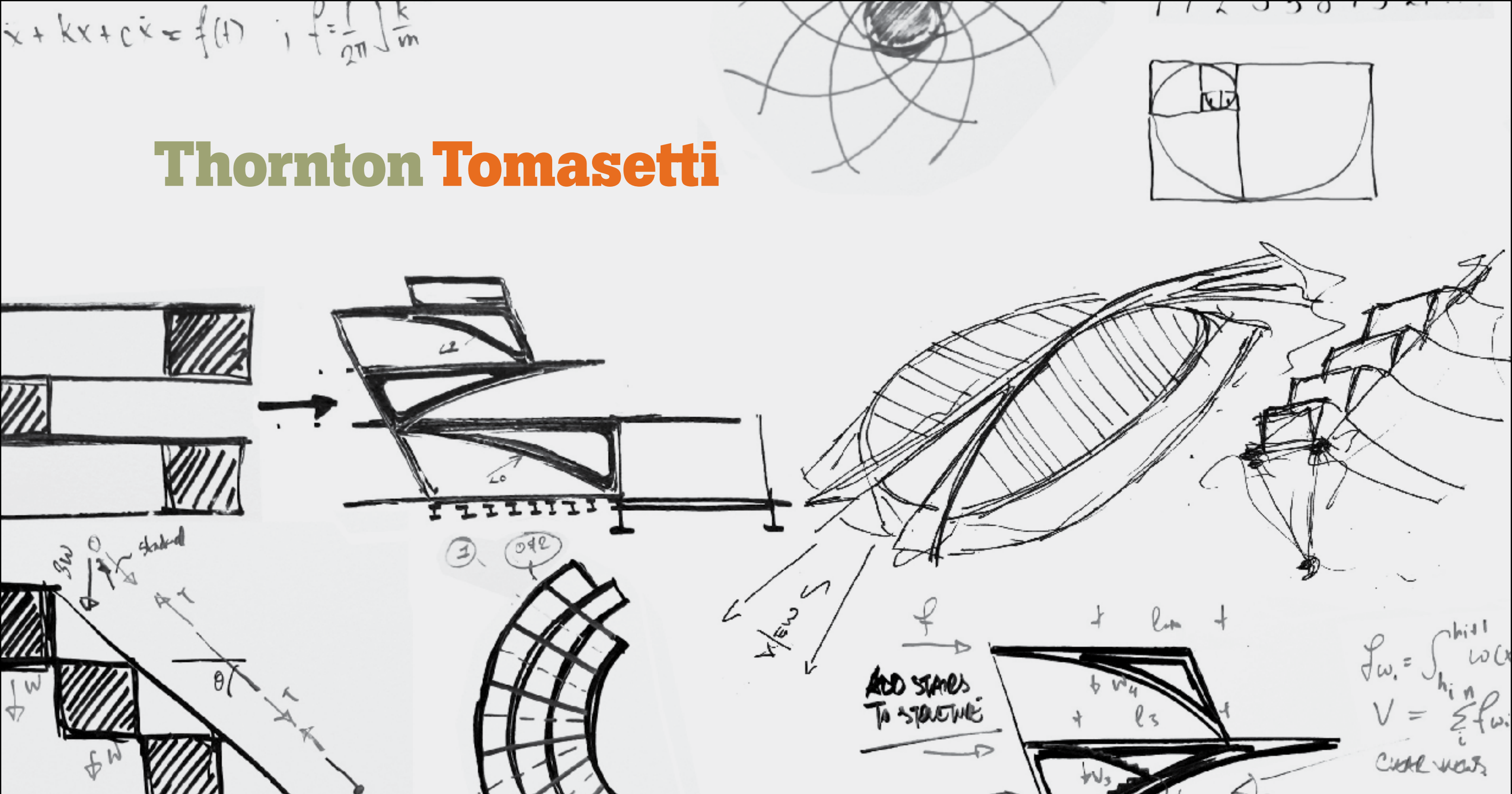
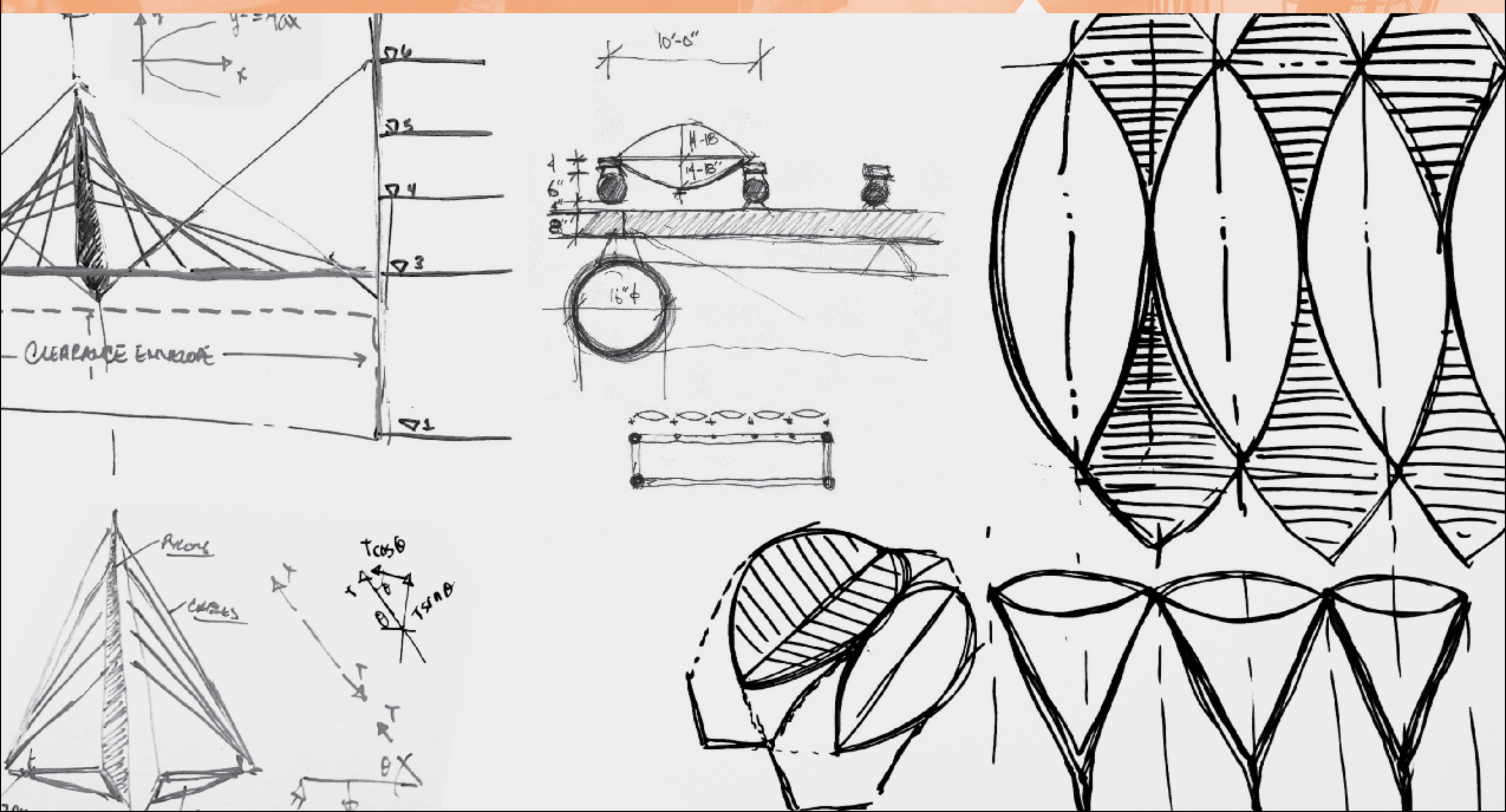
Thornton Tomasetti



Innovation

2013/2014 Annual Report



Thornton Tomasetti provides engineering, design, investigation and analysis services to clients worldwide on projects of every size and level of complexity. Our six integrated practices (see page 32) address the full life cycle of structures. Founded in 1956, Thornton Tomasetti today is an 800-person organization of engineers, architects and other professionals collaborating from offices across the United States and in Asia-Pacific, Europe, Latin America and the Middle East.

In this age of digital modeling and imaging, hand sketching is sometimes still the best way to unite the heart and the head. We built the front and back covers of this report from snapshots of whiteboards around our offices. They show innovation in action, from sketches of concept explorations (front) to our calculations for an entirely new kind of building dampening system (back).

Contents

Executive Message

In our prior two annual reports, we focused on two requirements for success: relationships and collaboration. They, in turn, are key ingredients that cultivate an environment where innovation can flourish, another requirement for enduring success.

Our industry is challenging and creative. Yet bold innovation is the exception, not the rule. Innovative technologies and building methods are out there, but our industry has been slow to identify and embrace them. As a noted science fiction writer has said, “The future is already here – it’s just not very evenly distributed.”

Part of the idea distribution problem is that creativity requires collaboration among stakeholders in order to flourish. The good news is that today’s collaborative tools enable the broad sharing of a building model across space and time, making virtual collaboration easier and more productive. Heightened collaboration lowers barriers to innovation, so we believe everyone must have a voice at the virtual table, early and often.

Danny Bright

Tom Scarangello and Bob DeScenza stand “in” a 3D laser scan of a New York hospital basement. We conducted the scan to establish baseline MEP data following CAT-90 Sandy. For more about our laser scanning capabilities, see pp. 10–11.

We are also living in an era of unprecedented access to information. Fifty years ago you had to travel to experience what was new. Now, it’s brought to you instantly by Twitter, or it’s a few clicks away on a blog or YouTube. Combining collaboration tools with a wealth of interactive information creates conditions in which new ideas can take flight. And new ideas that make the leap to innovation become the engine that advances society.

“Combining collaboration tools with a wealth of interactive information creates conditions in which new ideas can take flight.”

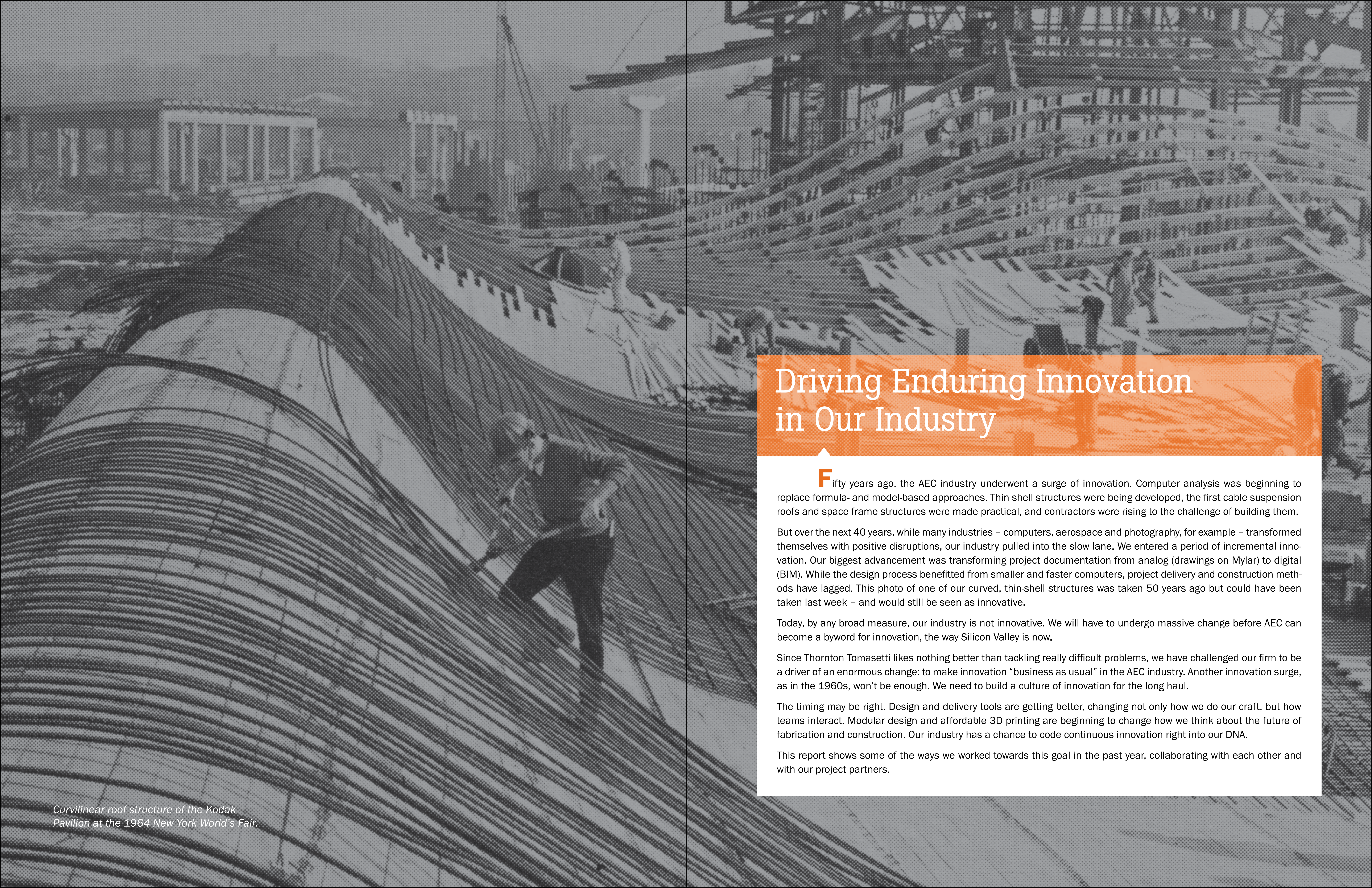
At Thornton Tomasetti, we are passionate about becoming a driver of innovation in our industry. We have a history and culture that give us a running start. We put a high value on looking beyond the obvious to solve the real problem and on seeing opportunity where others focus on risk. We develop and implement strategies that lower cost and risk for our clients. We strive to make our firm an idea meritocracy, cultivating and investing in ideas from inside and outside our firm – a place where the author’s title is irrelevant and the quality of ideas is all that matters.

