchor v4 assumes all loads, tension and shear, are applied at a single point. In other words: *eccentricities of applied tension = eccentricities of applied shear force(s)*

Layout Window: Show the layout of anchor arrangement as per the inputs provided by the user. Scroll the middle mouse wheel in order zoom in and hold the middle mouse button to pan the figure accordingly.

 **Zoom Extents:** On clicking resizes and fits the entire geometry into the Layout Window.

 **Precision Zoom:** Once clicked, a specific area of the Layout Window can be zoomed in by drawing a rectangle around that area.



 **Take a Snap:** Copy a screenshot of the layout window to the clipboard.

ANCHOR PROPERTIES

ADHESIVE ANCHORS

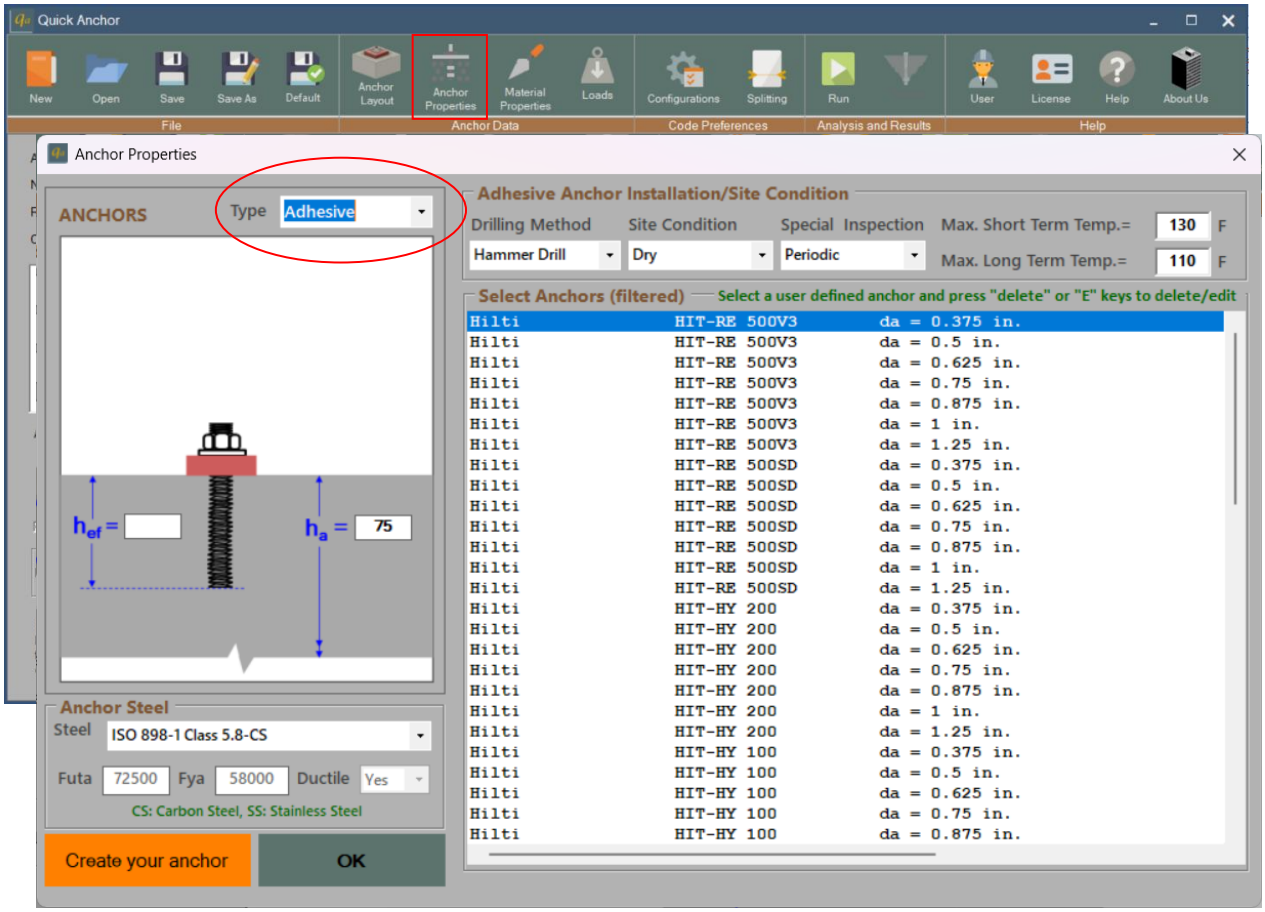


Figure 2 – Adhesive Anchor Input

Type: Select anchor type – headed bolts, headed studs, hooked (J- or L-) bolts, adhesive, undercut, screw or expansion.

h_{ef}: Specify the effective embedment depth of the anchor(s) in inches.

h_a: Specify concrete depth, h_a, in inches.

Adhesive Anchor Installation/Site Condition: Provide information on site conditions and anchor installation method for adhesive anchors.

Drilling Method: Drilling method for adhesive anchors.

Site Condition: Provide site conditions (Dry/Saturated/Water-Filled/Underwater) for adhesive anchors.

Special Inspection: Inspection method for adhesive anchors (Periodic/ Continuous).

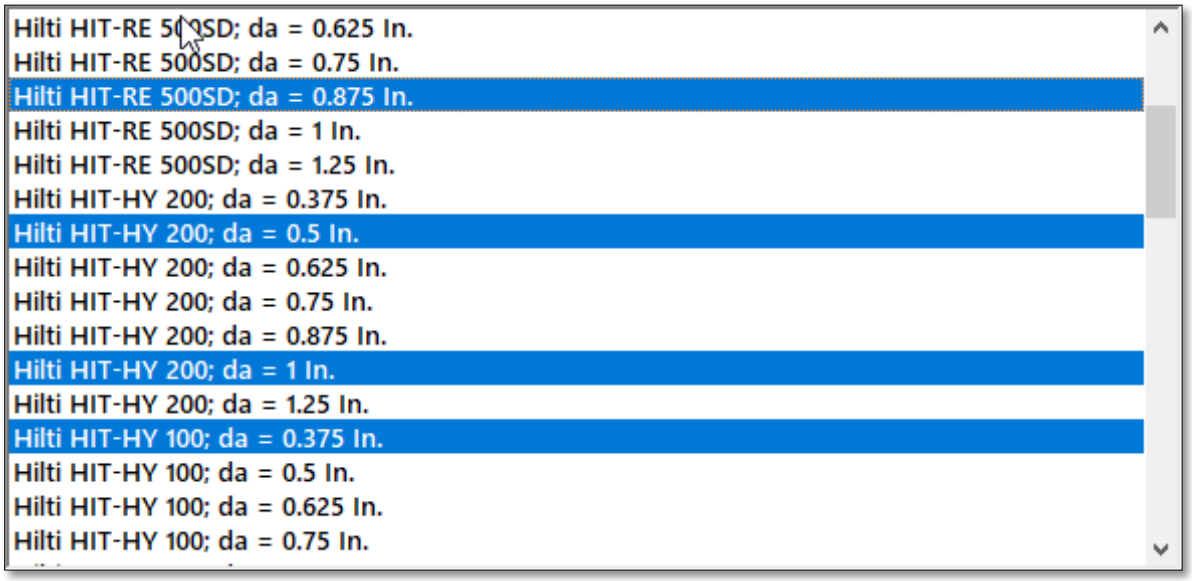


Figure 3- Select Multiple Anchors in the List to Analyze them Together

Select Anchors List: Provides the entire database of post-installed anchors (adhesive/undercut/expansion). One can choose multiple of them and run for it at one go.

Anchor Steel: Select the grade of anchor steel from the built-in options or select "Other" to use a different material. When one of the built-in options is selected, the steel tensile strength, f_{uta}, is automatically selected by the program. All these options are also considered to be ductile as per the definition of "ductile steel element" given in ACI 318 D.1. When "Other" option is selected, the user needs to specify f_{uta}. Additionally, when "Other" is selected, the user is presented with two more input parameters (Figure 4) that need to be specified – one to specify the yield strength of the anchor steel (**Item a**), and the other to select if the user-defined anchor steel is ductile as per ACI 318 D.1 (**Item b**).

Not all grades of steel are available for all types of anchors. For example, ASTM A 307 Grade C is for hooked bolts only, and not for headed bolts or studs.

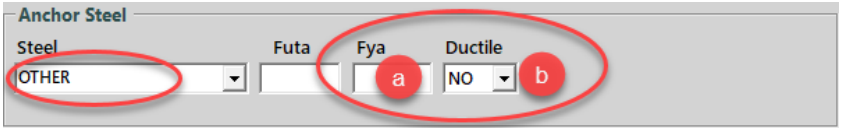


Figure 4 – Additional Input Parameters for User-Defined Anchor Material

UNDERCUT ANCHORS

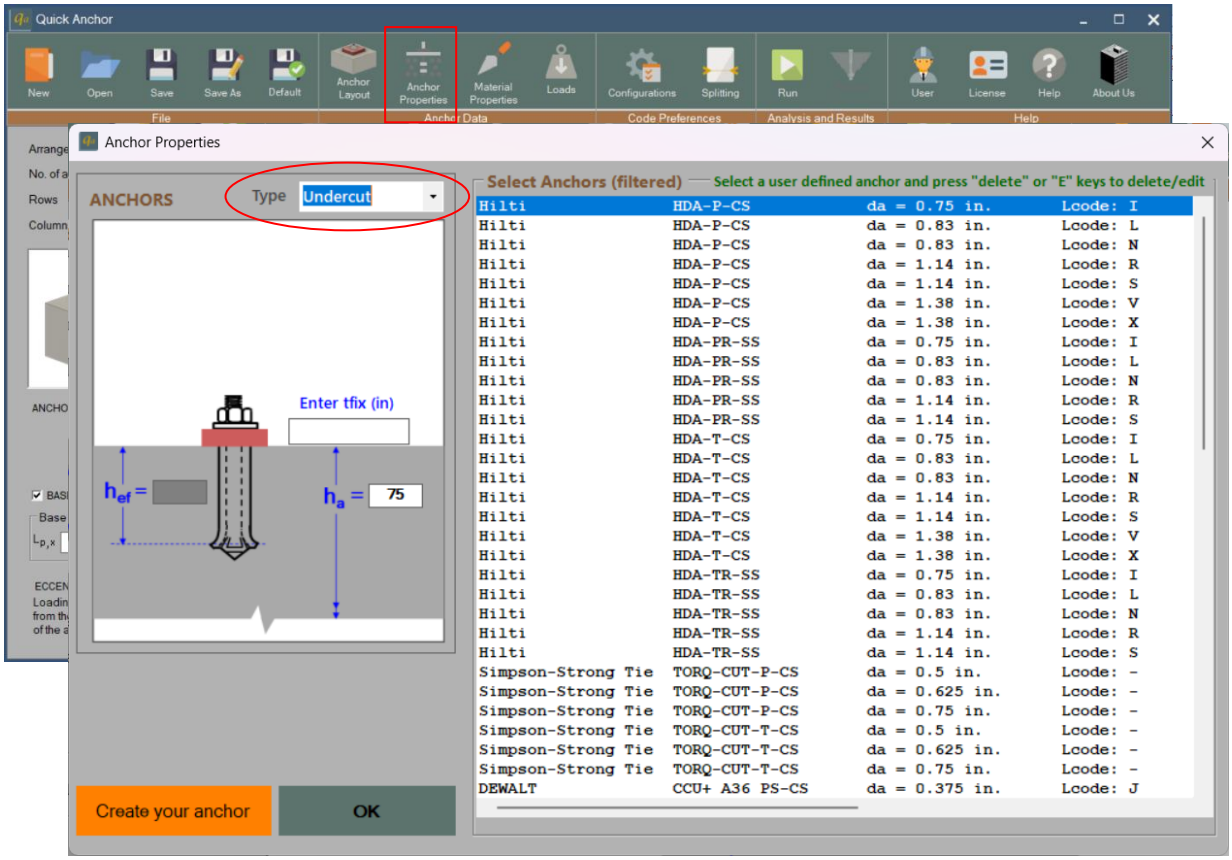


Figure 5 – Undercut Anchor Input

Enter tfix: Enter fixture thickness in inches.

Undercut anchors list includes a complete description for each individual available anchor; manufacturer, diameter, steel, and min embedment depth.

