A Magazine for Specifiers and Engineers

precast solutions

SPRING 2012

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ASTM C1719

A New Benchmark for Quality Assurance in Septic Tanks

By Phillip Cutler, P.E.

The recent release of an ASTM testing standard creates a new benchmark for quality assurance that could boost the marketability of precast concrete septic tanks.

ASTM International's new ASTM C1719, "Standard Test Method for Installed Precast Concrete Tanks and Accessories by the Negative Air Pressure (Vacuum) Test Prior to Backfill," was developed under ASTM's technical sub-committee C27.30, which falls under the main ASTM Committee for precast products, C27.

Prior to the release of the new standard, precast manufacturers, engineers, specifiers and regulators could rely only on a manufacturing reference for testing watertightness of precast concrete septic tanks – ASTM C1227, "Standard Specification for Precast Concrete Septic Tanks." The new C1719 standard contains elements of C1227 for septic tanks and is also similar to the previously developed ASTM C1244, "Standard Test Method for Concrete Sewer Manholes by the Negative Air Pressure (Vacuum) Test Prior to Backfill." ASTM C1719 is different from C1244 in that it provides a vacuum test method for installed precast tanks and accessories as an "installed system." The scope of the new C1719 standard covers tanks for onsite wastewater treatment and storage, grease interceptors, grit/oil separators, water storage and other applications requiring watertight construction and installation.

Excellent marketing tool

The new C1719 standard can be used with confidence by manufacturers and installers of precast tanks and systems as a marketing tool for their businesses when asked by an Authority Having Jurisdiction (AHJ) for an ASTM test method of the effectiveness of an installed system. Armed with this nationally recognized and consistent negative air pressure (vacuum) method for testing watertightness of systems prior to backfill also eliminates the need of carting huge quantities of water to your site for a water test. A water test, while serving the purpose for testing a tank, does not completely address the entire installed system (as does the C1719 vacuum test) and is clearly much less sustainable. What do you do with all that water after the test is complete?

Test equipment and method

The equipment required to perform a negative air pressure (vacuum) test is not sophisticated. As stated in section 6 of the C1719 standard, the testing equipment consists of pumps, vehicle vacuum devices and even a high-performance shop-style vacuum cleaner. Most devices are easily operated and the test can be performed in a few minutes using the vacuum method, unlike the hours or even days needed to perform the same test with water.

Like ASTM C1227, C1719 tests apply a vacuum to the sealed system to a level of 4 in. of mercury (Hg) for a duration of five minutes. If the gauge holds without pressure loss, the system passes. If the vacuum level drops, it is reapplied and the test is restarted. A tank or system failing to hold vacuum may be repaired per the manufacturer's recommendations and/or evaluated for not holding negative pressure and retested following such repair.

Manufacturers and installers of precast tanks should notify and promote to their local AHJ that these standards exist and are the best tools to adopt for the production of precast concrete septic tanks and for watertightness testing of tanks of all types and installations. Those regulating and specifying communities requiring watertightness testing of tanks and systems after installation and prior to backfill can be assured of a precast concrete system's watertight integrity by using the C1719 standard. PS

Phillip Cutler, P.E. is the director of Technical Services and Plant Certification for NPCA.

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ON THE COVER:
The Lewis & Clark Confluence Tower in Hartford, Ill., demonstrates the beauty, strength and versatility of precast concrete. See page 14.

Photo courtesy of Lewis & Clark Confluence Tower (www.confluencetower.com).

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NPCA
Precast ... The Concrete Solution

The CUP Awards

The Creative Use of Precast (CUP) Awards recognize projects that promote the innovative and cost-saving advantages of precast concrete over other materials.

ABOVE GROUND FIRST PLACE

Company: Anchor Concrete Products Ltd., Kingston, Ontario

Project Name: Kingston Monorail Test Track Project for Bombardier Transportation Canada

Bombardier Transportation Systems, a world leader in high-speed mass transit, awarded a contract to Anchor Concrete to manufacture and supply beams for 1.125 miles of precast concrete monorail track. The project included 124 straight beams with lengths ranging from 22 ft to 38 ft, 19 transition beams 33 ft in length and 20 super-elevated curved beams also 33 ft in length.

To provide an exceptionally smooth ride, all beams had extremely tight tolerances of +/-0.08 in. in a 5 ft straight edge, +/-0.12 in. in width at any location and +0.16 to -0.31 in. in any 38 ft length. This was achieved by using in-house innovations such as:

- building two straight molds in tandem to resist deflections;

Montclair University Parking Structure
Photo courtesy of Anchor Concrete Products Ltd. (www.anchorconcrete.com)

Opposite Page: Kingston Monorail Test Track Project for Bombardier Transportation Canada
Photo courtesy of Nitterhouse Concrete Products Inc. (www.nitterhouse.com)

- creating jigs for accuracy and repeatability of rebar cages;
- producing very detailed drawings;
- implementing a procedure to flip and roll the units to eliminate surface damage;
- pouring the beams upside down to ensure consistent textured finish on the top surface;
- creating a method to position the beam end bearing connection plates which required a high degree of coordination with the rebar cage due to the quantity of Nelson studs.

It was uneconomical to build specific molds for each type of the 19 special beams, so Anchor Concrete designed a system of proprietary adjustable molds. Quality control included a targeting system for lasers, calibrated tape measures and laser measuring devices. Systems of go/no-go gauges and a custom-designed recording spreadsheet were used to show compliance with tolerances.

Installation of the monorail track onsite was planned for four beams per day, but due to the accuracy of both construction and the precast elements, 12 to 16 beams were installed some days, reaching as many as 18 installations on the final day.

If high-speed rail is the future of mass transit, this project demonstrates that precast concrete is well equipped to go along for the ride.

ABOVE GROUND SECOND PLACE

Company: Nitterhouse Concrete Products Inc., Chambersburg, Pa.

Project Name: Montclair University Parking Structure

Montclair State University is New Jersey's second-largest university and is continually growing. One of its goals is to increase the student body to 18,000, but with that comes the need for investment in infrastructure to support the influx.

The University hired a team responsible for designing and constructing a new $7\frac{1}{2}$-level precast/prestressed concrete parking structure with 1,532 spaces. The resulting design replicates the Spanish mission-style architecture of the other campus structures and incorporates a walkway at the southern corner of the structure that connects the facility with the existing campus pedestrian circulation system.

A key innovation by Nitterhouse Concrete was the use of bolt-on precast concrete arches. The arches on the main facades were fabricated in individual pieces that were added after the installation of the spandrel panels. The bolt-on precast arches were easily shipped and saved money compared with rounded arch spandrels. The spandrels were designed with relieving angles to allow for the connections. The resulting aesthetic effect was that of a full-rounded arch spandrel at a fraction of the cost.

It was also important that the parking structure harmonize with the Spanish Colonial architecture of the rest of the campus. The precast concrete materials used proved to be the perfect material as the architects were able to create fluid rounded shapes at the tops of stair and elevator towers. Precast design flexibility allowed for the creation of detailed stepped forms and corbels in the spandrels, while insets and reveals provided a base for decorative tile that surrounds entry and exit points of the garage stair towers.

The precast/prestressed concrete components included 63 columns with a variety of architectural finishes, 68 beams, 600 double tees, 18 solid slabs, 6 precast panels and 169 prestressed panels with architectural finishes, and 99 horizontal light walls.

Fort Rosecrans National Cemetery POW Sculpture Base
Photo courtesy of Universal Precast Concrete Inc. (www.universalprecast.com)

Opposite Page: Magnetometer Stabilization Caissons
Photo courtesy of US Concrete Precast Group-Southern California (www.us-concreteprecast.com)

ABOVE GROUND THIRD PLACE

Company: Universal Precast Concrete Inc., Redding, Calif.

Project Name: Fort Rosecrans National Cemetery POW Sculpture Base

Universal Precast Inc. (UPC) was commissioned by a group of ex-POWs in the San Diego area to commemorate American POWs with a custom precast concrete decorative base for a POW sculpture at Fort Rosecrans, San Diego. It is located near the entrance to the Miramar Annex of the Fort Rosecrans National Cemetery.

UPC was hired by the sculptor, Richard Becker, to create the sculpture base. The project involved the fabrication of a large, one-piece decorative pedestal to hold up a bronze sculpture created by the artist. The base's diameter is 7 ft and is 5 ft tall.

In order to create this design, UPC made a highly custom multi-piece mold after many rendering sessions with the architect and the local POW organization. The base was then made in a single, monolithic pour with tan integral concrete color.

This process was made a little more difficult by the design requirements of a recessed time capsule, and

five round recesses needed to hold bronze seals for each of the five military branches. Cast-in letters on the front spell "LIBERATION," which is the name of the memorial statue.

The design includes fluted vertical sides, and the top surface of the base was polished to give it a marble-like finish. The end result was a very artistic and visually appealing base design.

By producing the pedestal in precast concrete rather than granite or marble, the manufacturing time was cut to about two weeks, as opposed to many months of hand sculpting out of other materials. The estimated total cost savings for using precast concrete was between \$10,000 and \$20,000.

The finished sculpture and base received a lot of publicity when it was revealed at a grand opening ceremony at the Fort Rosecrans National Cemetery.

UNDERGROUND FIRST PLACE

Company: US Concrete Precast Group-Southern California, San Diego, Calif.

Project Name: Magnetometer Stabilization Caissons

When the military needed to stabilize sensitive military equipment 60 ft deep in the Pacific Ocean due to the tidal action creating interference, it was precast concrete that delivered the best solution to a touchy problem.