While we recognize that driving our industry to remake itself is an ambitious goal, one that will take years and dedication to achieve, we are committed to the journey. Join us.

Tom Scarangello
Chairman & CEO

Robert DeScenza

Bob DeScenza
President



Curvilinear roof structure of the Kodak Pavilion at the 1964 New York World's Fair.

Driving Enduring Innovation in Our Industry

Fifty years ago, the AEC industry underwent a surge of innovation. Computer analysis was beginning to replace formula- and model-based approaches. Thin shell structures were being developed, the first cable suspension roofs and space frame structures were made practical, and contractors were rising to the challenge of building them.

But over the next 40 years, while many industries – computers, aerospace and photography, for example – transformed themselves with positive disruptions, our industry pulled into the slow lane. We entered a period of incremental innovation. Our biggest advancement was transforming project documentation from analog (drawings on Mylar) to digital (BIM). While the design process benefitted from smaller and faster computers, project delivery and construction methods have lagged. This photo of one of our curved, thin-shell structures was taken 50 years ago but could have been taken last week – and would still be seen as innovative.

Today, by any broad measure, our industry is not innovative. We will have to undergo massive change before AEC can become a byword for innovation, the way Silicon Valley is now.

Since Thornton Tomasetti likes nothing better than tackling really difficult problems, we have challenged our firm to be a driver of an enormous change: to make innovation "business as usual" in the AEC industry. Another innovation surge, as in the 1960s, won't be enough. We need to build a culture of innovation for the long haul.

The timing may be right. Design and delivery tools are getting better, changing not only how we do our craft, but how teams interact. Modular design and affordable 3D printing are beginning to change how we think about the future of fabrication and construction. Our industry has a chance to code continuous innovation right into our DNA.

This report shows some of the ways we worked towards this goal in the past year, collaborating with each other and with our project partners.

Our History of Innovation

1956

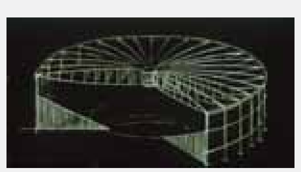
LEV ZETLIN FOUNDS THE FIRM

Dr. Lev Zetlin's passion for creative uses of structural systems and materials inspired him to found a firm where he could pursue unconventional projects and opportunities for innovation. Convinced that "the dream of today often becomes the reality of tomorrow," he conducted groundbreaking research into hyperbolic paraboloids, thin folded plates and thin shell structures. He also hired engineers who shared his vision, among them Charlie Thornton and Richard Tomasetti.

1960

FIRST DOUBLE-BICYCLE WHEEL ROOF

Built on a tight site with poor soil conditions, the Utica Memorial Auditorium (N.Y.) needed a very light roof. Lev Zetlin designed the first "double-bicycle wheel" cable-suspended roof, with top and bottom chords tensioned to different frequencies to control vibration from wind. This lightweight system provided a column-free interior and cost less to build than a conventional roof.



1964

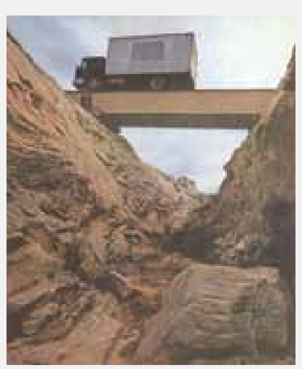
AMERICAN INNOVATION EMBODIED AT THE NEW YORK WORLD'S FAIR

The exposition's futuristic pavilions were a perfect match for Lev Zetlin's interest in novel materials and systems. The New York State Pavilion had a 320-foot cable-suspended roof; the Kodak Pavilion featured a thin reinforced-concrete shell roof with a freeform "moonscape" shape; and the Travelers Insurance Exhibit (below) used steel cables and ribs to form a space frame using pre-stressing in three dimensions.

1970

A BRIDGE MADE OF PAPER

We were approached by International Paper to design a functional paper bridge for an advertising campaign. Built using only cardboard and glue, the bridge spanned more than 40 feet and was able to support a truck.



1971

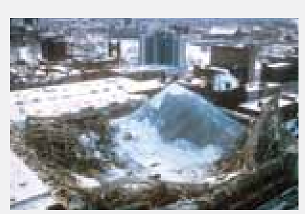
HYPARS USED FOR STRUCTURAL SHEAR TRANSFER

To achieve obstruction-free spaces large enough for four Boeing 747 jets, we designed super bay hangars with huge cantilevers using light-gauge metal deck webs in hyperbolic paraboloid (hypar) configurations, a practical application of Lev Zetlin's research in the early 1960s. The two American Airlines hangars are still in use today at the San Francisco and Los Angeles international airports.

1978

COMPUTER MODEL USED TO ANALYZE A COLLAPSE

Our investigation of the roof collapse at the Hartford Civic Center (Conn.) included computer modeling of post-buckling behavior for a sequential failure analysis that was able to track interactions of multiple members. The collapse load determined by the model was very close to the estimated weight of the snow that accumulated on the roof before it fell, validating the accuracy of the model.



1983

FIRST STRESSED-SKIN TUBE TOWER

The new stressed-skin tube system, developed for the 54-story BNY Mellon Center in Pittsburgh, Pa., used exposed (not fire-proofed) structural steel façade panels to reduce wind sway. After multiple reviews we convinced the building department that the new system was safe and met the intent of the code. This paved the way for using non-protected sway-resisting structural elements in other buildings.

1987

SUPER COLUMNS + OUTRIGGERS REVOLUTIONIZE TALL BUILDING DESIGN

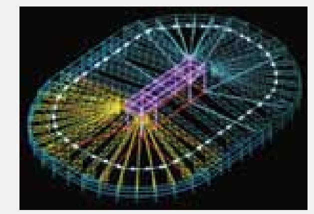
Our structural design for the 925-foot One Liberty Place in Philadelphia, Pa. used a new kind of lateral system, with multi-story "super diagonal" outriggers engaging super columns. The total width of the building – instead of just the core – resists wind forces, while transfers focus building weight on the perimeter super columns to counteract uplift forces and maximize column area and stiffness. This project has been a prototype for supertall buildings ever since.

Krzykol, Wikimedia Commons

1993

FIRST TIED-ARCH ARENA ROOF

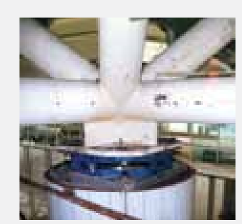
We were the first to apply the tied-arch bridge concept to an arena roof. We recognized that these roofs didn't require traditional, fully-diagonalized trusses. Our design for Honda Center in Anaheim, Calif. used shallow top chord trusses that were easy to fabricate, transport and erect, with separate bottom chords to maintain structural strength and stiffness.



1999

"PROTO PBD" AT ATATURK INTERNATIONAL AIRPORT

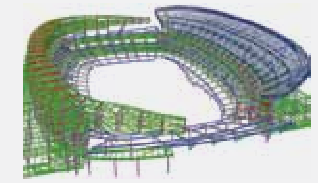
After the Izmet earthquake, we were asked to retrofit a nearly complete new terminal to improve its seismic performance. We explored new performance-based methods and developed new tools and modeling methods to test proposed solutions. We used friction pendulum bearings to isolate the roof – reducing demand on the columns below – and added steel jackets to increase column ductility. This provided seismic performance well beyond local design requirements.



2001

3D COMPUTER MODEL AS CONTRACT DOCUMENT

When Chicago's Soldier Field was renovated and expanded, we created a model of the steel frame in Tekla, and then delivered it as part of our contract documents. The model was used by the steel and cladding fabricators to expedite connection detailing and façade panel design, while communicating with the design team in 3D.



2004

CONSTRUCTION SUPPORT SERVICES ESTABLISHED

Our engineers have always worked with constructability in mind, but in 2004 we launched construction support as a formal service. Advances in computer technology allowed us to offer integrated 3D modeling, connection design, steel detailing and construction engineering in-house (see pp. 14–15). By 2010, rising demand for these services led us to establish a full-scale practice to better support our clients and address their increasing project delivery needs.

2007

FIRST FIM

Our investigation of the deadly I-35W bridge collapse in Minnesota generated a staggering amount of documentation. To manage it, we attached each piece of data to a 3D Revit model of the bridge and developed the first forensic information model (FIM). It allowed the forensic team to access all available information about a specific girder, for example, simply by clicking on it in the model. See pp. 22–23.

2010

JOINED THE AIA 2030 COMMITMENT

We were the first primarily structural engineering firm to sign on to the program, which works toward the goal of carbon-neutral buildings by the year 2030 (see p. 30). This commitment led to the establishment of our Building Sustainability practice and corporate sustainability department in 2012.

AIA 2030™

2012

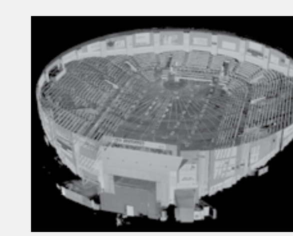
CORE STUDIO FORMALIZED

In 2012, we took stock of the people, programs and tools advancing innovation within Thornton Tomasetti. We formalized an R&D program to identify and support original ideas across the firm and hired more advanced computational modelers and application developers. Then we created a virtual studio to encompass these activities. Every employee, anywhere, engaging in innovation works under the CORE studio umbrella. See pp. 18–19.

2013

SCANNING THE AUD

In 2013, we returned to the Utica Memorial Auditorium. We used our portable 3D laser scanner to create a detailed record of the 54-year-old structure's condition. See pp. 10–11.



Challenge Design and build an Olympic stadium in a high seismic zone in about half the usual time.

Innovation Unconventional use of a piled raft foundation and custom design automation supported an ambitious project timeline.

An 18-Month Sprint

Baku Olympic Stadium, Azerbaijan

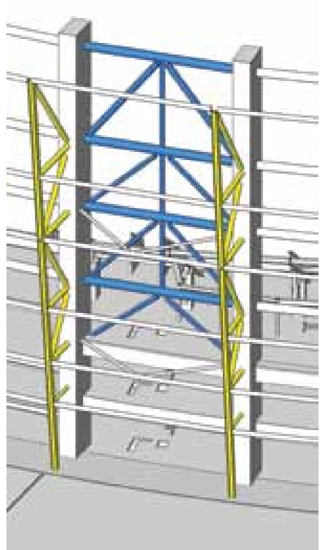
The latest fast-track speed champ in our sports portfolio is the Baku Olympic Stadium. Instead of the typical 30 months to design and build a stadium of 68,700 seats, the project will take only 18 months (excluding interior work), thanks mainly to design and construction taking place in parallel. The stadium is scheduled to host the inaugural European Games in June 2015.

