Yanzhou Verteiler 3: Crew arranges heat exchanger tubing at Yanzhou hospital site in China *(Photo: Enercret)*

FEATURE ARTICLE

International Cooperation Expands Energy Foundation Technology

Energy foundations continue to gain popularity worldwide. Industry experts and academics from four continents are working together to advance this environmentally-friendly technology.

Professor Heinz Brandl, Vienna University of Technology, who pioneered the technology some 30 years ago, said Austria, Germany and Switzerland have completed the most energy foundation projects he knows of. England has added more in recent years, according to Brandl, and China and [South] Korea also are adopting the technology, mostly with Austrian know-how. Australia is starting the technology as well. Brandl lists additional countries with energy foundation projects: Belgium, Canada, Dubai, Finland, France, Italy, Japan, Liechtenstein, Netherlands, Slovakia, Spain and the United States.

Europe

Recent activity in the United Kingdom and mainland Europe indicates significant steps toward refining the design of energy foundation piles.

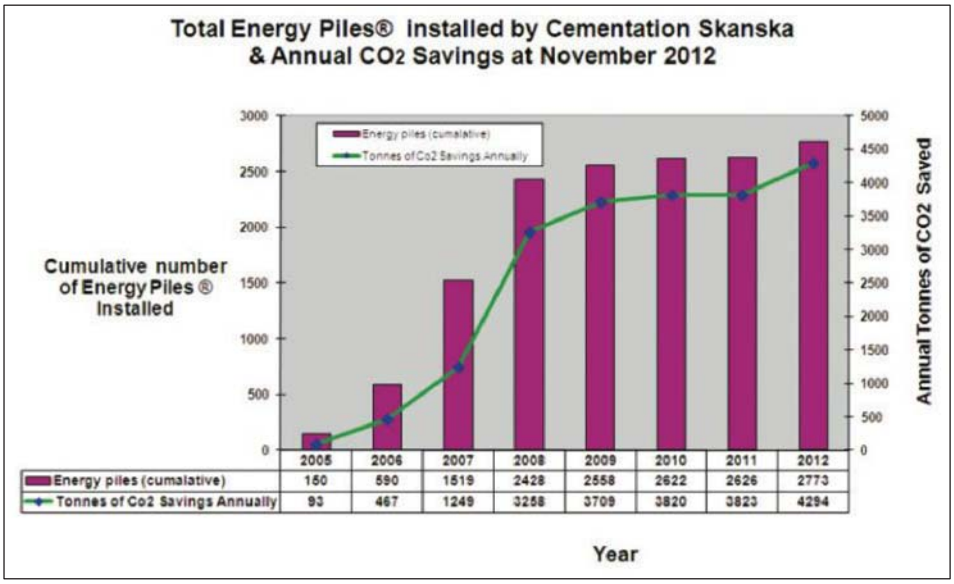
Research. "Thermo-mechanical behaviour of energy piles," published June 2012 in *Geotechnique,* summarizes the results of three published field studies. The article was co-authored by Binod L. Amatya, Halcrow Group Limited, London; Kenichi Soga, University of Cambridge; Peter J. Bourne-Webb, Instituto Superior Techico, Lisbon; Tony Amis, Geothermal International (GI), Coventry, England; and Lyesse Laloui, Ecole Polytechnique Federale de Lausanne (EPFL), Lausanne, Switzerland. Energy foundation piles were studied in buildings at Lambeth College in England, EPFL in Switzerland and Bad Schallerbach in Austria.

The field studies examined pile-soil interactions that occur as energy foundation piles expand and contract during heating and cooling cycles. The authors attributed differences in pile response to thermo-mechanical load among the three trials, mostly, to ground conditions, end restraint and thermal load. They concluded that the heating and cooling of energy piles are unlikely to have detrimental effects on buildings, provided that:

- Design concrete stresses are not exceeded.
- Conventional factors of safety for skin friction and end bearing are maintained.
- Foundation settlements are limited.

"Energy Pile Performance and Preventing Ground Freezing," presented at the 2012 International Conference on Geomechanics and Engineering in Seoul, South Korea, addresses concerns that excessive temperature changes in the ground affect pile capacity. Such concerns may result in overly conservative energy foundation designs, specifically temperature limits for the thermal fluid circulating in the piles. Authors Fleur Loveridge and William Powrie of the University of Southampton, U.K., and Tony Amis of GI, used typical heating and cooling demand profiles applied to numerical models of pile heat exchangers to examine the likely temperature differences between the thermal fluid and the ground during heat pulses of different magnitudes and durations.