Because of severely tight parameters for the stabilization of this equipment, precast concrete was the only viable material of choice. Steel would rust and composites could not handle the tidal action or pressure from the water. Precast concrete covered all of the parameters. The tight time span required that forming be completed in a matter of three weeks, start to finish.

Eight 36-in. diameter cylindrical tubes rising 22 ft out of the ocean floor contained the magnetometer equipment for the U.S. Navy's minesweeper range. Precast concrete round piles were designed to slip over the tubes, and caissons were designed to slip over the round piles/tubes. The caissons were filled with 6-in., low-iron stone, capped with a precast top and grouted in place. Precast scour mats were used around the structure to prevent erosion.

In addition to severely tight parameters, U.S. Concrete Precast Group-Southern California needed to

Georgia Street
Pedestrian Promenade
Photo courtesy of Norwalk Concrete Industries (www.nciprecast.com)

adapt its production to the extremely sensitive nature of the equipment. There could be no ferrous or steel content, so all reinforcement had to be fiberglass and zip-tied. The aggregates also had to have low iron content, and the cement could not be supplied by any plant that uses steel-belted radials for heating its kilns. The precast scour mats, normally attached and tethered with steel cable, had to be connected with graphite composite rope.

Since no molds existed, a precast concrete inner core was formed and the exterior was created from steel mold outer jackets. The caisson shell was also cast from that formwork. The structure was then lifted to a casting location that contained the outer formwork with the perimeter of the caisson base. The fiberglass bar reinforcing for the base was then tied to the protruding fiberglass bar reinforcing from the caisson shell.

Each base is 20 ft x 28 ft 6 in. x 12 ft, weighing in at a whopping 279,600 lbs. Each cap is 14 ft 3 in. x 9 ft 5 in. x 4 ft 6 in., and weighs 65,280 lbs. The structures were loaded at the plant and shipped at night with California Highway Patrol escorts. At the harbor, they were loaded onto a heavy cargo barge with a 500-ton crane. The units were barged to the site about a mile from the San Diego coast and set into place with the 700-ton barge crane. By using a precast solution to stabilize the existing magnetometers, the project saved the military $1.7 million.

UNDERGROUND SECOND PLACE

Company: Norwalk Concrete Industries, Norwalk, Ohio

Project Name: Georgia Street Pedestrian Promenade

There are few annual events that draw the level of attention the Super Bowl garners. The city of Indianapolis spent the last two years preparing for the spotlight, including the complete renovation of a three-block stretch of Georgia Street that served as an entertainment focal point outside the stadium. Bookended by the Indianapolis Convention Center on the west and Bankers Life Fieldhouse (formerly Conseco Fieldhouse) on the east, the street was transformed into Super Bowl Village and was visited by more than 150,000 people during the run-up to the big game.

Underneath this newly constructed pedestrian promenade sits an innovative precast concrete water-recycling stormwater sluiceway, but it wasn't originally planned that way. Norwalk Concrete Industries was initially contracted only for load-bearing grade beams, but after looking at the initial design, the precaster convinced the contractor that a custom all-precast solution would provide many benefits over the originally specified cast-in-place structures.

 

 

More than 700 precast components were cast, including U-shaped sections using continuous precast elements and segmental L-shaped walls about 4-ft-by-4-in. high on each side of the trench. The design also included vaults cast in two pieces at 52,000 lb per half, with H20-rated aluminum hatches and a fiberglass-grated partial false floor for drainage.

The precast option meant less digging, which can cause major headaches on busy downtown streets. The precast structures also fit neatly into the small footprint, with pieces delivered as needed, ready for rapid assembly. With the Super Bowl deadline looming, the precast option was not dependent on weather and also provided greater on-site safety, less site disruption, and reduced interference to street-front businesses. The original 12-in.-thick Cast-in-place (CIP) footing was also reduced to 7 in., providing a considerable cost savings.

The precast design allowed the contractor to avoid heavy cranes on site, make site elevation adjustments to match precast components and reinforce embedment for CIP closure points and jobsite sequencing. In addition, casting continued off-site at a time when site conditions would have prevented any cast-in-place work. The precast option reduced the contractor's jobsite labor crew, and enabled the contractor to leapfrog down the project as needed. In other words, the contractor was able to take advantage of the many benefits of precast over cast-in-place construction.

This project provides the perfect example of how the natural advantages of precast concrete can cause contractors to rethink traditional CIP designs.

UNDERGROUND THIRD PLACE

Company: Garden State Precast Inc., Farmingdale, N.J.

Project Name: Bronx River CSO

Management of wastewater is a vital part of our society, and often precast is called upon to complete the job. The Bronx River Combined Sewer Overflow (CSO) project, a successful partnership between Northeast Remsco and Garden State Precast, is a perfect example of why precast is often the material of choice.

The Bronx River CSO Netting Facility consists of 23 precast concrete sections. These sections form a three-chamber, post-tensioned unit for removal of solids from the combined sewer outfall.

Bronx River CSO
Photo courtesy of Garden State Precast Inc. (www.gardenstateprecast.com)

The Netting Chamber is the first unit and measures approximately 18 ft 8 in. x 41 ft x 20 ft 4 in. The bar screens and net mountings are installed within this chamber. The second chamber is the tidegate chamber. A large 7 ft x 7 ft cast steel tidegate is mounted within this section. The final chamber is the turning chamber. This chamber is used to reduce the flow back to the size of the outfall box culvert, and to provide an angled deflection in the box culvert. A precast concrete gravity retaining wall then encloses the facility on three sides.

The use of precast concrete reduced the cost by allowing the pumps to be shut off and the excavation flooded after installation, eliminating the need for an overnight pump tender. The contractor was also able to use shoring from another project due to the reduced installation envelope.

The as-needed delivery of the precast pieces allowed the contractor to fill holes in his schedule with the precast installations, thus rainy days became profitable and labor could be redirected as needed. The project is located adjacent to a school, so savings were also realized by a reduction in required traffic diversions.

The use of precast also allowed for watertight joints in three directions through the use of two different sealing methods, and match casting was accomplished with a variance of less than 1 in. in 43.75 ft. The design required the unit to be modeled in engineering software to check not only design loads but handling and rotational stresses, and the facility submittal was reviewed by nine agencies for approval. All approvals were acquired, and the casting and installation went smoothly.

ABOVE GROUND HONORABLE MENTION

Company: ARTO Brick and California Pavers, Gardena, Calif.

Project Name: Mariachi Plaza

For more information, see *Precast Solutions* Winter 2011.

Company: Nitterhouse Concrete Products Inc., Chambersburg, Pa.

Project Name: Riddle Memorial Hospital West Parking Garage and Pedestrian Bridge

Company: Smith-Midland Corp., Midland, Va.

Project Name: Camp Lejeune Mock Afghan Village

Company: Speed Fab-Crete, Fort Worth, Texas

Project Name: Woodall Rodgers Deck Park

For more information on this project, see *Precast Solutions* Spring 2011.

UNDERGROUND HONORABLE MENTION

Company: Gillespie Precast, Chestertown, Md.

Project Name: Camp Pecometh Centralized Wastewater Treatment Plant

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Infrastructure as Public Art

Infrastructure blends art and function with architectural precast concrete.

By Kirk Stelsel

Precast concrete walls, bridges, barriers and more have long been staples of our nation's infrastructure due to their durability, dependability, quality and ease of installation. Strong and silent soldiers, precast elements dutifully do their job but go largely unnoticed as they blend into roadway landscapes.

In recent years, though, a new trend has elevated these vital components to so much more than just, well, dependable infrastructure. Forward-thinking transportation agencies and municipalities have begun using precast concrete components with integral colors, custom finishes, insets and more to significantly improve the aesthetics of our daily surroundings, in addition to providing structural service.

In Florida, for example, highway sound walls now come to life with inset regional wildlife such as manatees, alligators, fish and flamingos. Other states have chosen designs that reflect the local culture through the use of colors, shapes, or form-liner finishes and coloring that mimic the look of natural stone or wood textures – all with the long service life of precast concrete.

Precast concrete bridges can convey a community's architectural style and enhance our environment as well – while serving their primary purpose of spanning everything from gullies to gorges. Whether the product you need is a short-span bridge or a comprehensive solution that can traverse a major river, precast can provide the attractive, long-lasting design you need.

Precast panels can incorporate exquisite detailing to add local flavor.

Across the map, State DOTs and road agencies are gaining public approval and strong support for custom precast infrastructure treatments that make our daily commutes a more pleasant experience. The choice of precast concrete infrastructure with beautiful finishes is nearly endless – roundabouts, MSE walls, and even permanent median barriers with architectural finishes and plantings. To see what precast concrete can do for you, visit http://precast.org/precast-possibilities. PS

Kirk Stelsel is NPCA's assistant director of Communication.

Precaster's Notebook: Installing a Doghouse Manhole

By Gary K. Munkelt, P.E.