EXPANSION ANCHORS

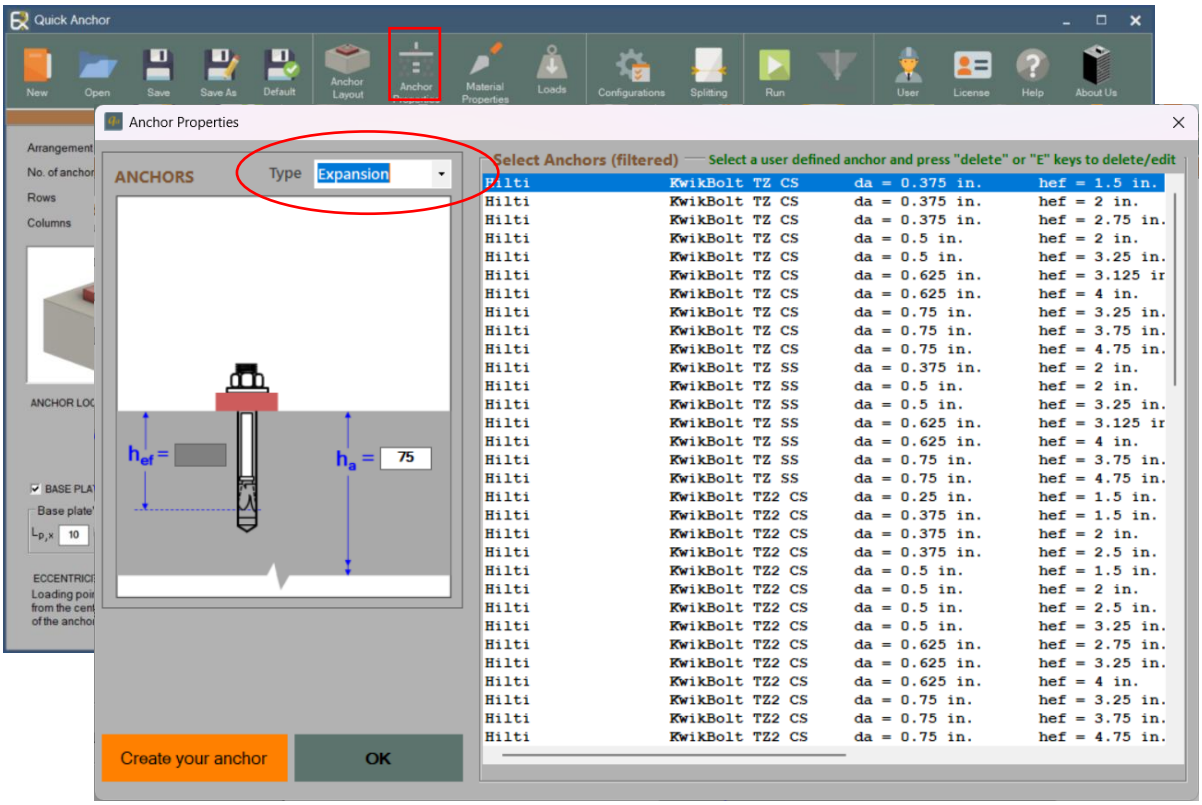


Figure 6 – Expansion Anchors Input

Expansion anchors list includes a complete description for each individual available anchor; manufacturer, diameter, steel, and min embedment depth.

SCREW ANCHORS

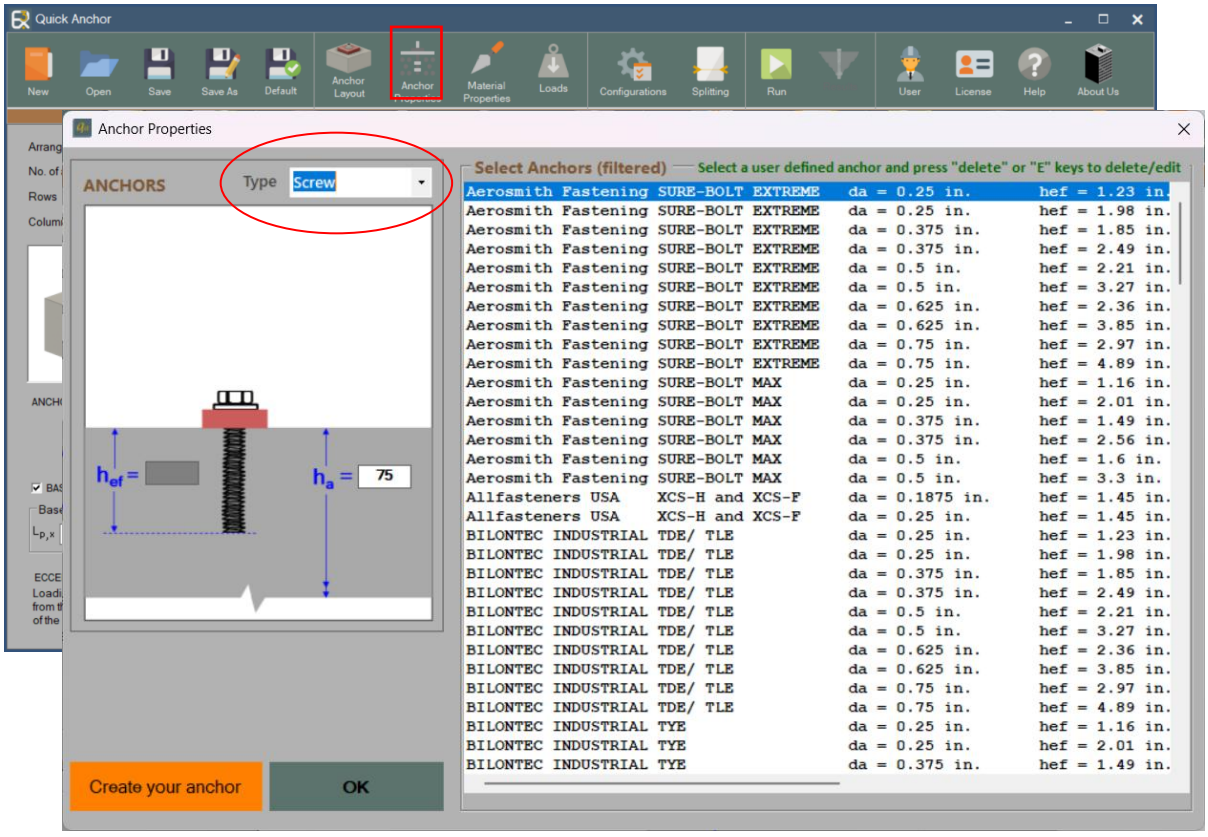


Figure 7 – Screw Anchors Input

Screw anchors list includes a complete description for each individual available anchor; manufacturer, diameter, steel, and min embedment depth.

POST INSTALLED USER DEFINED ANCHORS

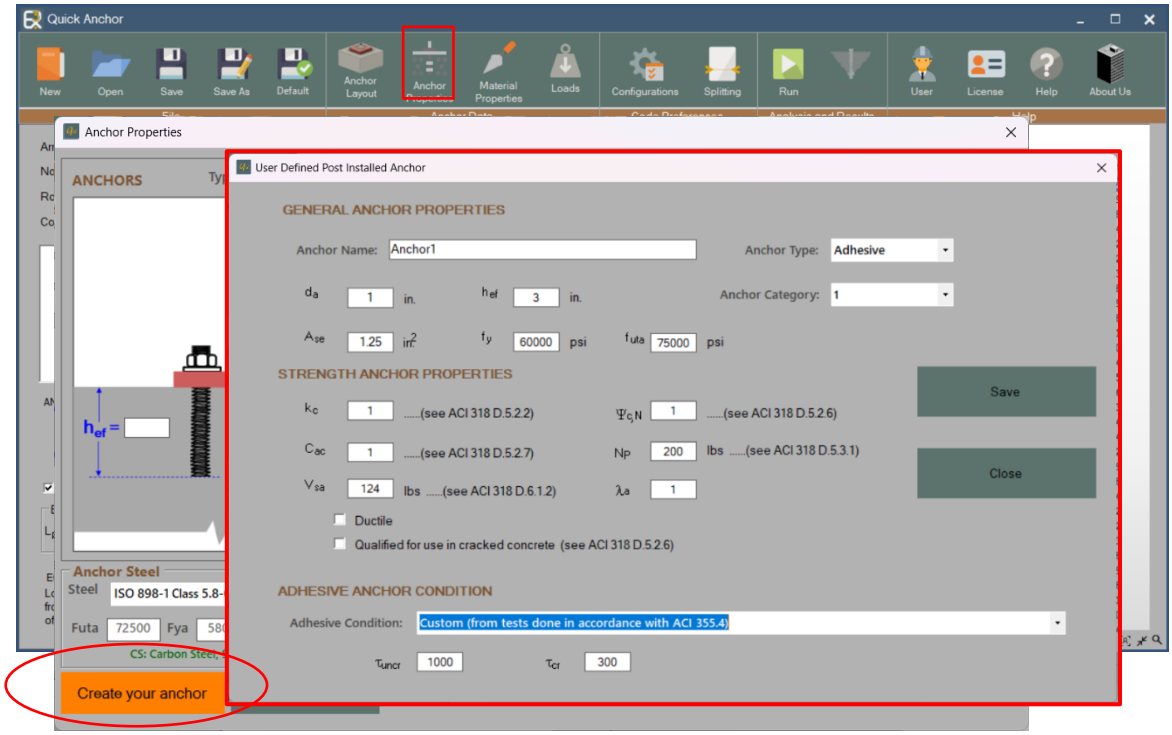


Figure 8 – Post Installed User Defined Anchors Input

Anchor Name: Insert anchor name.

Anchor Type: Select anchor type – screw, adhesive, undercut or expansion

Anchor Category: Select anchor category – one, two, three.

f_y: Specify yielding stress of the anchor in psi.

f_{uta}: Specify maximum strength of the anchor in psi.

K_c: Coefficient for basic concrete breakout strength in tension

C_{ac}: Critical edge distance required to develop the basic strength as controlled by concrete breakout or bond of a post-installed anchor in tension in uncracked concrete without supplementary reinforcement to control splitting, in.

V_{sa}: Nominal shear strength of a single anchor or individual anchor in a group of anchors as governed by the steel strength, lb.

$\Psi_{c,N}$: Breakout cracking factor used to modify tensile strength of anchors based on the influence of cracks in concrete

N_P: Pullout strength in tension of a single anchor in cracked concrete, lb.

λ_a: Modification factor to reflect the reduced mechanical properties of lightweight concrete in certain concrete anchorage applications.

Ductile checkbox: Check if the anchor is governed by ductile yielding of the anchor steel.

Qualified for use in cracked concrete checkbox: Check if the anchor is qualified to be used in cracked concrete.

Torque-controlled expansion anchor with a distance sleeve separated from expansion sleeve checkbox: Check for torque-controlled expansion anchor with a distance sleeve separated from expansion sleeve, (ACI 318-19 R17.7.2.2)

Adhesive condition: Specify installation, moisture and temperature conditions for adhesive anchors (ACI 318-19 Table 17.6.5.2.5)

τ_{uncr}: Characteristic bond stress of adhesive anchor in uncracked concrete, psi.

τ_{cr}: Characteristic bond stress of adhesive anchor in cracked concrete, psi.

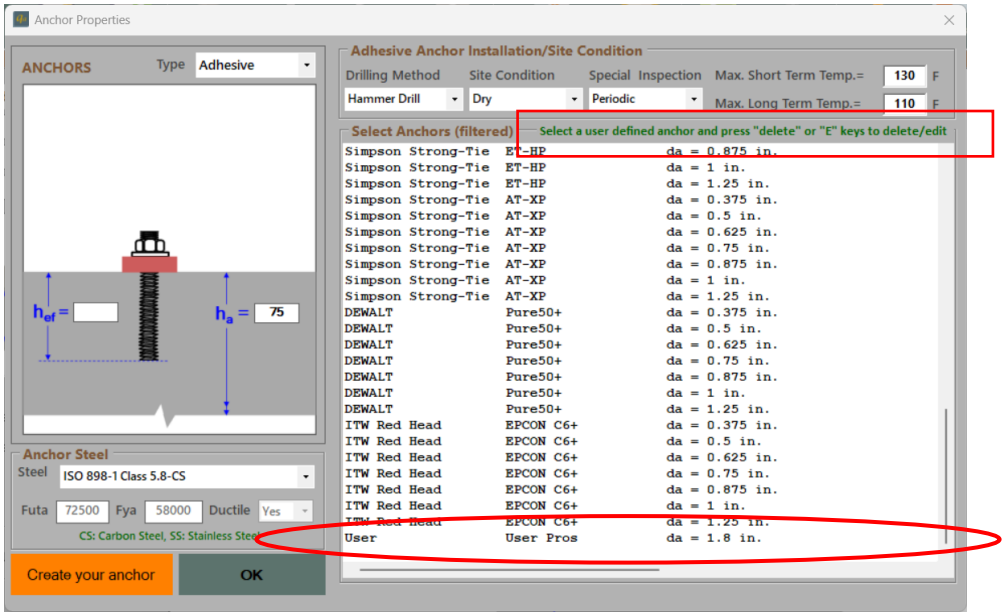


Figure 9 – Delete and edit user defined anchors

An unlimited number of post installed used defined anchors could be added to the anchor's list in Anchor Properties form. These user defined anchors will be ordered in accordance to the anchor type . Furthermore, these user defined anchors could be deleted or edited by selecting the targeted anchor and press "delete" or "E" from the keyboard. Duplicated names are not allowed.

