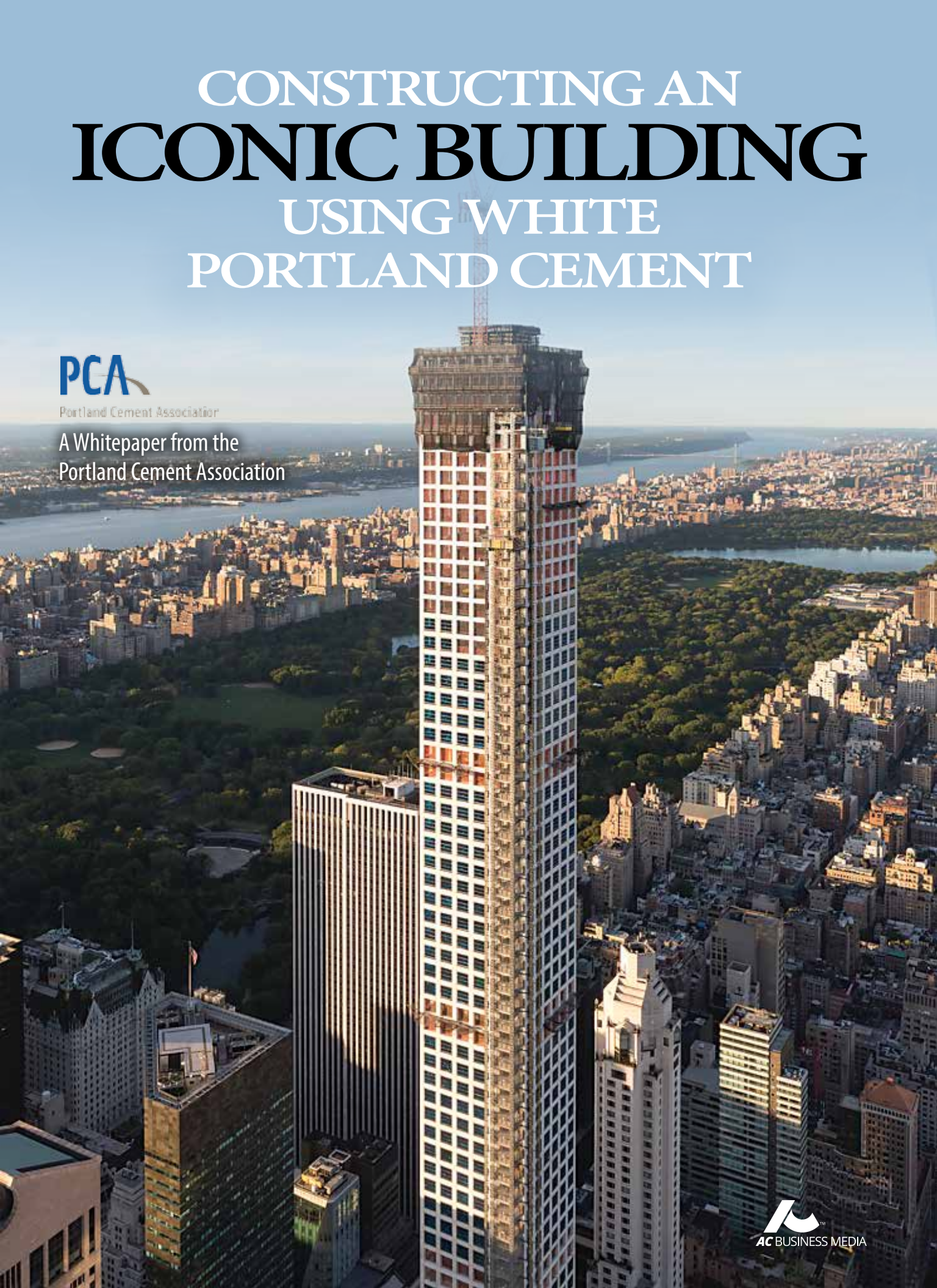


CONSTRUCTING AN ICONIC BUILDING USING WHITE PORTLAND CEMENT



Portland Cement Association

A Whitepaper from the
Portland Cement Association



Constructing an **ICONIC BUILDING** Using White Portland Cement

Creating architectural concrete with white portland cement. Concrete dominates the super-tall market.