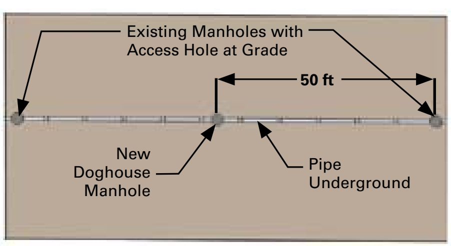

Fig. 1 PLAN VIEW
Information from Contract Drawings

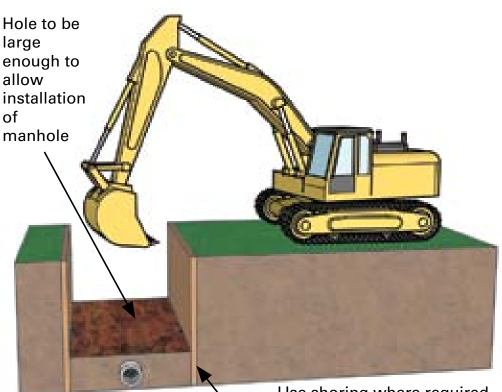

Fig. 2

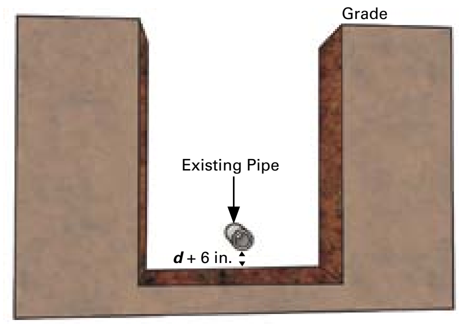

Fig. 3

Step 1: At the job site, locate the pipe where the manhole will be installed. Information should be shown on contract drawings. This information should include the location of other pipes in the area (contact local utilities) and surface indicators such as manhole frame and grate, and valve boxes (See Fig. 1). Another option is to use electronic equipment to locate pipes underground.

Step 2: Excavate the soil above the pipe. Use shoring to protect the soil from collapsing according to safety regulations. (See Fig. 2)

Step 3: Continue excavation along each side of the pipe and below, taking care to avoid damaging the pipe. Excavate to a distance of ***d*** plus 6 in., where ***d*** is based on the type of pipe, type of use and type of supporting blocks used. See *Precast Solutions*, Winter 2012 issue for derivation of ***d***. (See Fig. 3)

Step 4: Install ¾ in. stone 6 in. thick, and compact it to provide a solid base until the bottom slab is poured. After excavation and compaction are complete, the hole is ready for installation of the doghouse manhole.

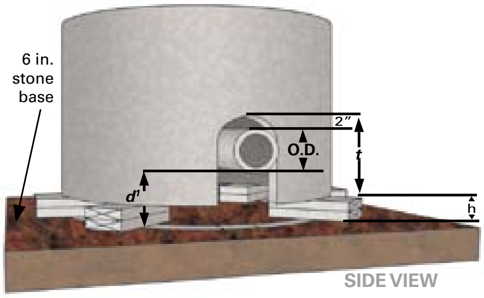

Fig. 4

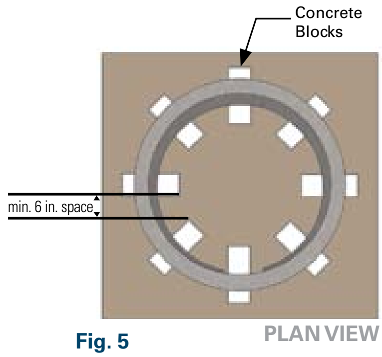

Fig. 5

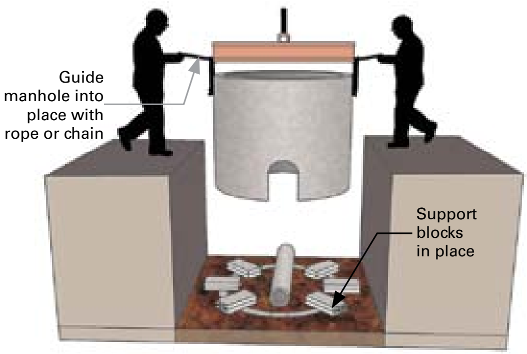

Fig. 6 INSTALLING MANHOLE

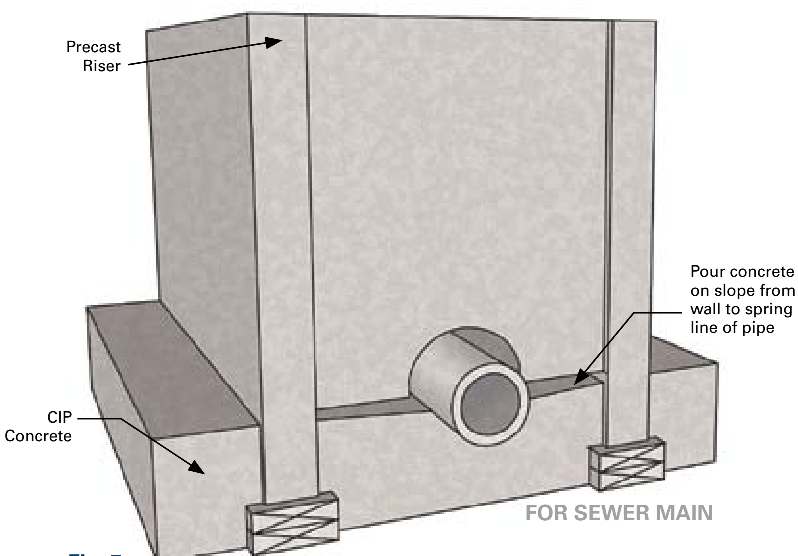

Fig. 7

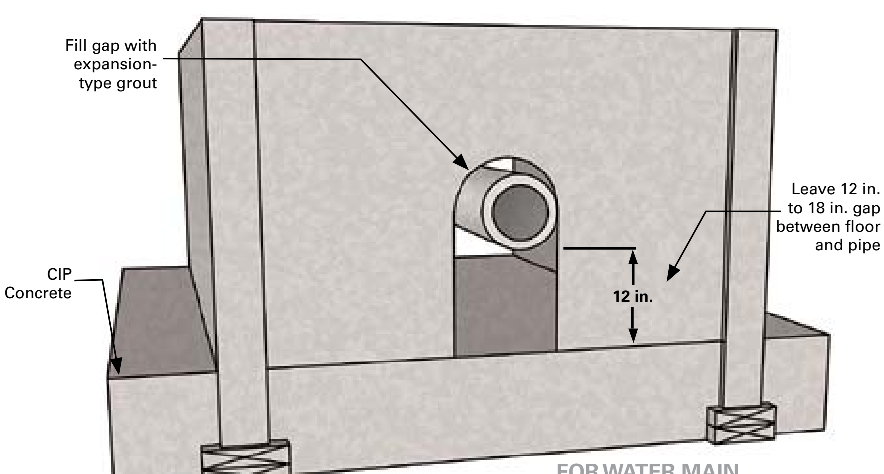

Fig. 8

Step 5: Use blocks to support the manhole until a permanent bottom slab can be poured. The height of the blocks should be 2 to 5 in. Anything higher than 5 in. can create an unstable condition before the bottom slab concrete is poured; anything lower than 2 in. will interfere with the movement of the concrete under the precast section when the bottom slab concrete is poured.

To determine the height (***h***) of the blocks, use the formula below.

$$h = d^1 + \text{O.D.} + 2 \text{ in.} - t$$

Check the distance (d^1) from the stone base to the bottom of the existing pipe. Add the outside diameter of the pipe plus 2 in. (see *Precast Solutions*, Winter 2012). Subtract measurement (t) from the bottom of the manhole to the top of the U-shaped cutout. Fig. 4 shows how it would look after the manhole is installed.

Concrete blocks make excellent support and become an integral part of the bottom slab. The number of supports depends on the strength of the soil and the amount of block surface area exposed to the soil. (See Fig. 5)

If the soils are weak, the 6 in. depth of ¾ in. stone will provide a strong base and require a minimal amount of supports. It is important that at least 6 in. of space be maintained between blocks to allow concrete to flow under the precast section and provide a shelf outside; this is necessary to assure that loads from above are distributed over the entire surface of the bottom slab.

Step 6: After the support blocks are installed, the precast section can be lowered into position. Take care to avoid damaging the existing pipe. Use a rope or chain on each side of the hole to guide the structure into place (see Fig. 6). Do not allow anyone in the excavation until the manhole structure is resting securely on the bottom.

Step 7: In sewer manholes, pour concrete (sloping from wall to pipe to avoid puddling) to form an invert. Use expansion-type mortar to fill the cavity. (See Fig. 7)

In utility boxes, pour concrete to form the bottom slab. Use expansion-type mortar to fill openings. (See Fig. 8) **PS**

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PROJECT PROFILE

Project: Lewis and Clark Confluence Tower, Hartford, Ill.

Project Owner: Village of Hartford, Ill.

Project Architect: KAI Design & Build, St. Louis

Project Engineer: THP Limited Inc., Cincinnati, Ohio

Precast Manufacturer: High Concrete Group LLC, Fishers, Ind.

ENGTH IN UNITY

THE TWO TOWERS OF THE LEWIS AND CLARK CONFLUENCE TOWER WORK TOGETHER TO ACHIEVE NOT ONLY A UNIQUE DESIGN BUT A CAPACITY FOR WITHSTANDING SEVERE SEISMIC STRESS AND WIND LOADS.

By Deborah R. Huso
Photos courtesy of KAI Design & Build (www.kai-db.com)
Cover photo courtesy of Lewis & Clark Confluence Tower (www.confluencetower.com)

In 2000, with the bicentennial celebration of the 1803-1806 expedition of Meriwether Lewis and William Clark approaching, the village of Hartford, Ill., just northeast of St. Louis, wanted to mark the event in a meaningful and enduring way. It was at Camp River Dubois that Lewis and Clark launched their "Corps of Discovery" exploration of the Louisiana Purchase within sight of the confluence of the Mississippi and Missouri rivers, the third-largest river confluence in the world.

