Software Can Assess Structural Integrity Of Older Masonry Structures

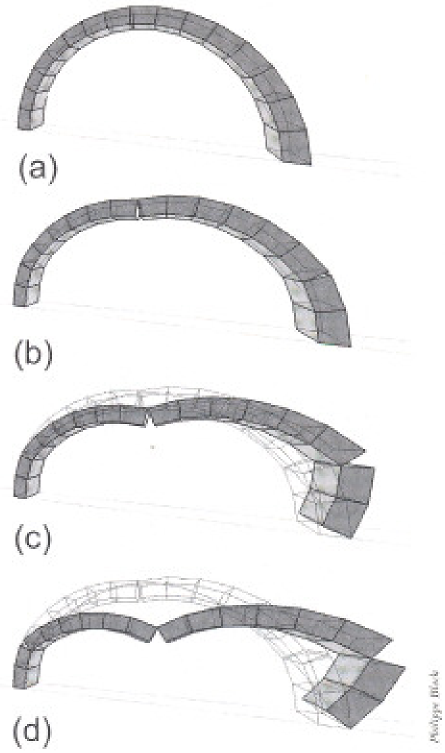
A three-dimensional modeling program similar to that used in modeling the clothing of characters in computer games is being developed at the Massachusetts Institute of Technology (MIT) to quickly and easily assess the structural integrity of masonry structures of historical importance. The program employs a system in which virtual models are created by using a series of particles, or point masses, connected by elastic springs. Users will be able to input the geometry of buildings, for instance, the width and height of a cathedral buttress or the shape and thickness of a vault, and immediately observe the effects of compressive forces within the structure.

The software is being developed by John Ochsendorf, an assistant professor in the Building Technology Program at MIT, along with his graduate students, to demonstrate the fact that older masonry buildings that are severely cracked may still be safe. The effort is part of a larger, $500,000 study—funded by the Andrew H. Mellon Foundation, located in Princeton, New Jersey—of Romanesque churches in central France that is being conducted by an interdisciplinary team of art historians, engineers, computer scientists, and architects. According to Ochsendorf, while newer buildings made of steel or concrete depend on the strength and stress resistance of their materials, older masonry buildings have low stresses and typically depend on their geometry for their structural integrity. For this reason, analyzing older structures is a difficult challenge. "If you look at a historic masonry building, it's filled with cracks," says Ochsendorf. "It's quite common to find vaults that have large cracks within them, yet they've been standing for centuries." He also notes that it is not uncommon to find a wall in such a structure that is out of plumb by several feet, yet the structure remains standing. The bell tower in Pisa, Italy, is the most famous example.

The software is based on the work of computer scientists in the graphics and gaming industries who developed a system based on particles and springs to lend realism to clothing and other flexible objects. Realizing that this system could also be used to model forces in masonry structures was a breakthrough for Ochsendorf, who was seeking a way to quickly assess the structural integrity of the French churches. "We don't have very good tools for quickly checking the equilibrium conditions, so we've been developing our own in-house software at MIT that could be useful for finding the forces in these buildings," he says. "We really are taking a page directly from computer science."

The program is being written in Java. It reveals complex networks of equilibrium forces in three dimensions for buildings acting under their own weight. Users can change the geometry of the applied loading, add or subtract structural elements, or change the support conditions while the simulation runs. During the simulation, the network of forces at work in the model will continue to move as they find their equilibrium positions. More than one equilibrium solution may exist, according to Ochsendorf. If no solution exists, the user must intervene.

Ochsendorf says that the program will be able to do a better job than conventional tools of finding the compressive forces because it enables users to explore a range of possible answers for statically indeterminate problems—such as those found in older masonry structures—that contain an infinite number of equilibrium solutions and an infinite number of sets of internal forces. According to Ochsendorf, existing tools used to analyze concrete and steel do not provide an accurate measure of the safety of a building because they do not account for the large displacements or the heterogeneous nature of the old masonry. They also assume that the analysis is a problem of elasticity and that the material can withstand tension. "Historic masonry buildings can really take only compression and have no capacity for tension," says Ochsendorf. He adds that existing software assumes small displacements (much less than 1 in. [25.4 mm]), whereas typical displacements in buildings of historical importance that occur over the centuries often are on the order of several feet.



Software informed by particles and springs for assessing the structural integrity of older masonry structures is being developed at the Massachusetts Institute of Technology: (a) an undeformed arch; (b) movement of the support system that forms a stable three-hinged arch; (c) excessive support movement causing a four-hinged collapse mechanism; and (d) progressive collapse from spreading supports.

Although the software is currently in the conceptual stage, Ochsendorf says it shows great potential and could enable engineers and architects to discover new design forms and shapes that have physical meaning. It could also be particularly useful in the United States, where there are many masonry buildings, says Ochsendorf.

Once the software is fully developed, it will be available at no cost online. Existing tools developed by Ochsendorf and his students to analyze masonry structures are already available (see http://web.mit.edu/masonry).

—*Karen Trimbath*