The Case for Three Significant Figures

By Phillip C. Pierce, P.E., F.ASCE

How many of you notice the number of significant figures presented within your firm's calculations? Prior to the advent of pocket calculators, engineers prepared their calculations by hand, supplemented with a slide rule. Their tool of choice was the traditional 10-inch slide rule limited to three figures. The few who owned a 20-inch slide rule could interpolate results to four figures. Of course, they were able to carry hand calculations out to as many figures as desired, but there was rarely a need to do so. Senior engineers would even counsel and coach young or inexperienced staff to limit their results to fewer digits with appropriate round-off. The rounded values were an acknowledgement of the many levels of unknowns or assumptions made in each string of calculations. This training was just one of the ways mentors challenged young staff to develop a sense of judgment about the results. Accuracy was important, but what mattered even more was having an understanding of the results.

Then the calculators came.

The rapid proliferation of affordable small calculators brought forth a tendency to copy down the results from a display without much reflection. Older staff could still employ "rapid mental arithmetic" to provide an approximate answer with a properly placed decimal point as fast as, or even faster than, one could with one of these "new-fangled" machines. However, most engineers simply pulled out a calculator and recorded the output, which almost always showed at least eight digits. With the development of affordable programmable computers, engineers began relying on them to perform tedious and repetitive calculations. More refined analyses came afterwards and invariably provided an ever-increasing number of digits, implying even *more* precision and *more* accuracy.

To the detriment of the profession, the retirement of seasoned practitioners is making way for new generations consisting largely of slaves to software and hardware. Gone are the days when production staff prepared Fortran language programs to perform complex calculations, such that the programmer actually had to know what the program did and assumed. Now business economics often demands the purchase or lease of available software to use without proper training. Sometimes the software does not even include detailed explanations of its built-in assumptions. It is no wonder that errors of use are commonly made. Veterans must be the only ones who remember the real definition of "GIGO" – garbage in, garbage out! As a consequence, staff is finding it more difficult to recognize erroneous, impractical or misleading results.

True, some engineers continue to do routine – and sometimes not so routine – calculations with spreadsheets. They can be wonderfully beneficial tools, but often these engineers make little effort to limit the number of digits shown in the results, let alone ensure that values are labeled with their units.

And it is not just calculations! Values are sometimes shown on construction drawings that are not only totally impractical, but also inappropriate. What good are concrete dimensions to the nearest

1⁄16th inch; jacking pressures to the nearest psi; or stations, elevations and offsets to the thousandths of a foot? It is pretty obvious why construction workers laugh at engineers when they show up in the field.

How about estimates of construction cost? Does anyone really think that an engineer can estimate the unit price of an item for a construction bid to the nearest penny and honestly believe it? The same can be said about quantity estimates. This is why round-off is imperative.

Precision has almost become a sport. Staff members argue about the "accuracy" of their work and mark up each other's values, which are neither accurate nor precise, for correction during the checking process. They do all of this while wasting the precious commodity of time. But what use is extra time when it will only be spent driving the profession to distraction?

Compounding this absent-minded tendency to believe and copy down whatever the computer output says is the ever-increasing complexity of codes and standards. As an aged bridge engineer, it boggles this author's mind that we have allowed our national design specifications to evolve to the point that it now takes a wheelbarrow to transport a hard copy. The average length of the roughly 600,000 bridges in the United States is about 150 feet. Is such a large number of detailed provisions really necessary to design such a bridge? To one without much experience with other types of structures, the *International Building Code* seems just as bad in this regard. Too many staff members wade blindly through these documents, believing in their necessity and then maintaining the same level of complexity in all of their work.

Senior staff and managers are obligated to train newcomers to the profession to recognize the limitations of the community's knowledge about loads, force analysis, stress/deflection predictions and most other aspects of structural behavior. Newly designated "professional" engineers will not truly attain that status until they understand and carry on the tradition of developing good engineering judgment based, at least in part, on these kinds of issues. Three significant figures and an appropriate level of skepticism should regain their status as the standards of our industry.▪

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