Deanna Barnes, Hartford's project manager, says the village held a series of ad hoc community meetings to design a tower that would offer views of the rivers' confluence and also memorialize the historic partnership between the two explorers. She said the idea for a tower that would offer views of the two rivers stemmed from the hope of putting local residents and visitors back in touch with the waterways. "We wanted people to visit a viewing tower and then be inspired to go visit the rivers themselves," she says.

As the village looked for a site, the local fire department helped out by bringing a lift so that members of the village's Viewing Tower Committee could experience different heights for viewing the rivers. They learned the viewing platform for the tower would have to be 150 ft tall to allow for a full, panoramic view of the rivers' confluence.

PRECAST OFFERS THE DESIGN SOLUTION

The original design concept for the Lewis and Clark Confluence Tower called for a cast-in-place (CIP) structural core for the tower with precast architectural panels to serve as the tower's fins. But after discovering the cost savings and design control offered by an all-precast structure, the architectural firm worked with High Concrete Group, the precast manufacturer, to convert the design accordingly.

The project was funded entirely by grants and private donations, but because of the challenges of acquiring the funding, the confluence tower, associated park area and museum, took many years to build. Even though the village of Hartford broke ground on the project in 2002, it was not officially completed until 2010. The towers stood, fully erected, for several years without handrails on the stairs, while the village of Hartford worked to acquire more funding to complete the entire park project.

But this was to be no ordinary tower. It needed to

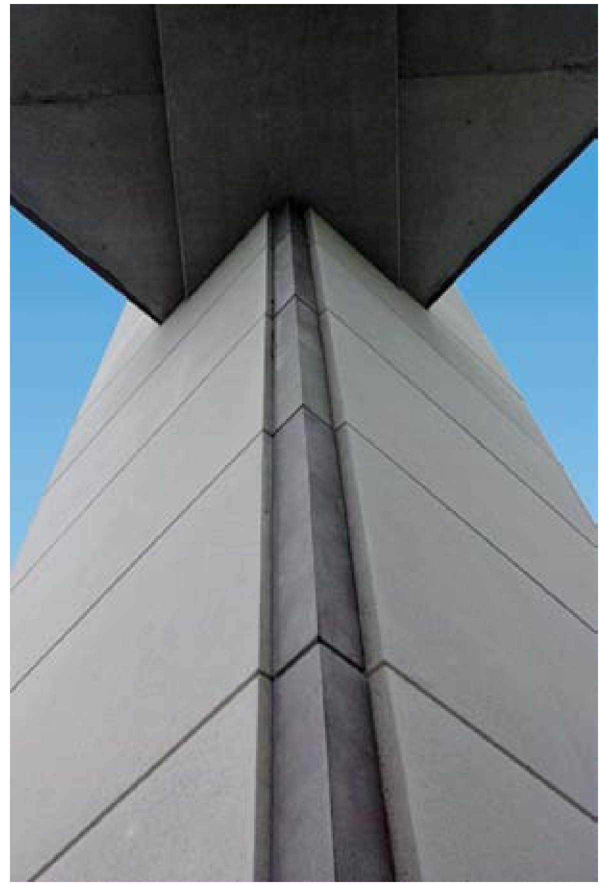
Construction actually began in 2002, but the monument did not open until 2010, as owners worked to secure funding to complete the grounds and museum.

reflect the symbiotic relationship of the two explorers it sought to memorialize. The Lewis and Clark journey was the only U.S. military expedition to go forth with two captains. President Thomas Jefferson designated Lewis as the head of the expedition, but the young explorer wanted his longtime friend to enjoy the title of captain as well, to have equal command over the expedition's corps of 50 men. As it turned out, the two men complemented one another perfectly with Lewis serving as the journey's naturalist and Clark as its cartographer.

The friendship and partnership between the two explorers was the basis for the tower's design, completed by KAI Design & Build of St. Louis. "[Lewis and Clark] are epitomized for their dedicated relationship, where the combined strength of the two exceeded the sum of the individuals," KAI's project manager Steve Smith explains. Smith notes that it was the idea of the two explorers as a single entity in our historic remembering of them that inspired the two-tower design of the expedition launch memorial. "KAI came up with the concept where each tower stood for one of the icons, and the bridge platforms represented their continuity through the entire expedition," Smith adds.

Consisting of two shafts of equal size and height, one representing Lewis, the other representing Clark, the towers rise 19 stories or 190 ft with one shaft containing the elevator, the other a stairwell. Three viewing platforms join the three towers at 50, 100 and 150 ft, symbolizing the working partnership of the two individual explorers.

Apart from serving as lookout, the viewing platforms also serve a structural purpose, allowing the tower shafts to work interdependently much like the explorers they symbolize.



Making a tricky design work in practice

THP Limited Inc., the engineering firm for the project, received the contract to work on the Lewis and Clark Tower while the client was still expecting to build a CIP structure. "They were concerned, however, about it being structurally sound because it was so skinny," says Shayne Manning, principal-in-charge with THP. The structure is 190 ft tall but only 13 ft 9 in. wide at the base. "We decided it would be structurally feasible to use precast, but because of the aspect ratio [height-to-least width ratio = 13.8], we could see the wind having a dynamic response."

In an unusual design, the precast panel fins that achieve the tower's fluted look increase in size as tower elevation increases, establishing a sense of openness at the top of the structure. "The fluting was actually easier with precast than CIP," Smith explains. To create the fluted look, the panels were cast using self-consolidating concrete (SCC). Smith says precast concrete offered a distinct time and cost savings advantage because of the repetition of the panel shapes. "As the tower goes up, you have the duplication of the two towers, which are both the same all the way to the top," he notes.

Manning says there were only a few different panel shapes and sizes in the project, with the structural panels that make up the towers' sides accounting for more than 170 of the pieces. These panels were over 1 ft thick and consisted of varying dimensions of the same shape that increased slightly in size to create the fluted expansion of the towers as they grew higher. "As the height increased, each panel got a little bit wider on the two sides that had the winged-look panels," Manning explains.

Connecting all of the panels offered a small challenge. The design-build team had to consider how to connect the rebar between the precast panels. The idea was to vertically align the connecting precast panels by aligning the splice sleeves at the base of each panel with the projecting vertical reinforcing bars at the top of the precast panel below. "As the panels went over one another, the rebar would grab the sleeves," explains

▲

Precast concrete fins give the towers their fluted appearance, with viewing platforms at 50, 100 and 150 ft connecting the towers and symbolizing the partnership between the two explorers.

Above and Opposite Page: The site was dedicated on Sept. 23, 2010, and has hosted about 40,000 visitors since its opening.

Jason Martin, project structural engineer with THP.

The structural engineers considered the joining of the panels critical to the ability of the tower to withstand seismic stress given its location within the New Madrid seismic zone. The area around St. Louis was struck by a series of earthquakes 200 years ago, affecting a land area 10 times as large as the infamous 1906 San Francisco earthquake.

Like the towers, the viewing platforms, too, increase in size as the tower height increases. The lower one is 32 ft across and the highest, at 150 ft, is 36 ft across. The platforms were pivotal to the tower's structural design, particularly for maintaining the square shape of the elevator tower. Unlike the stair tower, it did not have internal diaphragms. Because it is so difficult to attain a moment connection at the inside corners with vertical precast panels, the connection of the three observation decks to the tower wall panels helped to maintain the square shape. The decks also keep the towers from rotating in high winds, removing the potential for structural twisting.

The decks themselves presented problems because of their size. As one precast unit, each deck would have been too large to transport by truck, so High Concrete cast each one as two pieces with support from a single center connector beam that spanned the space between the two towers. Both platforms are semi-cantilevered as well.

The tower's tall and narrow design, however, promised challenges with regard to wind-load carrying capacity as well as response to seismic activity. Before tower construction even began, designers subjected the structure's plans to wind testing to make sure the design could withstand severe weather and geologic events and to establish the human comfort level at the various viewing platforms in the event of high winds.

"Because of the structure's [high] aspect ratio, the design team decided that wind tunnel testing was needed to determine the response characteristics in crosswind loads and dynamic torsional loads caused by vortex shedding," explains Lyle Bowman of High Concrete Group. The test lab performed 50 different wind load combinations to test the strength of the tower's design in response to varying wind directions, modal coupling and correlation of wind gusts.

The completed structure consists of 256 precast panels weighing in at about 4 million lb, and comprising 24,700 sq ft. The tower portion of the project cost $4.8 million with the cost of the precast accounting for about $1.35 million.

The Lewis and Clark Confluence Tower held its dedication ceremony Sept. 23, 2010, on the anniversary Lewis and Clark returned to the site of the Mississippi's and Missouri's confluence at the close of their journey to the Pacific Coast. Barnes estimates the facility has had about 40,000 visitors since then. On a clear day, visitors to the tower can see not only the confluence of the Missouri and Mississippi rivers but also the Gateway Arch in St. Louis 19 miles to the south.

"This project really helped me realize the flexibility of precast for building a very tall, thin building," says Manning. "You generally think of precast for parking garages, floors or building facades, but here we had architectural and structural precast working together as a single unit. Every single piece is structural and architectural in purpose." **PS**

Deborah R. Huso is a freelance writer who covers home design and restoration, sustainable building and design, and home construction.

Dream Home

Making an Impenetrable Case For Precast Concrete Construction

Hurricanes, tornadoes, carpenter ants and termites are good reasons to build your new home with precast concrete. There are many more.

