Researchers at Missouri University of Science and Technology are bridging a gap between an ancient structural element and modern technology.

Led by Dr. John J. Myers, S&T researchers are working with designers at HC Bridge Co. to combine an ancient concrete arch form - dating back to the Roman empire - with a composite shell to create bridge beams that are designed to last 100 years. Tucked inside durable, fiberglass composite shells, the lightweight beams are supported by a concrete arch and anchored by seven wire tendons, which serve as the system's tension tie.

"The composite shell protects the system from the elements, extending its service life and reducing the maintenance expenses that might normally be needed in a traditional bridge girder," says Myers, associate professor of civil, architectural and environmental engineering at Missouri S&T. "It also serves as a formwork for the construction of the concrete arch system."

The system uses a high-performance concrete, known as self-consolidating concrete, which can flow easily into tight and constricted spaces without needing vibration to remove trapped air or allowing the coarse aggregate to separate from the cement paste.
Using advanced concrete materials and composites for bridges and other infrastructure applications has been a key focus for Myers, who was recently appointed to serve a three-year term on the Federal Highway Administration’s Long-Term Bridge Performance Program Expert Task Group Advisory Committee.

Tucked inside durable, fiberglass composite shells, the lightweight beams are supported by a concrete arch and anchored by seven wire tendons, which serve as the system's tension tie.

At the end of the project, the three new bridges will be located in Douglas, Dade and Reynolds counties. The bridges will be funded in part by the Missouri Department of Transportation's Safe and Sound bridge program, which is currently replacing or rehabilitating more than 800 of the state's poorest bridges.

Habor Technologies in Maine was commissioned to manufacture the composite shell and housing for the beams. Myers says the technology is flexible enough to allow for the arch's self-consolidating concrete to be poured either at a precast facility or at the job site directly.

"Quality control is often better at a precast facility since the concrete is batched in a very close proximity to the beam," Myers says. "It's also often more cost-effective to pour at that type of facility because these bridges are in a rural part of the state."

The first two bridge beams were cast at a ready-mix plant in Mountain Grove, Mo., and a precast plant in Virginia, respectively. The final bridge will involve placing concrete at the job site after the beams are erected into place.
"In all cases, lower capacity cranes can set them in place because it's a lighter weight, more efficient structural system," Myers adds.

Myers and two S&T graduate students are working on the project with Dr. Glenn Washer, associate professor of civil and environmental engineering at the University of Missouri-Columbia.

Masonry Cement Mortar in High Seismic Design Applications

Jamie Farny

The 2011 Masonry Standards Joint Committee (MSJC) Building Code Requirements and Specification for Masonry Structures (TMS 402-11/ACI 530-11/ASCE 5-11) and earlier editions do not allow the use of masonry cement mortar in Seismic Design Categories D and higher for masonry walls that are part of the seismic force-resisting system. However, the latest research supports the use of masonry cement mortars in seismic structural applications. Research affirms certain basic principles, and lays the groundwork for proposed changes to the 2013 edition of the Masonry code (TMS 402/602). Among those principles:

- Structural performance of fully grouted reinforced masonry walls in response to earthquake forces is dominated by grout and reinforcement; it is unaffected by mortar formulation.
- Proper wall-tie spacing and adequate attachment to the supporting structure are key factors to ensuring stability of veneer; use of high strength mortars and joint reinforcement with seismic clips is not necessary to achieve required performance.

"Masonry cement" started appearing between 1918 and 1932 as an alternate to traditional portland cement-lime mortar. Masonry cement simplified the production of good quality, consistent mortar on masonry projects. In 1932, the Standard for Masonry Cement (ASTM C91) debuted, and by the late 1900s masonry cement was being used in a majority of masonry constructed in the U.S. However, when the MSJC masonry code was introduced in 1988, it maintained the Uniform Building Code (UBC) limitations on the use of masonry cement mortars in lateral force resisting (participating) structural members in areas with high seismic risk. This limitation was based on historical use of portland cement-lime mortars in regions of high seismic activity and data indicating that the flexural bond strength of unreinforced masonry prisms constructed using masonry cement mortars tends to be lower than that obtained on prisms made using portland cement-lime mortars.

