BRICK DESIGN:

What the Third Pig Knew

By Cathy Murphy

After the wolf blew down the straw house and the stick house (and, by some accounts, filled up on fresh pork), he came to the third pig's house — the one made of brick. The wolf knocked on the door and said, "Little pig, little pig, let me come in," and the pig answered, "Not by the hair on my chinny chin chin." So the wolf huffed, and he puffed, and he puffed, and he huffed, but he couldn't blow the brick house down.

Figure 1: This otherwise attractive building had to be evacuated because of hazardous spores inside caused by inadequate or missing flashing of the masonry veneer. Photo courtesy Norm L. Cooper, P.E.

As the story of the three little pigs illustrates, masonry structures can be quite durable. But in order for this to be the case, the engineer and the mason have to do their jobs properly. Regardless of the requirements established by the engineer, the owner will experience problems if the mason doesn't follow them. Issues arise when the structural engineer's design isn't as constructible as it could be or when certain aspects of the design are overlooked or ignored.

This gap between what is designed and what is actually constructed has created a stigma about masonry's quality. Jerry Painter, president of Painter Masonry in Gainesville, Fla., said that when structural engineers find flaws in masonry construction, they naturally tend to design less masonry. In addition, he said that unless engineers are working on large projects with sophisticated owners or state governments, they tend not to inspect construction work at all. In this situation, some engineers compensate by over-designing masonry projects.

Both of these situations create additional problems. When engineers overdesign, costs increase. And when they choose other materials because they aren't confident in the mason's abilities, they're missing out on the benefits of a quality product. When designed and constructed appropriately, masonry is versatile, durable, aesthetically-pleasing, environmentally-friendly, and resistant to fires and earthquakes.

Of course, problems can happen with any type of building material — not just masonry. According to Gary C. Hart, Ph.D., P.E., a principal and division head with New York-based Weidlinger Associates Inc. and former president of the Masonry Society, "Masonry gets a [reputation] as having worse quality control than concrete or steel, but I'm not really sure that's true. I think by the nature of masonry, maybe it shows when the quality of construction is bad a little more than steel and concrete because you have a lot of water leakage problems that tend to show up. But if you're talking about placement of steel or welding, I'm not sure there's a big, big jump in quality by going to concrete or steel. The problem is more widespread than people would like to believe. They like to pick on masonry, but I think it's just a fundamental problem with attitude and accountability of contractors."

Figure 2: Missing and inadequate flashing behind brick siding caused leaks into a house, which caused hazardous spores. Photo courtesy Norm L. Cooper, P.E.

THE ISSUES

Before we can solve the problems related to masonry construction, we must know the origins of the problems. Structural engineers alone can't solve every issue that affects their projects. Some are industry-wide issues that would require a great deal of time and input to change. Others are specific problems that engineers can identify on jobsites and have contractors fix or solve in other ways.

For example, Painter said that one of the most common problems he sees occurs when electrical, plumbing, and HVAC components are designed to go through a structural wall. "When the wall is heavily reinforced and grouted, and all of a sudden we start getting all these components that have to go through or be in our wall, they conflict with our rebar and grout," he said.

Norm Cooper, P.E., chief engineer with Realty Engineering, Inc., a nationwide firm based in Canyon Lake, Texas, said that he has served as an expert witness in over 200 cases in several states involving inadequate masonry. Cooper identified eight problematic areas in masonry construction, including flashing, cracking, ties, arches, alignments, mortar, weep holes, and defective brick. Following is an explanation of each area.

Flashing

Problems with flashing are the most serious, according to Cooper, because they lead to water penetration, which can cause rot, hazardous spores, and mold. He estimates that about 15 percent of the masonry buildings he's inspected had problems with flashing. In fact, some occupants have been forced to evacuate after Cooper and his staff detected these anomalies, which are generally caused by improper construction. Flashing errors can be extremely detrimental to the health of a building's occupants. W.T. "Dusty" Yaxley, P.E., a forensic and consulting engineer in Tampa, Fla., said that in one case, he detected a dangerous type of mold in the house of a family of three. Because of the mold, the young daughter developed serious respiratory problems and the father, who was only in his 30s, developed irreversible brain damage that was so severe that he was unable to work.