By Sue McCraven

Is a precast concrete home measurably different from everything else out there in the homebuilding market? Can a case be made for the overriding advantages of precast concrete in contrast to older, more conventional designs like wood-framed or filled concrete block construction? The most credible answer is found by examining the facts.

Evidence for the use of precast concrete systems is revealed in expert testimony from an Engineer of Record (EOR), project architect, builder/contractor and precast producer. After viewing exhibits for and against precast concrete, the homeowner delivers the final verdict. Court is in session.

Logical Exhibit A: An open-and-shut case for storm resistance

The very best reason for building a home out of precast concrete is the strength and integrity of the material, specifically precast concrete's resistance to storm damage. The frequency of billion-dollar disasters caused by storms and bad weather are depicted in the map on page 23. No matter where you build, you can benefit from the storm resistance of precast concrete walls.

Creepy Exhibit B: Termites can't eat concrete

In the second Exhibit, "B" stands for bugs of the destructive kind. Speaking of home insect infestation and subsequent damage, does a precast concrete home make sense anywhere in the country? From the invasive carpenter ants of U.S. and Canadian northern forests to the ever-hungry termites of more temperate southern regions, a precast concrete home is the best defense against residential insect infestation.

In the United States, termites cause more dollar damage than tornadoes and hurricanes combined.[1]

[1] U.S. residents spend an estimated $5 billion annually to control termites and repair termite damage (Source: www.termites.com/information/statistics).

Whether located in northern or southern states, 90% of American homes are made with wood framing where termites and carpenter ants wreak billions of dollars in home damage every year.[2]

Precaster's Explosive Exhibit C: A 2 x 4 traveling at 296 mph

There's no question that Floridian homeowners, in particular, know dangerous weather. "We've had more than enough experience with hurricanes and tornadoes to understand the severe damages to homes from high winds and driving rain," says John Blanchard, general manager of Quick Wall, a division of Manning Building Supplies, in Lakeland, Fla. In concrete block construction, storm winds were so strong that water was pushed through the exterior stucco, through the block and into homes, leaving behind long-term mold and rot damage.

"Our 5-in. or thicker insulated precast concrete walls use 7,400 psi, self-compacting concrete that is resistant to water penetration as well as damage from flying projectiles during storms," adds Blanchard, "and we can back up these claims with results from a certified testing lab." Orlando's Certified Testing Laboratories data showed that the precast concrete wall system will:

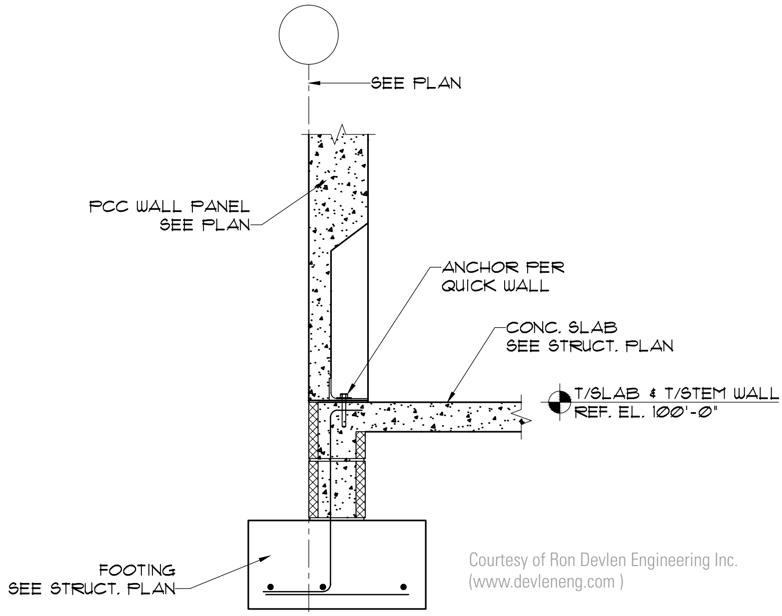
- Exhibit zero water penetration after four days of constant water pressure;
- Resist missile-impact penetration from a 9-ft-long 2 x 4 traveling 296 mph;
- Withstand resisted vacuum and compression tests that simulate tornado forces;
- Pass uniform static cyclic loading that duplicates Category 5 (140 mph) hurricane wind forces; and
- Provide an insulation R-value of 8 and a fire-resistance rating of 1 in./hr.

This gorgeous, 4,200-sq ft coastal style home in Pelican Reef, Fla., has 6-in. thick, precast concrete walls that can withstand Category 5 hurricane-force winds.
Photo Courtesy of John Valdes & Associates (www.johnvaldesandassociates.com)

[2] Source: http://bct.eco.umass.edu/publications/by-title/controlling-termites-and-carpenter-ants/

Precast Concrete Wall on Slab

(Scale: ¾ in. = 1 ft)



Courtesy of Ron Devlen Engineering Inc.
(www.devleneng.com)

© Michael Pettigrew | Dreamstime.com

Architect's Exhibit D: Freedom of design

"The fact that precast concrete construction is termite-proof is a huge factor for any home built on the southeast coast," says Les Thomas, an architect in St. Augustine, Fla. In fact, the Florida building code requires that for termite infestations, contractors spray the soil under slabs with insecticide and cut off all stucco treatments above ground level so that exterminators can check for termite tubes. "If there is any wood in a home," says Thomas, "termites will find it in a warm, humid climate." While a precast concrete home is resistant to insects, Thomas has discovered more important advantages from an architect's point of view.

"Round windows and curved wall panels are some of the design options that are afforded by precast concrete," says Thomas. "The precast system is especially well suited for coastal style homes, because it allows us to angle a house against strong winds while opening it up to the best ocean views for the owner." Thomas cites the pros and cons of building with insulated precast concrete walls panels:

1. Tight precast tolerances mean the system fits together perfectly. Precast works well for two-story home construction, because the walls line up vertically so there is no problem with first-and second-floor alignment;
2. Rapid construction: Walls go up in a few days, where a conventional concrete block design would take weeks of installation. The faster the home goes up, the lower the labor costs.
3. The building site must be accessible by crane for erecting the precast panels.

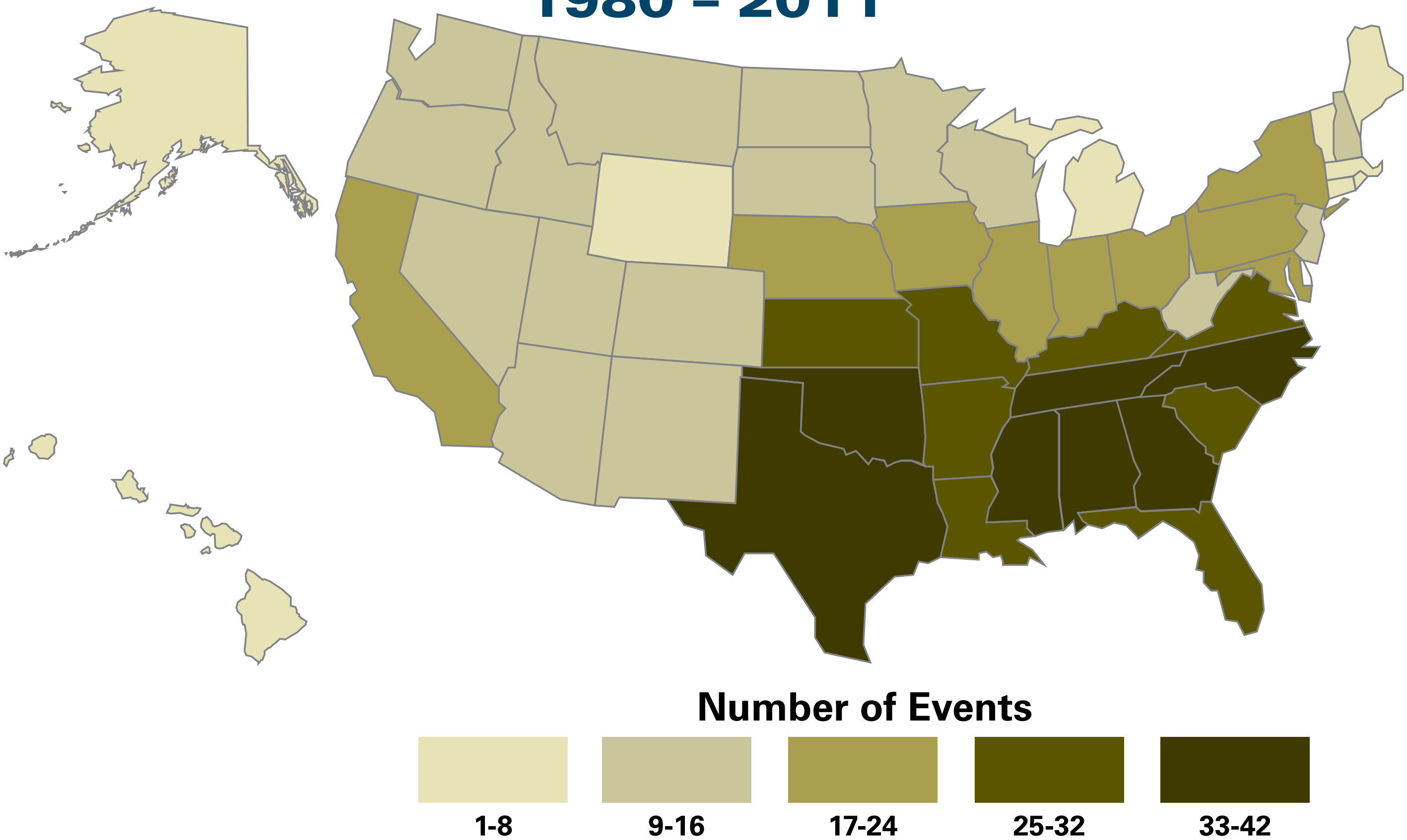
Engineer's Exhibit E: Engineers like precast quality and rapid erection

For Bill Freeman of Freeman Design Group Inc., Lake City, Fla., the precast concrete home in St. Augustine's Davis Shores was his first experience with a precast design. "The biggest advantage of the Quick Wall system in my opinion is the speed of construction," said Freeman. "Secondly, I was impressed with the strength of the wall system. The precast engineer made my job easy. He gave me the specs on how to connect the wall to the foundation and to the roof. The engineering was very efficient." The only challenge Freeman faced was the unstable soil conditions (shallow sand and shell fill over organic marsh material) that necessitated more than 60 helical pilings that went down 30 to 40 ft.

