Computer aids for masonry structural design

Computer programs that speed engineering calculations make it easier for designers to work with masonry

By Kenneth A. Hooker

Mark McGinley, an architectural engineering professor at North Carolina A&T State University in Greensboro, conducts seminars on the Masonry Designers' Guide for The Masonry Society. Although the audiences for the seminars consist mainly of structural engineers, McGinley is surprised by how many attendees tell him they always design masonry buildings empirically: “They say, 'We don’t get paid enough to go through a rational design, so we just produce a design we know will work.'”

Empirical design may be an expedient way to produce masonry we can confidently expect to perform as required, but it seldom produces the most elegant or economical solution to a design problem. If designers rely too heavily on conservative empirical formulas, they’re likely to view masonry as too inefficient and expensive to use as a structural material.

Performing the myriad calculations required for rational design can be laborious, but computer programs specifically written for masonry structural analysis and design ease the burden considerably. The computer’s ability to calculate quickly and automatically makes it much more feasible for a designer to test various wall configurations to determine which design is most efficient.

Association programs help keep masonry competitive

Because making masonry easier for engineers to design is one key to maintaining and increasing its market share, industry organizations have taken the lead in developing and distributing software programs. The National Concrete Masonry Association (NCMA), Brick Institute of America (BIA), and regional groups such as the Arizona Masonry Guild and Concrete Masonry Association of California & Nevada all offer engineering programs for sale.

BIA director of engineering and research J. Gregg Borchelt says BIA considers the kinds of questions and problems designers pose to staff when determining
software needs. Among state groups, those in the West have been most active in software development, because engineered masonry is more prevalent where the Uniform Building Code has jurisdiction.

So far, though, masonry lags behind competitive structural materials in the number and comprehensiveness of programs available. McGinley says that the major comprehensive structural analysis and design programs all include modules for steel, wood, and concrete design, but not for masonry.

D-I-Y software

Some structural engineers, such as Phil Shinn, with EQE Theiss in St. Louis, agree there is a need for more and better masonry software. Shinn says, “Good masonry design software would increase engineers’ comfort level with the material. Without much experience doing structural masonry design, engineers tend to overdesign, increasing safety factors unnecessarily and, at the same time, driving up the cost.

“The codes require so many different load combinations to be considered now, you might have to check 25 different cases just to design a column. A good computer program allows you to plug in all these factors and performs the calculations for you, saving a lot of time.”

Shinn found a way to meet his own need for electronic design assistance: “I’ve developed my own masonry programs—one for slender wall design and one for masonry columns—and I know some other practicing engineers who have done the same. In a way, that’s good. In writing a program, I come to understand the design process clearly, and I know how the numbers are derived.”

Edgar Glock, executive director of the Masonry Institute of St. Louis, has been surveying architects and engineers on their use of computers for masonry design. Glock says he’s learned that “many engineers have developed their own structural masonry programs. There seem to be two reasons—first, there aren’t a lot of comprehensive programs available; and second, engineers feel a certain distrust of programs they haven’t developed themselves. Many of them are leery of using other people’s numbers, and they’re concerned about their own liability for any errors that could be built into commercially available software.”

What to expect from engineering software

A good structural engineering program, whether purchased or self-written, streamlines the design process significantly. The engineer enters data based on prompts that appear on the computer screen; then the computer uses the data to perform the necessary calculations automatically. To design a masonry wall, the engineer would enter the following information (Ref.):

1. Whether the wall is to be clay

Masonry engineering programs

Following are brief descriptions and sources of some computer software available for the structural design of masonry:

**ARCH—Brick Masonry Arch Analysis.** Performs structural analysis of reinforced brick masonry segmental, semicircular, and jack arches. **Requires:** MS-DOS and color monitor **From:** Brick Institute of America

**CAVWALL—Design of Nonbearing, Non-reinforced Masonry Cavity Walls.** Architectural and engineering design of cavity walls, partitions, and parapets of clay brick and concrete masonry units. **Requires:** Macintosh II **From:** National Concrete Masonry Association (NCMA)