Besides health-related problems, leaking from improper installation of flashing can also lead to structural deterioration. Painter recently encountered this situation on a retrofit project originally constructed in the 1950s. He said his workers took some limestone coping off the top to investigate behind the panel and found many rusted anchors, including a 3⁄16-inch galvanized steel strap that was "practically rusted away."

Cooper said one reason for the improper flashing installation is that building codes are quite brief and aren't specific enough about how to install the flashing. Although he said the Brick Industry Association (BIA), based in Reston, Va., provides more specific guidelines in its technical documents (available at www.bia.org), these documents are not always consulted.

Several common scenarios can create problems during or after installation of flashing. Gregg Borchelt, P.E., vice president for BIA, named all of the following:

- Flashing not properly installed from a height standpoint — without a sufficient rise from the brick through the airspace to the flashing attachments to the backing.
- Improper sealing of flashing elements.
- Flashing damaged by subsequent construction such as welding taking place above the flashing and creating sparks that burn holes in the flashing.

Cracking

Cooper noted that poor drainage creates many cracking problems, particularly on jobsites with clay soils. High and variable clay moisture causes loss of bearing capacity and shrinking or swelling, moving the foundation, usually unevenly. Although building codes specify the drainage slopes that should be used, architects, engineers, and contractors alike often ignore them. In fact, Cooper said it is the most repeated problem found by his firm's many thousands of inspections. He estimated that drainage slopes aren't graded properly over 50 percent of the time.

Figures 3-5: Interior water damage and organisms caused by inadequate flashing. Photos courtesy Norm L. Cooper, P.E.

Borchelt states that cracking problems tend to show up with time, especially with concrete frames that undergo creep and shrinkage and with moisture expansion of brick veneer. He said these are typically just aesthetic problems, but if they're left unattended, very high compressive stresses in the brick wythe could develop, which increases the potential for that segment of the masonry to come off the wall.

According to Borchelt, if the vertical support isn't designed and detailed correctly, there is cracking of one of two types. "If you have a horizontal spandrel section of masonry separated by horizontal bands of windows, [and] the spandrel beam isn't designed [for] the weight and

stiffness of the brick veneer, you can get some vertical or sometimes diagonal step cracking in the brick wythe," he said. "That tends to happen more in steel framed structures, where people just don't take into consideration the fact that masonry tends to act as a beam of its own. If there are not appropriate deflection limits on the supporting structure, you can get the masonry acting as the beam, and if it doesn't have sufficient strength, you get the vertical cracking."

"The second circumstance," he continued, "would be when you have a continuous vertical section of brickwork with a shelf angle supporting that brickwork at each floor or at alternate floors. In that circumstance, if the angle supporting that brickwork isn't detailed properly to account for both differential movement between the building frame and the brick veneer or deflection of steel angle itself, you get some spalling and sometimes vertical cracking at that shelf angle. That's probably more common than the first circumstance."

Of course, cracking can also occur because of construction problems. Borchelt said that locating vertical expansion joints correctly is important for crack control.

"It's not uncommon to see some misplacement of the vertical or horizontal steel or substandard vibration of the grout that's in the cell with the steel," said Hart. "Sometimes it causes cracking, which raises the flag for the owner to call in an attorney or an engineer, and then they start arguing about whose fault it is. The culprit, in my experience, is usually the contractor, who just wants to build faster than he should, so he puts too much water in or doesn't worry about how much water, or doesn't vibrate it."

Yaxley explained a common problem that can cause cracking: "You find everything (in the cells to receive grout), from coffee cups to plates to plugs and all kinds of things. What normally happens is they have a little tin thing they call an ashtray that they put in the top of the block (to stop grout flow.) Then they leave that out where they want the grout poured down the hole into the wall. If there's not a rod sticking out there when the mason gets to the top, then he doesn't put the little ash tray in, which means that it doesn't get filled with grout; even though the reinforcing bar may be stuck out of the foundation, it's just not there at the top. So when the engineer goes out to check for filled cells, and he takes a hammer and thumps along the edge… if he knocks a hole, often... he'll find the rebar at the bottom, but it doesn't continue on to tie in with the tie beam, which is not an uncommon problem."