Research

Beginning in 2005 and continuing until 2010, a project under the direction of Dr. Franklin Moon, Drexel University, focused on the performance of reinforced masonry bearing walls and compared results of partially grouted and fully grouted masonry walls to identify differences in behavior mechanisms. Although partially grouted and fully grouted masonry shear walls responded differently to loads, one thing was clear: mortar formulation did not have a significant effect on the strength and behavior of fully grouted walls.

In a separate project (2006 to 2010), the U.S. National Science Foundation's Network for Earthquake Engineering Simulation (NEES) program sponsored research on Performance-based Design of Masonry and Masonry Veneer. The research team was led by Dr. Richard Klingner, University of Texas at Austin, and included academia and representatives from the masonry industry. Wall types studied included both concrete masonry unit (CMU) and wood frame assemblies with clay brick veneer on the exterior.

Experiments looked at:
Structural masonry’s response to seismic loads to compare how different grouting conditions and mortar formulations affected that response.

Masonry veneer’s response to seismic loads over wood frame and grouted CMU backups.

Tests included full-scale walls subjected to both in-plane and out-of-plane quasi-static and dynamic loading; wall segments in a lab; wall segments on a shaking table; and full-scale prototype buildings on a shaking table. Shaking-table tests were conducted using two ground motion records from the 1994 Northridge (California) Earthquake, one with strong acceleration pulses and the other motion more demanding in the frequency range of interest with a much longer duration of strong shaking. Repeated cycles of the earthquake loads were applied and gradually increased to 2½ times the original earthquake motions.

Careful coordination of dimensions and details of the test specimens permitted direct comparison of the quasi-static and dynamic test results.

For the CMU construction, it was observed that mortar formulation has negligible influence on the seismic response of fully grouted, special reinforced masonry shear walls; reinforcement and grout are more important.

Performance

Experimentation showed that current MSJC requirements for veneer ties are adequate for high seismic conditions and continued use of masonry cement mortar. Both corrugated and rigid veneer ties sustained ground motions in excess of the Design Basis and Maximum Considered Earthquakes (DBE, MCE).

Shaking-table tests showed that veneers constructed over wood-stud backing, and designed in accordance with code provisions, can sustain ground motions far in excess of the DBE and MCE when adequately attached to supporting structure. One veneer failure occurred due to pullout of nails installed in wet wood. As a result, the 2011 MSJC was modified to require higher pullout strength for tie attachments to wood-studs. In the CMU building specimen and the shake-table CMU wall specimens, the in-plane veneer and its connectors performed well under repeated earthquakes above MCE without falling off the CMU. All out-of-plane CMU walls with clay masonry veneer performed well in the shake-table tests under repeated earthquakes above MCE. In all shake-table testing conducted, the out-of-plane connectors securely held the CMU wall and the veneer for well above MCE.

Conclusions

Fully grouted participating elements in high seismic areas can be built with mortar formulated using masonry cement and provide acceptable performance. The veneer research also indicates that inclusion of joint reinforcement and seismic clips is not necessary to achieve required performance in high seismic design applications, validates existing wall-tie spacing criteria of the MSJC, and supports continued use of Type N masonry cement mortars in veneer. Changes consistent with these findings have been proposed for the 2013 MSJC code.

Jamie Farny is Market Manager, Buildings, for the Portland Cement Association. He is a member of the Construction Requirements and Seismic subcommittees of the Masonry Standards Joint Committee, which develops the masonry code and specification.
References


1 World Trade Center offers warm welcome

- By STEVE CUOZZO
- Last Updated: 12:22 PM, May 25, 2012
- Posted: 11:52 PM, May 24, 2012

EXCLUSIVE
FUTURE SHOCK: Here’s a sneak peek at what 1WTC plaza will look like. This is the first rendering of how the base of 1 World Trade Center will look up close — a shimmering, richly textured facade on four sides of glass, stainless steel and aluminum.