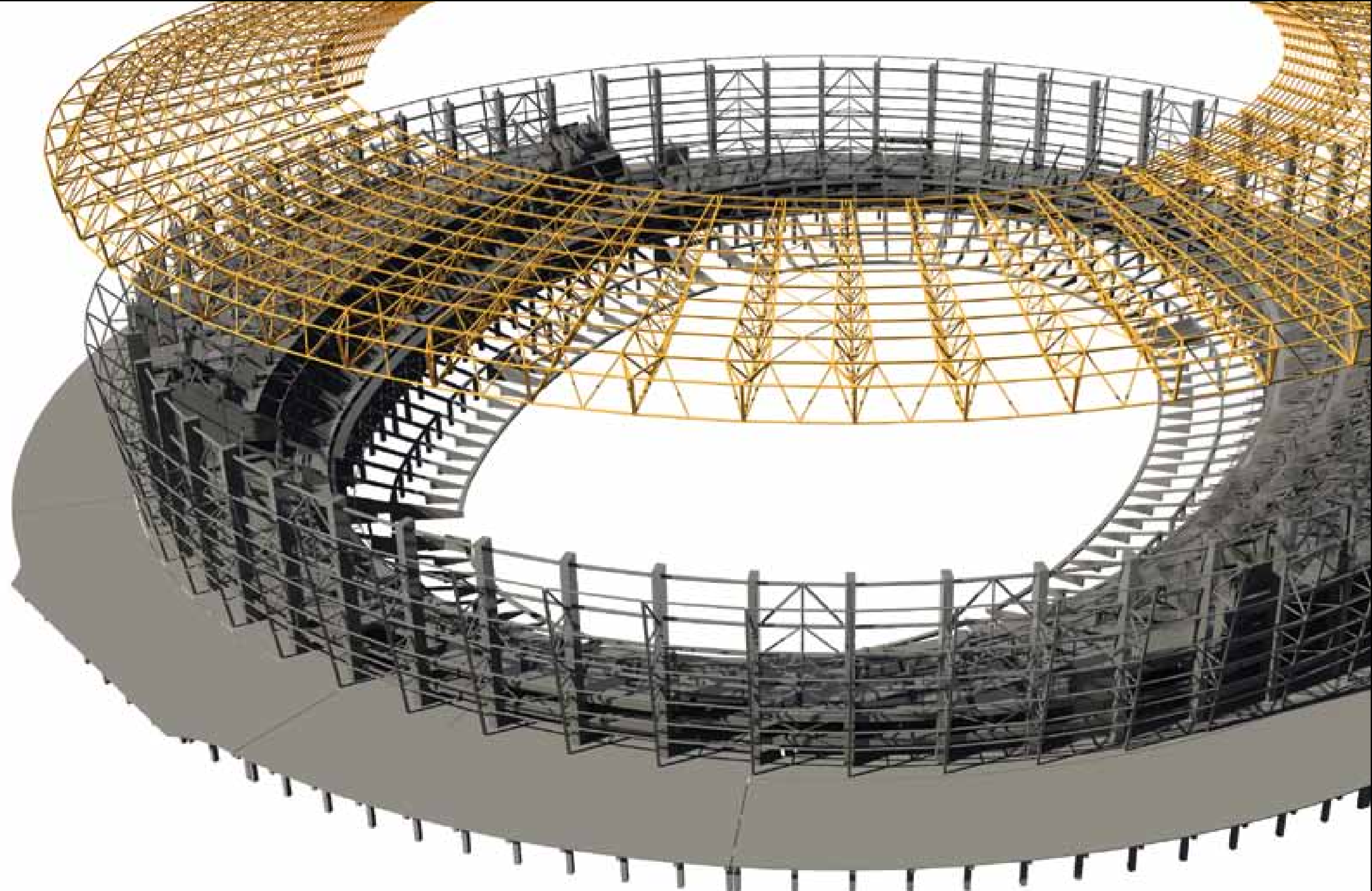
“Unlike most projects, the construction deadline is determining the design, not vice versa,” said Hi Sun Choi, who is leading our structural design team. “The contractor was on the project from day one. Based on the construction schedule, they tell us the design schedule for each element.”

To maximize design flexibility, the team opted for a piled raft foundation, which is more typical of high-rise buildings than stadiums. The raft allows construction to commence while design is still in flux.

Our modeling approach also supported the accelerated schedule. Baku is in a highly seismic zone, so checking seismic provisions was integral to the design process. We wrote a custom script for an automated design routine that pulls shears and moments from the SAP model and checks beam and column reinforcement against seismic code provisions. This allowed us to design more quickly than with SAP alone, completing the sizing and final design in several days instead of several weeks.

The architect preferred an inverted V chevron design to X cross-bracing but, to adequately resist seismic forces, the horizontal members of the chevrons would have to be very large. To solve this problem, we added a zipper column (below), a vertical tie that runs down the center of the chevrons, to transmit out-of-balance forces to the top of the system where they are resisted elastically. This reduced horizontal tube diameter and thickness by about 80 percent and allowed the use of less expensive rolled tube instead of custom fabricated tube.





A Tekla model of the stadium roof (yellow) over a Revit model of the stadium, with the raft foundation visible.

Part of the our Baku Olympic Stadium team: from left, Iliana Karagiannakou, engineer; Hi Sun Choi, senior principal; and Kevin Legenza, associate, who oversaw multiple modeling applications.

Walter Smith

PROEJCT TEAM

Owner: *SOCAR;* ***Architect:*** *Heerim Architects & Planners Co.*
Contractor: *Tekfen Construction*

THORNTON TOMASETTI

Structural engineering

Challenge Often the best way to gather and quantify information about a damaged structure is through 3D laser scanning, but using consultants – writing specs, reviewing proposals and directing technicians in the field – takes valuable time.

Innovation We brought 3D laser scanning technology in-house and taught our forensics experts how to use it, reducing the time needed to acquire and analyze laser-based data.

To hold the 3DS 120 laser scanner steady on a windy day in the field, Viviana Vumbaca finds one of the scanner's few blind spots.

A photo (top) and point cloud rendering of a bridge damaged by a ship. The 3D model generated by the laser scanner can be used as the basis of a FIM that stores documents, photos and other information related to the investigation.

Danny Bright

Tom Duffy and Francesca Brando, a senior engineer, pack up the 3DS 120 laser scanner. The white globes are reference spheres, artificial targets used to register multiple scans so they can be combined into a complete point cloud.

Scanning the Horizons of Forensic Investigation

Portable 3D laser scanners are a powerful forensic tool. The ability to quickly capture detailed and accurate digital reproductions aids our forensic and property loss consulting teams in assessing and analyzing structures of all types. "The laser scans pick up all of the geometry. If it's done well, it makes a true 3D model that you can base measurements on, spin around, fly inside of and manipulate," said Senior Vice President Tom Duffy.

We've used consultants for this work, but it takes time to get them on board – when time is of the essence – and also increases costs for our clients. Because the technicians usually aren't engineers or architects, they don't always know which portions of a structure are relevant to the investigation. And consultants don't deliver all the data: we get a cleaned-up version we can navigate but not dig into.

In 2013, we bought a Faro Focus 3DS 120 laser scanner. In the hands of our trained forensic architects and structural and MEP engineers, this tool increased in value. "When you do the scans yourself," said Project Director Viviana Vumbaca, "you understand the data better. You learn the machine's capabilities and limitations, so you can get the best use out of it." We can do scans of critical areas as they're discovered, check initial results, and make immediate adjustments if needed. "It's a faster, more efficient process this way," said Vumbaca. "We can get what we need on the spot."

We also get access to all the information. If an analysis doesn't tell us what we want to know, we can dive back into the data and keep looking for the information that can help us give our clients the answers they need.

Narayan Mahon

Vice President Edward Peck, Senior Associate Richard Plotnick and Senior Engineer Alloy Kemp examine ETFE samples.

Design with a Clear Advantage

Minnesota Multipurpose Stadium, Minneapolis, Minnesota

When the Minnesota Vikings and the Minnesota Sports Facilities Authority asked for a retractable roof on their new stadium, we asked why. They wanted the feel of an open-air stadium, with the protection from the elements that today's fans demand. Our specialists in building skin design, structural engineering, kinetic mechanization and sustainability collaborated to identify options to achieve this effect without the high cost – in construction and maintenance – of a retractable roof.

The solution? A dual approach that pairs a transparent 240,000-square-foot roof with an operable façade. Large glass panels in an end wall pivot open for natural ventilation and frame the city skyline. Both roof and doors will admit natural light open or closed, another advantage over an opaque movable roof. The roof will be clad in ethylene tetrafluoroethylene (ETFE) foil panels and will be the largest ETFE roof in the United States and the first stadium roof of its kind in the country.

This solution affords additional benefits. Because ETFE is very lightweight and very strong, less steel is needed to support the roof. This reduces both construction cost and the carbon and energy embodied in the overall structure. The light and warmth from the sun will also trim the energy required for lighting and heating. These features will assist the stadium's bid for LEED certification while creating a dramatic fan experience.

Designing a complex structure of this magnitude is no simple task. But Edward Peck, who directed the building skin design, doesn't think doing the design work was the biggest challenge. What was? Convincing the owners that using an innovative material was the right decision. "They asked a lot of questions. They wanted to know for sure that an ETFE roof was viable," Peck said. He presented details of several past projects that successfully integrated ETFE. "I was able to answer all their questions, so they could feel confident it would work. It's all about our team helping the client feel comfortable with the innovation we put forward."

Challenge Bring an outdoor feel and views of the surrounding Minneapolis cityscape inside a stadium while providing protection from the cold northern climate.

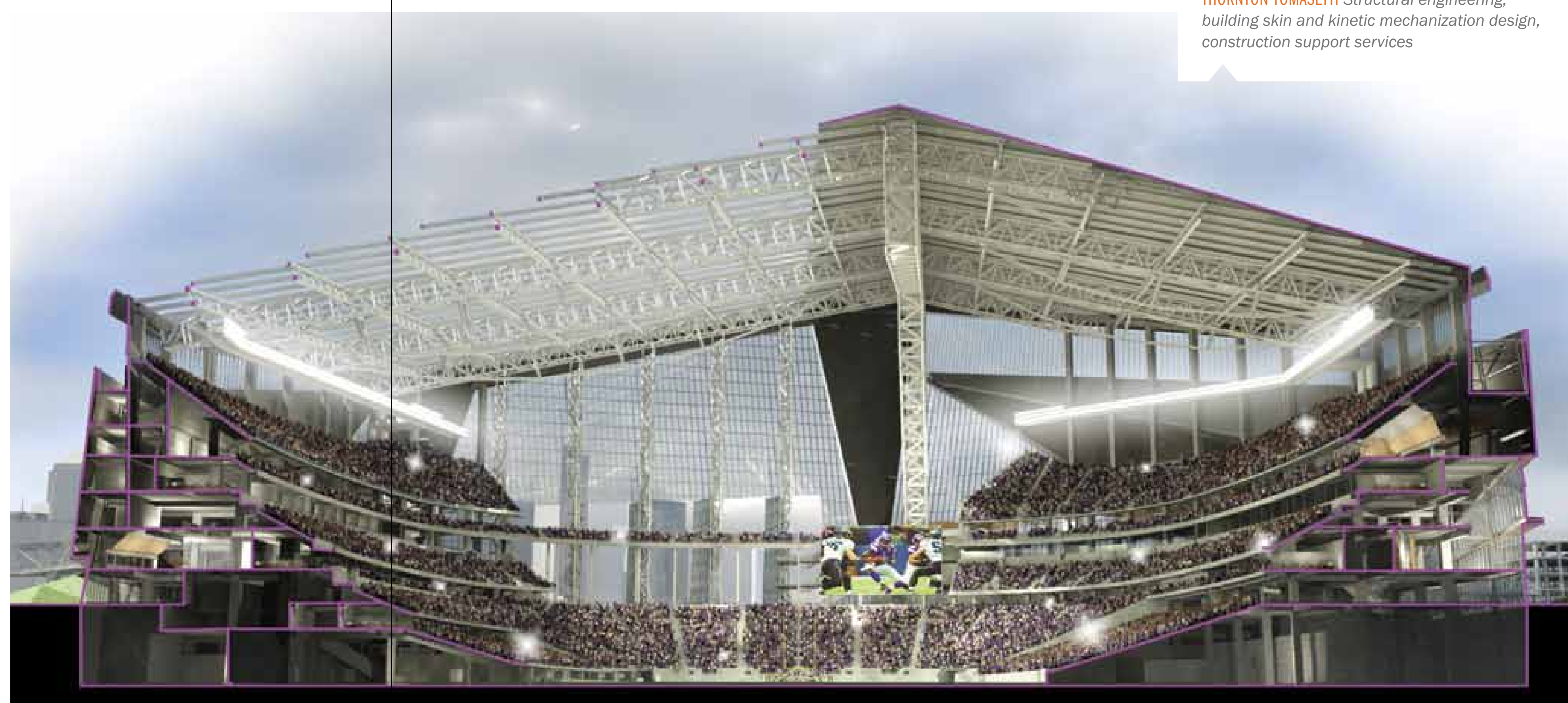
Innovation We proposed a new way to let in light and air by pairing operable wall panels with the largest ETFE roof in the United States — in a configuration that increases efficiency and creates an unmatched fan experience.