CAST-IN PLACE ANCHORS

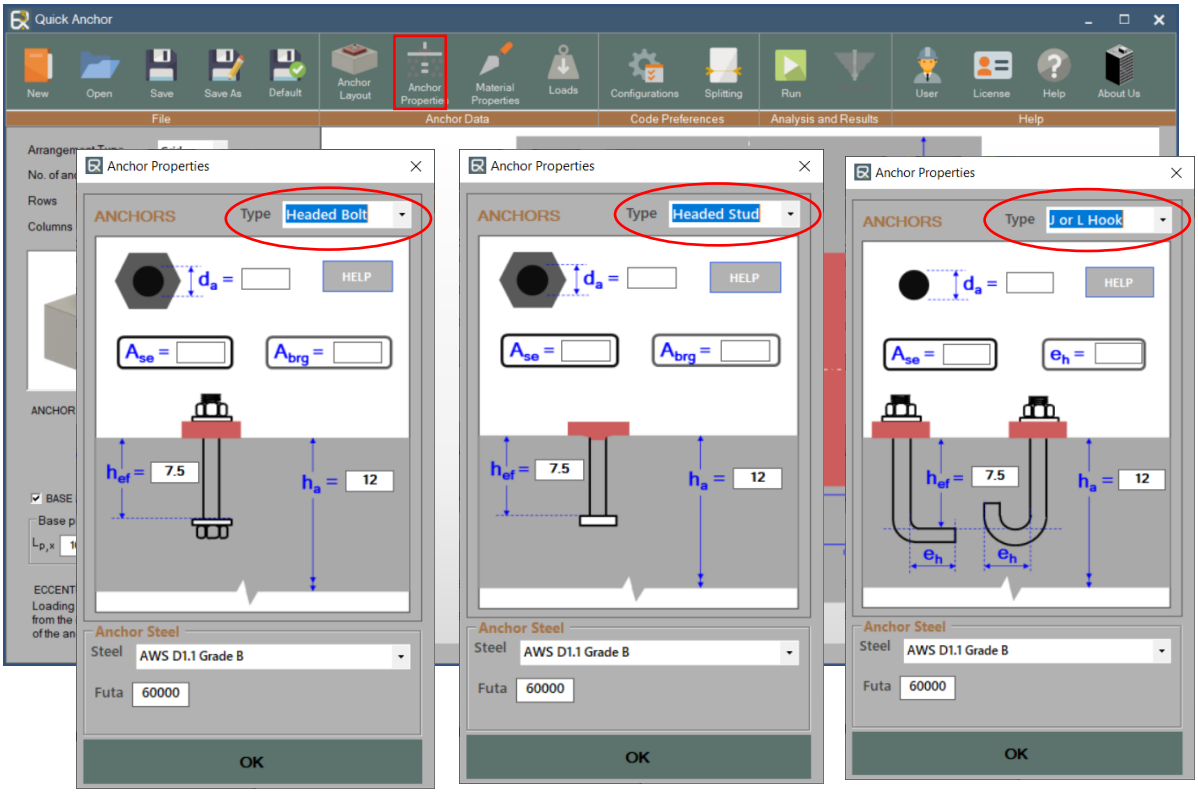


Figure 10 – Cast-In Headed Studs, Headed Bolts, and Hooked Bolts Input

d_a: Specify anchor diameter, d_a (d_o in ACI 318-05), in inches. User can also click on the "Help" button to choose a standard diameter from a drop-down menu.

A_{se} and A_{brg}: Specify the effective cross-sectional area of a single anchor, A_{se}, and bearing area of the head of a headed anchor, A_{brg}, in square inches. When hooked (J- or L-) bolts are used, the bearing length of the hook (e_h) is specified, in inches instead of A_{brg}.

Effective cross-sectional area of threaded rods is calculated from the following formula:

$$A_{se} = \pi \left(d_o - \frac{0.9743}{n_t} \right)^2 / 4$$

where n_t is the number of threads per inch of the anchor.

When headed studs or bolts are used, the bearing area of the anchor head, A_{brg}, is calculated by simply subtracting the gross shank area of the anchor (not A_{se}) from the area of the head.

Anchor Area Calculator

A calculator has been provided to facilitate the computation of A_{se}. Click on the "Help" button to open the calculator, which appears in a separate window. In the calculator, user can type in a diameter (in inches) in the box provided or simply choose from a list of standard diameters from a drop-down menu. When a standard diameter is selected, the value of n_t is obtained automatically based on the selected thread type ("Coarse Thread" or "Fine Thread"). However, when the user chooses to enter a custom diameter, the value of n_t also needs to be specified.

To calculate A_{brg} of one of the listed anchor diameters, the user simply needs to choose the anchor head type ("Hex", "Heavy Hex" or "Square"). When using a custom diameter, the user also needs to specify the dimension F of the head.

Once A_{se} and A_{brg} have been calculated, click "OK" to import the values into the corresponding boxes in the main window of the program.

The calculator provides anchor diameters up to 1 1/2 inches for Fine Thread and/or Square Head anchors. For other types of anchor, the calculator can help the user with anchor diameters up to 4 inches.

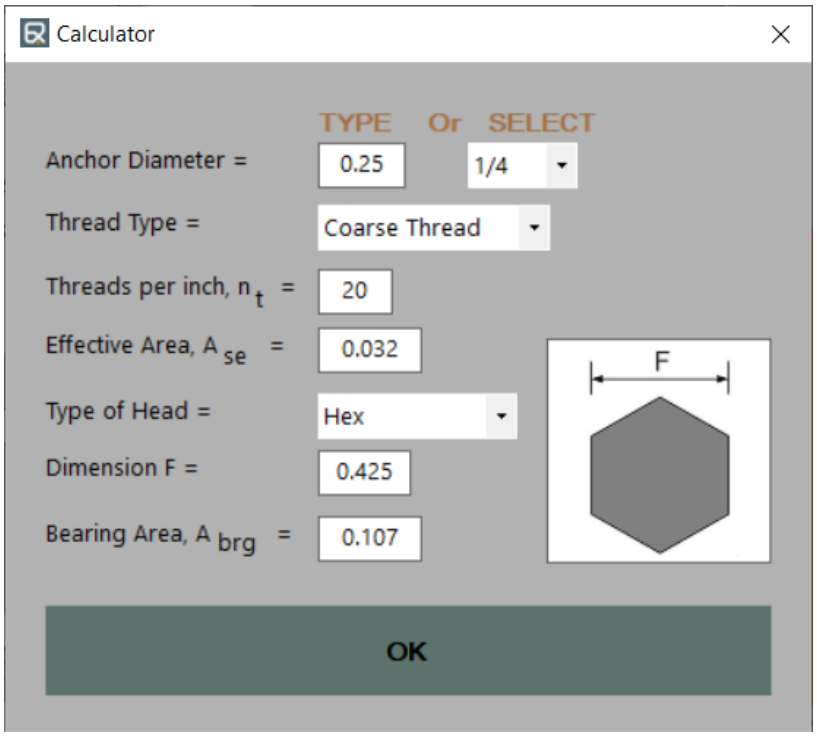


Figure 11 - Cast-In Place Anchor Area Calculator

MATERIALS AND REINFORCEMENT

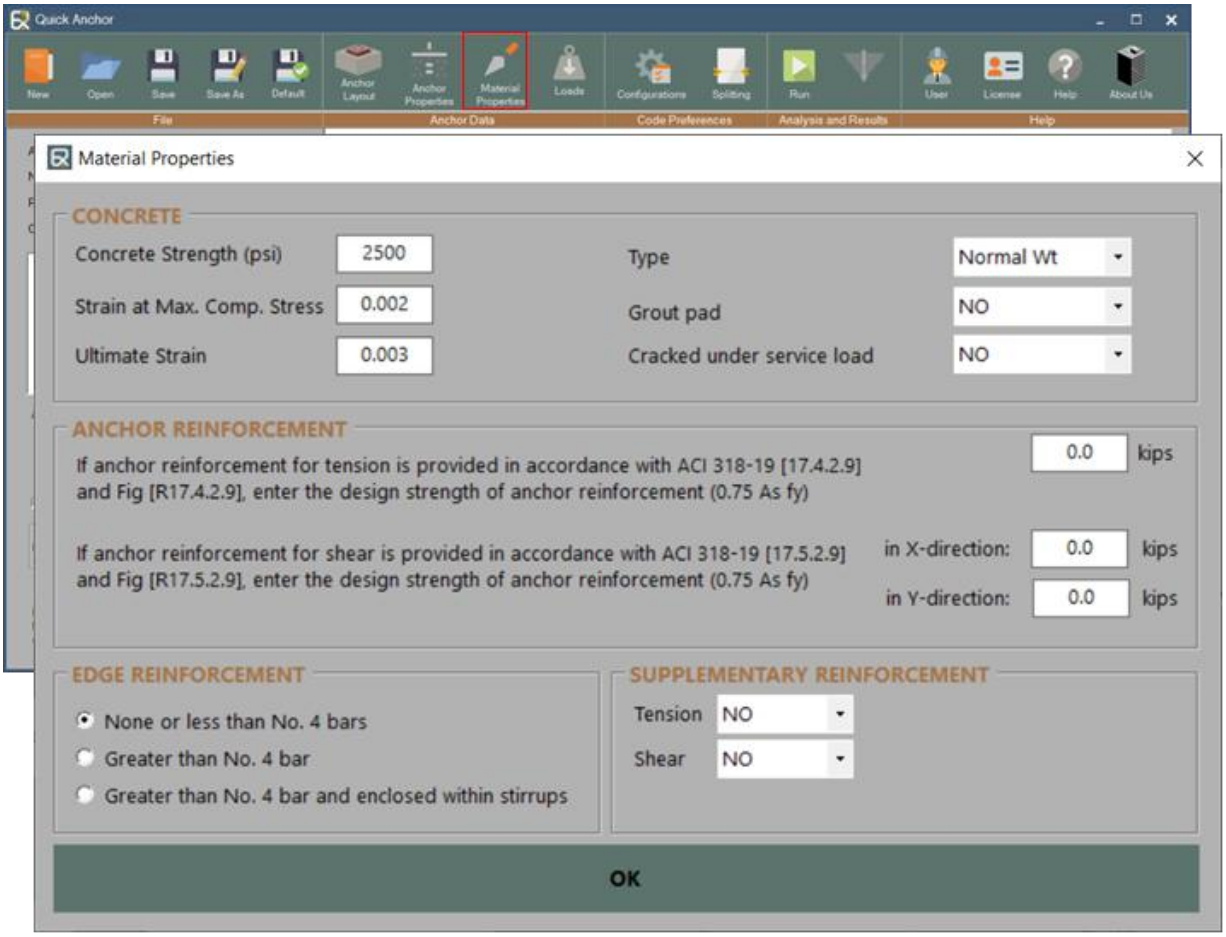


Figure 12 – Materials and Reinforcement Input

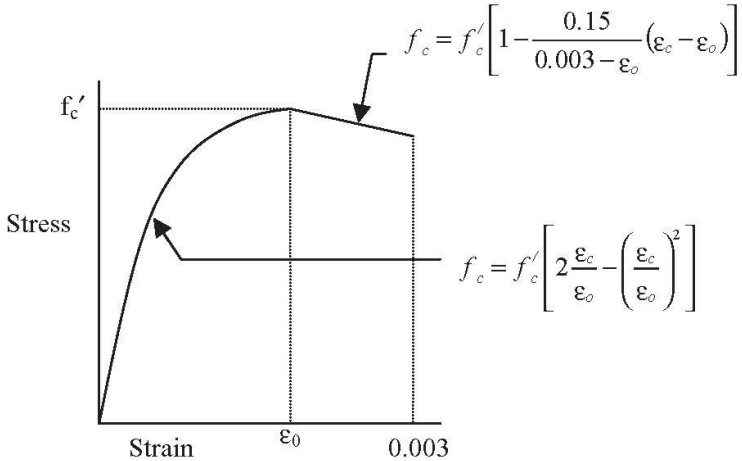


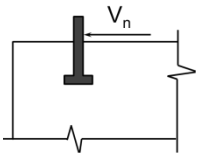
Figure 13 – Theoretical Stress-Strain Curve of Concrete

Grout pad: Specify whether grout pads are provided between the anchors and the concrete base or not. This affects the calculation of steel strength of anchor in shear.