Bill Freeman of Freeman Design Group Inc., Lake City, Fla., says of his first experience with a precast concrete home, "I was very impressed with the strength of the wall system."
Photo Courtesy of Freeman Design Group, Inc. (www.freemandesign.net)

With more than 15 years of structural engineering experience in precast concrete, Ron Devlen, P.E., of Devlen Engineering Inc. in Lake Mary, Fla., might be

Billion Dollar Weather/Climate Disasters 1980 – 2011



an expert witness as a precast concrete specifying engineer. "All engineers understand that a plant-produced product will offer much tighter tolerances than any system constructed at the job site," says Devlen. "The most important asset of precast concrete walls is durability – you've got this huge, 6-in. to 8-in.-thick wall panel, a monolithic piece of concrete, instead of concrete masonry units (CMUs) with many joints, vertically and horizontally."

Both engineers cautioned that homeowners must make detailed decisions earlier in the process with a precast concrete system. 3D modeling can help clients visualize the isometric interior views of the home and make these early-on decisions. "One disadvantage might be cost," said Freeman, "because the precast walls are a more expensive material than wood frame or concrete block construction. But I would think the rapid construction might offset the price increase."

Contractor's Exhibit F: A rare find is a contractor/builder who understands precast systems

"The greatest challenge when building a precast home in an established residential community," said John Valdes of John Valdes & Associates, St. Augustine, Fla., "is accessibility for the large transport trucks and the 200-ton mobile crane used to 'fly' the panels into position." Valdes was the builder for both precast homes featured in this article.

"Precast concrete homes, in my opinion, if designed and built correctly, are the answer to storm wind resistance," says Valdes. He points out, however, that a precast home is only as strong as its weakest link, which for his clients are the 140-mph impact-resistant windows. For the homebuyer concerned about "fire, hurricanes, tornadoes or termites," says Valdes, "precast concrete makes sense and is less expensive than filled CMU construction once you get above one story." The Davis Shores home was erected in four 10-hour days with a six-man crew plus a crane operator, whereas a CMU home would require a seven-man crew working six weeks or more to lay up and pour the cells for the same home.

While strength and speed of erection are at the top of Valdes' list of precast concrete advantages, as a builder he is the first to explain why contractors seem averse to anything new. Valdes explains that "new" to a contractor means: "untested; an expensive learning curve; risk; liability; and potential loss." To counter this natural aversion to something new, the precast

Precast concrete walls will resist Category 5 hurricane winds, 2 x 4s travelling at 296 mph and termite infestation. Quick Wall, A Division of Manning Building Supplies (www.precast-homes.com) supplied the 8-in. thick insulated precast concrete walls made with 7,400 psi strength concrete with an insulation R-value of 8 and a fire rating of 1-in./hr.
Photo courtesy of John Valdes & Associates (www.johnvaldesandassociates.com)

industry has work to do. Precasters need to educate contractors and address any hesitation to building with a new system by providing everything from engineering assistance and an experienced erection crew to information on precast concrete's advantages and how rapidly built homes mean more jobs completed and more profits.

Owner's Exhibit G: Silence and security are the basis for a homeowner's final verdict

Testimony from the EOR, the precast concrete specifying engineer, the precast producer and the contractor builds a strong case for the advantages of precast concrete homes and also explains potential drawbacks. But there's one important person we haven't heard testimony from: the homeowner.

Bill and Shelley Desvousges have lived in their Pelican Reef home for more than a year. "We knew we wanted to build a precast concrete home," says Shelley Desvousges, a retired judge, "but we were surprised on so many levels. It's not just the solidity and security of our home, but even with lots of windows, it is cozy and quiet – we actually have to look outside to see if it's raining." Precast concrete was less expensive than a CMU home, and the Desvousges wanted to feel confident in the security of their dream home during hurricane season.

The verdict would be the homeowner's assessment: "The precast concrete walls are why I love this home," said Desvousges. "It feels so solid, so cozy, so good!" And the heating and cooling bills in their precast home are consistently lower than that of their smaller first home. ps

Sue McCraven, NPCA technical consultant and Precast Solutions editor, is a civil and environmental engineer.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Geotechnical & Soils Engineering:

A Solid Foundation

By Evan Gurley

In addition to agriculture, people have historically used soil as a construction material for foundations, buildings and flood control. As early human settlements expanded, structures were erected and supported by formalized foundations. Until the 18th century, however, no theoretical basis for soil design had been developed, so the discipline relied more on past experience than science.

Leaning Tower of Pisa: something is up

Several foundation-related engineering problems, like the differential settlement of Italy's Leaning Tower of Pisa, prompted a more scientific approach to examining the subsurface. The earliest documented advances in soil mechanics occurred in 1717 when Henri Gautier developed earth pressure theories for the construction of the retaining wall. Since then, there have been significant advancements in the science and engineering behind soil mechanics. In 1925, there was major progress with the publication of *Erdbaumechanik* by Karl Terzaghi (considered to be the father of modern soil mechanics and geotechnical engineering). Terzaghi developed the principle of effective stress, demonstrated that sheer strength of soil is controlled by this effective stress, and created the theories of foundation-bearing capacity and the rate of settlement due to consolidation.

Structural performance depends on firm footing

Today's geotechnical engineers perform investigations to obtain information on the physical properties of soil and rock underlying (and adjacent to) a site and use this data to design earthworks and foundations for proposed structures. Geotechnical investigations include surface and sub-surface explorations to ensure that the proposed building site's soils and/or bedrock are suitable for placement of precast concrete structures.

Proper installation of precast concrete products is critical for maintaining structural integrity. The modular nature and simple joint connections of precast concrete components enable fast assembly. Proper installation once on site ensures structural performance while maintaining a safe work environment.

Precast concrete products differentiate themselves from alternative products in that the load-carrying capacity of precast concrete is derived from its own structural integrity, not from the adjacent soil or consolidated backfill. A precast concrete product can be designed as a separately engineered unit or system to withstand all loading conditions, unlike other products that must rely on adjacent soils to meet specified in-service strengths.

Subgrade soil conditions will affect the overall performance of any bearing structure, therefore it is important that precasters adhere to local and industry-wide standards, codes and best practices when dealing with the actual design, site preparation and installation of precast concrete products. Producers can also assist the owner, contractor and inspectors through organized and accurate scheduling of materials, construction procedures, contract documents, plans and specifications.

Precast concrete complies with industry best practices

Precast concrete manufacturers adhere to local and industry-wide standards (ACI, ASTM, etc.) and

Diminishing Soil Pressure

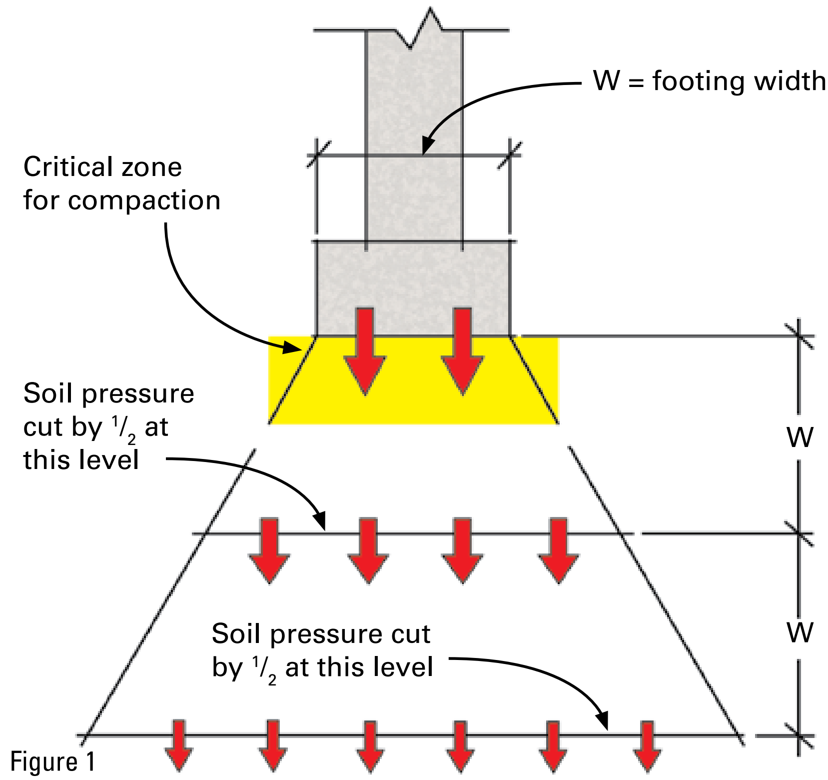


Figure 1

regulations that specify precast concrete products are to be placed and installed on level, compacted gravel, sand or stone sub-bases. Compacted gravel or stone sub-bases allow water to drain away from the installed product, minimizing the possibility of settlement. Rainwater standing or running alongside an installed underground product may cause differential settlement. If soil grading is such that water runs alongside a precast concrete product during rainfalls, the water can flow under the edge of the precast structure and carry away the supporting soil.