The 1.7 million square-foot stadium will seat 65,000 spectators when it opens in 2016. Our integrated services – which include multidisciplinary design as well as construction support services such as steel connection design and advanced modeling – are increasing the efficiency of the design and construction process and helping the project team meet a tight schedule.

PROJECT TEAM

Owner: *Minnesota Sports Facilities Authority*
Main Tenant: *the National Football League's Minnesota Vikings;* ***Architect:*** *HKS, Inc.*
Contractors: *Mortenson Construction and THOR Construction*

THORNTON TOMASETTI *Structural engineering, building skin and kinetic mechanization design, construction support services*



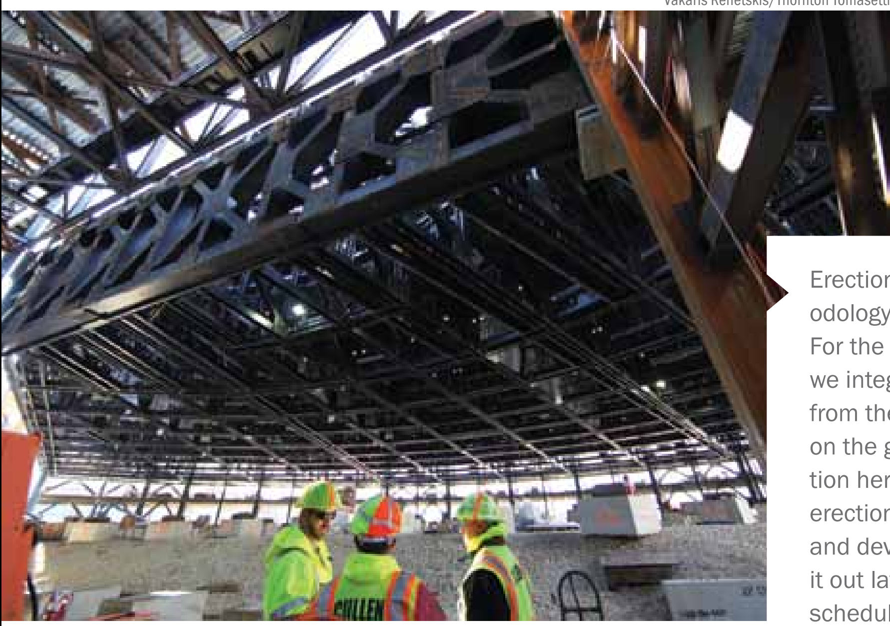
Courtesy HKS, Inc.

Integrating Construction Engineering and Design

Most engineering design firms see erection and construction engineering as risks to be avoided. We approach these tasks differently.

Our structural designs keep constructability in mind. By incorporating large or technically challenging construction operations into our design approach, we can streamline the process – especially important for fast-track projects. Our design knowledge of the structure enables a better erection engineering solution, and iteration between design and erection engineers leads to optimization of both.

Vakaris Renetskis/Thornton Tomasetti



The 275-foot truss that supports the roof.

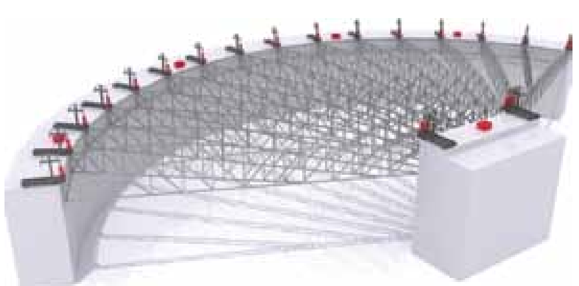
Designing a Roof to be Lifted: An Epic Story

Verona, Wisconsin

Erection engineers don't usually develop a detailed methodology for building a roof until construction is underway. For the 14,300-seat auditorium at Epic Systems, however, we integrated the erection engineering into the roof design from the start, allowing the 4,200-ton roof to be assembled on the ground and then lifted into place. "The key innovation here," said Brian Volpe, Thornton Tomasetti's lead erection engineer, "is that this whole project was conceived and developed around the lift. By not taking a 'we'll figure it out later' approach, we shaved 12 to 18 months off the schedule and reduced risk for everyone involved."

PROJECT TEAM ***Owner:*** *Epic Systems Corporation;* ***Architect:*** *Cuningham Group Architecture;* ***Steel Fabricator:*** *LeJeune Steel;* ***Contractor:*** *J.P. Cullen & Sons*

THORNTON TOMASETTI *Structural engineering, erection engineering, connection design, building skin consulting*



Model showing the roof and the strand jacks that lifted it into position.

Vakaris Renetskis/Thornton Tomasetti

Strand jacks (orange) in position during the roof lift operation.

Courtesy Skanska USA

The most innovative part of the project was tight coordination between our structural design team, the fabricator and the contractor. "Nothing was off-limits," said Zach Kates, the Thornton Tomasetti project manager. "We worked like an extension of the fabricator and became part of the construction team. A lot of people see risk in getting into fabrication and construction – 'what if the steel doesn't fit?' We have a different attitude: we have confidence in our people doing the connection design and coordination and we believe this actually reduces our risk."

Save Two Months: Turn the Project Sequence on its Head

Exploration Tower
Port Canaveral, Florida

In a typical project, shop drawings and fabrication model detailing are done after bid documents have been submitted and the steel is ordered. Since the fabricator is working with incomplete information, even a well-managed project might involve 50 to 100 requests for information (RFIs).

For the seven-story Exploration Tower, we reduced bid cost by 10 percent, slashed RFIs to a total of five, and saved two months in the construction schedule by changing the typical sequence. Through close collaboration of our structural and construction support teams, we produced the connection design and the full fabrication model before bid documents were finished, and then issued the fabrication model electronically to the steel bidders.

PROEJCT TEAM ***Owner:*** *Canaveral Port Authority* ***Architect:*** *GWWO Inc./Architects;* ***Construction Manager:*** *Skanska USA;* ***Building Fabricator:*** *Met-Con*

THORNTON TOMASETTI
Structural engineering, construction support services

Crane Engineering Solves a Setback Problem

Columbus, Ohio

The setback between floors of the Wexner Medical Center at Ohio State University called for an innovative approach to bracing one of the tower cranes, located more than 140 feet from the concrete cores. To anchor the crane we could have used a leave-out bay, which would have had to pass through complex spaces on the imaging floors. Instead, our construction support team designed and detailed a temporary 60-foot tower, supported by the building roof, for the crane to tie into. Because we also served as the project's structural engineer, the temporary work and reinforcing of the main structure was performed quickly and cost-effectively.

PROJECT TEAM ***Owner:*** *Ohio State University;* ***Architect:*** *HOK* ***Associate Architect:*** *Moody Nolan;* ***Construction Manager:*** *Turner Construction / Lend Lease;* ***Steel Fabricator:*** *Cives Steel*

THORNTON TOMASETTI *Structural engineering, construction support services*

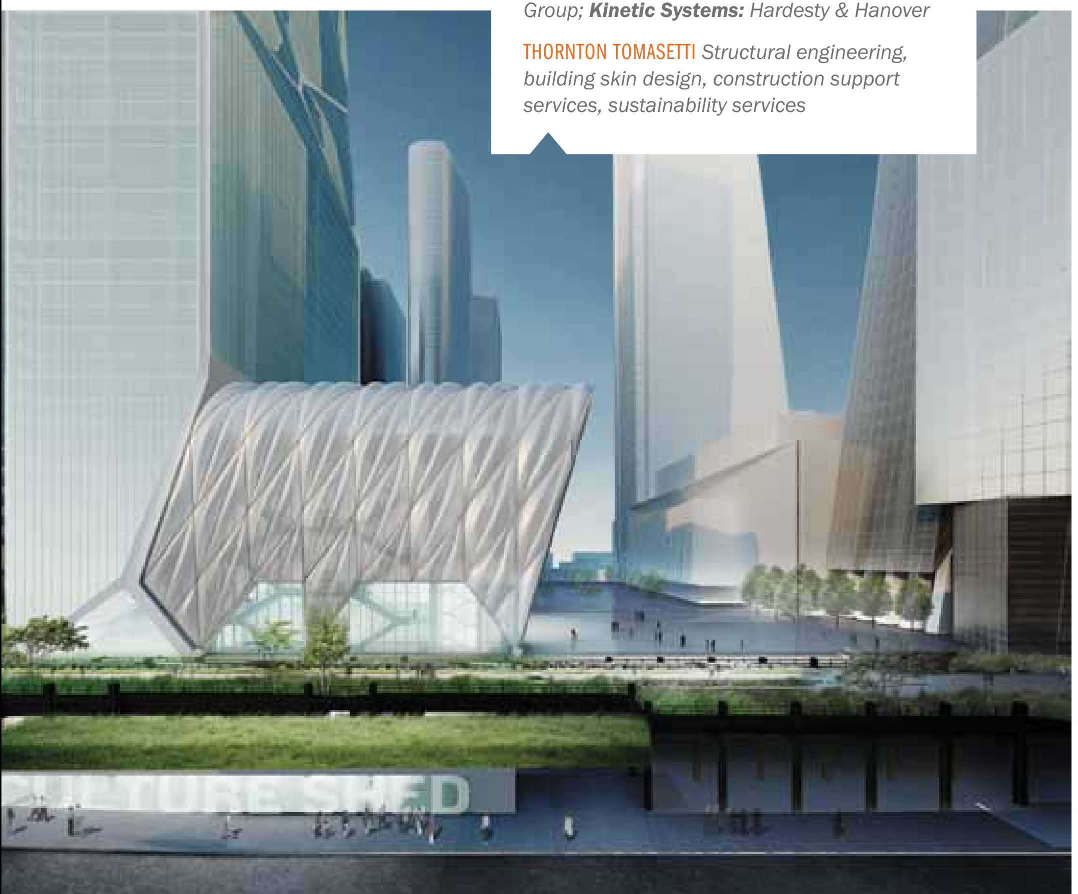
The crane is tied in to a temporary tower, cantilevered from the roof of the hospital structure.

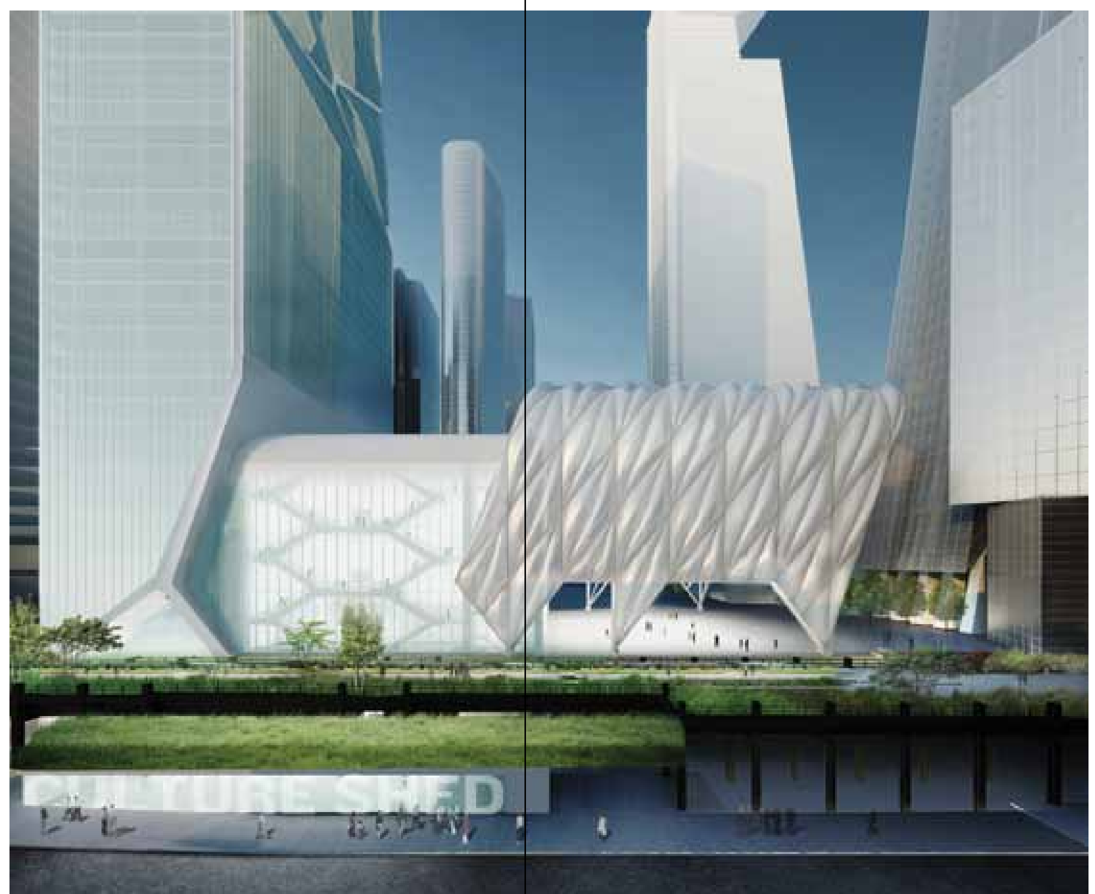
Challenge A translucent, movable building with exposed structure

Innovation Adapt and repackage conventional systems in an unconventional way

PROJECT TEAM ***Owner:*** *Culture Shed Inc.* ***Architects:*** *Diller Scofidio + Renfro/Rockwell Group;* ***Kinetic Systems:*** *Hardesty & Hanover*

THORNTON TOMASETTI *Structural engineering, building skin design, construction support services, sustainability services*





Courtesy Diller Scofidio + Renfro

We have worked on many movable structures, but this is our first movable building, complete with MEP, a lighting grid and black-out shades. "It looks like a building," said Justin Nardone, of our CORE studio, which modeled the skin design and structural diagrid. "But it's really a kinetic sculpture that has to perform structurally."