Ties

Although metal ties are required between brick veneer and the structure of a building, it's difficult to detect whether they're adequately placed after a project is completed. This problem can be serious. "Sometimes, ties are missing or inadequate, and you start having movement of the brick siding, which can be hazardous," said Cooper.

Borchelt said that when he observes buildings after earthquakes and tornadoes, it's "relatively common" to find that contractors have either completely omitted veneer ties or haven't placed them properly. They should be embedded in mortar joints and able to transfer wind loads from the veneer to the backing system. He's not sure why contractors completely omit the ties but said that when they aren't embedded properly, it could be because there's too great a dimensional tolerance variation between the backing wythe and the backing system that's attached to the structural frame versus the dimensional tolerance of the brick veneer, which generally has to be tighter in plumb and alignment than the structure in back of it. If the tie doesn't fit properly, the contractor might change the shape of the wire to fit without understanding the consequences.

Arches

Cooper often sees arches over openings rather than headers or lintles. "When you build a brick arch," he said, "if it's done right, the brick itself will hold up [the arch] without a steel header because it's got a proper height versus the width of the arch. But we find maybe 20 percent are not adequately built, [and] sometimes not adequately designed. They can crack and can fail and be hazardous."

The arches fail for different reasons. For example, Borchelt said they may miss sufficient abutment on the side to prevent spreading, or the pier supporting a column might be too high to rotate.

Alignments

Although it's usually only an aesthetic problem, Cooper said he's observed many projects where requirements for alignment of horizontal and vertical construction are not met.

Figure 6: Blocked (or missing) weepholes cause water accumulation, rot, and hazardous spores. Photo courtesy Norm L. Cooper, P.E.

Mortar

Cooper said he's seen problems with mortar in about five percent of the construction he's inspected. Sometimes the mortar has inadequate strength. "If you can scrape it out with a screwdriver, it's not going to meet strength requirements," he said. "In other situations, if the brick is very absorbent, it sucks the moisture out of the mortar, which doesn't allow it to adhere to the brick and creates cracking."

Yaxley said, "You'd be hard-pressed to go out on a job and find appropriate quality control for mortars. It doesn't matter what is specified." To compound the problem, it's impossible to verify the specific mortar strength that was used on a given project after it's hardened.

Weep holes

Cooper notes the weep holes are often missing or blocked, which can create some of the same types of problems caused by inadequate flashing. During construction, mortar droppings in the airspace behind the veneer can plug or clog weep holes. Borchelt said that these droppings can also provide bridging so that water can come in contact with the sheathing and get into the building.

Sometimes problems occur after construction as well. Yaxley said owners and even some contractors don't understand why weep holes are used and that masonry is designed to be water resistant, not waterproof. In some cases, buildings may be adequately constructed, but when the owner sees evidence of moisture toward the bottom of a wall and notices the weep holes, he or she calls a renovation contractor, who plugs the holes without realizing the consequences.

Defective brick

Although defective brick is much more rare than any of the other problems mentioned above, Cooper said he has observed projects where the brick has simply been inadequate. In these situations, the outer portion of the brick flakes out of the wall, or the bricks themselves crack internally.

WHY THE ISSUES EXIST

One reason some of these problems occur is the lack of masonry education in many college engineering programs. "Sometimes I think there are engineers who may not understand masonry," said Painter. "Masonry's not something that's taught in a big way in engineering and architecture schools." In fact, he said that only one masonry class is taught for one semester per year at the University of Florida. In other schools, no masonry classes are taught, let alone required.

Of course, problems exist on the construction side as well. According to Painter, who's been working in the business for 33 years, "There is a shortage, and we as an industry have really failed over the last couple of generations in properly training the ongoing workforce." To worsen the situation, Painter said that the mason's job has gotten much more complicated over the past