Having a level, sound sub-base specified for placement of a precast concrete product is crucial as the weight of the structure is distributed directly to the supporting soil. Soil pressure from direct loading is greatest immediately beneath the precast concrete product, and the load distribution spreads out as the depth of the affected soil increases. Figure 1 illustrates the distribution of loads beneath a foundation/footing and points out the location of the critical compaction zone. If a product is installed with improper compaction, the critical zone would be the first place for failure due to settlement or structural shifting.

Informed installation

In order for installed precast concrete products to be as effective as possible, engineers, contractors and building officials who address underground installations should have a thorough understanding of installation best practices. Precast concrete manufacturers typically provide proper best practices and installation literature and/or assistance to the end user of the precast product, based on engineering calculations and industry guidelines. In addition to providing the appropriate literature and assistance, precast concrete manufacturers frequently check the installation sites prior to the installation or upon request.

Designing a precast concrete product with proper accuracy is just as essential as placing and installing the product on a properly prepared subgrade. Unsound design practices, whether preproduction or site preparation, can jeopardize the service life of the structure. Adherence to all local and industry-recognized codes is essential in construction and design practices; failure to follow best practices could result in costly product and site remediation.

Site preparation

Things to consider during the site preparation phase of the project:

- Review the approved site plan to confirm lot lines, precast location, length and elevations.
- Schedule preconstruction meetings.
- Verify the on-site soil conditions.
- Call the local utility companies to confirm the location of underground utilities.
- Obtain all necessary building permits.
- Confirm drainage to avoid erosion or buildup of water behind the structure.
- The contractor/installer is responsible for the positive drainage away from the precast structure during construction.

Excavation

Excavation is one of the first factors that should be addressed in the design of a subgrade.[1] During excavation, the contractor should be required to remove any materials that do not comply with the IBC[2] code (rubbish debris or organic material) or other specified codes and standards. Removing materials and soils listed in the IBC codes helps create a level, firm subgrade and eliminates settlement or shifting (causing cracking) that can occur on sites with poor substrate.

It also must be realized that while excavating the soil, excavation forces loosen up the adjacent undisturbed soil by mixing air into the substrate, which decreases soil density. A decrease in soil density results in a loss in the load-bearing capacity, or the loss of the ability of the soil to adequately support loads. Proper compaction of the disturbed native soil or imported fill material is needed for excavation-affected soils to regain their intended design-density properties. All excavation and consolidation factors, geotechnical considerations and related variables must be taken into account in the design stage.

Foundation preparation

Foundation soils should be excavated as required to the dimensions shown on the plans. Soil should be inspected by the geotechnical engineer to confirm that the bearing soils are similar to the design criteria. Foundation soils are to be proof-rolled and compacted to a minimum of 95% of the maximum dry density (ASTM D698, Standard Proctor) and inspected by the owner's engineer[3] prior to placement of leveling pad materials. The contractor is required to replace any unsuitable soils discovered during excavation at the direction of the geotechnical engineer.

Backfill

The engineer specifies the compaction of all fill materials in proper lifts, whether native soil or a granular fill material, to provide a dense, flat subgrade. If the fill material is not compacted uniformly, uneven settling of the precast concrete product can occur, resulting in cracking. If the engineer calls for backfill lifts that are too deep to facilitate proper compaction, the product resting on fill soil could be subject to leaning, buckling and possible collapse.

Compacted fill material

Compaction is the process by which the strength and stiffness of soil may be increased and permeability may be decreased by a specific degree of consolidation. There are six reasons why proper fill materials and compaction methods are essential for designing a sound subgrade for an installed precast concrete product. Properly compacted subgrade soil:

1. Provides stability;
2. Reduces water seepage and swelling;
3. Reduces settling of soil;
4. Prevents soil settlement and frost damage;
5. Increases the load-bearing capacity; and
6. Provides good drainage properties that can prevent weakening of the foundation.

If improper fill materials are used, adverse effects such as settlement, differential settlement, leaning or tipping of the installed precast concrete product may occur. Differential settlement will damage the installed precast concrete product by producing (usually vertical, possibly diagonal or stair-stepped) cracks and other symptoms of structural movement. Improper use of compaction machinery may inflict damage to the installed precast concrete product in the form of breaks, buckling or leaning.

Conclusion

Some precasters do not deal directly with the site preparation and installation of underground products. Rather, they rely on seasoned geotechnical engineers who understand how a precast concrete product is to be installed according to local and industry-wide codes/regulations dealing with the existing soil conditions and best practices.

Precasters who do it all, including the site preparation and installation of a product, realize the importance of proper installation and best practices and ensure that local codes and regulations are met. For example, precast concrete retaining wall producers have developed an excellent field installation best practices manual[4] and continue to educate the industry with the development of literature and their continued involvement with standards development. PS

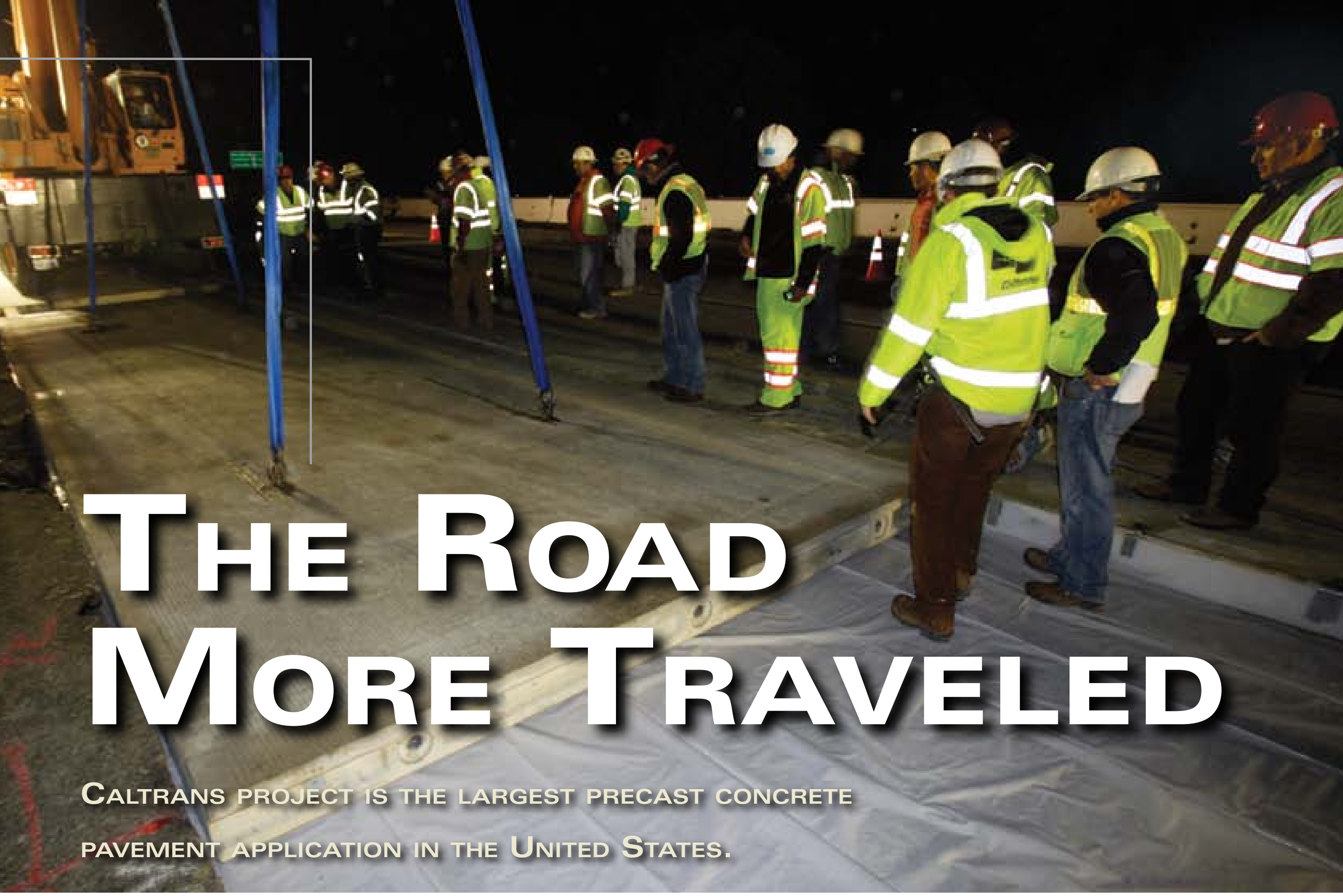
Evan Gurley is a technical services engineer with NPCA.

[1] See "Prevent Excavation Cave-in Fatalities," by Evan Gurley, March-April 2012 *Precast Inc.* magazine.

[2] International Building Code

[3] "Engineer" refers to the owner's designated organization or trained and experienced individual with authoritative charge over engineering functions and responsibilities.