Innovation as Simplicity

The Culture Shed, New York, New York

This jewel box in the Hudson Yards development combines many challenging design goals and requires an integrated response, calling on our structure, skin, sustainability and construction support practices, as well as our services in kinetic engineering and computational modeling. Our mandate, with architects Diller Scofidio + Renfro/Rockwell Group, is to design a uniquely flexible and elegant space. So our approach is to find the path to simplicity.

The Culture Shed will be an indoor/outdoor assembly/performance space. Its fixed component is a four-story museum exhibition space. A movable "shed" will extend on tracks to provide an expanded, temperature-controlled public venue. Fully deployed, the Shed will double the building footprint.

Through use of cloud-based technology, teams in multiple offices were able to coordinate their work on a sophisticated 3D model that will be used for fabrication and construction. This design process was enhanced by collaboration on the model directly with the architects, as well as feedback from steel fabricators from an early stage.

The Shed's walls will be clad in ETFE cushions, a material we proposed based on its minimal weight and high strength. Daylighting and radiation analysis informed the ETFE frit patterns. An inner layer of ETFE material can be repositioned to respond to daylighting or thermal conditions as well as programmatic needs.

The Shed moves on six bogies (wheeled assemblies), each of which has wheels six feet in diameter and bears 2,000 tons – more than bogies at any stadium roof. The wheels will be custom built, but the drive system and motors are off the shelf. Operable doors will allow the expanded space to be open to the environment or protected. "One goal was to keep the kinetic systems hidden from view but safe, reliable and serviceable," said Tom Duffy, Thornton Tomasetti's leader of the kinetic system design. "The biggest innovation is the simplicity of it."

Danny Bright

Bob Katchur and Matt Ostrow of Diller Scofidio + Renfro with Scott Lomax of Thornton Tomasetti.

Most of the time, Chris Erwin (left) designs building structures, Dan Ciorba works in our building performance practice and Kristen Erickson is a construction support engineer. But in 2013, each had an idea for an innovation, which they pursued as part of our borderless CORE studio.

In

2013

individuals from across the firm submitted

33

R&D proposals

and

27

contributors

representing

100%

of our practices

invested

8,200

hours in

22

projects.

Look inside for highlights.

Narayan Mahon

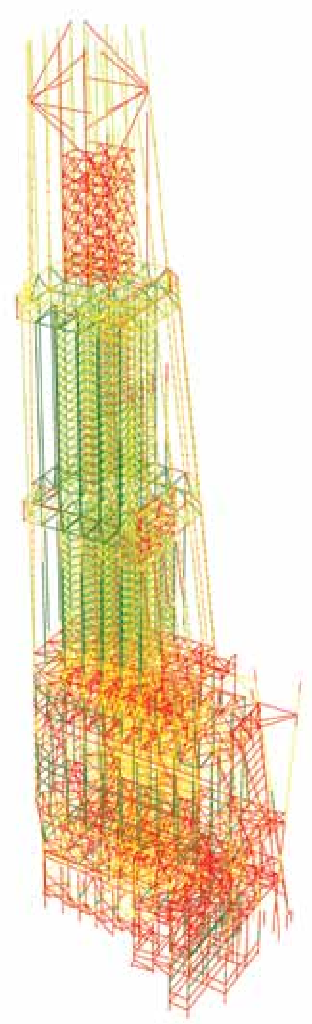
CORE studio

Our CORE studio is a firm-wide virtual incubator of ideas. Its name denotes the union of computational modeling and research and development, which are at the core of our mission to increase the value we bring to clients through innovation. The studio coordinates R&D, develops custom software and apps, designs workflows to optimize project realization and develops computational models.

Visit www.CORE.ThorntonTomasetti.com for up-to-date info on our innovation projects.

Taming Sway Becomes Automatic

To control how much a tall building sways when exposed to wind or seismic forces, engineers first design for strength, then up-size some structural members to reduce deflection. Excess material increases costs, so you get the biggest bang for the buck by augmenting the elements that do the most work. Senior Engineer Alfonso Oliva used application programming interfaces (APIs) to automate the time-consuming, iterative process of finding and optimizing these members. A database transfers information between SAP2000 (analysis), Microsoft Excel (design optimization) and Grasshopper and Rhino (visualization). The application greatly speeds the process and also increases accuracy by eliminating manual data transfer.



Known as opTTool, the application currently works with 2D models. A version for 3D models is under development. This 3D test shows an intermediate stage in the process: green denotes optimized structural members.

Rendering of the Commonground space, due to open in 2014.

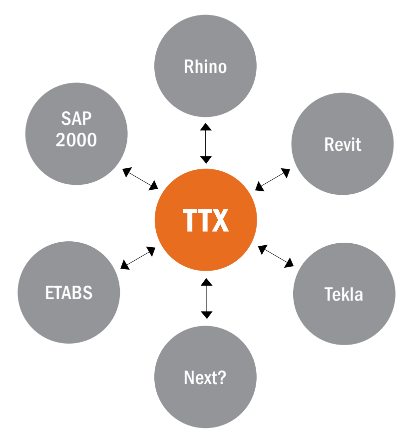
Courtesy Diller Scofidio + Renfro

Designing a Green Tension Cable Structure

At only 13,000 square feet, the Commonground community green space at Wishard Hospital in Indianapolis, Ind. presented large-scale structural challenges. The trellis structure, designed to support native vines, is built with steel rods only 1.25 inches in diameter (plants won't attached to wider rods). To ensure stability of the structure and achieve a fractal-like cable pattern, we used a form-finding "precalculation" of cable geometry to speed up finite element modeling – potentially saving weeks in calculation time. Vierendeel trusses in the corners add lateral stability.

PROJECT TEAM ***Owner:*** *Eskenazi Health;* ***Architect:*** *Diller Scofidio + Renfro* ***Contractor:*** *Gibraltar Construction;* ***Landscape Design:*** *OLIN*

THORNTON TOMASETTI *Structural engineering*

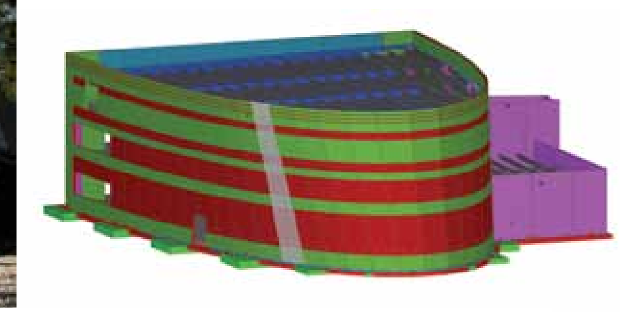


TTX is built to be expandable. We continually work to integrate additional programs to increase its usefulness. What's next for TTX? You name it.

Joseph Gamble

Suhendi Widjaja, project engineer, and Vanessa Da Rocha, BIM modeler, helped develop the façade design for the training facility.

In this Tekla model, red denotes glass panels and green is precast concrete panels. The gray strip highlights the desired sloping interface.



Parametric Modeling for a Corporate Training Facility

The sloping façade of this 443-seat, bullet-shaped training facility in Florida has different rates of curvature at the top and bottom of the ellipse, presenting a significant nonlinear form-finding challenge. To achieve the architectural vision and meet the owner's budget and schedule, we applied parametric modeling to rationalize the shape of the façade panels. We took the architect's bounding dimensions, with the top and bottom ellipses from the 2D CAD file, imported them into Rhino and then used Grasshopper to develop a constructable, economical flat panel geometry.

PROJECT TEAM ***Architect:*** *Song & Associates;* ***Precaster:*** *Coreslab Structures;* ***Structural Steel Fabricator:*** *Trident Building Systems, Inc.*

THORNTON TOMASETTI *Structural engineering, parametric façade modeling*

Innovative Interoperability

The proliferation of design software platforms has made the use of one-to-one translators an increasingly unmanageable way to achieve interoperability. So last year we launched TTX, a platform that can "talk" directly to multiple programs, translating data across modeling, analysis and documentation applications. TTX allows project teams to focus on their specialties in the platform of their choice; then it makes updates in all applications, without the need to re-translate the entire model.

Since the launch, we have continued to develop plug-ins to extend the usefulness of TTX. Users can now review project revision history by date, time, user or analysis program; can roll back all models to review an earlier version of the project; and can easily run reports on a wide variety of elements and parameters. In the works is a web-based viewer and project management interface.

Synchronized Geometry @ Grand

We were hired to help coordinate the slab and façade geometry at the Wilshire Grand Center in Los Angeles, Calif. We developed a custom tool that automatically synchronized project architect AC Martin's Rhino and Revit models, then used the combined data to generate two further Revit models. The first produced the architect's documentation of the façade panelization; the second provided the information needed by the façade consultant. For more information about the project and its structural design, see pp. 28–29.

Bess Adler/Thornton Tomasetti

Going Green with PANDA

CORE studio collaborated with our Building Sustainability practice to create a platform that performs concept-level analysis of whole-building energy use and daylighting. The Grasshopper plug-in PANDA (Parametric Analysis of eNergy and Daylight Autonomy) draws on the simulation engines of EnergyPlus, Radiance and Daysim to quickly analyze the impact of design variables such as geometry, floor heights and window-to-wall area ratios. Results are displayed in an easy-to-understand Excel spreadsheet. The PANDA plug-in allows engineers and designers who aren't sustainability specialists to easily evaluate the environmental ramifications of early design options so they can make greener choices.

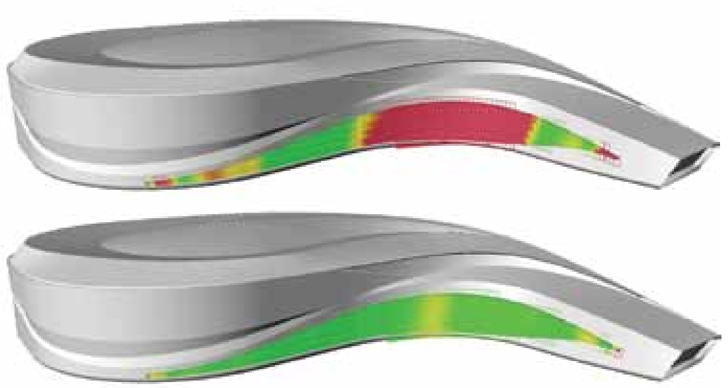
Building Sustainability Project Director Colin Schless, Integration Applications Developer Mostapha Roudsari and Intern Chris Mackey (not shown) collaborated on PANDA, which they developed through the firm's R&D program.

A Leap Forward in Efficient Panelization

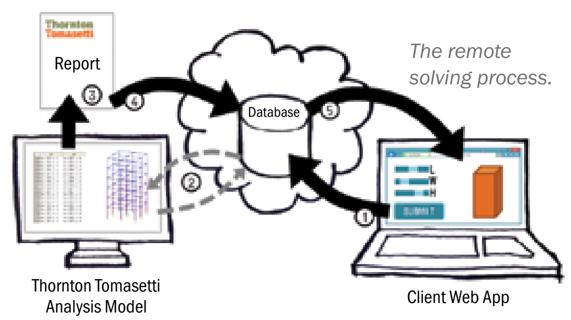
The swooping curves of Rogers Place, in Alberta, Canada, challenged our computational modelers to find a better way to rationalize its façade panel configuration. Senior Computational Designer Ben Howes scripted a custom tool that uses Kangaroo – a Grasshopper plug-in developed for form-finding – to speed development of the sinuous roof and façade. Panelization of curvilinear forms is a time-consuming process that requires analysis of many variables. Kangaroo is a physics engine: its job is to bring forces into equilibrium. Ben realized that by entering panels as force members, the program would instantly push and pull them into balance, providing a basic configuration that we could then refine using tools designed specifically for panel rationalization.