AUTHOR *Sharon Boranyak, Independent Technical Writer, Topeka, Kansas*



Current design practices, the authors said, typically do not allow thermal fluid temperatures to fall below 0°C *and* require a 2° safety margin. In contrast, the authors' calculations of typical operational temperature patterns applied to a 600 mm (24 in) diameter pile determined that, even for a fluid temperature of -1°C, the edge of the pile remained at least 1°C above freezing. Thus, the authors concluded that less-conservative fluid temperature limits could be adopted because:

- A temperature gradient between the fluid and the pile edge always exists.
- Short-term, high-magnitude heat fluxes do not reach the pile edge; the concrete is effectively insulating the ground from these variations.

Professor Brandl comments that while a fluid temperature of -1°C is of course possible, he is not much in favor of "squeezing" theoretical limits in practice, noting his concern about additional risk of long-term detrimental effects to concrete. The Austrian energy pile limit of 0°C, he said, "is still economical."

New Thermal Pile Standard. In September 2012, the U.K.'s Ground Source Heat Pump Association (GSHPA) released a thermal pile standard. GI's Tony Amis said the new GSHPA standard provides information for the materials and general specifications of a closed-loop thermal pile system. The standard also covers internal pipe work up to and including manifolds, flushing valves, arrangements up to the entrance of header pipes into the plant room. The standard is available for purchase at www.gshp.org.uk/shop.html.

High-Profile Projects. EFPL's Professor Laloui said roughly 50 projects have been completed in Switzerland since the early 1990s. The most impressive, he said, is the Dock Midfield, Zurich Airport. The terminal, completed in 2003, is 500 m (1,640 ft) long and founded on 350 cast-in-place piles with diameters of 0.9-1.5 m (3-5 ft), 306 of which are thermally activated with 5 U-loops vertically distributed around the pile perimeter, he said. The geothermal piles coupled with the heat pump, geocooling scheme, and a refrigerant tower, provide 85% of the building's heating and cooling demand.

The Spring 2011 *Deep Foundations* featured the largest energy foundation project in the U.K. for "One New Change," a $250 million mixed-use development in London. Authors Julian Crawley and Tony Amis of GI, and Peter Smith of Cementation Skanska reported the ground source heating and cooling scheme 400% efficient compared to the 90% efficiency of a standard gas condenser boiler. "The system provides upward of 10% of the building's energy needs, but meets all the stringent new planning requirements for CO_2 reduction," said Smith, Cementation Skanska's geothermal manager. The system, with 219 Energy Piles® and two waterwells, has been operating for the past three years and delivers 1.6 MW of heating and 1.7 MW cooling. The process is estimated to save 900 tonnes (1,000 tons) of CO_2 emissions annually."

Cementation Skanska worked with GECCO2, a U.K.-based GSHP/geothermal design and build contractor, which has installed three Energy Piles® for The Leadenhall Building in London. The piles, measuring 2.1 m (6.9 ft) and 2.4 m (7.9 ft), are considered some of the largest energy foundation piles in the U.K., said Matt Love, managing director of GECCO2. Each pile will contain a total of 300 lm (984 ft) of collector pipe. Known as the "Cheese Grater" because of its tapered shape, the 50-story building is expected to be completed in 2014.

GECCO2 also is involved in energy foundation projects at three Crossrail stations and the Shell Centre, all in London; and an energy pile research and development project in Rugby, Love said. He added that 30% of GECCO2's business is devoted to energy foundations, partnering not only with Cementation Skanska, but also with Bauer Technologies, Expanded Piling, and Balfour Beatty Ground Engineering (BBGE).

The Crossrail development is currently the U.K.'s largest civil engineering project, said Cementation's Smith, noting Energy Piles and Energy Walls® are being installed into several of the underground station walls and piles for [future] over site developments."

Amis, business development director at GI, said his company is installing geothermal loops at five Crossrail stations across London. Placing geothermal loops into foundation elements "is seen as the only method for meeting various planning requirements," he said. "Renewable energy targets have to be met on the subterranean installations in order to meet [future] requirements for above-ground developments once station work is complete."

"We have recently started energy pile design work at London Bridge Station for Network Rail, and expect to start installing loops into piles in the middle of 2013 with Bachy Soletanche, to provide a cooling solution that will save [roughly] 80 tonnes (88 tons) of CO_2 annually," Amis continued. "London Bridge Station is currently being upgraded following the opening of the Shard, the tallest building in Europe."

Activity in Asia

Energy pile projects are underway in Japan and in China.

Japan. Professor Katsunori Nagano, Hokkaido University, Sapporo, Japan, reported that roughly 50 buildings in Japan are using building foundation piles as heat exchangers. The technology, Nagano said, is becoming increasingly popular for school buildings and other public buildings, and homes. Several high-profile facilities have adopted the energy pile technology including the Tokyo international airport terminal building and the new Tokyo TV tower known as Tokyo Sky Tree.

