

Anchor Design Made Easy!

A Review of Anchor Design Software Considerations

By John Silva, S.E.

With the advent of strength design procedures for all of the primary structural materials (concrete, steel, wood, masonry), the basis for connection design between disparate materials (wood to masonry, steel to concrete, etc.) has become more uniform and, to some extent, more straightforward. Nevertheless, for some design tasks, the use of strength design methods has increased the number and complexity of design steps and has expanded the time required to solve what were previously viewed as routine design problems.

This is nowhere more true than in the design of anchorages to concrete, which until recently had been largely based on allowable stress design concepts. With the introduction of the 2003 IBC, the strength design procedures for anchorage to concrete detailed in ACI 318-02 Appendix D were officially adopted in jurisdictions across the U.S. Along with the change from ASD to LRFD with the attendant strength reduction factors, predictive equations and numerous failure mode checks, Appendix D introduced several new concepts including the effect of concrete cracking on anchor resistance, anchor reliability as determined through proper function tests and ductile failure requirements for seismic design.

Together with the relatively large number of new anchor systems on the market (self-undercutting anchors, hybrid torque-controlled adhesive anchors, etc.), the potential for confusion is clear. In some cases, design tasks that once occupied a few minutes could now stretch into hours, while appropriate design procedures are consulted, the possible anchor options are explored and documentation of the final design is prepared.

Thankfully, the number of anchor design programs available on the Internet has increased in recent years, providing the designer with several new options for attacking the anchor design problem with confidence and efficiency. While anchor design software has been available for some time, these new programs provide better interactive graphics and improved calculation algorithms. Furthermore, the fact that the strength design procedures given in ACI 318-02 are largely based on predictive equations, rather than tables of values, is beneficial from a programming standpoint as it reduces the need to continuously update the program database.

Nevertheless, several important considerations should be kept in mind when deciding which software to employ for a given design task. Several currently available anchor design programs have been reviewed, and this article discusses what, in the author's opinion, are the pros and cons of the software features and the relevant questions for assessing a specific program.

Design Basis

The design basis for any design software should be clearly stated, both on-screen as well as in the output. During the transition from ASD to LRFD procedures for anchor design, it

may be important that both approaches reside within the same software package. Available options may include:

- ASD design in accordance with manufacturer data
- ASD design in accordance with a specific product evaluation report (Evaluation Services Report, other) complying with a specific edition of the code (IBC, other)
- LRFD design in accordance with ACI 318-(year)
- LRFD design in accordance with ACI 318-(year) as modified by ICC-ES acceptance criteria AC193 or AC308 for a specific edition of the IBC
- LRFD design for nuclear facilities in accordance with ACI 349-(year)
- LRFD seismic in accordance with ACI 318-(year) and ASCE 7-(year)

Without exploring the nature of each of these options in detail, and recognizing that no one software package currently addresses all of the possible permutations generated by a reference standard-based code environment, it is important to realize that simply asking for a design that complies with the code will be inadequate for defining the relevant design parameters.

GUI and Input Flexibility

One of the most difficult aspects of assessing a specific anchorage problem may be defining the relevant geometric parameters. Anchor edge distances, spacings, embedment depths and loading directions, as well as the structural member proportions and reinforcing, may all play a role in determining the connection resistance. A "true-life" graphic user interface (GUI) that provides accurate and to-scale anchor layout information can be extremely useful in establishing whether a specific design approach "looks right" to the designer. (How many times have we seen computer output dictate a design solution that is out of scale to the member sizes, hole diameters, etc., associated with the connection?)

Furthermore, the ability to rapidly revise the design layout "on the fly" and to view the layout from a variety of angles with all relevant geometrical information shown goes a long way to increasing the software utility.

Calculation Engine and Benchmarking

Critical to the acceptability of any structural design software are the calculation algorithms used to navigate the complex interplay of design provisions contained in the governing design codes, evaluation reports, etc.

Most design software operates in the "design" mode, which means that it is intended to respond to a given set of parameters including material type, strength, geometry, and loading intensity and direction, and to return a list of possible anchor solutions. It may also be desirable, however, to have the option to "check" an existing



connection design by determining the connection capacity.

In all cases, a balance between calculation efficiency and design flexibility must be established in the program to avoid excessively long calculation times. For example, if the designer wished to know the resistance of a given anchorage to a single loading direction, the program should be able to generate this “capacity” with little effort. It also may be possible for the software to establish the anchorage capacity for two orthogonal loading directions. It may not be possible, however, for the software to assess the anchorage capacity for the full range of possible loading directions, in essence producing an “interaction surface,” without requiring your lunch break to return an answer, and as such this option is not typically available. As calculation speeds increase, however, the flexibility of the calculation engines will improve.

