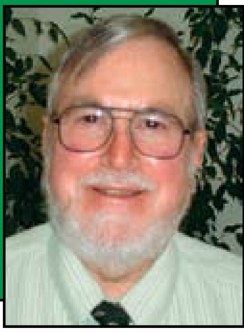

The New Structural Design Paradigm

By Richard L. Hess, S.E., SECB

I recently received a questionnaire from a structural engineering student on the use of various software packages by practicing engineering firms. The purpose of the questionnaire was to develop data for a graduate thesis on the usage of these programs for the analysis and design of structural projects.

Since my firm uses several of the programs, I was interested in replying; and, since my license predates their introduction, I did so from the perspective of someone who has done it with and without the assistance they provide.

While reading questions posed by someone from a younger generation than my own, who is in the midst of his academic pursuits and not yet acquainted with the nitty-gritty of putting his analyses and designs into the necessary specifications and construction drawings from which a contractor will build, I was forced into thinking about the learning process of young engineers and how things have changed with the computational tools that are now commonplace.

"…things have changed with the computational tools that are now commonplace

Not that the use of computers is really as new as is commonly assumed. When I was starting out, one of my supervisors developed a computer program to calculate the stresses in the steel floor plates of large storage tanks (I think they were around 150 feet diameter and forty feet high) placed on compressible soil at a new refinery. The accepted method of support for the deep cohesive soil conditions encountered was to put them on piles, but with more than a dozen of these tanks, that amounted to a major expense, which was worth spending some engineering time to try to avoid.

It was 1962 and our company had access to a computer, but it wasn't the kind that sat on one's desk. The geotechnical analysis told us that, if placed on the soil, the center of one of these tanks would settle approximately three feet more than the edge It is possible to place the relatively thin steel plates in a cone up configuration with that differential; but, what would the stresses be in the plates and in the lap joint filet welds as the cone transformed from a four-foot height to approximately one-foot height?

The theory of plates was known, but the calculation by slide rule was something else. The solution was for the engineer who understood how to do it to write the program, have it put on punch cards, and then wait for the number crunching to be completed.

"..the engineer had to know what he was doing, he had to thoroughly check the results, and therefore he was in control of the analysis and the subsequent design."

The difference between then and now isn't just that it is faster today, it is that the engineer had to know what he was doing, he had to thoroughly check the results, and therefore he was in control of the analysis and the subsequent design. Contrast that sequence to what I frequently see on the SEAOC listserver, where an engineer writes that he or she has to design a (fill in the blank) and wonders if anyone can tell them where the appropriate software can be obtained.

Thinking about this, I pulled off my shelf a book given to me by my first professor of structural engineering. *Engineering Analysis, An Introduction to Professional Method*, by D. W. Ver Planck and B. R. Teare, Jr. of Carnegie Institute of Technology (New York: John Wiley & Sons, 1954), was first published in 1954 as an aid in teaching courses in engineering analysis.

The premise of the book is that new design problems are treated by professional engineers in five stages:

1) defining the problem;
2) planning the approach to solutions and specifying the applicable principles;
3) executing the plan to reach a solution, i.e. calculations;
4) thoroughly checking the work; and
5) learning from the process and generalizing it for future use.

The authors believe that most academic work involves stage #3, where students practice executing the solution after the problem has been formulated for them, and then considering the mathematical result as the objective. However, the more important parts are stages 1, 2, 4, and 5. Rather than learning more powerful techniques of mathematical manipulation in stage 3, it is critical that the student learn how to handle the whole process of dealing with the engineering situation encountered, simplifying it, translating it into the kind of mathematics that is appropriate, and then carrying the work toward an engineering conclusion.

"…it is critical that the student learn how to handle the whole process of dealing with the engineering situation encountered…"

In reading the text fifty years later, it is interesting to note that the part appropriately played by the computer today is stage 3. This is the part that should be dictated by the prior development of the problem by the engineer (stages 1 and 2), and which should be checked and evaluated by the engineer after the number crunching is done (stages 4 and 5). How else can the engineer truly be in control of the design and know that the problem was accurately formulated before the calculated answer is obtained?

The philosopher and scientist, Thomas S. Kuhn, in The Structure of Scientific Revolutions (Third Edition, Chicago & London: The University of Chicago Press, 1962, 1970, 1996), explores and explains the process of evolution and revolution in scientific paradigms. For us, the structural engineering paradigm that was established in the early twentieth century is no longer intact. It is not only the development of individual high-speed computers that has changed this. The development of new materials, new construction machinery, and the expansion of available capital, in addition to the use of the computer, have transformed what can be built. However, the integration of the factors of consistently safe design and constructability with near optimum efficiency into an understandable paradigm has not yet occurred.

To be aware of this condition, and therefore to understand the limitations of "design" by computer, might lead to the avoidance of some disasters that are in the making.▪

Richard L. Hess, S.E., SECB, Fellow ASCE is a consulting structural engineer in Southern California. Mr. Hess specializes in structural retrofit of existing buildings and supports for non-building structures and non-structural elements. Richard is Past President of the Structural Engineers Association of Southern California and is currently a member of the STRUCTURE® Editorial Board.