Nagano noted that "very strong and deep foundation piles" are required for construction in Japan to withstand earthquakes. Three types of foundation piles are used: on-site casting concrete piles, precasting concrete piles and steel foundation piles.

Nagano and his team designed a performance prediction tool that was applied to the design of a heating and cooling system of a building at Sapporo City College. The software, available since 2006, has been used to design most GSHP systems built in Japan since then. Nagano said the tool features a fast-calculating algorithm that evaluates the maximum feasible heat supply from the energy pile system according to hourly heating loads including ventilation. Nagano added that the software's interface enables consulting and construction companies to generate visual outputs directly into proposal documents.

China. Austria-based Enercret has been awarded 10 energy foundation projects in China, most of them larger than any project in Europe, said Bernhard Widerin, Enercret's product manager. These projects include installation of energy absorbers in structural piles and diaphragm walls for major hospitals in Yanzhou and Wuhan. An even larger project is the 117,000 sq m (1,259,378 sq ft), 95 m (312 ft) high Wuxi Goulian Financial Tower in Wuxi. There, Enercret's geothermal scheme comprises 513 energy foundation piles at 35 m (115 ft) deep, 88 geothermal boreholes at 100 m (328 ft) deep, a riverbed, and 15,000 sq m (161,459 sq ft) of the tower's concrete slab.

Participating in energy foundation research with universities in Europe since the late 1980s, Enercret is now collaborating with researchers in China. EPFL's Lyesse Laloui, likewise, is working closely with academic colleagues in China who are actively researching Enercret's high-profile projects there. In addition, Laloui said he submitted a proposal in late 2012 to develop the technology in Hong Kong. Laloui's energy foundation research activities include in-situ testing, laboratory tests and numerical analyses, and software development.

Installation of energy foundation piles at Wuxi Goulian Financial Tower in China

Australia

Brandl said Australia is beginning to implement the energy foundation technology in cooperation with the University of Technology Vienna. "Direct Geothermal Energy from Geostructures," presented to the 2011 Australian Geothermal Energy Conference in Melbourne, was co-authored by Professor Malek Bouazza, Monash University, Melbourne; and Brandl's protégé, Professor Dietmar Adam, Vienna University of Technology.

Bouazza and colleagues noted that integrating geothermal energy pile systems into structural piles "is a very feasible and economically viable option" in certain areas of Australia. Since that study, local piling contractors — especially VibroPile Pty. Ltd. — have shown increasing interest in implementing the technology in commercial buildings in Melbourne, Bouazza said.

Meanwhile, Bouazza continues his research in the technology, conducting a full-scale load test on an energy foundation by incorporating multilevel Osterberg Cells (O-cells).

Interdisciplinary Approach

"Several contractors and designers have had negative experiences when starting to practice this innovative technology because 'the devil is in the details.' Learning by doing may be rather costly if particular experience is missing," says Brandl. He emphasized that proper geothermal energy utilization requires interdisciplinary design. "The geotechnical engineer, structural engineer, architect, building services designer and installer, heating engineer and specialized plumber should cooperate as early as possible to create a most economical energy system," he said. "In the first phase of operation, precise adjustment is recommended to optimize the performance of the engineering system."

Similarly, Crawley and colleagues noted in "One New Change," that they engaged early with the client, conducting a series of precontract workshops, where various teams demonstrated scheme feasibility and design before moving on to the planning, programming and construction. Close interaction among team members was essential to examine project risks and to enable to successful conclusion to the project.

To address the technology's myriad cross-disciplinary issues, the International Workshop on Thermoactive Geotechnical Systems for Near-Surface Geothermal Energy: from Research to Practice was planned for March 25-27, 2013 at EPFL in Switzerland. The workshop is intended "to serve as a synergistic discussion platform for engineering researchers, practitioners, scientists, equipment/material manufacturers, nonprofit organizations, and public agency policy makers ... to discuss and identify the technical and non-technical challenges encountered in implementing thermo-active geotechnical systems," said Guney Olgun, Virginia Tech, a workshop organizer.

A main intent of the workshop, funded by the National Science Foundation, is to develop a list of research and outreach priorities and an overall strategic plan to overcome these identified challenges. Among other workshop organizers are EPFL's Laloui; John McCartney, University of Colorado Boulder; Kenichi Soga, University of Cambridge, U.K.; and Mary Ellen Bruce, DFI. See page 65.

More information is on the workshop website: www.olgun.cee.vt.edu/workshop/.