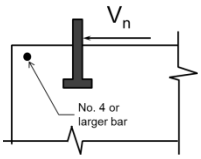
Supplementary Reinforcement: User can select a supplementary reinforcement configuration for tension as well as for shear. When supplemental reinforcement is provided for tension loading, it only increases the value of the strength reduction factor associated with concrete breakout in tension and concrete side-face blowout. When supplemental reinforcement is provided for shear loading, it increases the value of the strength reduction factor associated with concrete breakout in shear. Further, the shear supplemental reinforcement configuration selection has an effect on strength calculations when concrete is selected as cracked.

EDGE Reinforcement: Three options are provided:

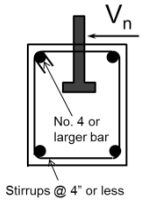
I) OPTION 1 – This option is selected when there is no supplementary reinforcement present between the anchors and the edge of concrete, or when supplementary reinforcement comprises of bars smaller than No. 4. (ACI 318-19)



II) OPTION 2 – This option is selected when No. 4 or larger bars are present between the anchors and the concrete edge. (ACI 318-19)



III) OPTION 3 – This option is selected when No. 4 or larger bars are present between the anchors and the concrete edge AND the bars are enclosed within stirrups spaced not more than 4 in. (ACI 318-19)



TENSILE ANCHOR REINFORCEMENT: When using ACI 318-08 or 318-11, Section D.5.2.9 or ACI 318-19 permits using design strength of anchor reinforcement for tension instead of concrete breakout strength, ϕN_{cb} or ϕN_{cbg}. If anchor reinforcement for tension is provided in accordance with ACI 318 Section D.5.2.9 and Fig. RD.5.2.9, specify its design strength using a strength reduction factor of 0.75. If no anchor reinforcement is provided, leave the value as zero.

SHEAR ANCHOR REINFORCEMENT: When using ACI 318-08 or 318-11, Section D.6.2.9 ACI 318-19 permits using design strength of anchor reinforcement for shear instead of concrete breakout strength, ϕV_{cb} or ϕV_{cbg}. If anchor reinforcement for shear in X-direction and/or in Y-direction is provided in accordance with ACI 318 Section D.6.2.9 and Fig. RD.6.2.9, specify its design strength using a strength reduction factor of 0.75. If no anchor reinforcement is provided, leave the values as zero.

APPLIED LOADS

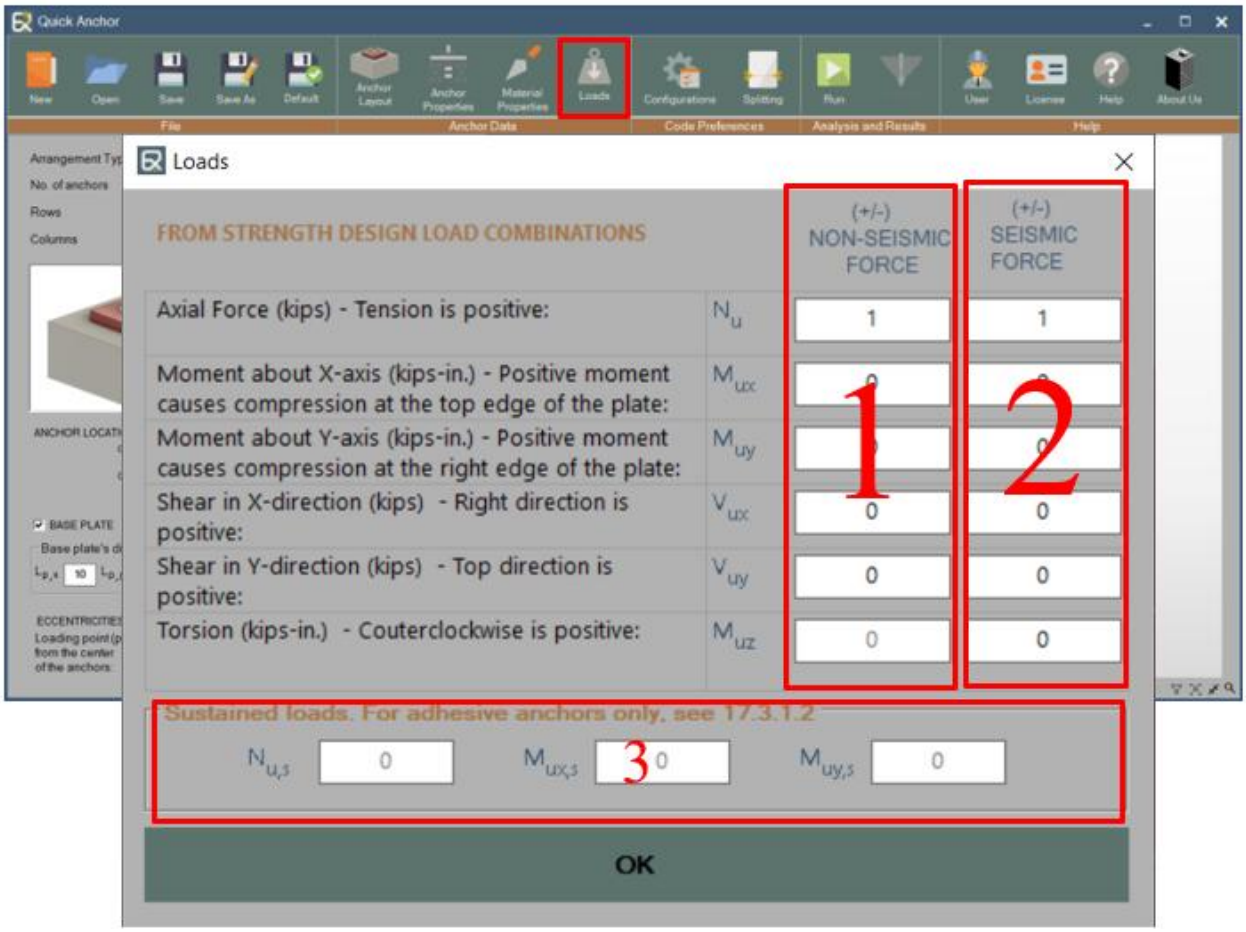


Figure 14 – Applied Seismic and Non-Seismic Loads Input

Items 1: Specify the non-seismic factored loads acting on the anchors as determined from the 2021 IBC strength design load combinations. Please note the correct sign for the desired direction of the load application.

Items 2: Specify the seismic factored loads acting on the anchors as determined from the 2021 IBC strength design load combinations. Please note the correct sign for the desired direction of the load application.

The specified seismic forces are used to determine if the special seismic requirements of ACI 318-11 and above are applicable or not.

Items 3: For adhesive anchors, specify the sustained loads, if present. See ACI 318-11 Sections D.3.5 and D.4.1.2 and ACI 318-19 for more information. Note ACI 318-11 and above need to be set as the governing code in order to use adhesive anchors in Quick Anchor v4.

CONFIGURATION

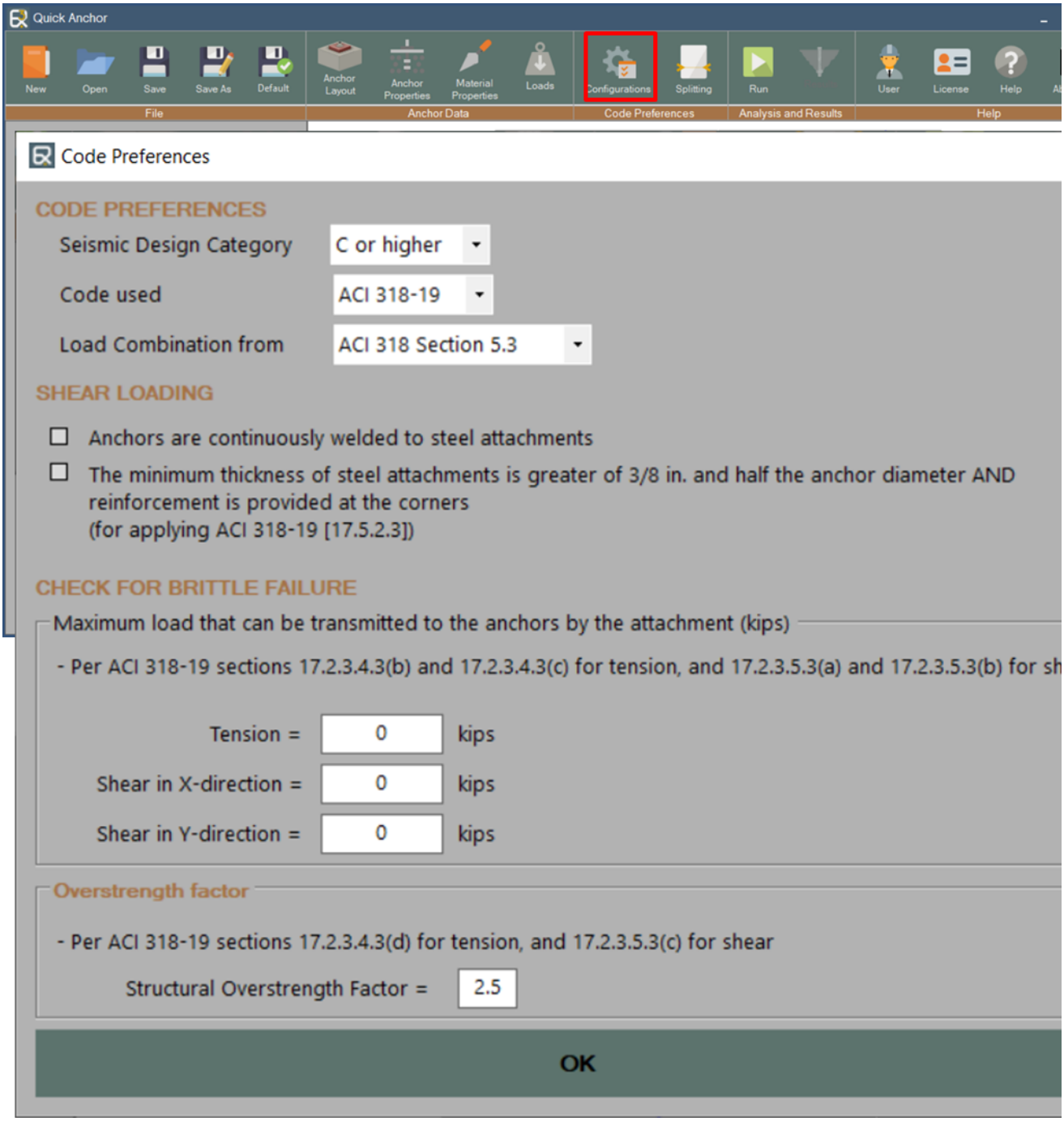


Figure 15 – Configuration Input

Seismic Design Category: Select if the structure is assigned to SDC *B* or *C or higher*.

Code used: Select if the strength calculation should be done in accordance with ACI 318-05, ACI 318-08, ACI 318-11 or ACI 318-19.

Shear Loading: These apply for cast-in headed studs, headed bolts, or hooked bolts, for the purpose of ACI 318 Section D.6.2.3 and above. By default, both boxes are unchecked.

Check for Brittle Failure: Specify the maximum loads that can be transmitted to the anchors by the attachment. Anchors can be designed for these loads to avoid meeting the ductile failure requirement of anchors when designed for seismic loading.

Overstrength Factor: Specify the structural overstrength factor, Ω_0. Anchors can be designed for factored loads amplified by Ω_0 to avoid meeting the ductile failure requirement of anchors when designed for seismic loading.