By Joe Nasvik

Named for its address, 432 Park Avenue is an upscale condominium project located in the heart of Manhattan, close to Central Park, Rockefeller Center, and Broadway. It is the tallest residential structural concrete building in the western hemisphere at just under 1,400 feet in height, also remarkable because of its small footprint — 93 feet square. Exterior faces consist of white concrete columns and horizontal spandrel beams with 10 x 10 foot windows allowing wide range views of Manhattan.

Developers Macklowe Properties and CIM Group, New York City, conceived the idea for the \$1.25 billion project. Construction for the building began in the fall of 2012 and the building “topped out” in October of 2014.

The structural concrete work was performed by Roger & Sons (R&S), New York City, a third-generation family business started in 1975. With experience in mid-rise and high-rise concrete construction, including two 500-foot tall buildings and the concrete work for the “Building 4” project at the World Trade Center, they had the necessary references to bid the Park Avenue job.



The exterior faces of the building feature cast-in-place concrete made with white portland cement. The goal was to provide an architectural light colored concrete that shows the richness of concrete as well as a sustainable finish. Photos by Joe Nasvik

Engineering the structure

The building consists of two structural tubes, one inside the other; the core and the external columns. The two-foot thick core houses the elevators, emergency stairs, and utilities. It provides safe access for occupants and primary load-carrying capacity

for the building. The forty-four inch wide exterior columns spaced 15 feet, six inches apart are connected by horizontal spandrel perimeter beams (also 44 inches wide) to form the exterior perforated tube, the depth of these elements decreasing as the building goes up. Ten-inch



The decision to use #20 grade 97 rebar for vertical reinforcement reduced congestion and was cost productive. With the deformations in a threaded pattern, couplers could be used to join bars together and transfer load. Photos by Joe Nasvik

thick highly reinforced concrete floors join core to columns and act as a diaphragm, adding stiffness to the building.

For tall buildings, engineers must consider wind shear. The strength and shape of the structure are selected and designed to resist wind forces. Two windowless, open floors every twenty stories house mechanical equipment and allow wind to pass through the building to reduce wind shear. In addition a “tuned mass damper” on the top floor reduces building acceleration.

Upgrading the normal Grade 60 steel rebar to Grade 97 rebar for vertical reinforcement reduced congestion. The No. 20 (2-1/2 inch diameter) “thread bars” are delivered to the site pre-cut with a threaded pattern. They are joined by threaded couplers for transferring load. Pete Rodrigues, R&S’s manager for the project, says material was more expensive but reduced labor, making it a cost effective choice.

Planning for construction

Building a project of this magnitude requires much preparation, planning, and value engineering. From the start, R&S enlisted the help of sales engineers from DOKA, and PERI Formwork Systems, to include the latest in forming technology.

The specifications required a four-day cycle per floor for the first 50 floors and a three-day cycle after that. Each cycle starts with casting the core structure — two floor levels above floor construction. The external columns and perimeter beams follow by one day and are cast with white portland concrete. Casting the floor is the last operation before moving all the formwork up to the next level.

Establishing and tracking horizontal and vertical geometry for a building like this is challenging because it constantly vibrates due to

wind and construction activity. The solution: a fully integrated system from Leica: GPS receivers, triple frequency antennas, tilt meters and a one-second robotic total station with software to locate points even during building movement.

Forming systems

R&S used DOKA’s new “SCP Super Climber” forming system to build the core. It consists of inside and outside gang forms surrounding the core, along with three completely decked out levels of working and material storage platforms all moving as one unit. A deck carries the concrete placing boom and a three ton, 50-foot telescopic crane boom for lifting reinforcing steel, and supports five floor levels of temporary stair towers for worker access and egress. Forms are stripped from the concrete each day after placement. One button activates hydraulic cylinders that lift the entire assembly to the next level to start the next cycle.