This article is a follow-up to "Energy Piles Gain Traction in North America," in the Sept/Oct 2012 issue of this magazine.

Benefits of Energy Foundations

In his keynote lecture, "Energy Piles and Other Thermo-active Ground-source Systems," presented at the 2010 Danube-European Conference in Geotechnical Engineering, Professor Heinz Brandl, Vienna University of Technology, cited these benefits of energy foundations:

- Environmentally friendly, nonpolluting and sustainable source of energy
- Reduces fossil energy demand, hence CO_2 emissions
- Promotes compliance with international environment obligations (i.e., Kyoto, Toronto targets)
- Lower running costs and life-cycle costs than conventional systems
- Low maintenance
- Increased personal comfort in the interior of buildings due to the larger heat-radiating surfaces of walls and floors
- Optimal hygrothermal behaviour, especially important for museums and art galleries
- No storage of fossil fuel required
- Geothermal cooling replaces conventional air conditioning, often thought to be loud and unhygienic
- Can be easily combined with other energy systems
- Supported by government grants and incentives in many regions
- Geothermal energy costs are not prone to unpredictable price fluctuations
- The embedded primary heat carrier circuits in energy foundations prevent damage of pipework or groundwater pollution

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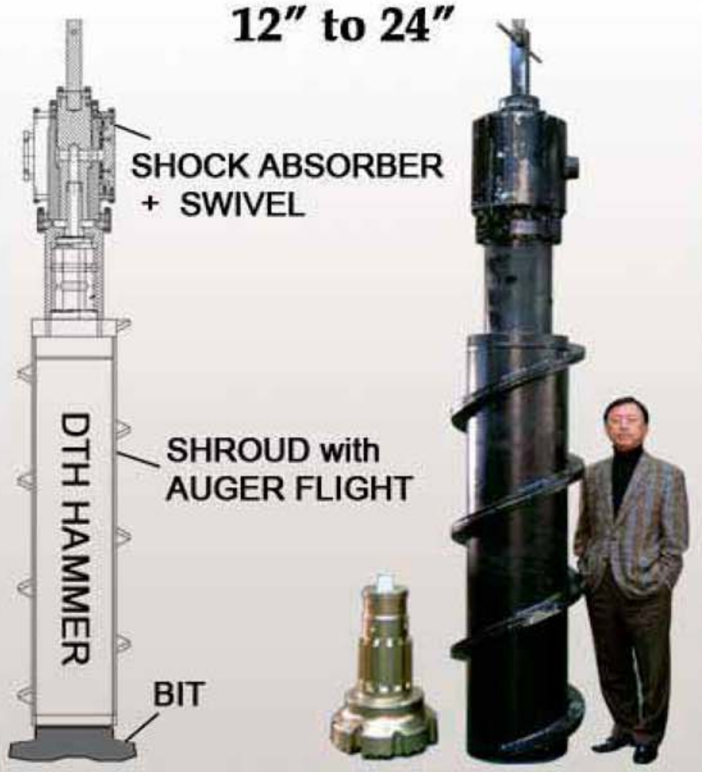