CONCRETE SPLITTING

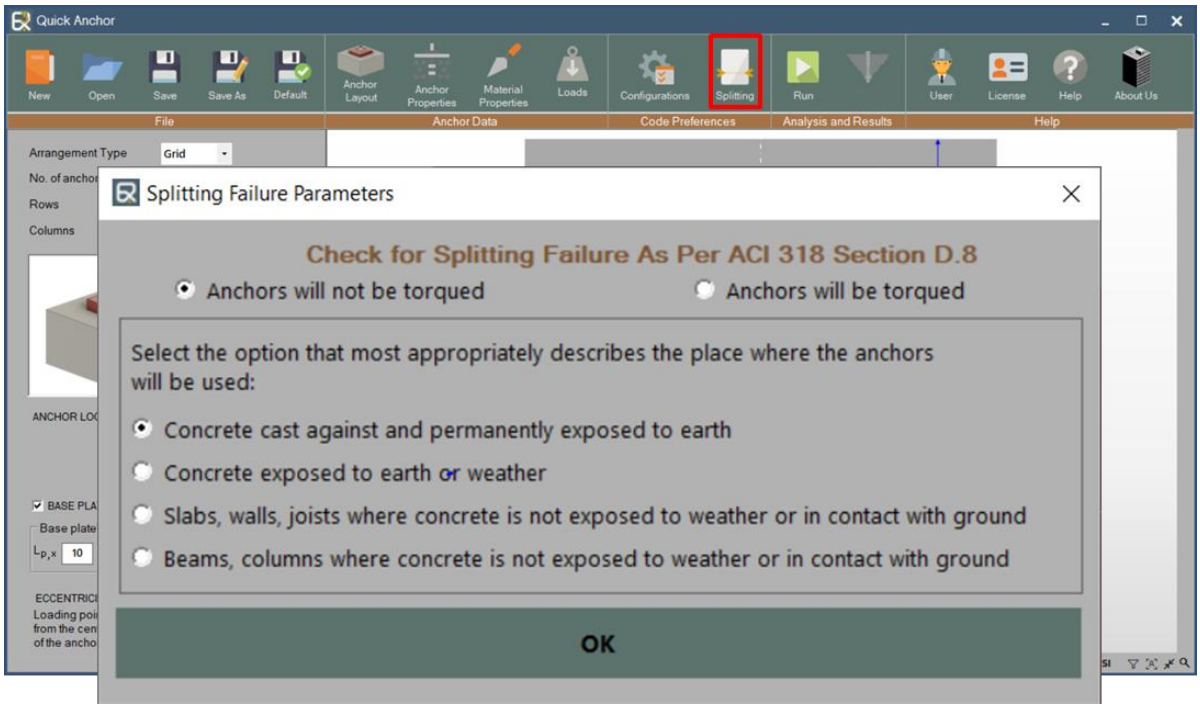


Figure 16 – Concrete Splitting

A tool to check for a possible splitting failure in tension can be accessed as shown in Figure 13. The tool checks if the anchor spacings and the edge distances specified in the input conform to the requirements of ACI 318 Section D.8 and ACI 318-19. This check is optional in Quick Anchor and does not need to be done for the purpose of strength calculation. However, it is strongly recommended that the user do this check in order to make sure that the requirements of ACI 318 Section D.8 and ACI318-19 are satisfied. The user needs to first specify the anchor diameter as well as all four edge distances and the anchor spacings (for a group of anchors) for the checking tool to run properly.

The checking tool opens in a separate window. When “Anchors will be torqued” option is selected, the checking tool simply displays if the anchor spacings in X- and Y-directions (for a group of anchors) as well as all the edge distances meet the minimum values specified in Section D.8 for the anchor diameter being used. The user has the option of either selecting a smaller diameter anchor or increasing the distance (spacing and/or edge distance) that failed the check.

When the option “Anchors will not be torqued” is selected, the user also needs to select the type of place where the anchors will be used. If any of the anchor spacing or edge distance fails the check, depending on the place where the anchors will be used, the user may get an option of using a smaller diameter just for the purpose of calculation (ACI 318 Section D.8.4). When this option is available, it is shown at the bottom of the window and the smaller diameter that can be used in accordance with Section D.8.4 is also mentioned.

RESULT VIEW

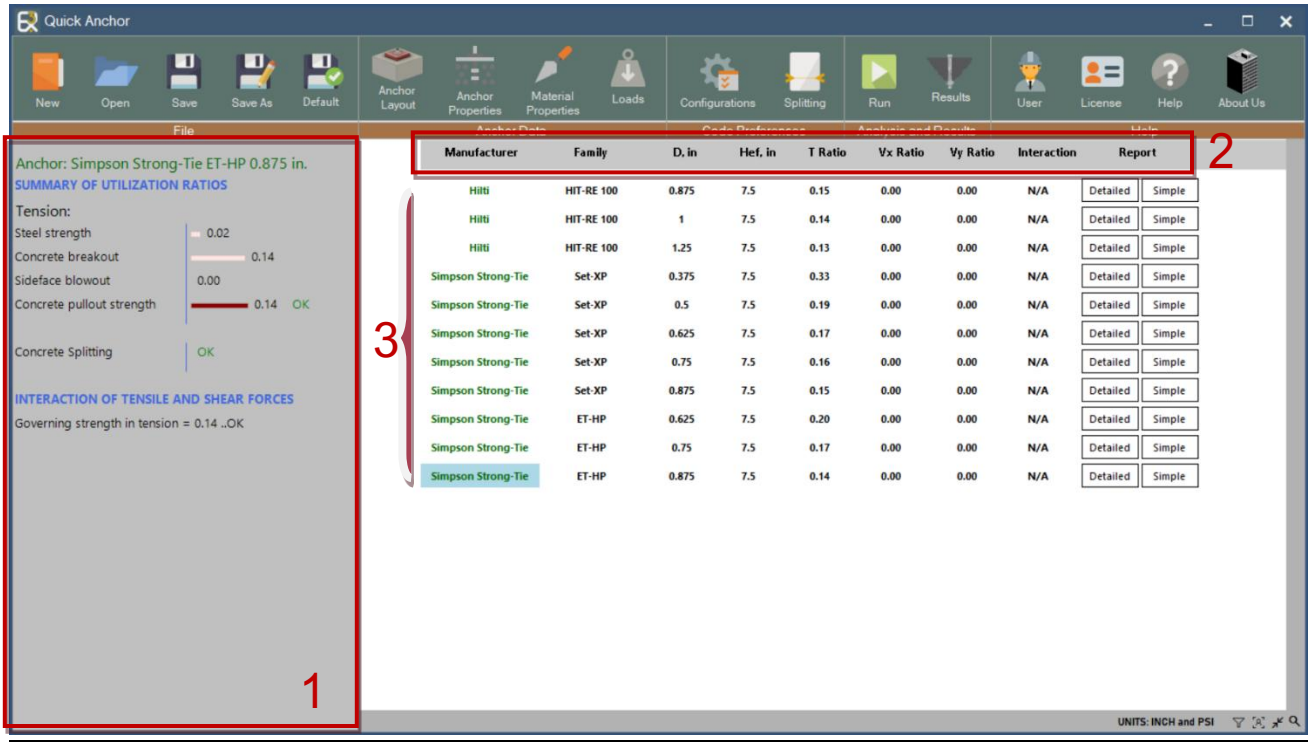


Figure 17 – Result View

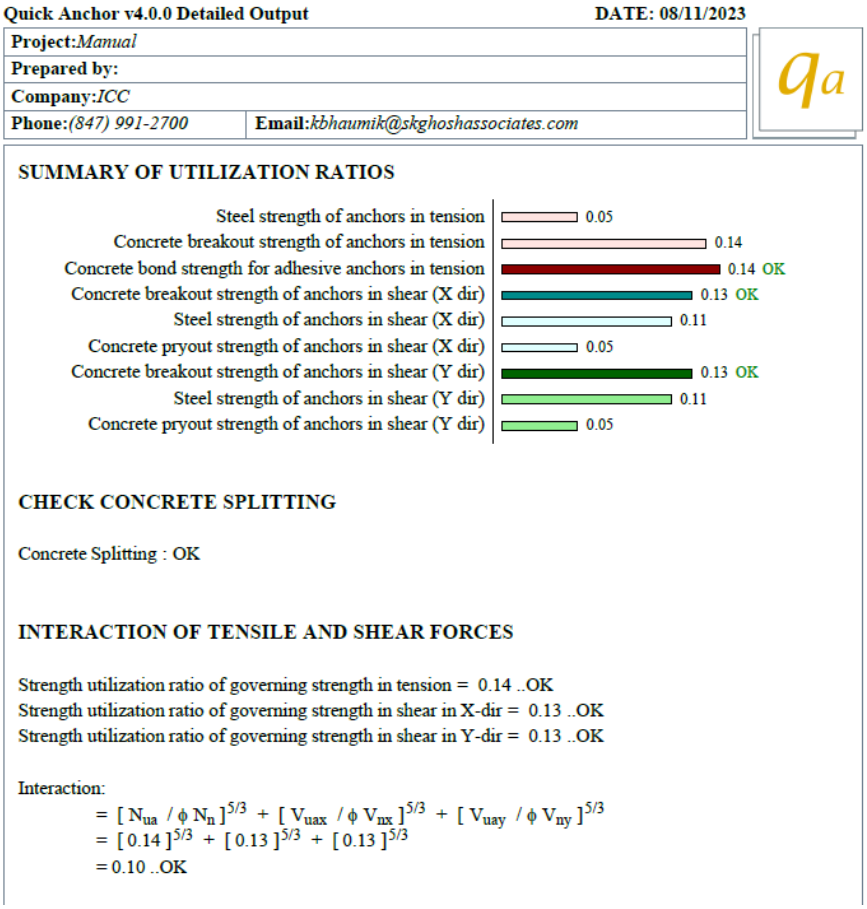
After running the analysis for one or multiple anchor layouts selected, we get a summary of all the results in **Result** page.

Result Summary (Section 1): Section 1 displays a summary of the results of the highlighted anchor. It is divided into summary of utilization ratio for each applied load as well as the interaction of tensile and shear forces.

Table of results (Section 2): The table of results contains a brief description of all the applicable anchors. For each anchor, the table displays: the manufacturer, anchor family, Diameter, embedment depth (h_{ef}), tensile force T ratio, Shear in x-direction V_x ratio, shear in y-direction V_y ratio, interaction between the tensile and shear forces ratio and couple button to generate a detailed and a simplified calculation report, respectively.

List of Anchors (Section 3): This section contains all the applicable anchors in terms of minimum thickness and minimum embedment depth.

OUTPUT INTERFACE



Quick Anchor v4.0.0 Detailed Output **DATE: 08/11/2023**

Project: *Manual*	
Prepared by:	
Company: *ICC*	
Phone: *(847) 991-2700*	**Email:** *kbhaumik@skghoshassociates.com*

SUMMARY OF UTILIZATION RATIOS

Steel strength of anchors in tension	0.05
Concrete breakout strength of anchors in tension	0.14
Concrete bond strength for adhesive anchors in tension	0.14 OK
Concrete breakout strength of anchors in shear (X dir)	0.13 OK
Steel strength of anchors in shear (X dir)	0.11
Concrete pryout strength of anchors in shear (X dir)	0.05
Concrete breakout strength of anchors in shear (Y dir)	0.13 OK
Steel strength of anchors in shear (Y dir)	0.11
Concrete pryout strength of anchors in shear (Y dir)	0.05

CHECK CONCRETE SPLITTING

Concrete Splitting : OK

INTERACTION OF TENSILE AND SHEAR FORCES

Strength utilization ratio of governing strength in tension = 0.14 ..OK
Strength utilization ratio of governing strength in shear in X-dir = 0.13 ..OK
Strength utilization ratio of governing strength in shear in Y-dir = 0.13 ..OK

Interaction:

$$= [N_{ua} / \phi N_n]^{5/3} + [V_{uax} / \phi V_{nx}]^{5/3} + [V_{uay} / \phi V_{ny}]^{5/3}$$
$$= [0.14]^{5/3} + [0.13]^{5/3} + [0.13]^{5/3}$$
$$= 0.10 \text{ ..OK}$$

Figure 18 – Detailed Report

Each time Quick Anchor is run, a separate output window will be displayed. User will be able to select to Simple Output or Detailed Output on this window. “Simple report” shows a summary of the results and key parameters for a quick analysis. On the other hand, the “detailed report” illustrates all the details of the analysis. All needed equations and figures are clearly demonstrated in the detailed report. The detailed report makes it easier to follow all the steps of the analysis. Where the simplified report is more suitable for quick decisions of the anchors.

GENERAL LAYOUT

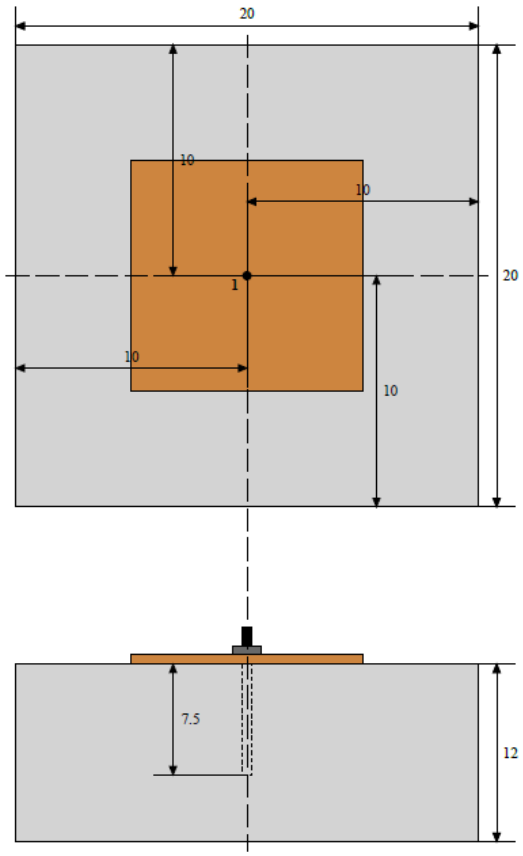


Figure 19 – Detailed Report (General Layout)

2. Strength utiliztion ratio [for preventing brittle failure of anchors, see [17.2.3.4.3(a)]:
= Applied load / 1.2 times the nominal steel strength = 0.03

2. CONCRETE BREAKOUT STRENGTH IN TENSION, ϕN_{cb}

Considering active anchors in tension:
c_{right} = 10.00 in.; c_{left} = 10.00 in.; c_{top} = 10.00 in.; c_{bottom} = 10.00 in.; h_{ef} = 7.5 in.