While bickering goes on over the iconic office tower’s crown, its street-level face is just as vital — not only to Condé Nast employees who will move in by 2015, but to the millions of visitors to the 16-acre WTC site.

The “podium” design by Skidmore Owings & Merrill is the end product of a tortured history that included the dumping of an earlier scheme over costs and fears its custom-fabricated glass would too easily shatter.

The new image released by the skyscraper’s owners, the Port Authority and the Durst Organization, shows for the first time how its fortified base — a cube 185-feet on each side — will look to people arriving for work.

Preliminary renderings last year suggested a monolithic, corporate-looking wall despite a supposed “pleated” effect.

But the image shown here promises a warmer welcome. It is articulated by vertical glass fins protruding from panels of stainless steel slats. The fins will be arrayed in patterns that will vary as they move up the facade.

Perforated aluminum screens behind the steel slats will be illuminated, making the entire tower podium glow by night — a suitable companion to the lit-up base of 7 World Trade Center nearby.

Cladding the podium will cost $40 million. Installation is to start in October.

The re-do of the base is the latest chapter in the former Freedom Tower’s complicated saga, including architect David Childs’ original design being scuttled over security concerns and the tower having to be moved from its original site.

Childs then redesigned the entire building. The finished project reflects his work on the soaring octagonal “shaft,” but no longer on its apex or base — a hybrid result it will be left for future generations to judge.

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Supervisors have challenging jobs -- responding to management, assisting associates and team members, responding to challenges that may crop up in safety, quality and delivery. Their positions can be described at times as being between a rock and a hard place, says Mike Wroblewski.

Wroblewski, director of the Kaizen Institute USA, outlined the five skills of a lean supervisor in a recent webinar on a broader topic titled: "A Day in the Life of a Lean Supervisor."

He described the skills:

1. **Knowledge of Work.** A lean supervisor should know how all of the processes and all of the work in the area where he has responsibility -- inside and out and backward and forward, says Wroblewski. "All of the elements in the work should be known by the lean supervisor."

2. **Knowledge of Job Responsibilities.** The lean supervisor should understand, from a management perspective, what is expected of the role. He should know the company policies, work rules, union contracts if applicable. The supervisor should be skilled in what he needs to deliver from a management perspective.

3. **Ability to Kaizen:** The lean supervisor should have a "good foundation" of basic kaizen skills, including such tools as 5S, practical problem-solving, PDCA. "Those should all be comfortable skills within a lean supervisor," Wroblewski says.

4. **Ability to Lead:** The Kaizen Institute USA director points out the importance of this role: "[The associates'] first leader, their front-line leadership staff, is the key person who sets the culture of the company expectations."
5. **Ability to Teach:** This is possibly the most under-appreciated skill of a lean supervisor in most manufacturing companies that Wroblewski visits, he says. They are expected to enforce; better is the ability to teach.

Having, or developing such skills, is key to creating a team environment to pursue continuous-improvement objectives, he says.

The webinar was presented by the [Gemba Academy](#).

**Behind the scenes at the 49ers' Santa Clara stadium construction**

*Silicon Valley / San Jose Business Journal by Lauren Hepler, Economic Development Reporter*

Date: Tuesday, September 25, 2012, 6:05pm PDT - Last Modified: Tuesday, September 25, 2012, 6:21pm PDT

Lauren Hepler

Construction crews at the new 49ers stadium use a crane to lift equipment for escalators that will bring fans to luxury suites.
With half of the steel frame for the San Francisco 49ers new $1.4 billion stadium in Santa Clara now completed, Project Executive Jack Hill on Tuesday guided a tour of progress on the construction. Many of the 400 total iron workers, electricians, plumbers and stone masons at work on the project are pulling double shifts from 6:30 a.m.-midnight six days a week to ensure that construction stays on schedule. They are working with 18,000 tons of steel and four rare 338-foot cranes, in addition to massive piles of other raw materials.