DOKA’s self-climbing rollback system is also being used on this project. The five-floor level climbing system surrounds the perimeter of the building to provide workers with multiple levels of wide, safe work decks for setting and stripping forms, removing anchors, patching the architectural exterior surfaces,



With the core structure on the right and the exterior columns and spandrels on the left of the photo, the 10” thick “flat plate” floors act as a diaphragm, joining the two vertical elements together. Photos by Joe Nasvik

and windows. It also supports columns and perimeter beam forms. These custom-made hinge-forms have stainless steel face sheets (for an as-cast white portland architectural finish), allow stripping of columns and perimeter spandrel beams as a unit, and are rolled backward on the climbing platform so that the entire assembly can be hydraulically moved to the next floor in a single operation.

Concrete, the most important part

The performance requirements for the concrete were developed by the engineer, requiring:

- High compressive strength — up to 14,000 psi
- High modulus of elasticity (MOE) — 7.7 msi (millions of psi)
- Self-Consolidating Concrete (SCC) — 30-inch spread requirement.
- White portland cement concrete with good color consistency
- Low heat of hydration — columns and other building elements were considered mass concrete, not to exceed 160°F.
- A pumpable mix for the entire height of the building
- Two-hour plus working time
- Low shrinkage
- Concrete floors "walking-hard" within five hours of placement in all weather
- Mixtures must have the same performance criteria in all weather
- Sustainable mixtures — 70 percent portland cement replacement with pozzolan materials.

Ferrara Bros. Building Materials Corp. has a long-standing business relationship with R&S and provided helpful information during the bid phase. Ferrara likes demanding concrete projects. Their subsidiary, Aggregate and Concrete Testing LLC, is one of only three NYC concrete producers licensed by the NYC Department of Buildings to issue its own mix designs. Ferrara's admixture supplier, BASF, was brought in early on and started working on mix

Working with white portland cement

Ready-mix producers and concrete contractors typically have little experience with white portland cement concretes, where different cement chemistry can affect behavior.

Cement clinker is composed of four primary chemical compounds that are carefully regulated by cement manufacturers; tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminatoferrite (C_4AF). The C_3S is primarily responsible for early setting and strength gain, C_2S for ultimate strength, C_3A for early heat generation and early strength, while C_4AF allows manufacturers to reduce the temperature needed in the kiln. C_4AF also imparts the gray color to cement. Making

portland white is primarily achieved by limiting the amount iron and magnesium oxides (C_4AF), which is normally about 8 percent of the clinker but is 1 percent or less in white portland. This reduction increases the percentages of the other ingredients, causing the overall strength of white portland to increase too.

Chemical admixture performance is closely related to cement chemistry, especially to the C_3A content, which can vary significantly between any given cements. Knowledge of cement chemistry and admixture interaction allows ready-mix producers, manufacturer representatives, and admixture experts to work together to produce concrete mixes that meet project requirements. Early involvement is critical.



By pressing a button R&S certified staff move the core forms, temporary steps, the placing boom, and a 6-ton crane 16-feet upward to start construction at the next level.

Photos by Joe Nasvik

development eight months prior to the start of construction. They did an Eco Efficiency Analysis, measuring the concrete's impact on the environment, water emissions, and transportation impacts.

In the past, designing concrete to meet high MOE requirements required casting samples and running tests a year or more in advance of the project. Predictive modeling software has drastically cut this time. Test mixes and mock-up panels

so critical for architectural concrete applications were tested and placed at one of Ferrara Bros. batch plants. These confirmed high early strengths for each of the high-compressive strength white cement mixes, pumpability, consistent setting times in all ambient temperatures, and concrete temperatures 160° F maximum.

Architectural mixes included local coarse and fine aggregates, slag, silica fume, high-reactivity

metakaolin (a light colored calcined clay that adds strength and increases the concrete density), white portland and gray portland cement, and admixtures to manage the low w/cm ratios, provide slump and setting time control. Not all ingredients were used in each mix. Ferrara says performance was maintained through constant changes (mostly by tweaking admixture dosages) to manage ambient conditions, transportation time, and placement issues, as allowed by NYC's current Building Code.