Proper benchmarking of the software is mandatory and should include a clear comparison of manually worked problems with the program output. Furthermore, a process for recording and addressing issues raised by software users should be in place.

Output

The utility of a given software package is defined by its output in terms of format, detail and portability. Critical elements of the output include:

1. An input echo, either as a list of actual input values, or preferably, in the form of clear graphics defining the design geometry with all relevant parameters.
2. A listing of the design equations used, the intermediate values derived and the “reasoning” behind choices made by the design software in response to the design parameters.
3. A clear summary of the controlling design values and the anchor options. This may include information regarding the structural efficiency of each design option as a percentage, with 100 percent indicating a design that just fulfills the design requirement.
4. The ability to generate output in various formats for use with other software.

Other Options

In addition to calculating anchor resistance, a complete anchor design software package may include one or more of the following features:

1. CAD drawings for the selected anchor products for use in the generation of construction documents
2. Specification text for the selected anchor.
3. Installation instructions.

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4. Photos or other representations of proprietary anchor products.
5. Technical documents, such as manufacturer's data and/or approvals for calculation back-up.

Technical Support and Updating

Rapid and competent technical support is vital to the success of all structural design software, both to address the ever-changing world of computer platforms, graphic environments and processor designs, as well as to provide specific information regarding the software's approach to specific design scenarios and to assist with unique design cases. Technical support may be Web-based, include phone-based interaction with technical staff or on-site personnel training. Less useful are lists of frequently asked questions, expert systems, and computer-generated responses.

Anchor Design Software Packages

There are currently several anchor design software options available to the designer. These fall into three main categories:

1. Freeware issued by anchor manufacturers to support their product line;
2. Software oriented toward baseplate design and focusing on cast in anchors; and
3. Specialty software created by trade associations, consulting engineering firms and third-party software developers.

Vendor (Manufacturer) Freeware

Anchor design programs that address U.S. codes and standards are currently available for free download from several anchor manufacturers. Design software offered by anchor manufacturers has the advantage of representing specific proprietary products in the most detailed manner possible, including both design and layout information in one package. Quality control is dependent on the degree of benchmarking performed by the manufacturer and the popularity of the software, since widely used programs are likely to contain fewer bugs. It is not unreasonable to request information on benchmarking and error reporting from manufacturers offering such software. Finally, most vendor software is made available as a download free of charge, although you may be required to provide address and email information as part of the download process.

On the other hand, vendor software is limited to the manufacturers' own product lines. None of the manufacturer software packages reviewed include the option to design generic cast-in headed anchors, or J- or L-bolts, in accordance with the code.

Baseplate Design Software

Many vendors of general structural design software packages also provide specific solution modules for the baseplate design problem.



They generally offer limited anchor design options, focusing primarily on the strength of the bolt to the exclusion of concrete failure modes. While it is possible that these products will be updated in the future to include anchor design in accordance with the latest LRFD procedures, they are at present primarily useful for determining the anchor load distribution.

Third-Party Software

Anchor design software packages developed by trade associations, consulting engineering offices and 3rd party developers have in the past largely focused on the original strength design provisions contained in Sec. 1923 of the *Uniform Building Code* and earlier editions of ACI 349. These provisions, based on an approach known commonly as the "45-degree cone method", have since been eclipsed by the Concrete Capacity Design method as contained in ACI 318 and adopted in the *International Building Code*. However, it is important to note that some types of post-installed anchors may not be suitable for design using the provisions of ACI 318 Appendix D, and that prequalification of post-installed anchors, both to ascertain their suitability and to provide product-specific design parameters, is required by the code.

Spreadsheet-based programs offer a user-friendly format for analysis of specific types of problems such as anchor bolt design. Usually, these programs are designed to perform calculations according to one code, and many of the programs are limited in the scope of bolt patterns available for analysis. However, they do allow for rapid assessment of cast-in anchor bolt connections and, in some cases, post-installed anchors when appropriate product-specific data is provided by the user.

Summary

A number of options are currently available for calculation of anchor bolt capacity in accordance with code requirements. As a matter of good practice, a clear understanding of the design basis used for all calculations should be obtained from the software provider before using a specific software package. In particular, careful attention should be paid to the assumptions for determining the anchor capacity associated with concrete failure. ■

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