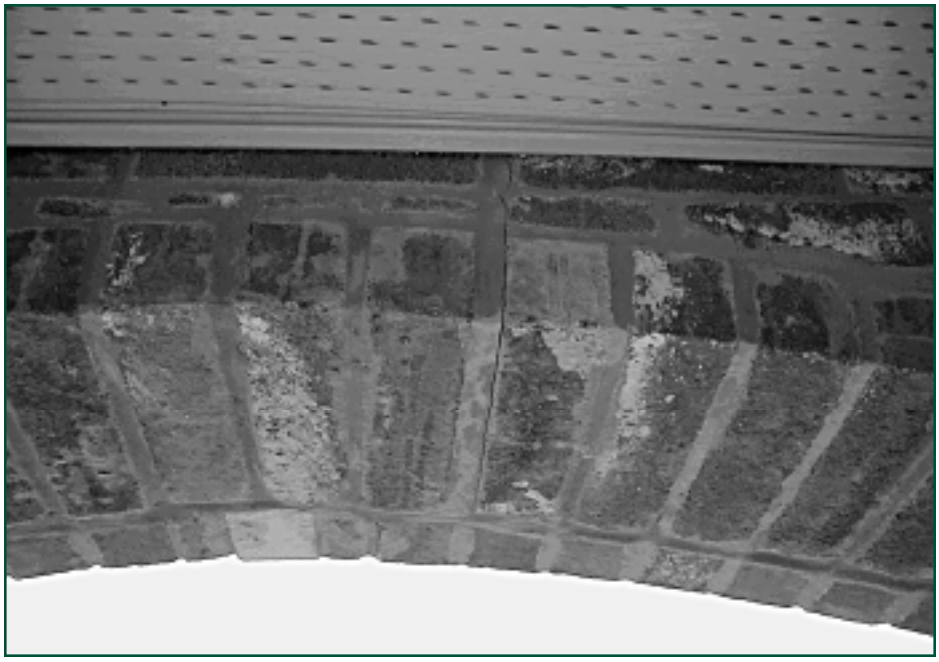

Figure 7: Arch with inadequate height cracked and subject to hazardous failure. Photo courtesy Norm L. Cooper, P.E.

two decades. Masonry walls are being used as shear walls more often, and there's more to learn about rebar, grout, anchoring, et cetera. "Twenty years ago, we never saw a number 8 in a masonry wall," he said.

Figure 8: Inadequate metal ties between masonry and framing cause horizontal cracks, outward bowing, water entry, and risk of hazardous failure. Photo courtesy Norm L. Cooper, P.E.

Yet Painter said that many masons are resistant to training. "Masons generally just want to lay block… You try to explain to them that the rebar needs to be where the rebar needs to be — it needs to be at this space or centered where it's designed, the two bars need to be bundled or they need to be separate — there are issues there that the structural engineer calls for. You try to get guys to understand the whys, but most don't want to know." Although Painter said training programs have improved in Florida in the past few years, in general, he feels that masons aren't given a lot of time for training because the pace of construction is so fast: "They're trained fast, they're trained on the job, and quality is secondary to productivity," he said.

Tight schedules also increase construction problems in other ways. Painter said that in many cases, his crew isn't given enough time to give the engineer the expected product. In fact, it's not uncommon to lay block in the morning and grout the same afternoon because of scheduling. About two years ago, when the industry had a problem keeping up with block production, his crew actually laid block that was made the day before, then grouted it later that afternoon.

Yaxley said a major problem is the lack of accountability for quality control in the construction industry. As he put it, "The contractor depends on the subcontractor, who depends on the people working for them. Everyone depends on the inspector, who doesn't look, and the engineer and architect aren't responsible. What it comes down to is that nobody's looking." Yaxley also said that it's tough for the engineer to make the contractor build according to plan. "The contractor gets upset … and the owner gets his project delayed."

Hart agreed with Yaxley. He compared criticizing the contractor to making a citizen's arrest. "You know it's going to occupy gobs and gobs of your time," he said. "The whole system is set up to make it very, very difficult to fulfill your obligation."

THE SOLUTIONS

Some problems can be solved by the structural engineer in practical ways. For example, Cooper said that if engineers specified the use of BIA's documents, it would reduce the likelihood of many of these problems, including flashing, cracks, arches, and mortar.

Borchelt suggested that engineers could build a jobsite mock-up that includes portions of the structural frame and all the components of the exterior walls to make sure the pieces fit together properly, that they have a proper airspace, that they have ties that provide proper embedment in the masonry wythe as well as to the backing system, and that there is a possibility to keep that airspace clean as construction goes on.