**CMD-94 Concrete Masonry Design.** Verifies out-of-plane forces, in-plane forces, axial loads, and flexural capacities. Based on 1994 UBC requirements. **Requires:** MS-DOS and Lotus 1-2-3 or compatible spreadsheet software **From:** Concrete Masonry Association of California & Nevada

**DAYSTAR MASONRY.** Concrete masonry wall analysis and design program for Windows®, with graphical user interface. Calculates and displays shear, axial, moment, combined stress, and shear stress diagrams. Design can be based on UBC, BOCA, or SBCCI codes. **Requires:** Windows® 3.1 **From:** Daystar Software Inc.

**IMFLEX.** Calculates the moment-curvature relationship for hollow unit masonry shear walls. **Requires:** MS-DOS **From:** Concrete Masonry Association of California & Nevada

**MASDESIGN—Loadbearing Masonry Wall Design.** Calculates flexural and shear stresses of hollow concrete masonry walls and amount of vertical reinforcement required. **Requires:** MS-DOS **From:** NCMA

**MASFEAS—Structural Feasibility Program.** Assesses feasibility of using loadbearing masonry shear walls as the primary lateral load resisting system for multistory buildings. **Requires:** MS-DOS **From:** NCMA

**MASRET—Masonry Retaining Walls.** Considers earth pressure coefficients, bending moments, bearing stability, overturning, sliding, and reinforcement for concrete masonry cantilever retaining walls. **Requires:** MS-DOS **From:** NCMA

**RFWALL: Designs retaining and foundation walls in accordance with UBC working stress or ultimate strength requirements. **Requires:** MS-DOS **From:** Arizona Masonry Guild

**SHWALL—Shear Wall Structural Engineering Analysis Program.** Spreadsheet analyzes concrete masonry shear walls in accordance with strength design procedures. **Requires:** MS-DOS and Lotus 1-2-3 **From:** NCMA

**SLWALL—Slender Wall Structural Engineering Analysis Program.** Spreadsheet analyzes single-span concrete masonry walls for resistance to lateral loads. **Requires:** MS-DOS and Lotus 1-2-3 **From:** NCMA

**TALLWALL.** Helps design tall, slender, and multistory walls according to UBC strength design procedures. **Requires:** MS-DOS **From:** Arizona Masonry Guild
brick or concrete masonry
2. Whether the work is to have special inspection or not
3. Whether the designer wants to pin or fix the base of the wall
4. The vertical span of the wall
5. The height of the parapet, if any
6. The intended spacing of cells to be grouted
7. The weight of the masonry
8. The dead and live loads from the roof and their eccentricity
9. The lateral loads on the wall, such as wind and earthquake
10. The yield strength of the reinforcing steel to be used and the 28-day masonry strength
11. The intended location of the reinforcing steel, such as the centerline of wall or in two layers

A good program analyzes these data and in seconds provides a solution, including (Ref.):
1. All moments, shears, and deflections every few inches of wall height
2. Maximum masonry compressive stress
3. Masonry strain
4. Amount of reinforcing steel required to satisfy ductility (and code)
5. Wall base to foundation dowel requirements
6. Optional wall reinforcing bar size and spacing data
7. Location of the neutral axis at the critical wall section

Christoph says the computer can be especially helpful in an iterative design process, where the idea is to try various combinations of reinforcement size and spacing to find the most economical design solution.

Christoph notes several goals to keep in mind when writing a program or shopping for one:
“First, make it very easy to use. If a program is too complicated, engineers are likely to continue doing calculations by hand. Second, users should be able to set up default values that reflect the materials and types of wall systems they tend to use most often.
Third, the program should allow users to save files for common walls and conditions so they can be retrieved for use in similar situations later on.”

As computers become ever more integral to the design process, engineers should be able to choose from an ever broader array of masonry design software. And greater use of computer aids should lead to greater use of engineered masonry as a structural system.

Reference