“IT’s gone extremely well,” said Hill, who previously helped build the Dallas Cowboys a new stadium. “The community has worked on this project for so long. It doesn’t take too much imagination to see what this is going to look like when it’s finished.”

Hill said construction for the stadium is currently about 15 percent completed, and there is “no reason” currently that it would not be ready for the beginning of the 2014 National Football League season as anticipated. He said crews – mostly composed of workers from the Bay Area – are expecting rain over the winter and currently trying to build themselves a "cushion" in case of any delays.

Hill is also helping to ensure that the final product contributes to the local community. “It’s going to be reflective of the Bay Area,” he said, emphasizing the team’s commitment to environmental standards in the project. “It also seems like there are a lot of businesses that want to be close to it.”

Between game days and other events at the stadium, Hill said local residents can expect employment opportunities at the arena and traffic to local businesses.

“I think the local economy will do very well,” Hill said.

Lauren Hepler covers economic development, sports, and hospitality for the Silicon Valley Business Journal. She can be reached at 408.299.1820

Related links:

Meet the Man Who Built a 30-Story Building in 15 Days

- BY LAUREN HILGERSEMAIL AUTHOR
- 09.25.12
- 6:30 AM
On this farmland in Hunan Province, Broad Sustainable Building plans to construct a 220-story skyscraper—the tallest in the world.

Photo: Noah Sheldon

Zhang Yue, founder and chairman of Broad Sustainable Building, is not a particularly humble man. A humble man would not have erected, on his firm’s corporate campus in the Chinese province of Hunan, a classical palace and a 130-foot replica of an Egyptian pyramid. A humble man, for that matter, would not have redirected Broad from its core business—manufacturing industrial air-conditioning units—to invent a new method of building skyscrapers. And a humble man certainly wouldn’t be putting up those skyscrapers at a pace never achieved in history.
In late 2011, Broad built a 30-story building in 15 days; now it intends to use similar methods to erect the world’s tallest building in just seven months. Perhaps you’re already familiar with Zhang’s handiwork: On New Year’s Day 2012, Broad released a time-lapse video of its 30-story achievement that quickly went viral: construction workers buzzing around like gnats while a clock in the corner of the screen marks the time. In just 360 hours, a 328-foot-tall tower called the T30 rises from an empty site to overlook Hunan’s Xiang River. At the end of the video, the camera spirals around the building overhead as the Broad logo appears on the screen: a lowercase b that wraps around itself in an imitation of the @ symbol.

In person, Zhang himself seems to move at an impossible time-lapse clip. He’s almost always surrounded by Broad employees, all wearing identical white button-front shirts (the uniform for the corporate office) and all offering papers for him to review or sign. When I arrive, he’s issuing a steady barrage of instructions while spinning himself around in his office chair. When he’s finally ready to start the interview, he abruptly stops spinning and, without looking at me, barks out, “Begin!”

The pace of Broad Sustainable Building’s development is driven entirely by this one man. Broad Town, the sprawling headquarters, is completely Zhang’s creation. Employees call him not “the chairman” or “our chairman” but “my chairman.” To become an employee of Broad, you must recite a life manual penned by Zhang, guidelines that include tips on saving energy, brushing your teeth, and having children. All prospective employees must be able, over a two-day period, to run 7.5 miles. You can eat for free at Broad Town cafeterias unless someone catches you wasting food, at which point you’re not merely fined but publicly shamed.
So far, Broad has built 16 structures in China, plus another in Cancun. They are fabricated in sections at two factories in Hunan, roughly an hour’s drive from Broad Town. From there the modules—complete with preinstalled ducts and plumbing for electricity, water, and other infrastructure—are shipped to the site and assembled like Legos. The company is in the process of franchising this technology to partners in India, Brazil, and Russia. What it’s selling is the world’s first standardized skyscraper, and with it, Zhang aims to turn Broad into the McDonald’s of the sustainable building industry.