Three (or all) edge distances are less then $1.5h_{ef}$. Therefore, h_{ef} is reduced to 6.67 in. .....[17.4.2.3]

$A_{Nco} = 9h_{ef}^{2} = 400.00$ in.^{2} and $A_{Nc} = 400.00$ in.^{2} .....[Fig. R17.4.2.1]

$N_b = k_c \lambda_a \sqrt{f'_c}\ h_{ef}^{1.5}$ lbs.....[17.4.2.2]
$= 24 \times 1.00 \times \sqrt{2500} \times 6.67^{1.5}$ lbs = 20.66 kips

Edge effect factor, $\Psi_{ed,N}$ .....[17.4.2.5]
$c_{a,min}$ = 10.00 in.
When $c_{a,min}$ is greater or equal to $1.5\,h_{ef}$, $\Psi_{ed,N}$ = 1.0

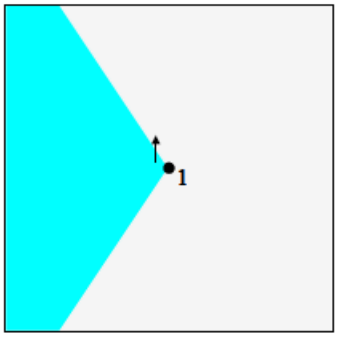
Factor for uncracked concrete, $\Psi_{c,N}$ .....[17.4.2.6]
Because concrete is uncracked under service load, $\Psi_{c,N}$ = 1.00

Factor for post-installed anchors without supplementary reinforcement, $\Psi_{cp,N}$ .....[17.4.2.7]
Critical edge distance: c_{ac} = 13.65 in.
$\Psi_{cp,N}$ = Maximum of $c_{a,min} / c_{ac}$ and $1.5h_{ef} / c_{ac}$ = 0.73

Design strength of the anchor (SDC C or higher):
$0.75\phi N_{cb} = 0.75\phi(A_{Nc} / A_{Nco})\,\Psi_{ed,N}\,\Psi_{c,N}\,\Psi_{cp,N}\,N_b$
$= 0.75 \times 0.65 \times (400.00/400.00) \times 1.00 \times 1.00 \times 0.73 \times 20.66 = 7.38$ kips

Figure 20 – Detailed Report (All the used equations)

Shear parallel to the edge:



Governing edge distance parallel to the shear, c_{a1} = 10 in.
c_{top} = 10.00 in.; c_{bottom} = 10.00 in.; h_a = 12 in.

Projected breakout area: width = 20 in.; height = 12 in.
$A_{Vco} = 4.5c_{a1}^2$ = 288.00 in.^{2} and A_{Vc} = 240.00 in.^{2} .....[Fig. R17.5.2.1(a) and (b)]
l_e = Min. of h_{ef} and $8d_a$ or from test reports for expansion anchors = 7 in.

V_b is the smaller of (a) and (b):
(a) $[7(l_e / d_a)^{0.2}\sqrt{d_a}]\lambda_a \sqrt{f'_c}\,(c_{a1})^{1.5}$ = 11.23 kips
(b) $9\lambda_a \sqrt{f'_c}\,(c_{a1})^{1.5}$ = 10.18 kips
Governing V_b = 10.18 kips

Edge effect factor, $\Psi_{ed,V}$ = 1.0 for shear parallel to the edge [17.5.2.1]
Factor for cracked concrete, $\Psi_{c,V}$ = 1.4
Factor for small concrete depth, $\Psi_{h,V}$ = 1.00
ϕV_{cb} = (1/1.00)×0.7 ×2×240/288.0)× 1.4× 1.00× 10.18 = 16.63 kips

Figure 21 – Detailed Report (Shear failure graphics)

COMPUTATIONAL BACKGROUND

Important Note:

This program skips strength calculation unless there is a corresponding applied load. In other words, tensile failure modes will be investigated only if the anchor formation is subjected to a tensile force (either from direct applied tensile axial load or from applied moments). Similarly, shear failure modes in X- or Y-direction will be investigated when the anchor formation is subjected to a shear force (either from direct applied shear load or from applied torsion) in the corresponding direction.

In addition, when computing the tensile strength of a group of anchors, this program excludes anchors not carrying tensile forces (check Anchor Forces table on the detailed output report). In computing the shear strength, the program starts the calculations considering active anchors carrying shear forces in desirable direction only. In other words, some anchors may carry compression forces in certain loading situations such as large, applied moments. These anchors will be excluded from the tensile strength calculation. Similarly, some anchors may take shear in opposite direction to the direction of applied shear load, mostly due to large eccentricity values or large applied pure torsion and will be excluded from the shear strength computations.

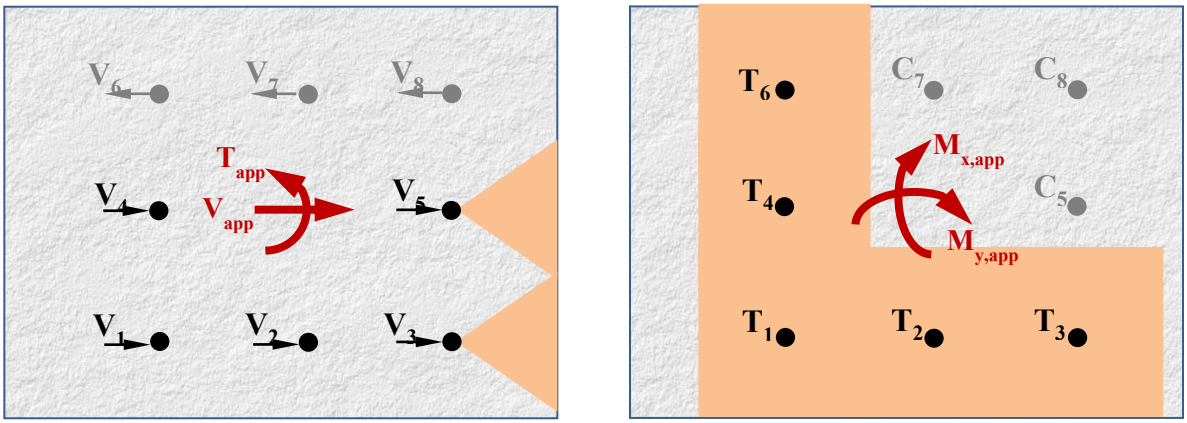


Figure 22 – Anchors Excluded from Strength Computation

1. STEEL STRENGTH OF ANCHOR IN TENSION

Design tensile strength of a single anchor is calculated as

$$\phi N_{sa} = \phi_{st} A_{se} f_{uta}$$

For structures assigned to SDC C or higher, a factor of 0.75 is applied to the above value when design is performed in accordance with ACI 318-05. With ACI 318-08 or -11, this factor is not required in this mode of failure.

In a group of anchors, the strength computed above needs to be compared against the maximum tension demand that occurs on a single anchor in the group. Conversely, this strength of a single anchor can also be converted to the strength

of the whole group by dividing it by the fraction of the total tension demand that the most heavily loaded anchor resists. For example, if the maximum tension demand on a single anchor is 40% of the total tension demand N_u, then the above design strength can be divided by 0.4 to compute the maximum tension that the group can resist. This approach makes it easy to compare the strengths obtained from different failure modes, so that a governing strength can be determined.

2. CONCRETE BREAKOUT STRENGTH OF ANCHOR IN TENSION

Design concrete breakout strength is calculated as:

$$\phi N_{cb} = \phi_{ct} \frac{A_{nc}}{A_{nco}} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \text{ , for a single anchor, and}$$

$$\phi N_{cbg} = \phi_{ct} \frac{A_{nc}}{A_{nco}} \psi_{ec,N} \psi_{ed,N} \psi_{c,N} \psi_{cp,N} N_b \text{ , for a group of anchors.}$$

Additionally, a factor of 0.75 is also applied when special seismic provisions are required by the code. In ACI 318-05 and -08, this applies to structures assigned to SDC C or higher. In ACI 318-11 and ACI 318-19, this applies to structures assigned to SDC C or higher provided the seismic component of the resulting tension is more than 20% of the total applied tension obtained from the load combinations.

For the purpose of concrete breakout in tension, anchors are considered to be in a *group* when the anchor spacing is not more than $3h_{ef}$. When the spacing between the anchor columns or the rows or both exceed $3h_{ef}$, one of the three cases described below can arise.

Case 1. $s_x > 3h_{ef}$ and $s_y \leq 3h_{ef}$: In this case, each anchor column acts in a group, but the columns act independent of one another (Figure 20).

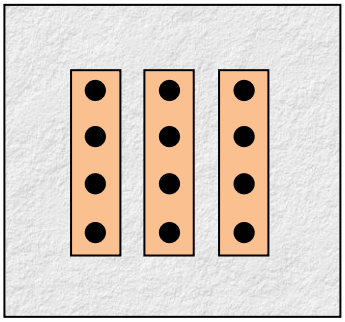


Figure 23 – Column spacing more than $3h_{ef}$

In this case, concrete breakout strengths of each column are calculated separately. Because only one column is considered at a time, eccentricity in X-direction, e'_{Nx}, is not considered in computing the eccentricity factor, and only e'_{Ny} is used. The effect of e'_{Nx} is accounted for while calculating the tension demand on each anchor column.

The strengths of each column of anchors is compared against the tension load carried by that column, and extrapolated to compute the strength of the whole anchor formation. It should be noted that the anchor column with the lowest strength may not produce the governing strength for the whole anchor formation if the demand on that column is also low.

Case 2. $s_y > 3h_{ef}$ and $s_x \leq 3h_{ef}$: Same approach as in Case 1. Strengths of each row are calculated separately, and the strength of the whole anchor formation is determined based on them.

Case 3. $s_x > 3h_{ef}$ and $s_y > 3h_{ef}$: In this case, all anchors act on their own without any group action in either direction. Thus, strengths of each anchor are calculated separately, and the strength of the whole anchor formation is determined based on them.

Please note, when using ACI 318-08 or ACI 318-11, user has the option to indicate if anchor reinforcement for tension is provided in accordance with ACI 318 Section D.5.2.9 and Fig. RD.5.2.9 by entering the design strength of anchor reinforcement calculated with a strength reduction factor of 0.75 ("MATRIALS AND REINFORCEMENT" input tab). If anchor reinforcement design strength is provided by the user, Quick Anchor will not investigate the concrete breakout failure of anchors in tension and will simply use the design strength of anchor reinforcement for tension instead of concrete breakout strength, ϕN_{cb} or ϕN_{cbg}.

3. CONCRETE SIDE-FACE BLOWOUT STRENGTH OF A HEADED ANCHOR IN TENSION

Concrete side-face blowout applies only for headed bolts or studs when anchor embedment depth, h_{ef}, is greater than 2.5 times the minimum edge distance, c_{a1}. Strength of a single anchor is calculated as

$$\phi N_{sb} = \phi_{ct}\left(160 c_{a1}\sqrt{A_{brg}}\right)\lambda_a \sqrt{f'_c}$$

Also, if $c_{a2} < 3c_{a1}$, then an edge distance correction factor $(1+c_{a2}/c_{a1})/4$ is applied to the above strength, where c_{a2} is the minimum edge distance orthogonal to c_{a1}.

Additionally, a factor of 0.75 is also applied when special seismic provisions are required by the code. In ACI 318-05 and -08, this applies to structures assigned to SDC C or higher. In ACI 318-11 and ACI 318-19, this applies to structures assigned to SDC C or higher provided the seismic component of the resulting tension is more than 20% of the total applied tension obtained from the load combinations.

For a group of anchors, possible side-face blowout failure is investigated in both X- and Y-directions. In the X-direction, two anchor columns closest the left and the right edge of concrete are investigated for potential side-face blowout failure. Similarly, for the Y-direction, two anchor rows closest the top and the bottom edge of concrete are investigated for potential side-face blowout failure.

While computing strength in any direction, two scenarios are considered as described below. Even though the description below illustrates failure in the X-direction only, the same is applicable to a failure in the Y-direction as well.