[4] NPCA's Precast Modular Block (PMB) for Retaining Wall Systems, Field Installation Best Practices Manual, is an example of available technical support literature. Visit http://precast.org/wp-content/uploads/docs/PMBInstallBPM.pdf (case-sensitive).



The Road More Traveled

Caltrans project is the largest precast concrete pavement application in the United States.

By Sue McCraven

The road to a bright future for drivers, taxpayers and precast concrete transportation products is being paved in sunny California.

Caltrans materials engineers are particularly excited about this I-680 project, as it includes some innovative construction methods – including a strategy to use precast/prestressed concrete paving slabs to replace damaged and worn-out road surfaces. This is the largest-ever precast concrete roadway application of its kind in the United States and is expected to reduce long-term roadway maintenance costs.

Con-Fab California Corp. of Lathrop, Calif., produced 8-ft to 36-ft long precast/prestressed concrete paving (PPCP) slabs for the 13-mile-long Caltrans rehabilitation project. State and federal roadway funds were used for the $54 million project, which began in January 2011 and is scheduled for completion this spring.

Repair to the 1960s-era infrastructure includes traffic lanes, shoulders and ramps that take on more than 170,000 vehicles per day. Work takes place at night when the lanes are closed to traffic, complementing the great advantages of precast concrete of durability and strength at installation, meaning that vehicles can drive on the lanes as soon as the panels are in position.

More than seven miles and six lanes of an eight-lane freeway between San Ramon and Alamo (suburbs of Oakland and San Francisco) were retrofitted with the 8.5-in.-thick precast concrete slabs. That's about 8,200 cu yd of precast concrete making up more than half of the project.

According to Caltrans, which began implementing its Long-Life Pavement Rehabilitation Strategies (LLPRS) program in 1998, the goal is to rebuild about 1,750 lane-miles of high-volume freeway with pavement materials designed to last more than 30 years with minimal maintenance. Durable precast concrete pavement slabs are well-suited for this mandate, as they will reduce the need for future interruptions from road repair projects and will ultimately save public resources for travelers down the road. **PS**

Sue McCraven, NPCA technical consultant and Precast Solutions editor, is a civil and environmental engineer.

Air Entrainment versus Air Entrapment

All air voids in concrete are not created equal. Find out the difference between beneficial air entrainment and accidental, or detrimental, air entrapment.

By Claude Goguen, P.E., LEED AP

In regions where temperatures can frequently fluctuate near freezing, freeze-and-thaw cycles pose one of the greatest challenges to concrete durability. Capillary voids will form during concrete production, so protection against capillary ice damage must be designed into the precast concrete product. Air-entraining admixtures are one part of the solution that will prevent damage from freeze-thaw conditions.

The importance of entrained air was first noticed during the 1930s, when certain highway sections were found to be more immune to the effects of freezing and thawing than others. Studies traced it to cement that was milled at plants using beef tallow as a grinding agent. The beef tallow was an unintended air-entraining agent, and it improved the durability of the concrete.

During hydration, the reaction of water and cement leaves capillary cavities, or voids, that become filled with water when a precast product is exposed to wet conditions. As the capillary water freezes inside concrete, it expands about 9% in volume. The water-to-ice volume change exerts internal pressure inside the concrete that exceeds its tensile strength, causing cracking, spalling and eventual disintegration. Entrained air pockets provide a relief system for internal ice pressure by providing internal voids to accommodate the volume expansion caused by freezing water.

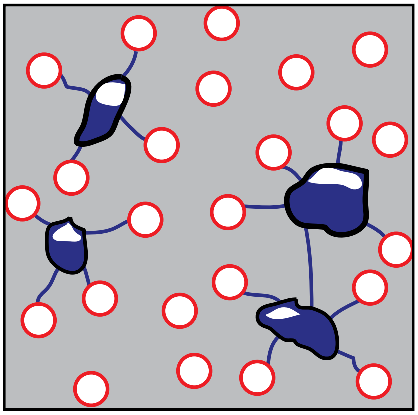
Entrapped air is problematic

It is important to note that entrained air is not the same as entrapped air. Entrapped air is created during improper mixing, consolidating and placement of the concrete. Air pockets, or irregularly sized air voids, are spread throughout the concrete and have negative effects on product appearance, strength and durability. Proper vibration techniques can be helpful in removing entrapped air.

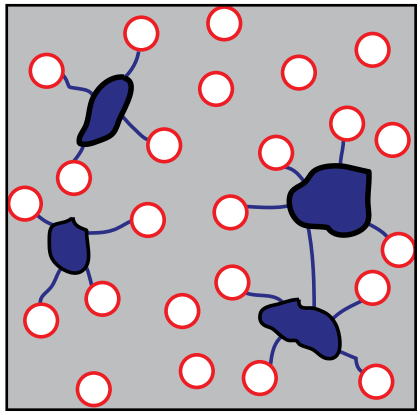
Entrained air is intentionally created by adding a liquid admixture specifically designed for this purpose. The goal is to develop a system of uniformly dispersed air voids throughout the concrete. Proper use of air-entraining admixtures ensures the development of the correct spacing, size (usually measured in micrometers) and amount of these voids. These voids absorb the pressure created by the expansion of the freezing water.

Spacing and size of entrained air make a difference

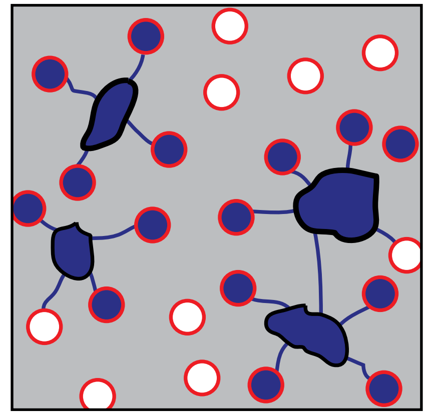
The criterion for spacing is defined as the maximum distance the water would have to move during freezing before reaching the safety valve, or capillary void, of an air reservoir. This recommended average "spacing factor" should not be greater than 0.008 in., according



As temperatures drop, pores created by air entrainment allow the water a place to go as it freezes.



During freezing, water in the capillary pores expands; however, water is also going toward air-entrained pores.



Under pressure, the water will be pushed into the air entrainment pores and not crack the concrete matrix.

to ASTM C457, "Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete."

The size of these voids is also important. The "specific surface" is the average surface area of the voids in hardened concrete per unit volume of air. The specific surface necessary for adequate resistance to repeated freezing-and-thawing cycles is recommended to be greater than 600 sq in./cu in.

One of the concerns with air-entraining admixtures is that they can decrease the strength of the concrete. Typically, an increase of 1% in air content will decrease concrete's compressive strength by approximately 5%. Therefore, it is important that air content be closely controlled. The NPCA Quality Control Manual for Prestressed and Precast Concrete Plants recommends air content tests be conducted for at least every 150 cu yd of concrete produced and not less than once a day when air entrainment is used. However, state and local specifications may require more frequent tests. The air content test should be conducted in accordance with either ASTM C173-10b, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method," or C231-10, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method." Note that ASTM C173 requires all samples for acceptance testing be taken from the middle third of the batch.

The recommended air content varies with the severity of exposure and aggregate size. For instance, 3/8-in. aggregate with a severe exposure (frequent freeze-thaw cycles) requires 7.5% air content, while the same aggregate with moderate exposure requires 6% air content. A 1-in. aggregate requires 6% for severe exposure and 4.5% for moderate exposure. Air-entraining agents are generally added to the mix in a range from 0.25 to 2 fl. oz./100 lb. of cementitious materials. This is a broad range, and proper dosage should be determined after consulting the admixture supplier, and considering mix design, materials and trial-batch test results.

Many mechanisms affect air content

Many factors affect entrained-air stability:

- Finer cements with low alkali content
- Fly ash mixtures and an increase in fine aggregates passing the No. 100 sieve
- Dust and very fine material on coarse aggregates
- Hard mixing water (high mineral content)
- Detergents that can add soap bubbles
- Other chemical or mineral admixtures such as water-reducing agents and superplasticizers used in the concrete mix
- Batch size and mixer settings (rotation rates and times)

Every mix component – from cementitious material to aggregates and water, as well as methods used for batching, mixing, placing, consolidating and finishing – can affect the final air content, so production steps must be monitored closely. All these production variables mean that trial batches are necessary to determine the appropriate amount of air entrainment.

What goes into air-entraining admixtures?

Today's air-entraining admixtures are primarily liquids produced from byproducts (salts) of wood resins. However, there are new products made from synthetic detergents, sulfonated lignins, petroleum acids, proteinaceous materials and sulfonated hydrocarbons. There are also particulate air-entraining admixtures composed of hollow plastic spheres and crushed brick. Although outside the scope of this article, there are air-entraining cements that meet ASTM C150, "Standard Specification for Portland Cement." These cements have an "A" identifier, such as Type IA or IIIA.

The specifications for air-entraining admixtures are covered in the ASTM C260-10a, "Standard Specification for Air-Entraining Admixtures for Concrete." This specification sets limits on the impact of the admixture for concrete bleeding, set time, strengths, compressive and flexural strengths, freeze-thaw resistance, and length change during drying. The manufacturer of the admixture should guarantee that its product meets this specification.

Entrained air is one of the critical techniques available to precasters to reduce the impact of freeze-thaw processes and ensure the durability of precast concrete in severe climates. Because so many production variables can affect air entrainment, careful monitoring and trial batch testing are the foundation for proper air entrainment and a long service life for exposed precast concrete products. PS

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