“Traditional construction is chaotic,” he says. “We took construction and moved it into the factory.” According to Zhang, his buildings will help solve the many problems of the construction industry. They will be safer, quicker, and cheaper to build. And they will have low energy consumption and CO₂ emissions. When I ask Zhang why he decided to start a construction company, he corrects me. “It’s not a construction company,” he says. “It’s a structural revolution.”
The Instant Skyscraper

Broad plans every step for construction speed, from how it designs floor modules to how workers load the trucks.

1// Identical modules
The floors and ceilings of the skyscraper are built in sections, each measuring 15.6 by 3.9 meters, with a depth of 45 centimeters.

Illustration: Jason Lee

Asked about his life story, Zhang avers that it’s too boring to discuss. (“This whole article shouldn’t be more than two pages,” he says.) But he goes on to attribute his success to his creativity and to his outsider perspective on technology. He started out as an art student in the 1980s, but in 1988, with the help of two partners, including his brother (an engineer by training), Zhang left the art world to found Broad. The company started out as a maker of nonpressurized boilers. While Zhang again insists that the story isn’t interesting enough to talk about, Broad’s senior vice president, a smiley woman named Juliet Jiang who sports a bowl haircut just too long to stay out of her eyes, is happy to fill in the gaps. “He made his fortune on boilers,” she says. “He could have kept doing this business, but my chairman, he saw the need for nonelectric air-conditioning.” China’s economy was expanding past the capacity of the nation’s electricity grid, she explains. Power shortages were a problem. Industrial air-conditioning units fueled by natural gas could help companies ease their electricity load, reduce costs, and enjoy more reliable climate control in the bargain.

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The AC units that Zhang still manufactures are gigantic, barge-sized affairs. The so-called microchillers weigh 6 tons; the largest is 3,500 tons and can cool 5 million square feet. The technology Broad employs, called absorption cooling, is an old one. Instead of using electricity to compress a refrigerant from a gas to a liquid and back again, nonelectric air conditioners use natural gas or another source of heat to turn a special liquid (typically a solution containing lithium bromide) into vapor; as the vapor condenses, it cools the air around it. Today, Broad has units operating in more than 70 countries, cooling some of the largest buildings and airports on the planet. These systems are all monitored from a central headquarters in Broad Town: When an air conditioner malfunctions in Brazil, an alarm goes off in Hunan.

For two decades, Zhang’s AC business boomed. But a couple of events conspired to change his course. The first was that Zhang became an environmentalist, a gradual awakening that he says began 10 or 12 years ago. The second was the 7.9-magnitude earthquake that hit China’s Sichuan Province in 2008, causing the collapse of poorly constructed buildings and killing some 87,000 people. In the aftermath, Zhang began to fixate on the problem of building design. At first, he says, he tried to convince developers to retrofit existing buildings to make them both more stable and more sustainable. “People paid no attention at all,” he says. So Zhang drafted his own engineers—300 of them, according to Jiang—and started researching how to build cheap, environmentally friendly structures that could also withstand an earthquake.

Within six months of starting his research, Zhang had given up on traditional methods. He was frustrated by the cost of hiring designers and specialists for each new structure. The best way to cut costs, he decided, was to take building to the factory—and as a manufacturer of massive AC units, he knew how factories worked. But to create a factory-built skyscraper, Broad had to abandon the principles by which skyscrapers are typically designed. The whole load-bearing structure had to be different. To reduce the overall weight of the building, it used less concrete in the floors; that in turn enabled it to cut down on structural steel. The result was the T30, 90 percent of which was built inside the factory. And Zhang says this percentage will only rise with future buildings: The more that happens in the factory, he says, the safer and less wasteful construction becomes.

