If You Want it Done Right, Do it Yourself

BY MATT THOMAS, S.E.

How hand-checks create the right balance, even in the digital age.

WE (ENGINEERS), both as a society and as a profession, have become dependent on our computers. They do everything we can imagine. They track our budgets, they enable us to draw and visualize, they allow us to communicate quickly with one another, and they perform design operations for our buildings.

As structural engineers, we use them in analysis and design to take over some of our fairly tedious, repetitive tasks like designing beams and columns. Theoretically, this allows us to design more efficient structures. But sometimes it seems that engineers, especially younger engineers, rely on computers too blindly, treating their results as gospel when using hand analysis could potentially show inefficiencies in their designs, and even catch costly design errors. We should endeavor to use these programs more cautiously.

One argument for caution in the use of computer design is that, especially for more inexperienced engineers, it doesn't allow you to "feel" the analysis and design of a building. That may seem like an oddly vague argument, but repeatedly doing hand calculations enables an engineer to gain invaluable knowledge about how a design is progressing and help develop that ever-elusive skill: sound engineering judgment.

Do enough calculations by hand, and you start to learn almost by instinct what loads a W12×19 will take or whether a W8×15 is a good "guess" size for a 30-ft-long girder (it isn't). These instincts will serve an engineer well. Oftentimes throughout design and construction meetings or site visits, architects, contractors, or engineers from other disciplines will ask if a beam or column size can be changed to accommodate a mistake, an enlarged duct, or some other design element. Being able to give an educated guess (to be confirmed by calculation later, of course) as to the answer is a valuable skill, which requires a thorough understanding of how loads will act on a member, as well as member capacities. It's tough to hone this skill by simply inputting loads into a spreadsheet or structural modeling program, which is, to some extent, a "black box"—you input the numbers, and the result spits out, with little knowledge of the steps involved in coming to that answer.

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Additionally, computers can miss important design checks. You might build a model and run an analysis and design program on it, assuming that unless the model shows up red (indicating failed members), you're in the clear. But you might not know that the program won't check, say, torsion, unless you specifically ask it to. And the option to check torsion might be buried within a sub-menu. You could potentially design and issue documents for an entire building this way, without realizing you need stiffening for torsion or some other important piece of the puzzle. But if you're checking things by hand, you would (hopefully) know to calculate all the forces you'd need to check every time you analyze a member and after a while, you'd get a good sense of whether torsion, shear, moment, or anything else is going to be a problem for your particular design.

Consider, as a lesson, the Hartford Civic Center. Its cutting-edge, space-frame roof design required the engineers to use design assistance from computer programs. Many assumptions were made in the computer program, which, in reality, did not hold true. The assumed dead load was 20% too low, the true unbraced length of some members was double what was shown in the computer programs, and many brace connections had a true eccentricity that was not assumed in the computer analysis. These errors, along with a lack of proper oversight during construction, doomed the roof, which collapsed in 1978. A thorough hand check of the computer assumptions and calculations should have revealed the errors inherent in the design. How? Because a good hand analysis should force the engineer to consider the assumptions at each stage of design. At a less dramatic level, we've all seen projects where, because the computer's output wasn't thoroughly checked by engineers, costly reinforcement or more framing had to be added during the construction phase.

Conversely, computers can occasionally miss certain helpful design provisions, rendering a design overly conservative. For example, some computer programs ignore compression steel when calculating the maximum allowable reinforcement in a concrete beam. This results in an error from these programs, which would require you to make your section larger rather than simply being able to add compression steel to achieve the desired result. A hand check of the results may show you some avenues for providing an efficient design that might not be immediately apparent from a computer design.

I'm not trying to minimize the usefulness of computers in the design process. Computers aren't evil. They are incredibly useful tools that provide great benefits—when used properly. However, we must always temper their use with checks and balances. Remember that you weren't hired for your data entry skills, but for your sound engineering judgment. MSC

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