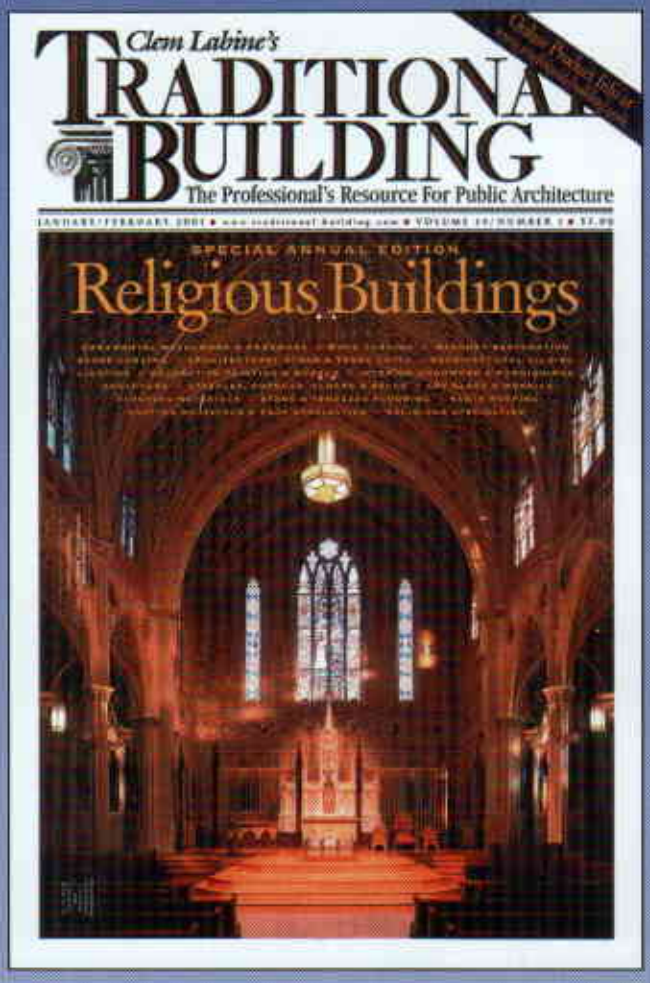
CINTEC

HOLDING IT ALL TOGETHER



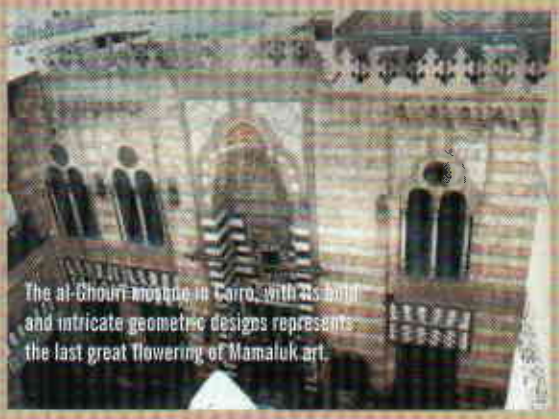
As featured in the American Publication
Clem Labine's
TRADITIONAL
BUILDING

HOLDING IT ALL TOGETHER

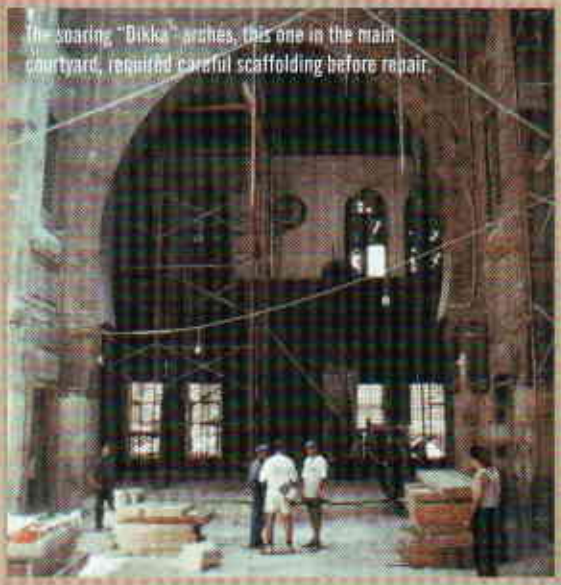
a venerable Mosque gets a new lease on life thanks to an in

by James R. Marshall

Seen from the outside, the arches on the three-story high structure presented a particular challenge: keystones had dropped and many stones had pushed out.



The al-Ghouri mosque in Cairo, with its bold and intricate geometric designs represents the last great flowering of Mamaluk art.



The soaring "Dikka" arches, this one in the main courtyard, required careful scaffolding before repair.

The Madrasa and Kangah of Sultan al-Ghouri (Madrasa Mosque) is one of Cairo's most venerable group of buildings. The complex was built in the 1500's during the reign of the last Mamaluk sultan, who died in 1516 in battle against the Ottoman Turks. The Sultan's funerary complex is in Old Cairo; on its west side is a kanqah and mausoleum, as well as a sabil kuttab. The minaret is a four-story rectangle about 50 metres (164ft) high. With its strong features, bold design, marble panels, and intricate geometries carved into the arches and ceiling, the Madrasa Mosque represents the last great flowering of Mamaluk art. The Mosque had functioned as both a mosque and madrasa continuously since its construction. Today, the Madrasa is the oldest teaching mosque in Cairo.