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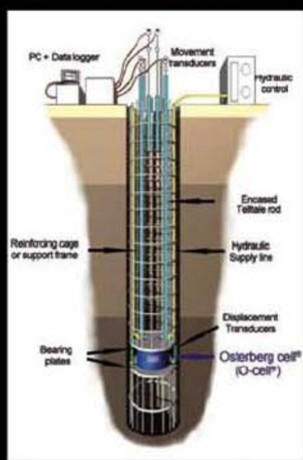
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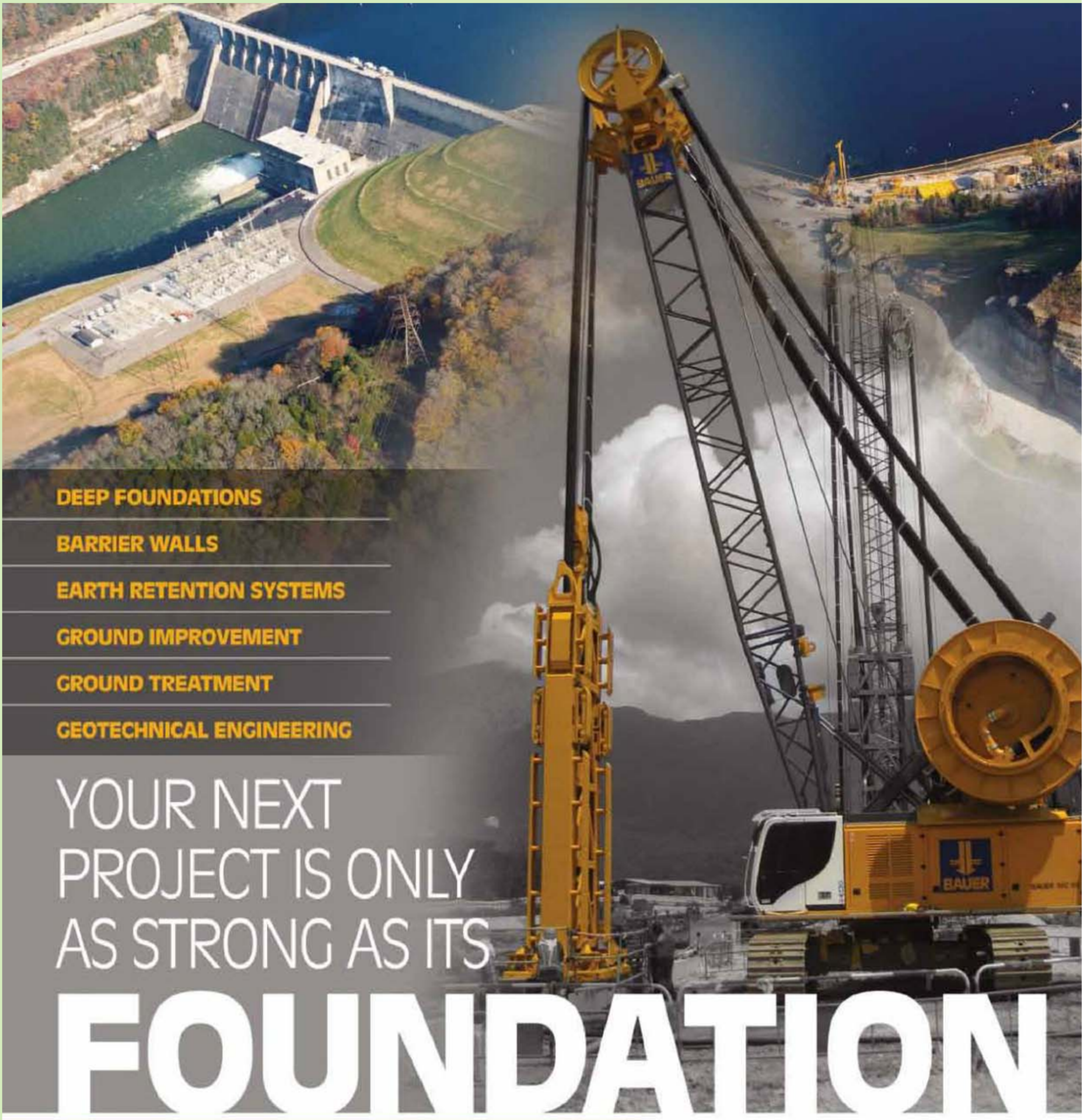
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Foundation Innovation in Florida

Aerial view of the foundation construction for the Oceana in Key Biscayne, Fla. *(photo credit smithaerialphotos.com)*

Underground garages and basements have long been avoided in South Florida construction. Most major construction is within a stone's throw of the ocean (or its little sister Biscayne Bay), and most builders are challenged by extremely high water tables and extremely pervious soils. Newly enacted zoning regulations calling for concealed parking provide further challenges. The Oceana project in Key Biscayne, Fla., was conceived in such circumstances. The project is a 16-story high-rise tower that houses 142 luxury condominium units, sitting astride an underground, 2-story parking garage. The tower and garage footprints are 38,000 sq ft (3,530 sq m) and 72,000 sq ft (6,700 sq m), respectively, and the excavation reaches down 17 ft (5.2 m) below the water table. Consultatio Real Estate Inc. is developing the project, under the leadership of architect Marcos Corti.

According to Vincent DeSimone, chairman of DeSimone Consulting Engineers of Miami, the project's structural engineer, "Recent code changes in Miami make it prohibitive to use available floor area above grade for parking because that use reduces revenue producing floor area. Until the advent of these code changes, there was little incentive to go deeper than a one-story below-grade parking level. The few attempts to park two levels below grade resulted in lawsuits and spotty success." DeSimone was one of the chief proponents of what became the foundation system at the Oceana. His firm, working with Layne Geoconstruction, had worked at The Cosmopolitan of Las Vegas, building a concrete wall around a five-level subterranean parking garage. The perimeter walls were founded on a dense limestone layer that created a seal against groundwater migrating upward. A hybrid version of this approach proved to be the winning design for the Oceana project.

