

Seismic Reinforcing of Masonry Walls With Shotcrete

by Bill Snow



(All photos courtesy of Larry Workman Photography)

Historic brick structure near the famous "Four Corners of the Law" intersection in Charleston, South Carolina

During the last few months Americans and people all over the world have been horrified by the stories and pictures of the devastating earthquakes in Turkey. Photos and newsclips showing hundreds of collapsed homes burying entire families have become all too commonplace. As residents of North America we are thankful that this sort of calamity doesn't happen here. The earthquakes we're used to seeing (mainly in California) cause inconvenience and in some cases property damage, injury and even some deaths, but nothing as catastrophic as in Turkey this year and Azerbaydzhan a few years back.

After all, we have those brilliant civil engineers and modern building codes that ensure that our buildings can "take" an earthquake. The truth is that earthquakes just like the ones in Turkey, Russia and even Mexico City have occurred frequently (in terms of geological time) over relatively large portions of the United States and the rest of the Americas. The New Madrid quake in present day Missouri caused the Mississippi River to run backwards for a short period of time. The Charleston earthquake of 1886 was felt hundreds of miles away and its scars are still vividly displayed in architectural oddities known locally as "earthquake bolts" on homes and buildings throughout the city.

While most building jurisdictions enforce proper codes in earthquake-prone areas there is the potential for devastating effects on large population centers

if an earthquake of any real magnitude were to occur. The timebombs waiting to explode include mostly unreinforced masonry structures, which were built prior to the development of modern seismic codes.

Every large city in any seismically active zone has a historic section—San Francisco, Seattle, St. Louis, Charleston, and Savannah to name a few. Almost by definition these historic districts are filled with old, quaint, unreinforced brick buildings. The architecture of these structures may vary tremendously due to age, era, local tastes, and climates, but the one thing they all have in common is bricks and mortar.

With few exceptions, the seismic resistance (ability to withstand lateral loads placed on a structure by an earthquake) of unreinforced masonry is practically ZERO. This is basically true with relatively new unreinforced masonry structures but on truly historic structures the opportunity for catastrophe is almost a certainty. There are streets in Charleston, South Carolina where it has been said for years that the only things holding the buildings up are the roofs, the floors, and each other. Most of these structures are one hundred to one hundred fifty years old. Many survived the 1886 quake and therefore offer some unsuspecting souls a false sense of security with respect to the structures being able to sustain another major seismic event.

Today's codes require new structures to be designed and built with resistance to lateral loading as a design criterion. Codes also require owners to use current seismic standards for the design of major renovations and remodeling. Such seismic upgrades often incorporate shotcrete as a construction method for existing structures since shotcrete is uniquely capable of providing a versatile, cost-effective way of installing shear walls and other structural members. This allows the buildings in question to endure the loads of a seismic event with minimal damage and/or injury to its occupants.

Buildings which have incorporated shotcrete in this manner include major hospitals, a federal courthouse, retail space, private homes, colleges, office buildings, and marine facilities to name a few. Most seismic upgrades utilize the shotcrete as an independent support mechanism with the existing structure acting as a form on one side. The ability of shotcrete to bond with this "form," thus incorporating it into the new load-carrying member, is an added bonus in the case of unreinforced masonry. The occurrence of falling bricks is vastly reduced during an earthquake if the bricks are held in place by shotcrete rather than old, deteriorated mortar. The adaptability of shotcrete to irregular shapes and obtuse planes often makes it the only cost-effective construction method for some structures.