Case 1. $s_y \leq 6c_{a1}$: The whole edge column acts as a group (Figure 21). Strength of this column is calculated as

$$\phi N_{sb} = \phi_{ct}\left(160c_{a1}\sqrt{A_{brg}}\right)\lambda_a\sqrt{f_c'} \times (1 + s/6c_{a1})$$

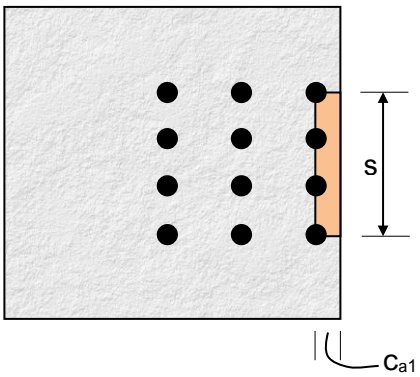


Figure 24 – Side-face blowout as a group

The design strength calculated above relates to the anchor column nearest to an edge (the right edge in Figure 21). This needs to be compared against the tension demand on that column only. Conversely, the above design strength can be scaled up by dividing it by the fraction of the total tension demand that this column resists to calculate the strength of the whole anchor group. For example, if the tension demand on the column shown is 40% of the total tension demand N_u, then the above design strength can be divided by 0.4 to compute the maximum tension demand that the group can support.

Case 1. $s_y > 6c_{a1}$: The whole column does not act as a group (Figure 22). Rather, individual anchors can undergo side-face blowout failure.

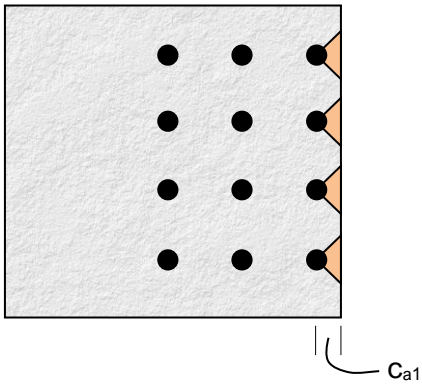


Figure 25 – Side-face blowout of individual anchors

In this case, the strengths of each anchor are calculated, and extrapolated to compute the group strength.

4. PULLOUT STRENGTH OF ANCHOR IN TENSION

Design tensile strength of a single anchor is calculated as

1. For headed studs and bolts, $\phi N_{pn} = \phi \Psi_{c,P} N_p = \phi c_{pt} \Psi_{c,P} \left(8 A_{brg} f_c'\right)$

2. For J- or L-hooks, $\phi N_{pn} = \phi \Psi_{c,P} N_p = \phi c_{pt} \Psi_{c,P} (0.9 f_c' e_h d_a)$

Additionally, a factor of 0.75 is also applied when special seismic provisions are required by the code. In ACI 318-05 and -08, this applies to structures assigned to SDC C or higher. In ACI 318-11 and ACI 318-19, this applies to structures assigned to SDC C or higher provided the seismic component of the resulting tension is more than 20% of the total applied tension obtained from the load combinations.

For hooked (J- or L-) bolts, if bearing length, e_h, is less than $3d_a$, pullout strength is not calculated due to insufficient bearing length. If e_h is more than $4.5d_a$, then the pullout strength is calculated assuming $e_h = 4.5d_a$, neglecting the excess bearing length.

For post-installed expansion and undercut anchors, the values of N_p is to be determined based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.2. This value needs to be obtained from the anchor manufacturer and entered in the appropriate place on the *Post-installed Anchor Properties* window as described before. If no value of N_p is supplied, the program will assume the anchor pullout failure not to govern.

For adhesive anchors, pullout failure does not apply.

In a group of anchors, the strength computed above needs to be compared against the maximum tension demand that occurs on a single anchor in the group. Conversely, this strength of a single anchor can also be converted to the strength of the whole group by dividing it by the fraction of the total tension demand that the most heavily loaded anchor resists. For example, if the maximum tension demand on a single anchor is 40% of the total tension demand N_u, then the above design strength can be divided by 0.4 to compute the maximum tension that the group can resist. This approach makes it easy to compare the strengths obtained from different failure modes, so that a governing strength can be determined.

5. BOND STRENGTH OF ADHESIVE ANCHOR IN TENSION

This failure mode is new to ACI 318-11. Design concrete breakout strength is calculated as:

$\phi N_a = \phi_{ctp} \frac{A_{Na}}{A_{Nao}} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$, for a single anchor, and

$\phi N_{ag} = \phi_{ctp} \frac{A_{Na}}{A_{Nao}} \psi_{ec,Na} \psi_{ed,Na} \psi_{cp,Na} N_{ba}$, for a group of anchors.

Additionally, a factor of 0.75 is also applied to structures assigned to SDC C or higher provided the seismic component of the resulting tension is more than 20% of the total applied tension obtained from the load combinations.

For the purpose of bond failure of adhesive anchors, anchors are considered to be in a *group* when the anchor spacing is not more than $2c_{Na}$, where c_{Na} is a parameter computed based on anchor diameter and characteristics bond stress of adhesive anchor in uncracked concrete, τ_{uncr}.

The characteristic bond stress in cracked concrete, τ_{cr}, as well as in uncracked concrete, τ_{uncr}, are to be determined based on the 5 percent fractile of results of tests performed and evaluated according to ACI 355.4. These values can be obtained from the anchor manufacturer and entered in the appropriate places on the "POST-INSTALLED ANCHORS" input tab as described before. The program also permits the use of the τ_{uncr} and τ_{cr} values given in ACI 318-11 Table D.5.5.2, provided the conditions listed in Section D.5.5.2(a) through (e) are satisfied.

When the spacing between the anchor columns or the rows or both exceed $2c_{Na}$, one of the three cases described below can arise.

Case 1. $s_x > 2c_{Na}$ and $s_y \leq 2c_{Na}$: In this case, each anchor column acts in a group, but the columns act independent of one another (Figure 23).

In this case, strengths of each column are calculated separately. Because only one column is considered at a time, eccentricity in X-direction, e'_{Nx}, is not considered in computing the eccentricity factor, and only e'_{Ny} is used. The effect of e'_{Nx} is accounted for while calculating the tension demand on each anchor column.

The strengths of those two columns are compared against the tension load carried by them, and extrapolated to compute the strength of the whole anchor formation. It should be noted that the anchor column with the lowest strength may not produce the governing strength for the whole anchor formation if the demand on that column is also low.

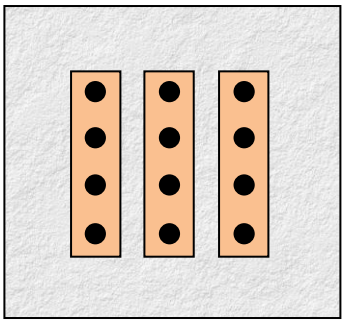


Figure 26 – Column Spacing More Than $2c_{Na}$

Case 2. $s_y > 2c_{Na}$ and $s_x \leq 2c_{Na}$: Same approach as in Case 1. Strengths of each row are calculated separately, and the strength of the whole anchor formation is determined based on them.

Case 3. $s_x > 2c_{Na}$ and $s_y > 2c_{Na}$: In this case, all anchors act on their own without any group action in either direction. Thus, strengths of each anchor are calculated separately, and the strength of the whole anchor formation is determined based on them.

6. STEEL STRENGTH OF ANCHOR IN SHEAR

When using ACI 318-11 (and above), Section D.6.1.1 requires the steel shear strength to be consistent with the assumed concrete breakout surface in shear. This means only those anchors involved in the governing failure mode of the concrete breakout in shear (please see the next section for more information) must be considered in determining the steel strength of anchor in shear. This provision does not apply when anchor reinforcement for shear is provided.

Design shear strength of a single cast-in-place headed stud is calculated as:

$$\phi N_{sa} = \phi_{sv} A_{se} f_{uta}$$

Design shear strength of a single cast-in headed bolt, hooked bolt, or post-installed anchors is calculated as

$$\phi N_{sa} = \phi_{sv} 0.6 A_{se} f_{uta}$$

For structures assigned to SDC C or higher, a factor of 0.75 is applied to the above value when design is performed in accordance with ACI 318-05. With ACI 318-08 or -11 or-19, this factor is not required in this mode of failure.

In a group of anchors, where the applied shear has an eccentricity with respect to the centerline of the anchor layout, the strength computer above needs to be compared against the maximum shear demand that occurs on a single anchor in the group. Conversely, this strength of a single anchor can also be converted to the strength of the whole group by dividing it by the fraction of the total shear demand that the most heavily loaded anchor resists. For example, if the maximum shear demand on a single anchor is 40% of the total shear demand V_u, then the above design strength can be divided by 0.4 to compute the maximum shear that the group can resist. This approach makes it easy to compare the strengths obtained from different failure modes, so that a governing strength can be determined.

If there is no eccentricity in the applied load, it can be assumed that all anchors share the load equally, and the above strength can simply be multiplied by the total number of anchors in the group, *n*, to obtain the strength of the whole group.

7. CONCRETE BREAKOUT STRENGTH OF ANCHOR IN SHEAR

Design shear strength of a single anchor or a group of anchors is calculated as

$\phi V_{cb} = \phi_{cv} \frac{A_{vc}}{A_{vco}} \psi_{ed,V} \psi_{c,V} V_b$, for a single anchor, and

$\phi V_{cbg} = \phi_{cv} \frac{A_{vc}}{A_{vco}} \psi_{ec,V} \psi_{ed,V} \psi_{c,V} V_b$, for a group of anchors.

For structures assigned to SDC C or higher, a factor of 0.75 is applied to the above value when design is performed in accordance with ACI 318-05 or -08. With ACI 318-11, this factor is not required in this mode of failure.

ACI 318-11 Figure RD.6.2.1(b) suggests a number of load cases to be considered while evaluating concrete breakout in shear. Below is a complete description of how the program implements them. The description below is based on shear in X-direction. However, the same approach is adopted for shear in Y-direction as well. An anchor arrangement of 2 rows and 3 columns is considered. It is assumed that shear is not distributed evenly over the two rows.

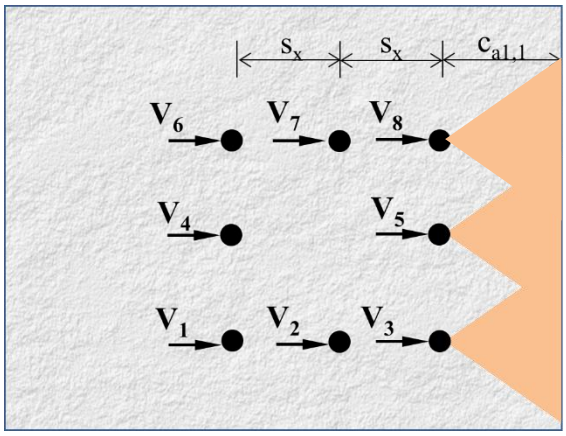
Please note, when using ACI 318-08 or ACI 318-11, user has the option to indicate if anchor reinforcement for X- and/or Y-direction is provided in accordance with ACI 318 Section D.6.2.9 and Fig. RD.6.2.9 by entering the design strength of anchor reinforcement calculated with a strength reduction factor of 0.75 (“MATERIALS AND REINFORCEMENT” input tab). If anchor reinforcement design strength is provided by the user, Quick Anchor will not investigate the concrete breakout failure of anchors in shear and will simply use the design strength of anchor reinforcement instead of concrete breakout strength, ϕV_{cb} or ϕV_{cbg}.

When anchor spacing in the direction of shear is greater or equal to the governing edge distance ($s_x \geq c_{a1,1}$), the following cases are considered:

Case 1: Breakout takes place from the 1st column

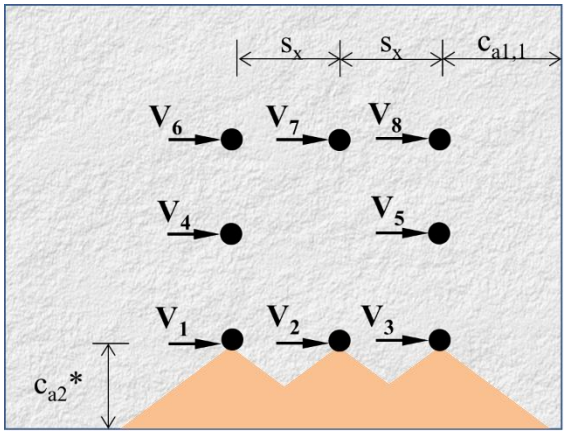
The whole anchor formation is analyzed under applied shear force in X-direction and/or applied tension. Anchors carrying shear forces in the desired direction (positive X here) will be included in strength calculations only.