PROJECT TEAM ***Owners:*** *City of Edmonton and Edmonton Arena Corporation* ***Main Tenant:*** *the National Hockey League's Edmonton Oilers* ***Architect:*** *360 Architecture;* ***Associate Architects:*** *Dialog and ATB*

THORNTON TOMASETTI *Structural engineering (with local partner Dialog), façade modeling services, construction support services*



Screen shots show Kangaroo in the process of finding a functional panelization scheme. Green denotes panels that have been brought within the specified maximum warpage constraint of 20 millimeters. Our innovative use of Kangaroo allowed us to evaluate different design options – and give feedback to our clients – more efficiently than ever before.

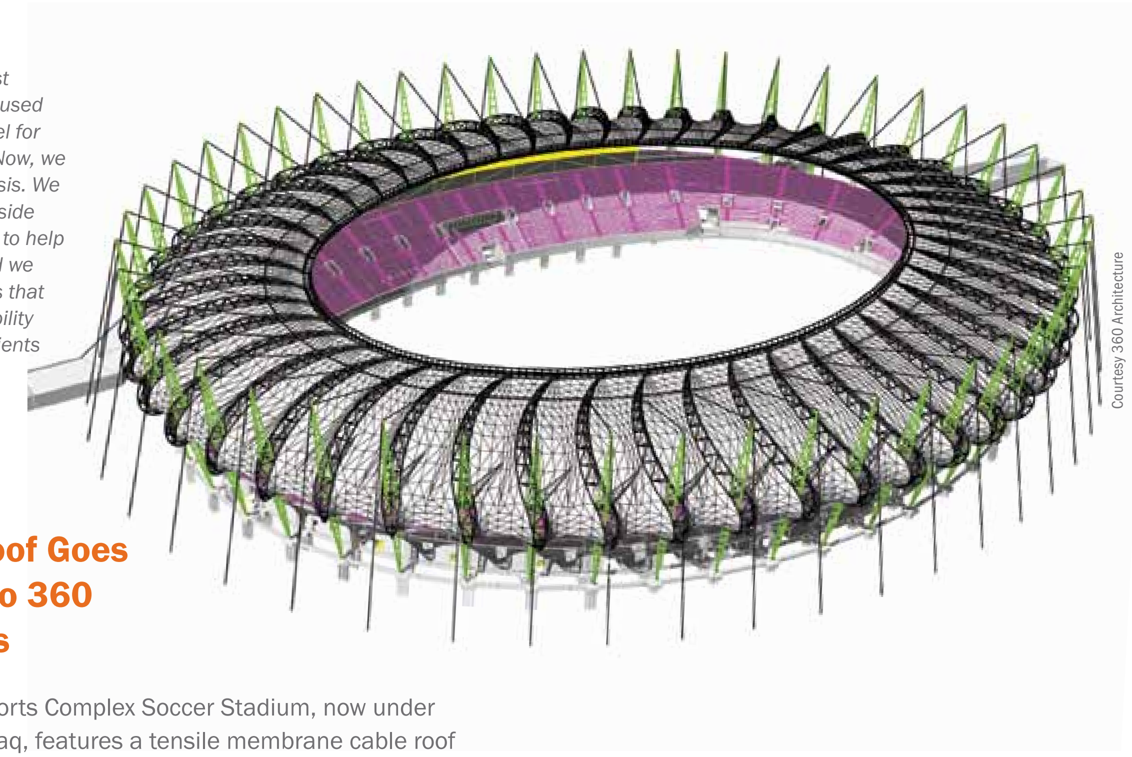


The remote solving process.

Remote Solving for Collaboration

Building designs change fast at the beginning of a project. We add value by quickly analyzing and responding to design iterations. To enhance this process, we developed automated work-flows that provide engineering analysis on design options in just a fraction of the usual time. We model the project and make it available online. The client adjusts various aspects of the model, then receives a report almost immediately on the basic engineering implications of the changes. Compared to the traditional process, remote solving methods eliminate days – or even weeks – from the time it takes to give our clients the information they need.

This roof was the first design for which we used a Grasshopper model for structural analysis. Now, we do this on a daily basis. We give feedback to outside software developers to help refine their tools and we develop new plug-ins that increase interoperability and help us serve clients more effectively.



Courtesy 360 Architecture

Stadium Roof Goes from Zero to 360 in Five Days

The Al Menaa Sports Complex Soccer Stadium, now under construction in Iraq, features a tensile membrane cable roof that was developed in less than a week. To meet the super-short design competition deadline, we set up camp in 360 Architecture's office and worked side-by-side for three days. Together, we built a Grasshopper model that allowed the team to study an array of design options from both architectural and structural perspectives, a process that usually takes months. On the fourth day, we used Geometry Gym software to assign material properties to model elements and import them to SAP for iterative engineering analysis. On day five, we used our custom translator to move the final geometry from SAP to Revit for documentation. On day six, our team won the project.

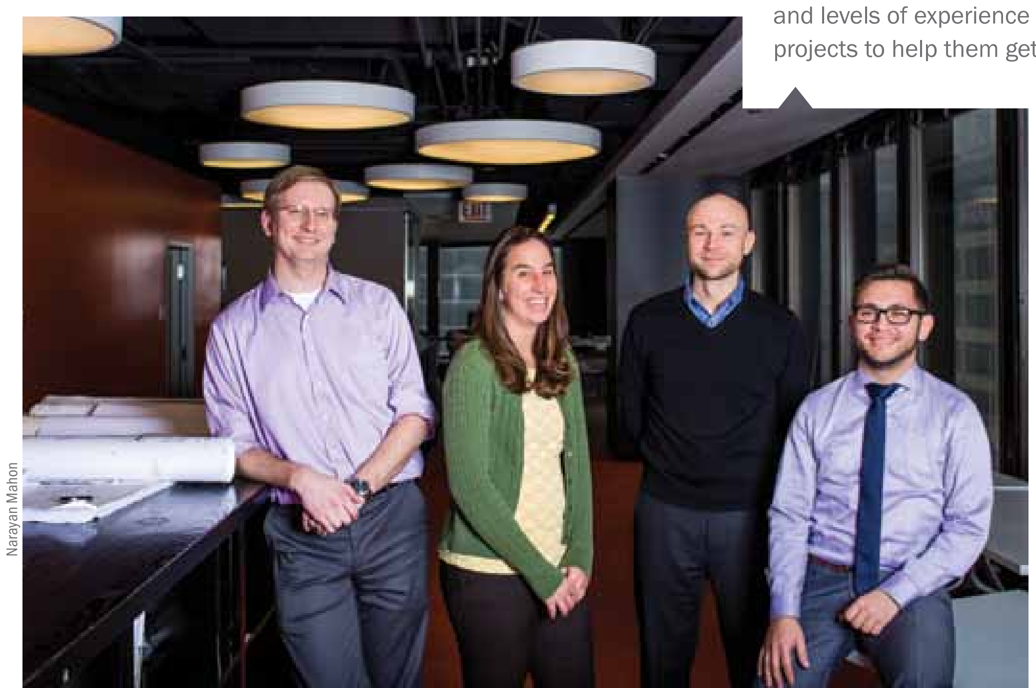
PROJECT TEAM ***Owner:*** *Iraq Ministry of Youth and Sports;* ***Architect:*** *360 Architecture* ***Contractor:*** *Anwar Soura for General Contracting*

THORNTON TOMASETTI *Structural engineering, building skin design*

R&D in Action

Inventing a new kind of building dampening and vibration mitigation system … exploring the application of performance based design principles to wind engineering … calculating the embodied carbon in the structures we design … teaching designers and engineers the C# programming language so they can easily extend the capabilities of standard software. These are just a few examples of the R&D projects our people are working on.

Our R&D approach nurtures innovation across the firm and cultivates collaborations with clients and other partners in the AEC industry, government research organizations, academia and beyond. We seek ideas from our people – in all locations, roles and levels of experience – and support promising projects to help them get started.



Narayan Mahon

Associate Chris Erwin, Project Engineer Kristen Erickson, Senior Project Engineer Nate Sosin and Designer Dan Ciorba were among the many employees who submitted R&D proposals in 2013.

Challenge Convert a 1964 office space into LEED v4 Platinum for Commercial Interiors

Innovation Beta test the new LEED v4 process for the U.S. Green Building Council

Helping Shape the New LEED Standard

650 California Street, San Francisco

When is an office also a laboratory? When it serves as a test bed for the new LEED v4 standard.

When we consolidated our three Bay Area offices under one roof, we jumped at the chance to be one of only 25 LEED v4 beta projects for Commercial Interiors, and only 123 of any sort worldwide.

We tested three notable changes introduced by LEED v4.

LEED v4 requires an integrative process that is not often applied on projects. “This is not a linear, but an iterative, collaborative approach that involves project stakeholders from visioning through completion of construction and then through building operations,” said Lynn N. Simon, senior vice president and sustainability leader for the office fit-out. “The HVAC engineer and building manager, for example, participate in the design process, instead of just being told to implement it later.”

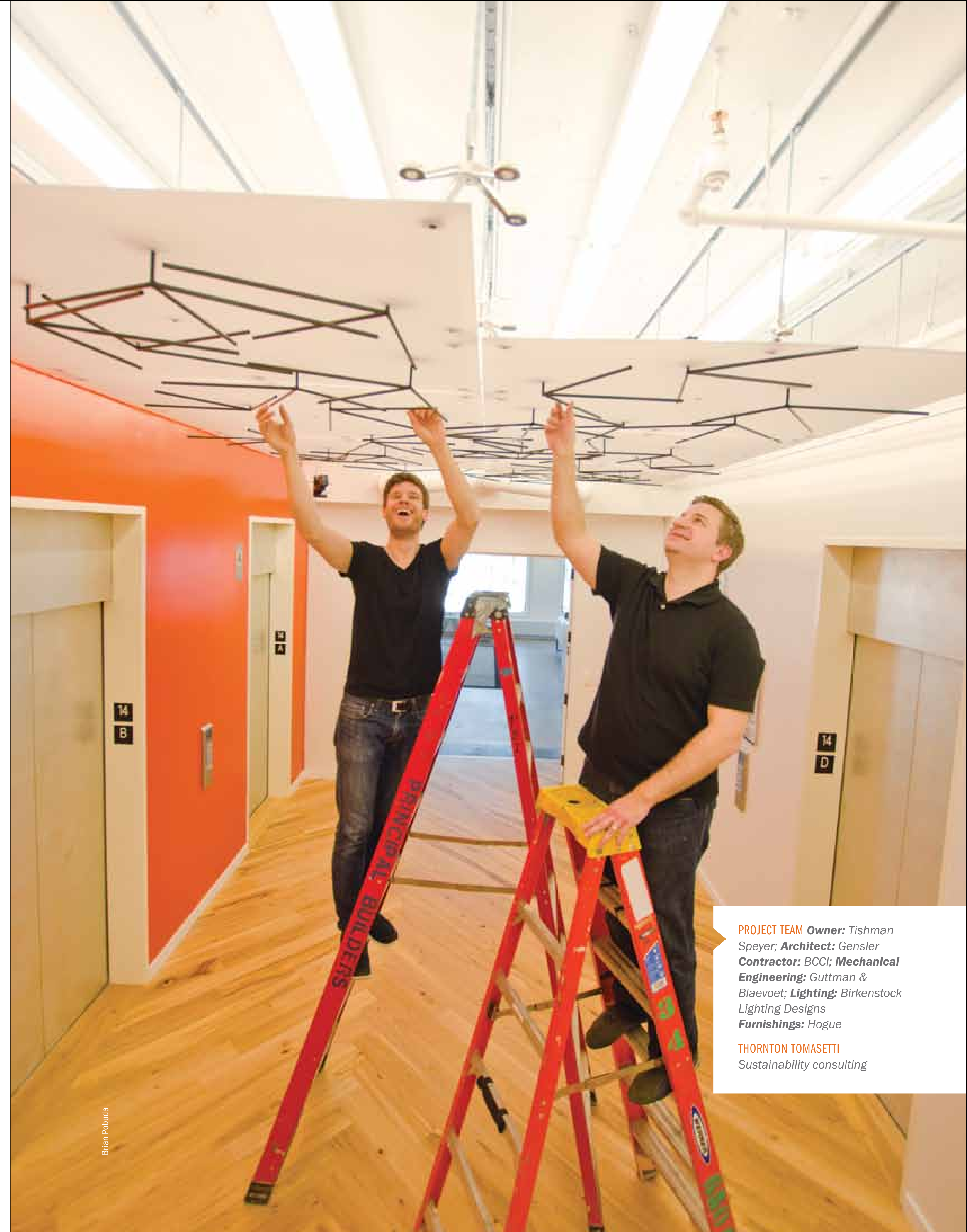
The newest – and perhaps most controversial – of the new LEED v4 categories is consideration of materials that have health and environmental product declarations. For example, does a manufacturer track a carpet’s carbon footprint, water resource use and effect of its manufacture on habitat or air quality? Not all products include declarations, though many manufacturers are racing to establish ratings so their products can be considered for LEED v4 projects.