Florida Geology

The vast majority of South Florida high-rise buildings in the last 30 years have employed an almost identical script: augercast piles and pile caps, wellpoint dewatering, occasional sheet piling, supporting a building in which a lower level of parking is either depressed only slightly into the earth, or more commonly positioned alongside the main tower. Barry Goldstein, P.E., is the principal engineer and president of KACO, the project's geotechnical engineer. He says, "The Florida geology is uniquely suited for augercast piles. The immature limestone is relatively weak in nature and allows for drilling with a continuous flight auger. This, in combination with the limestone's inherent porous structure allows for significant load transfer from a cast-in-place pile." This porosity carries a cost. Goldstein says this porous structure is what allows for permeability and very high water flow into excavations. Dewatering by conventional means can be performed only to certain depths as the volume of water required to be pumped, even in a small excavation, can exceed tens of thousands of gallons per minute.

Our firm, Coastal Construction, had experienced that tens of thousands of

AUTHOR *John Mills, General Superintendent, Coastal Construction*

gallons per minute. We had recently completed the St. Regis Bal Harbour for the Starwood Corporation, which featured a one-story, fully below-grade parking garage, which covered 300,000 sq ft (28,000 sq m), with deeper, core areas extending to 20 ft (6 m) below the water table. The project team included Coastal, Baker Concrete, Thompson Pump, and HJ Foundation. We completed construction to these depths without a bottom plug or tremie, but instead employed a vast array of pumps and a quarry's worth of gravel—maxing out at 42 large diesel pumps at peak—to depress the water table for 13 months. In addition to installing, fueling and constantly repositioning our pumps, water discharge was a tremendous challenge, making our logistics like a chess game, never opening more ground than we could maintain. Our firm was all ears when the opportunity to work on Key Biscayne with a new system presented itself.

New Urbanism

"New Urbanism" is the term applied to the planning movement currently shaping development codes nationwide. According to *Better Cities and Towns,* if New Urbanism can be boiled down to a single idea, it might be making places "walkable." Another of the movement's goals has been to conceal parking.

Sherri Gutierrez, project director for Oceana as well as vice president and office director at Arquitectonica, (the project architect) agrees. She says that many municipalities have re-examined their zoning codes in an effort to create better urbanism and toward re-inventing the pedestrian realm. As a result, ground floor area becomes priceless, forcing developers to look into below-grade parking. She points to projects such as Oceana in Key Biscayne and Brickell CityCentre in Miami. Several subcontractors have looked for creative solutions to build underground in "the dry." Below-grade parking may very well become the new norm, says Gutierrez.

From the development side, developer Corti says that as long as the cost of the product can justify it, below-grade parking can turn 200,000 sq ft (18,580 sq m) of above-grade parking area into an attractive pedestrian area. From a purely practical standpoint, Goldstein, of KACO, adds "as developable land has become less available, the use of basements has become more of a necessity."

In late 2009, Consultatio Real Estate acquired a 10 acre (4 ha) site on Key Biscayne. Initially, the below grade parking garage—in this case mandated as a condition of approval for the project—was to feature a sheet pile perimeter, with an augercast pile foundation, in combination with a tremie plug, facilitating construction of a hydrostatic slab. By late 2011, the steel sheets were on-site and pending permitting, construction was ready to commence. It was at this point that DeSimone introduced Corti to the Layne/Bencor team. Bencor is a slurry wall specialist and subsidiary of Layne Geoconstruction. At the same time, Consultatio brought Coastal Construction aboard to manage the construction.

plug and the walls) was very attractive. The plugs are environmentally sustainable since the virgin soil material is cemented in place and a concrete cylinder is produced. These cylinders are placed one against the other to create a continuous bottom plug to seal the bottom against ground water intrusion.

In addition, the team devised a separation wall bisecting the project, allowing excavation and construction of the tower to proceed in advance of the garage. The Layne team further proposed to install a test hole to full depth—at their own risk—consisting of jet grout walls and base, to prove the viability of their proposal. Corti set the condition that if upon excavation he could press a piece of tissue paper to the wall and it didn't stick, the job was theirs. Layne quickly mobilized, jet grouted the test area, and after a cure time, excavated the hole. On March 21, 2012, with all the teams' stakeholders assembled, Corti, along with the design team and engineers from Layne descended the ladder into what most described as the deepest hole they had ever seen in Florida. Corti pulled the tissue from his pocket, pressed it to the wall, and it fell to the ground. Florida Engineering, the excavation subcontractor, had excavated a smaller hole immediately adjacent to show the natural water table, less than 3 ft (1 m) from the surface. Layne