(a) Shear perpendicular to edge



Strength is calculated based on $c_{a1} = c_{a1,1}$
Strength is checked against $V_3 + V_5. + V_8.$

(b) Shear parallel to edge



Strength is calculated based on $c_{a1} = c_{a2}$
Strength calculated as $2\phi V_{cbg}$ with $\Psi_{ed,V} = 1.0$
[see ACI 318 Section D.6.2.1(c)]
Strength is checked against $V_1 + V_2 + V_3$

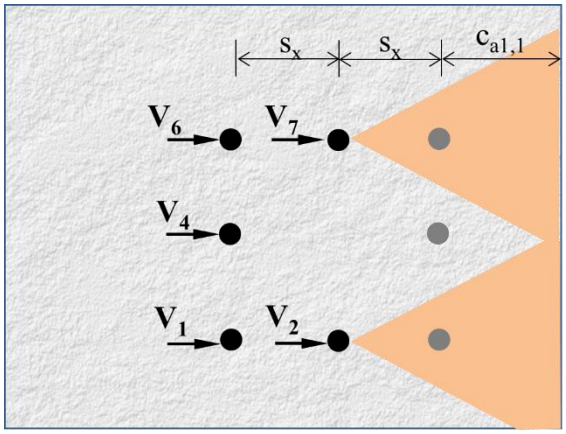
* c_{a2} = the distance to the top edge when calculating the shear strength of the top row of active anchor (strength would be checked against $V_6 + V_7 + V_8$)

When anchor spacing in the direction of shear is greater or equal to the governing edge distance ($s_x \geq c_{a1,1}$), the following cases are considered:

Case 2: Breakout takes place from the 2nd column

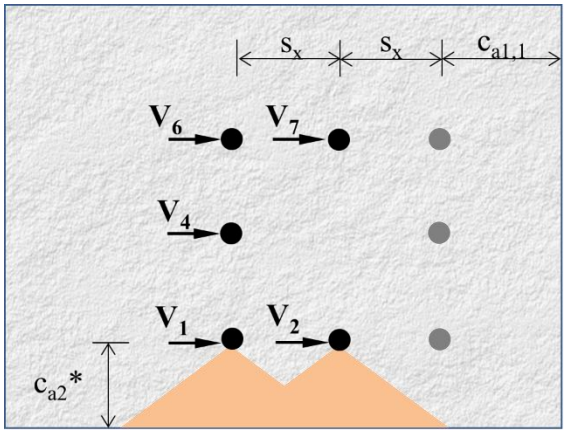
Excluding the 1st column, the rest of anchor formation (the 2nd and the 3rd columns) is analyzed under applied shear force in X-direction and/or applied tension. Among them, anchors carrying shear forces in the desired direction (positive X here) will be included in strength calculations only.

(a) Shear perpendicular to edge



Strength is calculated based on $c_{a1} = c_{a1,1} + s_x$
Strength is checked against $V_2 + V_7$

(b) Shear parallel to edge



1. Strength is calculated based on $c_{a1} = c_{a2}$
2. Strength calculated as $2\phi V_{cbg}$ with $\Psi_{ed,V} = 1.0$ [see ACI 318 Section D.6.2.1(c)]
3. Strength is checked against $V_1 + V_2$

* c_{a2} = the distance to the top edge when calculating the shear strength of the top row of active anchor (strength would be checked against $V_6 + V_7$)

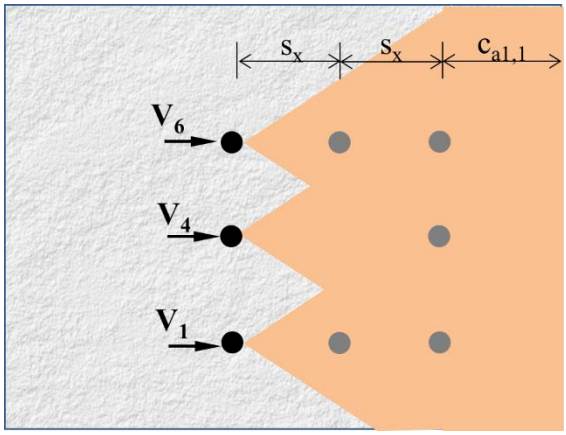
When anchor spacing in the direction of shear is greater or equal to the governing edge distance ($s_x \geq c_{a1,1}$), the following cases are considered:

Case 3: Breakout takes place from the 3rd column

Excluding the 1st and the 2nd columns, the rest of anchor formation (the 3rd column) is analyzed under applied shear force in X-direction and/or applied tension. Among them, anchors carrying shear forces in the desired direction (positive X here) will be included in strength calculations only.

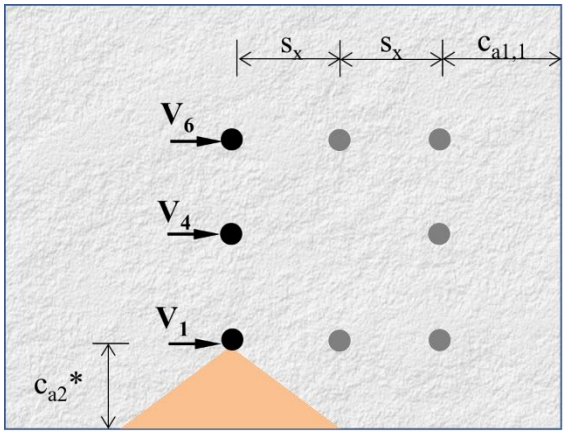
*****Note: only this assumption needs to be considered when anchors are welded to a common plate independent of *s*.**

(a) Shear perpendicular to edge



1. Strength is calculated based on $c_{a1} = c_{a1,1}$ +

(b) Shear parallel to edge



Strength is calculated based on $c_{a1} = c_{a2}$
Strength calculated as $2\phi V_{cbg}$ with $\Psi_{ed,V} = 1.0$
[see ACI 318 Section D.6.2.1(c)]
Strength is checked against V_1

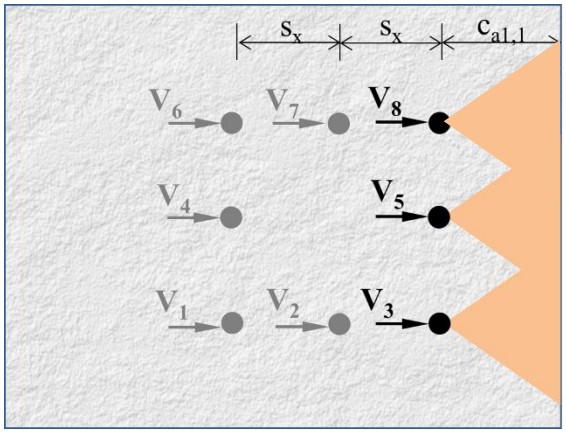
* c_{a2} = the distance to the top edge when calculating the shear strength of the top row of active anchor (strength would be checked against V_6)

When anchor spacing in the direction of shear is less than the governing edge distance ($s_x < c_{a1,1}$), the following cases are considered:

Case 1: Breakout takes place from the 1st column

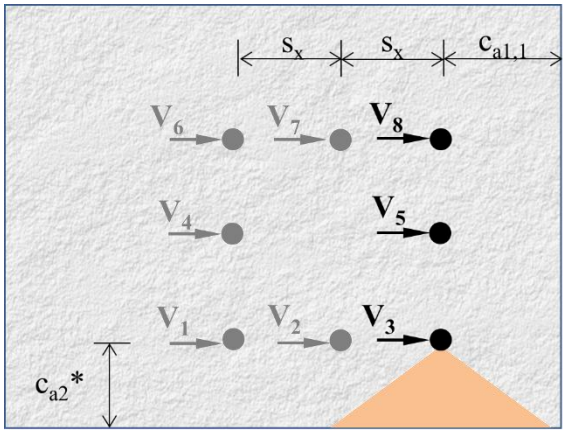
The whole anchor formation is analyzed under applied shear force in X-direction and/or applied tension. Anchors carrying shear forces in the desired direction (positive X here) will be included in strength calculations only.

(a) Shear perpendicular to edge



Strength is calculated based on $c_{a1} = c_{a1,1}$

(b) Shear parallel to edge



Strength is calculated based on $c_{a1} = c_{a2}$
Strength calculated as $2\phi V_{cbg}$ with $\Psi_{ed,V} = 1.0$
[see ACI 318 Section D.6.2.1(c)]

* c_{a2} = the distance to the top edge when calculating the shear strength of the top active anchor.

8. CONCRETE PRY-OUT STRENGTH OF ANCHOR IN SHEAR

Design pryout strength of one anchor is calculated as

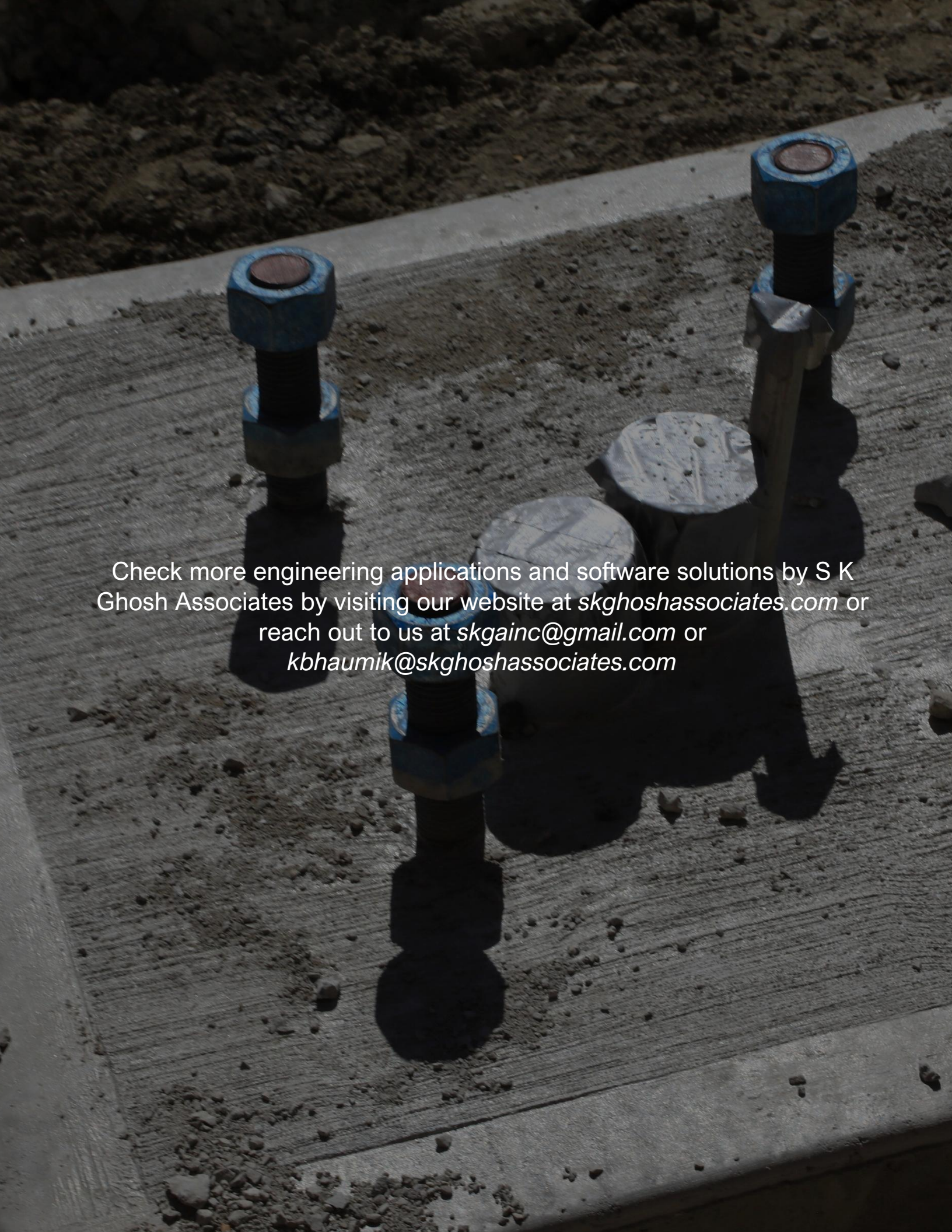
$$\phi V_{cp} = \phi c_{pv} k_{cp} N_{cp}$$

Design pryout strength of a group of anchors is calculated as

$$\phi V_{cpg} = \phi c_{pv} k_{cp} N_{cpg}$$

For adhesive anchors, N_{cp} (or N_{cpg}) is the smaller of the nominal strengths in concrete breakout in tension and the adhesive bond failure in tension calculated for active anchors carrying shear forces in the direction of applied shear. For all other anchor types, N_{cp} (or N_{cpg}) is the nominal strength in concrete breakout in tension calculated for active anchors.

k_{cp} = 1 for h_{ef} < 2.5 in. and
k_{cp} = 2 for $h_{ef} \geq$ 2.5 in.



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