Time, seismic forces and human beings, however, have not been kind to al-Ghouri. In fact, by the end of the 20th century, the mosque was in a very delicate state of equilibrium indeed. Though it has survived nearly 500 years, the toll of a rising water table, general neglect and earthquakes, particularly the big one of 1992, has brought the structure to the point of collapse. The mosque's floor undulated dramatically, and all of its walls showed severe fractures. Adding insult to injury, problems in the external walls had been exacerbated by shopkeepers enlarging the space available for the selling their wares by demolishing sections of masonry at the ground floor level making the earthquake damage even worse than it might otherwise have been.

The condition of the mosque was a great challenge facing the Egyptian Antiquities Organization, which is charged with the care of the complex. Urgent measures were required to reintroduce some structural strength and rigidity into the building. As a first step, the Madrasa was underpinned using a system of micropiling. The very high walls were still unrestrained and very vulnerable to the lateral forces that would be generated by the next inevitable earthquake. The large arched openings in the mosque are points of particular weakness. The walls are constructed of two opposing sandstone faces with the space between filled with rubble. It remained to tie the elements of the superstructure together in a way that would be strong and permanent and nearly invisible to preserve the historical and aesthetic aspects of the building.

The Antiquities Organization decided to go with an invisible anchoring system - the Cintec System- developed in England during the 60's to repair terracotta and hollow masonry units. The system had been used on other such high-profile projects as the repair of the fire damage at Windsor Castle and earthquake damage at Australia's Christchurch Cathedral. When the five-member Cintec team from the company's office in Wales, UK, arrived in Cairo, project leader Dennis Lee found that the mosque had already been subjected to traditional crack repair procedures such as bridging with bricks. However, certain damaged areas were still "live", and the authorities were anxious to upgrade the repairs in anticipation of the next earthquake. Because of the historic and religious importance of the structure, and the need for approval by heritage groups, it was essential that the new repairs be invisible. Thus the Madrasa was a candidate for the Cintec process not only because of the need for

A diamond drilling rig bores the long holes for insertion of the stainless steel anchor rods. Drill cores were saved and later used to plug the ends of the holes.

novative and discrete anchor system

invisibility but also because its walls, two meters (6 1/2ft) thick, are made up of two facing sandstone skins with a loose rubble fill. To use the Cintec System, holes are drilled into the hollow space, and the anchor rods are inserted; the rods have a polyester sock into which grout is pumped through a filler tube. The sock inflates, and the grout milk passes through its mesh, bonding to the stonework and moulding itself to the contours of the hole. Upon completion the anchor is not visible from the outside. Because the back of the anchor sock is the first filled, air is displaced toward the front, ensuring a void-free solid anchor. This system provides great strength without having to fill in the whole interior wall space — the system is strong only where it is needed most, according to Lee.

The overall plan for the mosque included installation of longitudinal ties in each of the stone facings of the wall over the arches to resist the natural thrust of the arch against the effects of the next earthquake. Transverse ties equal in length to the wall thickness would strengthen the wall. The Cintec "stitches" would finally be used to tie the roof to the perimeter walls, creating a diaphragm action, a recognized system for establishing earthquake resistance.

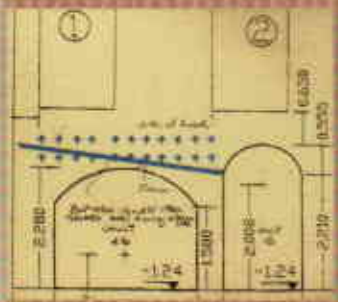
Lee and his team encountered several challenging hurdles. First, the Madrasa was still a functional mosque, which presented problems for the construction workers, particularly for non-Muslims (for example, would they have to work shoeless?). Fortunately, the Egyptian religious authorities solved this issue by suspending the building's religious status for the duration of the work. Second, the structure is built of the very dry local sandstone, which meant that it could not be wetted down. Third, the work was to be done primarily in August, the hottest part of Cairo's intense summer - not ideal working conditions for a team of Welshmen, particularly since a good deal of work would take place on the structure's roof. Fourth, the team from Wales would have to overcome communication problem with the locally recruited labor force. Finally, the walls were unstable, increasing the need for great care.

To deal with the heat, the Cintec team had to devise a system for cooling the water used to mix the grout. To preserve the sandstone, the team employed dry drilling with diamond bits, a technique that required full-face helmets and dust control measures. And because the aim was to make long lasting repair, the team selected 316 stainless steel rods (the highest non-magnetic grade) for the mosque project. The job required more than 1200 metres (3,937ft) of rods, many as long as 12 metres (39ft). For some of the roof arches, eleven 37mm (1 1/2in) rods were inserted in holes drilled to a diameter of 100 mm (4in). Over-all socks were used in diameters ranging from 20 mm (3/4in) to 300 mm (12in). To ensure invisibility of the repairs, the team preserved the diamond drill cores and used them to plug the anchor holes, sealed with a carefully color-matched grout.