Placing concrete

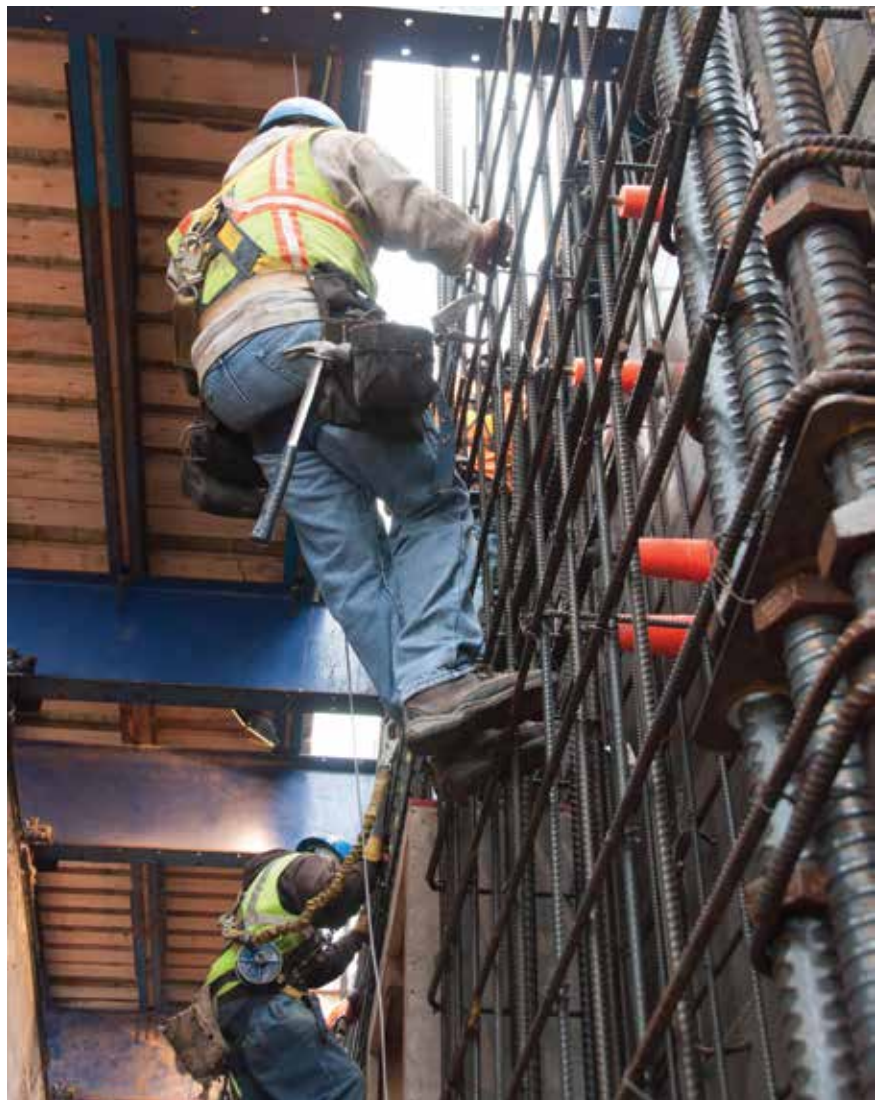
R&S dedicated two concrete pumps for the job (one stand-by pump) which delivered all the concrete to the placing boom on the core-form deck through a "slick line" mounted to the side of the building. Rodrigues says they typically placed concrete at 40 to 50 cubic yards per hour.

Concrete strength varies with building height — 14,000 psi for the first 40 floors, 12,000 psi for floors 40 to 51, and 10,000 psi for floor 51 and higher. During winter pours when temperatures were above 25° F, the space below the floor forms was enclosed and heated to ensure good setting times.