For masonry walls with reinforcement and grout, the mock-up can be used to verify proper placement. "Theoretically, the contractor should discover any problems or concerns in that jobsite mockup that could then be corrected before they get on to the actual construction itself," he said. The mock-up is typically part of the architectural requirements. Borchelt said, "The structural engineer might notice whether it's there or not, and if not, they might suggest to the architect that they should include it."

Perhaps more masonry education should be required in engineering programs. Borchelt also suggested that engineers who are less experienced with masonry projects could check out jobsites and talk to experienced engineers so that they can design buildings that are more constructible. "There's nothing like getting some experience beforehand," he said. "Don't let it happen on your project — learn from the mistakes and the successes of others." However, Cooper cautions that people can be experienced in building incorrectly and that knowledge of code requirements and good practice (such as adhering to the BIA documents) is also essential.

Painter thinks better coordination is needed between design engineers. He said that because masonry systems are generally held to tighter tolerances than other systems, structural engineers should require electrical, mechanical, and HVAC engineers to design their systems around structural masonry walls. "If the red iron guy is going to be out of plumb, he can be out of plumb in the other direction, away from us," he said.

Painter also suggested that structural engineers specify 48 to 72 hours between laying block and grouting, which could help with the time element masons face. And he said that the 1999 Masonry Standards Joint Committee "Code, Specification and Commentaries," which is referenced in the 2000 International

Figure 9: Inadequate drainage away from a building causes foundation movement, which causes brick (step) cracks. Photo courtesy Norm L. Cooper, P.E.

Building Code, could help alleviate construction problems because it requires more inspections. "Most people have felt over the past several years that the cost of additional inspections would be more than paid for by the eventual savings," he said.

Borchelt said that requiring more training, such as the program developed by the Bricklayers and Allied Craftsmen Union and perhaps a certification program could also help alleviate some of the construction problems associated with masonry. In fact, he said some states and cities, including Michigan, St. Louis, and Denver, have already taken the lead in requiring training for masons and masonry contractors, and Painter said Florida developed an apprenticeship program

Figure 10: Inadequate and sagging door header causing brick cracks. Photo courtesy Norm L. Cooper, P.E.

Figure 11: Brick misalignments out of tolerance. Photo courtesy Norm L. Cooper, P.E.

about seven or eight years ago.

But other problems aren't so easy to resolve and would require major industry changes. For example, Hart believes that owners should hire structural engineers to inspect construction work. "The responsibility has to lie with structural engineers because they're the only ones who understand the impact," he said. The structural integrity may or may not be compromised because the contractor is off by half an inch, but the structural engineer is the only one who can make that decision. "I think they should just charge the fee and do it right," Hart said. And Cooper said that, because city and private inspectors are rarely required to be licensed professional engineers, only a very small percentage of buildings are ever inspected by qualified structural engineers. He said the benefit would far exceed the cost if the codes required inspection by private-sector, licensed structural engineers.

A BRIGHT FUTURE

Despite the issues involved with its construction, masonry has many benefits, as seen by its strong history. It has tremendous potential as a building material, one that combines structure and finish. And masonry could be used even more frequently in the future — especially if some of the problems identified here are alleviated.

What do you think? Should engineering schools require masonry classes? Should international building codes and local governments require that owners hire licensed structural engineers to inspect construction work? Should masons or masonry contractors be certified? n

About the Author

Cathy Murphy is the features editor of *Structural Engineer*, a nationally-distributed, business-to-business magazine based in Alpharetta, Ga. A former high school English teacher, Murphy holds a bachelor's degree in English education and a master's degree in professional writing. She may be contacted at featureseditor@gostructural.com.

CATHY MURPHY

Roofing More Dangerous Than Coal Mining

ccording to an under-
guide published by
urance Information Institute (III), "…roofing work is considered even more hazardous than coal mining." The guide claims that one in five roofing workers will suffer injuries and job-related illnesses in the course of a year. It goes on to note that the injury and illness rate for roofing contractors is "more than double the average rate for all private industry and is higher than any (in the) construction industry." Most injuries, however, happen to workers with fewer than three years' experience, and many occur in the first month of an employee's hire.

—Roofing Contractor