Finally, LEED v4 considers daylighting quality, not just quantity, including measurement of reflectance values for everything in the space. “LEED v4 poses questions not asked before,” Simon said. “Illumination is no longer the only factor – it’s also about human health and occupant comfort.”

Jonatan Schumacher and Justin Nardone install a sculpture in the San Francisco office. Schumacher won a firm-wide competition to design a sculpture that illustrates the themes of innovation, collaboration and education. Selected from 13 submissions from six offices, the winning design was inspired by the work of artist Willem van Weeghel. Two rows of rotating bars display truss-like structural configurations in their movement. Sensors in the sculpture detect when people are under it, which disrupts the synchronized movement of the beams and creates a chaotic effect in that location. As the person walks away, the sculpture slowly returns to its harmonic movement. “It expresses the idea that we respond to our clients’ needs in a creative way and with many possible solutions,” Schumacher said.

At the end of moving day in November, San Francisco staff celebrated in the office’s central living room.

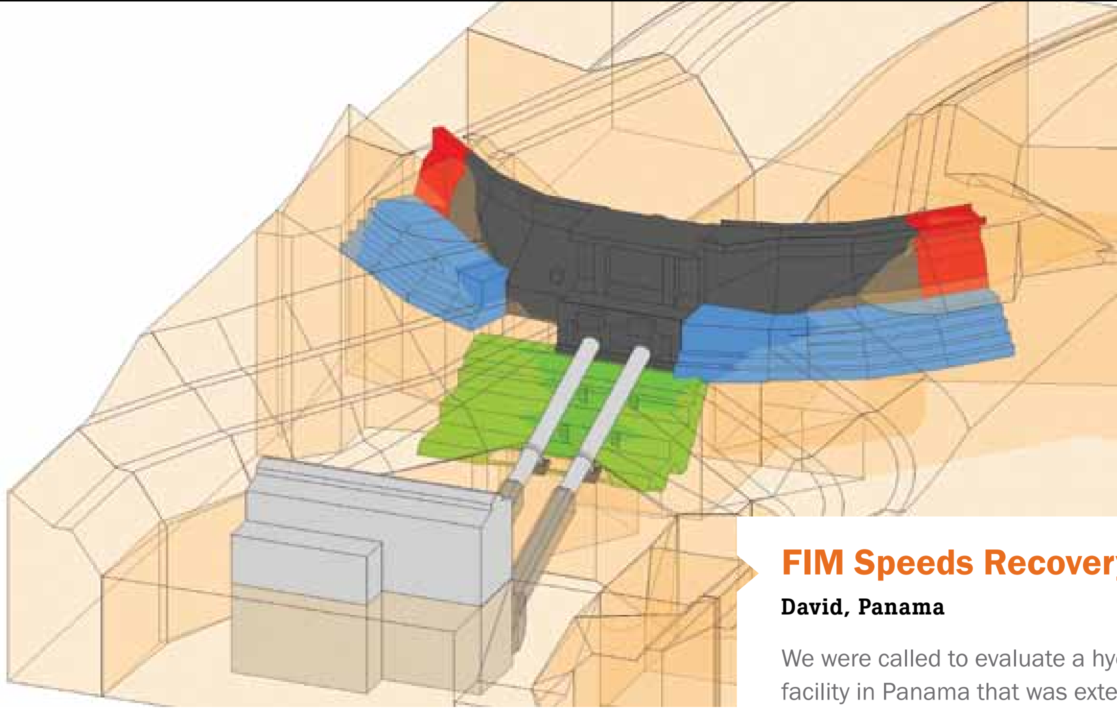
Steve Ratchye/Thornton Tomasetti



Brian Pobuda

PROJECT TEAM **Owner:** *Tishman Speyer;* **Architect:** *Gensler* **Contractor:** *BCCI;* **Mechanical Engineering:** *Guttman & Blaevoet;* **Lighting:** *Birkenstock Lighting Designs* **Furnishings:** *Hogue*

THORNTON TOMASETTI
Sustainability consulting



In this screen grab from our forensic information model, green, blue and red denote sections of concrete added during repair of the dam.

FIM Speeds Recovery

David, Panama

We were called to evaluate a hydroelectric facility in Panama that was extensively damaged by a flood following an embankment collapse. To organize our investigation, we developed a Revit-based FIM. The model allowed the adjusting team to easily visualize significant modifications in project layout made between design and construction, and also helped our analysis of the geometric properties of the concrete dam. Our FIM was also used to track progress of remedial construction and verify quantities of materials used to stabilize and retrofit the under-designed concrete structures.

THORNTON TOMASETTI *Forensic investigation*

Damage Evaluation

Nairobi, Kenya

After the September 2013 terrorist attack at the Westgate Mall, we evaluated the damage and determined engineering needs to return the facility to full pre-loss functionality.

The stability of a 100-meter-long retaining wall, partially supported by the structure, was a significant component of the investigation. We used laser scanning technology to evaluate the wall's condition and stability. This formed the basis of the FIM we used for structural analysis of the wall and bracing design for when reconstruction is underway.

THORNTON TOMASETTI *Forensic investigation*

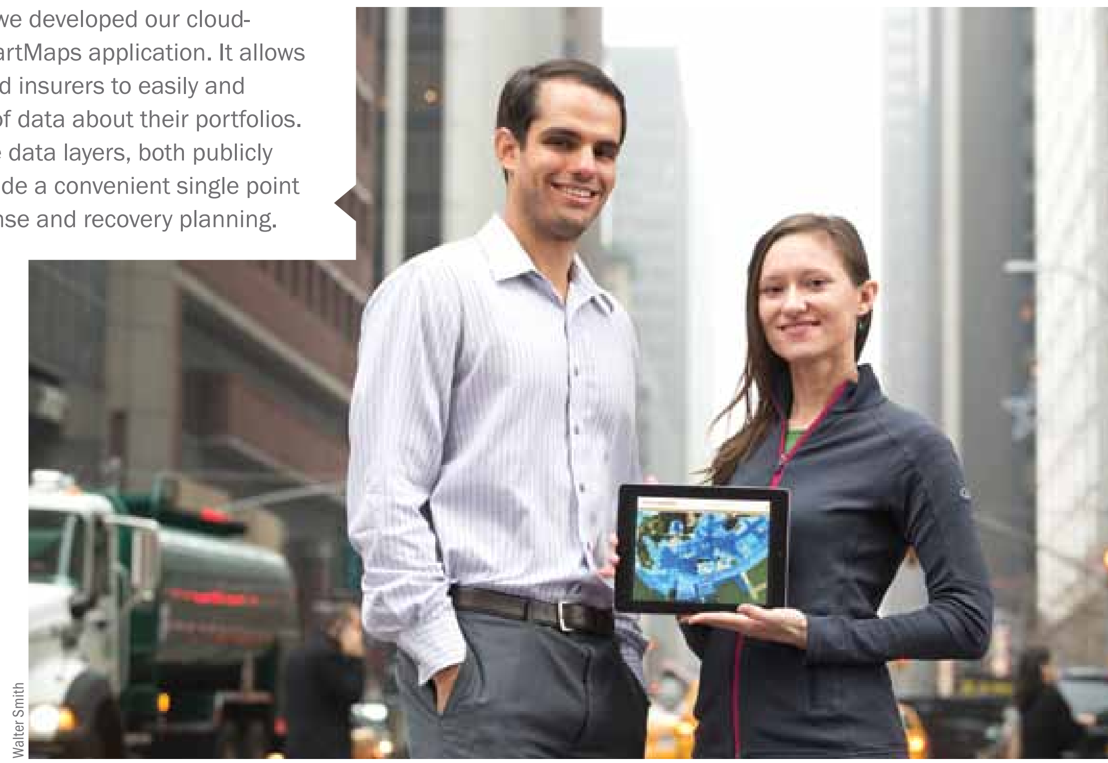
Managing Principal Gary Panariello was part of our team that conducted an inspection of the Westgate Mall in Nairobi.

Forensic Information Modeling: Smarter Decisions Faster

Just as building information modeling changed how we convey our design information, forensic information modeling (FIM) is changing how we organize, display, analyze, interpret and share investigative information. For the first time, a wide range of information – from digitized historical data to 3D laser scans – can reside on the same platform, leading to better, faster and more comprehensive analysis.

A New Portal for Property Data

During our CAT-90 Sandy response, we needed a fast and easy way to record, track and analyze data for hundreds of condition assessments. So we developed our cloud-based Thornton Tomasetti SmartMaps application. It allows property owners, managers and insurers to easily and securely access a wide range of data about their portfolios. Customizable views of multiple data layers, both publicly available and proprietary, provide a convenient single point of access to help speed response and recovery planning.



Walter Smith

Mark Andrews and Angela Brysiewicz (above), who helped develop the Thornton Tomasetti SmartMaps application, on Water Street in Manhattan's Financial District, which was hit hard by flooding from Sandy. We are using the same portal to manage earthquake assessment and recovery work in New Zealand. Mobile access allows data to be added or viewed on an iPad in the field, essential for linking distant parties and facilitating real-time coordination and collaboration.

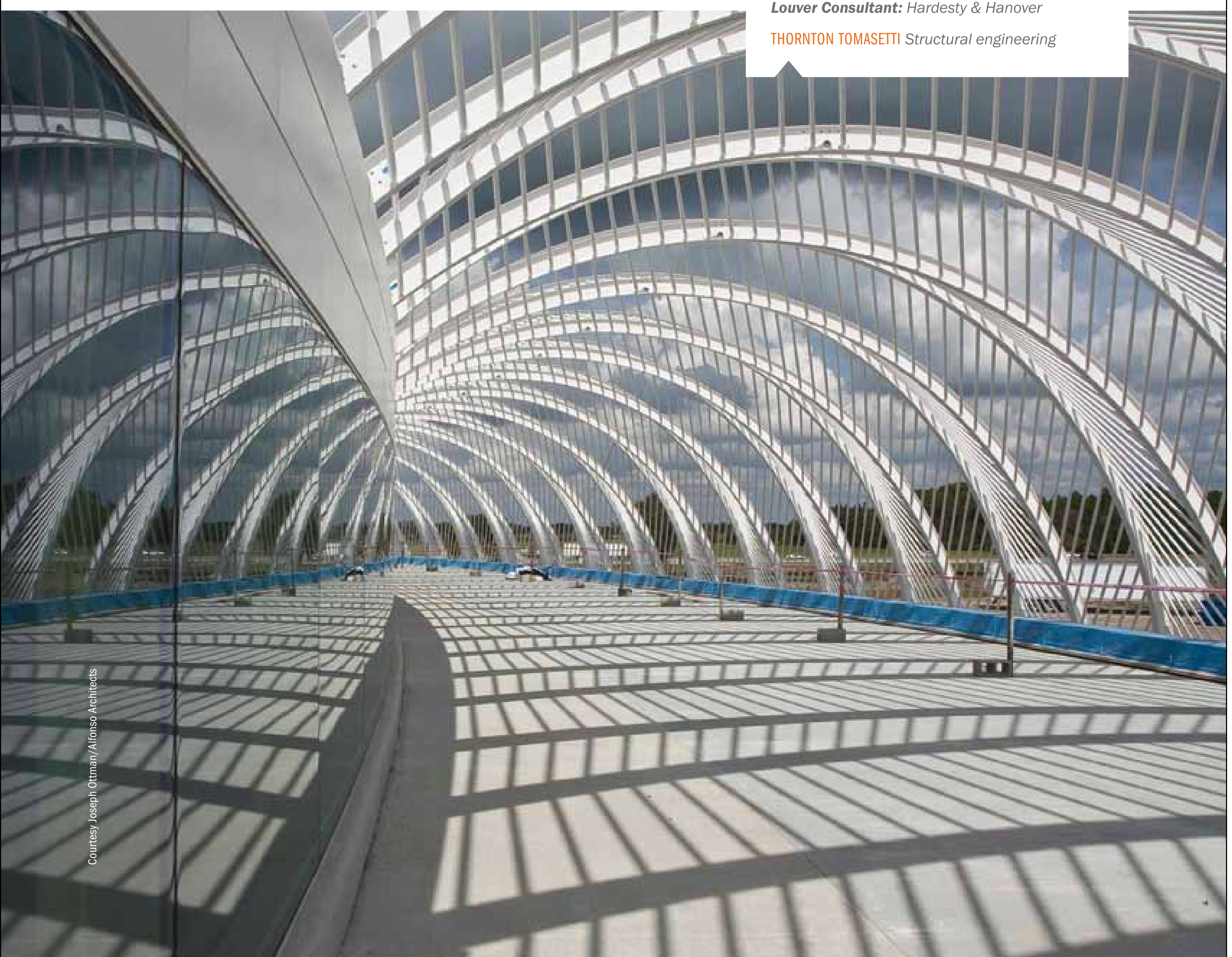
Chris Sheridan (below center) and team during a post-Sandy inspection of the East River rail tunnels, which bisect Manhattan to connect the east side with Penn Station.