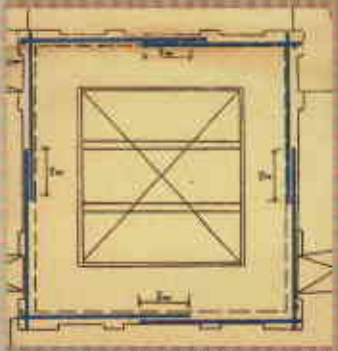
Due to the unsteady condition of the building, Lee and his team devoted considerable time to careful planning and scheduling. Once on site, their first task was to determine the anchor locations, then erect scaffolding. They developed a drilling schedule that addressed the "live" cracking areas first, so that the walls would be stabilized before work began on the roof.

The roof, which covers the Madrasa's open court yard, presented a particular set of problems. During the 1992 earthquake, the mosque was twisted out of square. The Cintec team determined that it was infeasible to pull the building back into square; instead they stabilized it in its out-of square position, which is not enough to be visible to the casual observer, according to Mr. Lee. The roof, three stories up, was supported by big arches out of which keystones had dropped, many stones were dangerously pushing out, and decorative elements had come loose. All of these problems had to be addressed.

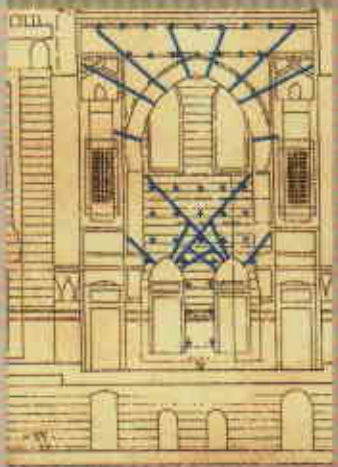
The final steps were color matching and additional work on some lower level arched vaults, where stones had to be replaced because of the activities of the former trades people. The whole project took about three months, according to Mr. Lee, including planning and communications. The satisfaction of the Egyptian clients is demonstrated by the fact that Cintec has been asked to look at several other potential projects in Cairo.



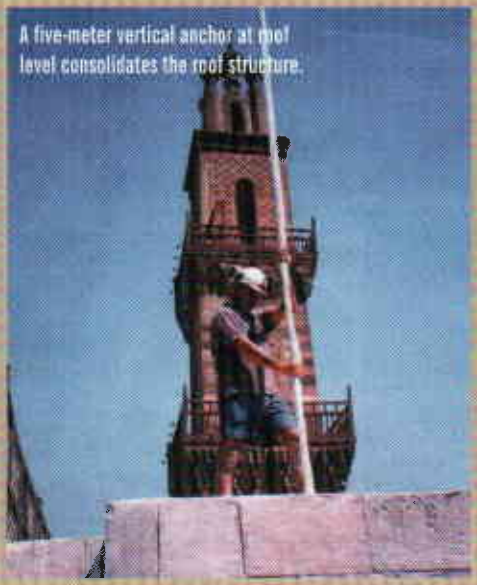
The walls above the ground-level arched vaults required both longitudinal and transverse reinforcing.



The roof structure, with its open central courtyard, was stabilized with long consolidation anchors.



Typical anchor placement for the arches and side walls.



A five-meter vertical anchor at roof level consolidates the roof structure.

Anchor insertion: Horizontal anchors stabilized the roof structure on the venerable al-Ghouri mosque.

Structural Reinforcement Anchors

- designed to the requirements of each application
- quickly installed
- age tested for durability
- fire resistant
- cementitious, therefore sympathetic to the structure
- invisible when installed
- controlled grout flow containment
- effective for structural repairs, ground anchoring, parapet walls & masonry arch strengthening

Drilled hole
usually double anchor body size

Main anchor body
available as square or circular hollow section or solid bar profile

Fabric containing anchor

Grout injection
moulds anchor to the shape and spaces within the wall

Inner wall substrate

CINTEC NORTH AMERICA

SECURING THE PAST FOR THE FUTURE

38 Auriga Drive
Suite 200
Nepean, Ontario
Canada K2E 8A5
Tel: 613-225-3381
Fax: 613-224-9042

5540 Connecticut Ave NW
Suite 220
Washington, DC
United States 20015
Tel: 1-800-363-6606
Fax: 1-800-461-1662

E-mail: **solutions@cintec.com**

Europe
Cintec International
Factory Road
Newport, South Wales
United Kingdom NP9 5FA
Tel: + +44(0) 1633 246614
Fax: + +44(0) 1633 246110
E-mail: **cintec@aol.com**

Australia
Cintec Australiasia Pty Ltd
40 Tyrrell St, PO Box 141
Newcastle
Australia NSW 2300
Tel: + +61 (0)2 4929 4841
Fax: + +61 (0)2 4929 7933
E-mail: **solutions@cintec.com.au**

Website: **www.cintec.com**