These theories are increasingly accepted by the sustainable building community in the West, where prefabricated and modular buildings are gaining in popularity. In New York, a 32-story modular building, the world’s tallest of its kind, is slated to go up near the Barclays Center arena in Brooklyn (though union disputes might result in a more traditional building instead). Two entirely modular developments have gone up in the suburbs of London. Both modular buildings (which are delivered to a site in prebuilt cubes) and prefabricated towers (closer to what Broad is doing) are safer to construct and easier to regulate than traditional structures, and both cut down on waste.

But modular and prefabricated buildings in the West are, for the most part, low-rise. Broad is alone—perhaps forebodingly alone—in applying these methods to skyscrapers. For Zhang, the environmental savings alone justify the effort. According to Broad’s numbers, a traditional high-rise will produce about 3,000 tons of construction waste, while a Broad building will produce only 25 tons. Traditional buildings also require 5,000 tons of water onsite to build, while Broad buildings use none.
Prefabricated skyscrapers can be inflexible. To create a lobby for this hotel, Broad had to stick an awkward pyramid onto the base.

*Photo: Noah Sheldon*

**Compared with the West's** elegant modular buildings, Zhang's skyscrapers are aesthetically underwhelming, to say the least. On a tour of the T30, my guide gestures at a scale model and says, “It’s not very good-looking, is it?” To create a sufficiently spacious lobby for the hotel, an awkward pyramid-shaped structure had to be attached to the base. Inside, the hallways are uncomfortably narrow; climbing the central stairway feels like clanging up the stairs of a stadium bleacher.
It’s worth noting, though, that the majority of apartment buildings going up in China are equally ugly. Broad’s biggest selling point, amazingly enough, is in the quality. In a nation where construction standards vary widely, and where builders often use cheap and unreliable concrete, Broad’s method offers a rare sort of consistency. Its materials are uniform and dependable. There’s little opportunity for the construction workers to cut corners, since doing so would leave stray pieces, like when you bungle your Ikea desk. And with Broad’s approach, consistency can be had on the cheap: The T30 cost just $1,000 per square meter to build, compared with around $1,400 for traditional commercial high-rise construction in China.

The building process is also safer. Jiang tells me that during the construction of the first 20 Broad buildings, “not even one fingernail was hurt.” Elevator systems—the base, rails, and machine room—can be installed at the factory, eliminating the risk of a technician falling down a 30-story elevator shaft. And instead of shipping an elevator car to the site in pieces, Broad orders a finished car and drops it into the shaft by crane. In the future, elevator manufacturers are hoping to preinstall the doors, completely eliminating any chance that a worker might fall.

While Jiang focuses on bringing Broad buildings to the world, her boss is fixated on the company’s most outlandish plan—the J220, a factory-built 220-floor behemoth that would just happen to be the tallest building in the world. It’s hard to say for sure that the 16-million-square-foot plan isn’t entirely a publicity stunt. But Zhang has hired some of the engineers who worked on the current height-record holder, Dubai’s Burj Khalifa, and Broad has created two large models of “Sky City” (as the J220 has been nicknamed). The foundation is scheduled to be laid in November at a site in Hunan; if everything goes well, the building will be complete in March 2013. All in all, including factory time and onsite time, construction is expected to take just seven months. Again, that’s assuming it really happens: When my guide at the T30 plugs in one of the models and the lights flicker on, he tells me, “My chairman says we have to attract eyes. We have to shock the world.”

But if all Broad ever does is build 30-story skyscrapers—in 15 days, at $1,000 per square meter, with little waste and low worker risk, and where the end result can withstand a 9.0 quake—it will have shocked the world quite enough.

Lauren Hilgers (lauren.hilgers@gmail.com) was based in Shanghai as a reporter from 2007 to July 2012.

Note 1. Correction appended [9/25/12:00 PM EST]: Broad’s skyscrapers cost $1,000 per square meter, not $1,000 per square foot.