Tower construction of Oceana showing excavation

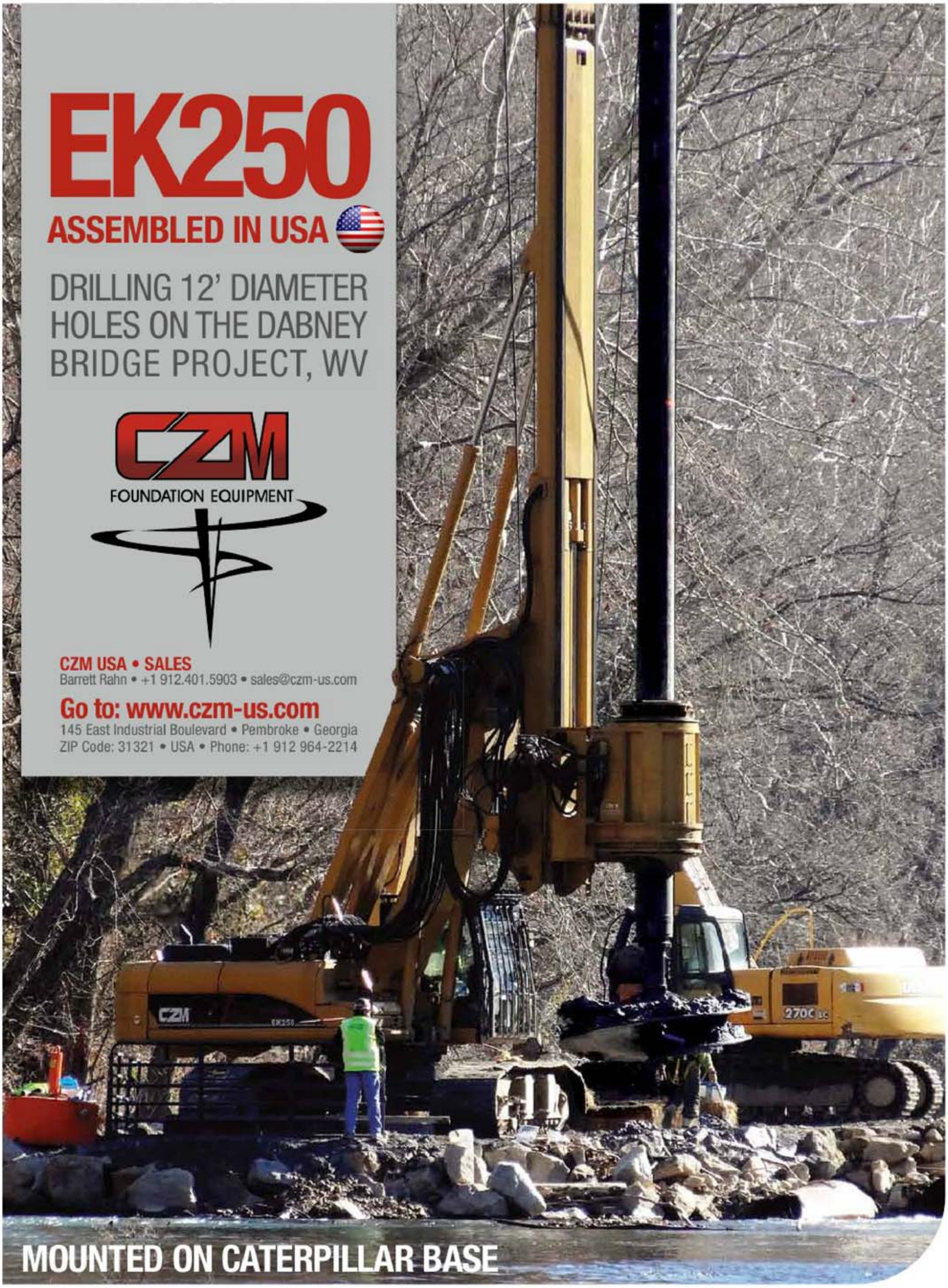
Corti was highly impressed by Layne executives' proposal to encircle the entire tower and garage with a slurry wall and barrette system—the barrettes supporting perimeter columns—and infill the entire footprint with a jet grout plug, on which large spread foundations would rest. The jet grout plug would serve as the water seal as well as the interface between the spread foundations and the rock below. He thought that the monolithic nature as well as the similarity of materials (between the

Slurry wall reinforcement at Oceana

had proved their system, and after a few technical approvals and brief contract negotiations, work was underway.