Incorporation of shotcrete shear walls made it possible to include this historic structure into a modern federal courthouse complex

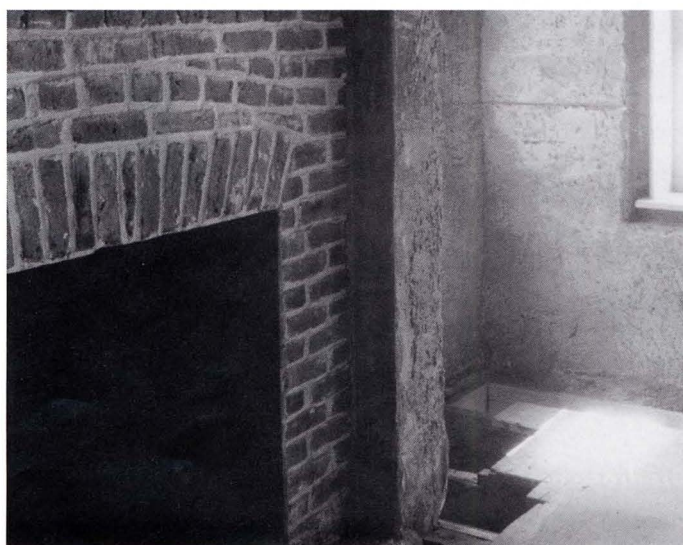
Design criteria and the extent of the shotcrete application varies from site to site. Some buildings incorporate shotcrete shear walls in conjunction with existing masonry walls to strengthen what is already there. If the mortar between the bricks is still intact and the design engineer is satisfied that the original structure still has structural value, this is often the most cost-effective route to follow. Steel reinforcement and wall thicknesses vary according to the load-carrying capacity required.

Some structures, such as the new federal court complex shown in the adjacent photographs, incorporate shotcrete as an independent load-carrying struc-

ture using the existing unreinforced masonry walls as a "form" only. Wall thicknesses varied from 18 inches (450 mm) below ground level to 6 inches (150 mm) on the third floor. Reinforcement ranged from double mats of No. 6 bars ($\varnothing = 19$ mm) to single mats of No. 4 bars ($\varnothing = 13$ mm) and several combinations of caged steel as design requirements dictated. The reason this approach was necessary was that the new courthouse incorporated and surrounded an existing two hundred year old unreinforced masonry structure in the completely new, modern complex. The old building will be subjected to live and dead loads which would have exceeded its structural capacity

when it was new. Obviously, a new structural design solution had to be established before modern loads could be applied. Due to the historic nature of the structure, and its proximity to the famous "Four Corners of the Law," demolition of the existing structure was unthinkable.

Another major structure in which shotcrete was incorporated was a portion of the Storm Eye Institute at the Medical University of South Carolina. The project was a vertical expansion of the existing building by adding three more floors and an enlarged mechanical mezzanine level to this seven story structure. Shotcrete shear walls were added



Shotcrete shear walls provide an internal support structure for this unreinforced masonry building



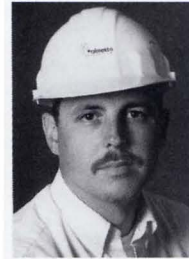
Seismic shear walls incorporated to add lateral support to an existing structure were critical to allow the addition of the top three floors in the vertical expansion of this medical center building

to the column and beam structures on the existing seven floors to enhance the lateral load carrying capacity of the building. Wall thicknesses ranged from 8 inches (200 mm) to 30 inches (750 mm) with reinforcing steel designed accordingly. Shotcrete was chosen as the construction method due to cost savings and acceleration of the overall speed of construction. The fact that the entire project was accomplished while the hospital was

in full operation is a testimony to the adaptability of the shotcrete method.

The structures shown in the photos demonstrate the versatility of shotcrete for seismic retrofit of both modern and historic structures. While seismic strengthening is of major interest in earthquake prone areas, it should be noted that wind loads in coastal areas are often the controlling or ultimate design criteria for many structures. Most of the

structures shown and referenced in this article are located in Charleston S.C., and may be subjected to lateral loads resulting from earthquakes and hurricane force winds over the design life of the structure. Shotcrete continues to be a widely used method of construction as structures are constructed, renovated, and upgraded in this area and throughout North America. ■



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