Weather is the uncontrolled variable, especially true for super-tall building construction, because conditions can be very different 1000 feet above grade. For instance, rain at ground level might be sleet, snow, or ice at the construction level. Wind speed increases and drops in temperature occur that can change setting times or cause surface crusting problems. While adjustments can be made to concrete mixes, worker safety and comfort takes precedence and should be considered in establishing pour schedules.

Concrete versus structural steel

Today almost all super-tall buildings, especially residential, are constructed with structural concrete. Concrete construction costs have decreased, primarily



The exterior forms for the core roll outward five feet on the blue I-beams at the top of the picture, allowing the iron workers room to place reinforcement. Photos by Joe Nasvik



Stainless steel-hinge forms for the architectural column and spandrel beams are attached to the self-climbing scaffold system and move with the scaffold.

Photos by Joe Nasvik

Looking down from above, workers use the top floor of the five story DOKA self-climbing deck system to erect column reinforcement.



Building Information

Height: 1396 feet from street level

Footprint: 93 feet square

Floor to Floor height: 15'6"

Finished Ceiling Height: 12'6"

Windows: 10 x 10 feet tri-pane glass

Residential Floors: 96

Residential Units: 104

Steel Reinforcement: 10,000 tons

Concrete: 70,000 cubic yards



due to improvements in concrete pumping and forming technology. Concrete provides a very safe working environment; workers stand on concrete floors or plywood floor deck, no one has to walk out on a steel beam.

Both owners and building occupants appreciate the advantages of concrete construction. If this was a structural steel building, more noise would be transmitted between floors and floor thicknesses would increase from the 10-inch thick

“flat-plate” concrete method used to 20 inches or more for steel beam construction, translating to fewer floors for the same height building. Structural steel construction typically requires a minimum five day cycle per floor.

Occupant comfort is improved in concrete buildings: they sway less due to wind shear than structural steel ones (building movement makes people nervous) and temperatures are more consistent even though energy costs are

The 10-foot square windows are moved into place from inside the building. Workers on a lower floor of the self-climbing deck secure them to the building and apply weather-seal.

Photos by Joe Nasvik

typically lower due to thermal mass.

Our world today is more concerned about sustainability and concrete structures offer advantages. Over 70 percent of the portland cement in the mixes for this project were replaced with supplementary cementitious materials (SCMs) to minimize the concrete’s carbon

Project Participants

Developer: CIM Group / Macklowe Properties, NYC

Design Architect: Rafael Viñoly Architects NYC

Executive Architect of Record: SLCE Architects, NYC

Structural Engineer: WSP Cantor Seinuk, NYC

Construction Manager: Lend Lease, NYC

Foundation: Mayrich, NYC

Concrete Contractor: Roger & Sons, NYC

Ready-mix Concrete: Ferrara Bros. Building Materials Corp, NYC

Concrete Consultant: BASF, Cleveland, Ohio

Core Forming System: DOKA, Little Ferry, New Jersey

Exterior Climbing Forms and Deck: DOKA

Floor Forms: PERI, Valley Cottage, New York

Concrete Pump: Putzmeister, Acworth, Georgia

High Strength Reinforcement: SAS Stressteel Inc., Fairfield, New Jersey

footprint. Clearly, many of the advantages of concrete apply to buildings of all heights, including low- and mid-rise structures, too.

432 Park Avenue

432 will receive a LEED certification upon completion. But the more important measure will be sustainability — how much energy the building will use over time, including its ultimate destruction and recycling. It could “live”

for hundreds of years with low maintenance and low energy costs.

There are several buildings in the world taller than 432 Park Ave but it's thought to be the tallest all-residential structure in the world and the second tallest building in the U.S., behind the Willis Tower in Chicago. The design is sleek and attractive, the construction and engineering are state-of-the-art, and its occupants will enjoy living in a safe, energy efficient environment. ■



R&S uses PERI's hand-set "drophead" floor forming system, allows workers to safely set them in place from below. Photos by Joe Nasvik



The requirements for the concrete mixes are challenging. Ferrara Brothers deliver pumpable SCC mixes that will eventually be pumped 1,300 feet straight up. Photos by Joe Nasvik