Layne commenced construction with a pair of Casagrande jet grout rigs supported by a remote complex of silos, mixers and pumps. The jet grouting quickly progressed westward across the site, reaching one-third of the footprint. The slurry wall operation, which had already mobilized, went to work with, initially, one Bauer hydromill, soon followed by a second. The hydromills initially completed the tower area, including bisecting wall allowing excavation to commence, and finished the garage area and demobilized. Concrete for the massive 30 in (0.76 m) thick walls was supplied by both CEMEX and Supermix, as the quantities and necessary rate of placement challenged either one alone. In the tower, after an initial drawdown of trapped water by means of wellpoint dewatering, excavation conditions ranged from dry to bone-dry. Subsequent dewatering of rainwater and excavation runoff was primarily handled with 0.5 horsepower, 2 in (5 cm) electric pumps or occasionally wet vacs, a far cry from the teams of diesel pumps usually seen at these types of projects. The massive tower spread foundations have been placed, and the tower structure is already well into the living floors. The garage excavation is nearing completion and garage structure work is well underway.

DeSimone says the system is trouble free in that it prevents water intrusion down to 3 stories and results in minimal ground water to remove during excavation—a dream solution to a serious zoning requirement. The construction of the plug system is so successful in Key Biscayne that DeSimone is working on this grout plug on three major projects in South Florida. Layne executive Peter Iovino says the project has dramatically advanced the below-ground construction process in South Florida and no doubt permanently reshaped the approach to building of deep structures." Oceana is expected to be complete in spring 2014.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Upcoming Activity: International Workshop

During March, the National Science Foundation is sponsoring a 2.5-day International Workshop on Thermoactive Geotechnical Systems to explore and advance the use of thermoactive geotechnical systems for near-surface geothermal energy as a sustainable geoengineering practice. The workshop will be at École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland, March 25-27. The event addresses engineering researchers, practitioners, scientists, equipment/material manufacturers, non-profit organizations and public agency policy makers to discuss barriers to implementation of thermoactive geotechnical systems. The organizers expect that the cross-disciplinary and international backgrounds of the attendees will help transfer practical experience from other countries that have successfully implemented this technology.

The International Advisory Committee includes Prof. Guney Olgun (Virginia Tech, U.S.), Prof. John McCartney (University of Colorado Boulder, U.S.), Prof. Lyesse Laloui (EPFL, Switzerland) and Kenichi Soga (University of Cambridge, UK). Industry liaisons are Prof. James Martin (Virginia Tech, U.S.) and Mary Ellen Bruce (Deep Foundations Institute, U.S.).

The workshop has a discussion forum format beginning with several introductory presentations outlining the state of research and knowledge on energy foundations. The breakout sessions and discussions focus on the following:

- Identification of major research thrust areas and technical challenges
- Identification of best practices for installation, laboratory testing, field testing
- Building codes, green certification and implementation issues, market challenges
- New technologies, applications, materials and equipment in near surface geothermal systems
- Characterization of thermo-mechanical soil behavior
- Soil-structure interaction in energy foundations
- Validation of design tools for thermoactive geotechnical systems
- Environmental impact calculations, life-cycle cost analysis
- Educating the new generation of engineers for sustainable practices

Summary reports from the workshop for each session and workshop minutes will be available on the workshop website http://www.olgun.cee.vt.edu/workshop/. Synthesis documents will be prepared and published from the collective summary reports.

COMMITTEE CHAIR TOM GURTOWSKI

Codes and Standards Committee

The Codes and Standards Committee is leading an industry-wide effort to review and prepare proposals to revise the 2015 International Building Code (IBC) Chapter 18 “Foundations” (to be implemented in 2018 IBC). Committee members are collaborating with representatives from the Pile Driving Contractors Association (PDCA), GeoInstitute of the American Society of Civil Engineers (ASCE), ASFE: The GeoProfessional Business Association, and ADSC: The International Association for Foundation Drilling to provide industry-agreed proposed changes to the building codes. Traditionally, this code has been written by structural engineers. The geotechnical community is working together to affect change that reflects the expertise and knowledge of geoprofessionals. The group is paying particular attention to the following sections of Chapter 18 (societies taking the lead are shown in parentheses):

1803 Geotechnical Investigations (ASCE/GI, ASFE, DFI)

1804 Excavation, Grading and Fill (ASCE/GI, ASFE, DFI)

1806 Presumptive Load-Bearing Values of Soils (DFI, ASCE/GI, ASFE)

1807 Foundation Walls, Retaining Walls and Embedded Posts, and Poles (DFI, ASCE/GI; ASFE)

1808 Foundations (DFI, ASCE/GI, ASFE, ADSC) Expansive Soils (ASCE/GI, ASFE), Concrete Foundations (DFI)

1809 Shallow Foundations (ASCE/GI, ASFE)

1810 Deep Foundations (PDCA, DFI, ASCE/GI, ADSC)

New sections and additions to Chapter 18 sections being considered include foundation testing, expansive and collapsible fills, and ground improvement.