Mark Andrews/Thornton Tomasetti

Challenge Design the focal point of a new college campus, with operable shading louvers and intricate exposed steel and concrete structures.

Innovation Tightly integrate project team members to fulfill the architectural vision while optimizing the design and kinetic systems to minimize cost and ease maintenance.

PROJECT TEAM
Owner: *Florida Polytechnic University;* ***Architects:*** *Santiago Calatrava and Alfonso Architects* ***Contractors:*** *Skanska USA/NuJak Development* ***Concrete Contractors:*** *Liberty/Baker;* ***Operable Louver Consultant:*** *Hardesty & Hanover*
THORNTON TOMASETTI *Structural engineering*


Courtesy Joseph Ottman/Alfonso Architects

Wing-like steel arches connect to curved concrete structural members.


©2012 — Santaigo Calatrava

The Innovation, Science and Technology Building, with louvers in the deployed position.

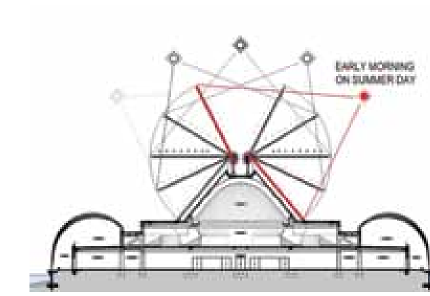
Architecture that Embodies Innovation

Florida Polytechnic University, Lakeland, Florida

The ultra-modern Innovation, Science and Technology building forms the heart of Florida Polytechnic University's new campus. Two features of the structure help it live up to its ambitious name and showcase our innovative approaches to design, fabrication and construction.

The building's signature feature is an array of wing-like shading louvers that move to continually optimize daylighting in the building's main space. The original concept called for two 250-foot-long movable arches to raise and lower the louvers. Working with the project team, we developed an alternative in which individual hydraulic pistons operate each of the 94 louvers. This allowed for a lighter, less-expensive structural support system and minimized the need for custom parts. The off-the-shelf kinetic systems will also be easier to maintain than the custom system of the original plan.

To create the building's curved and complex exposed concrete elements, we worked with the contractor to develop construction sequencing, formwork and shoring methods. Many of the tighter curves were achieved using board forming coated with auto body filler putty to get a smooth surface. "There was so much back and forth between us, the architect's team and the contractor," said Chris Christoforou, Thornton Tomasetti project lead, "that other team members commented they didn't see where the structural engineering ended and fabrication/construction began. That's close collaboration."



Shading analysis, showing (in red) the louver position to maximize shade on a summer morning. Other louver positions follow the sun's trajectory.

Danny Bright

Rebecca Jones, Thornton Tomasetti senior project engineer, with Robert Scymanski of KPF, Jason Halpert of Tutor Perini and Andrew Werner of KPF.

Hudson Yards Tower C

New York City

New York's first all-concrete, post-tensioned high-rise office building is rising at Hudson Yards. While steel-frame construction dominates the city's commercial building market, taller clear ceiling heights with a loft-like feeling, together with favorable cost and schedule, combined to persuade the developer to pursue an unconventional route.

PROJECT TEAM ***Developers:*** *Related Companies and Oxford Properties Group;* ***Architect:*** *KPF;* ***Contractor:*** *Tutor Perini;* ***Major Tenants:*** *Coach, L'Oreal, SAP*

THORNTON TOMASETTI *Structural engineering, construction support services, building skin design*

After all columns were drilled and placed in the ground, the first-level floor was cast on grade, then the next level down was excavated and poured. The hotel's seven basement levels were constructed this way.

Marriott Marquis

Washington, D.C.

How do you build a 1 million-square-foot hotel on a tight site in a city with strict height limits? You dig deep. Extending 100 feet below ground, the building is nearly as deep as it is tall. Site constraints made conventional excavation support impractical, so the team opted for top-down construction – a first in Washington, D.C. We tapped the firm's experience designing for top-down construction in New York, Chicago, South Korea and India.

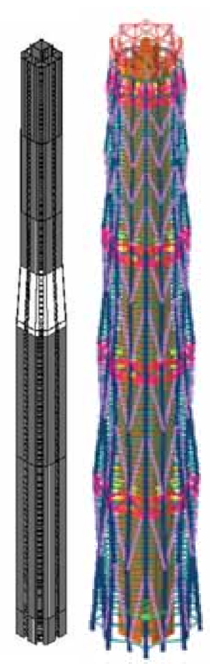
PROJECT TEAM ***Owners:*** *Quadrangle Development Corporation and Capstone Development;* ***Operator:*** *Marriott International, Inc.* ***Architects:*** *TVS Design and Cooper Carry, Inc.* ***Contractor:*** *Hensel Phelps;* ***CBE Partner:*** *A+F Engineers*

THORNTON TOMASETTI *Structural engineering*

Chengdu Dongcun Greenland Tower

Chengdu, China

The structure of this 468-meter tower includes the first sloping core wall system for a supertall building in China. Reducing the core size at the upper levels is a common way to increase usable floor space and reduce construction material and cost. Using a sloped wall to shrink the core requires more intensive engineering, analysis and creativity, but offers greater design efficiency than more conventional core reduction strategies. Our advanced computational modeling capabilities and experience with this system in other countries enables us to demonstrate its value and gain approval from the building department and expert review panel.



PROJECT TEAM ***Owner:*** *Greenland Group Chengdu Shu Feng Real Estate Development Co. Ltd.* ***Design Architect:*** *Adrian Smith + Gordon Gill Architecture* ***Architect of Record:*** *East China Architecture Design & Research Institute*

THORNTON TOMASETTI *Structural engineering*

Because this system has not been built in China before, we explored constructability issues during the early stages of design. We consulted with local contractors and learned that, due to advances in formwork systems, they could construct the sloping core walls without significant impact on the construction cost.

BW 1 Morumbi Empreendimento Imobiliario LTDA

The tower's two curving wings are linked by several "bridges" of multi-level office space. Our collaboration with the Medabil team and its consultants produced a successful structural solution.

WTorre Morumbi

São Paulo, Brazil

Most multi-story buildings in Brazil are concrete, but the developer and contractor wanted the faster construction speed offered by steel. We were hired by the steel fabricator to share our expertise in steel and composite high-rise design with the local project engineers. We joined a series of workshops in Brazil to review the structural design and discuss constructability issues. Establishing trust was critical to successful collaboration. In an early session we had a question about the lateral system design, so we sent the proposed configuration to our Chicago office and had it modeled overnight. "When we brought the analysis results to the meeting in the morning and started talking about possible solutions," said Vice President Jose Medero, "the team knew that we weren't there to criticize. We wanted to help."

PROJECT TEAM ***Developer:*** *BW 1 Morumbi Empreendimento;* ***Engineer of Record and Steel Fabricator/Erector:*** *Medabil Sistemas Constructivos S/A;* ***Architect:*** *Aflalo & Gasperini Arquitetos* ***Contractor:*** *WTorre Engenharia*

THORNTON TOMASETTI *Structural peer review and consulting*

Global Experience, Local Innovation

Design and construction practices have always varied by location. Different conditions, availability of materials and factors like wind or seismic activity all play a role in determining "how it's usually done" in any given place. Sometimes, though, the "usual" isn't the best solution. We look at every new project through the lens of our wide-ranging experience and ask: is there a better way? That's how our projects transform global experience into local innovation.

Nathani Heights

Mumbai, India

Tall and narrow, this 72-story residential tower is being built using composite construction for critical elements. The building's lateral system uses a high-strength concrete core with composite steel and reinforced concrete "mega columns" and outrigger trusses. This system has been used in towers around the world, but our structural design – developed jointly by staff in our Mumbai and Newark, N.J. offices – is one of the first of its kind in India.

PROJECT TEAM ***Owner:*** *Nathani Supariwala Realty;* ***Architect:*** *Skyline Architects* ***Wind Tunnel Testing Consultant:*** *RWDI*

THORNTON TOMASETTI *Structural engineering*

John C. Haas Archive of Science and Business

Philadelphia, Pennsylvania

When Chemical Heritage Foundation (CHF) needed new archive space but had limited expansion options on its Old City campus, a historic (circa 1855) but dangerously deteriorated brownstone offered an opportunity. The façade was preserved, but the rest of the building was demolished and rebuilt. The new structure was designed to house a 36-foot-tall mobile high-bay shelving system – the first in Pennsylvania – that provides 8,500 linear feet (more than a mile and a half) of shelf space in a building just 16 feet wide.

PROJECT TEAM ***Owner:*** *CHF;* ***Architect:*** *Always by Design* ***Contractor:*** *J.S. Cornell & Son, Inc.*

THORNTON TOMASETTI *Structural engineering, construction support services*

Behind the restored façade, a collection that includes the personal papers of significant scientists, engineers and innovators rests in a state-of-the-art archive.

Courtesy Paul S. Bartholomew

Performance-Based Design Gets to the Point

Wilshire Grand Center, Los Angeles, California

Above a sea of flat-topped downtown buildings capped by evacuation helipads, the Wilshire Grand Center stands out with its sail-shaped crown. The structural engineering team's use of a fire-resistant concrete core helped make this elegant profile possible, but a creative approach to other aspects of the design made the building feasible.

A PBD project requires more rigorous analysis than traditional code-based design. "With PBD, you end up learning a lot more about how the building works," said project manager Len Joseph. This knowledge freed the structural team to consider unconventional approaches, which, when combined in inventive ways, made the Wilshire Grand Center easier and less expensive to build.

One example is the use of buckling-restrained braces (BRBs) in outrigger trusses to resist lateral loads and control differential shortening. The BRBs – steel braces set inside concrete-filled steel tubes – improve seismic performance but aren't typically used in buildings of this size. To support the tower's enormous loads, our team designed mega-BRBs, sets of four conventional BRBs "matched and grouped together," said Joseph, "like four-horse teams."

Also innovative was the approach we used to coordinate the tower's five below-grade levels with Brandow & Johnston's design for the adjacent basement and podium. To ensure both separately modeled components work together, we used dummy frames to simulate the effect of each part on its neighbor. Senior Project Engineer Kerem Gulec developed a computational tool to optimize these dummy frames, helping both teams to produce more accurate, efficient designs.

When talented, creative engineers combine unconventional approaches in novel ways, they can create new solutions that benefit our clients through higher savings and lower risk.

Challenge In highly seismic Los Angeles, the owner's and architect's vision for a slender 73-story tower – the tallest west of the Mississippi – made traditional dual-system construction both impractical and prohibitively expensive.

Innovation The use of performance-based design (PBD) allowed our structural engineers to combine a variety of unconventional approaches into a unique solution that is easier and less expensive to build and outperforms a conventionally designed building.

Senior Project Engineers Ben Varela and Kerem Gulec and Senior Engineer Justin Schwaiger on site, just days before the project set a Guinness World Record for the largest-ever continuous concrete pour. More than 2,100 trucks delivered 21,200 cubic yards of concrete for the tower's foundation.

Ed Carreón

The mixed-use development's floors for parking, meeting rooms, hotel and offices each require different patterns of door openings into the core, which causes uneven loading and seismic behavior. To make the core design more uniform and economical, we established a single pattern of openings that could accommodate all uses, with the unneeded "phantom" openings on any given floor covered with drywall.

Courtesy AC Martin Partners

PROJECT TEAM
Owner: *Hanjin International/Korean Air*
Architect: *AC Martin Partners;* ***Structural Engineer of Record:*** *Brandow & Johnston*
Contractor: *Turner Construction*

THORNTON TOMASETTI *Structural high-rise design, including nonlinear performance analysis, through design reviews and permits, as a consultant to Brandow & Johnston*

Corporate Sustainability

Our corporate sustainability department helps us practice what we preach while reducing business costs, inspiring innovation and keeping us on top of industry trends. We're working to achieve ambitious goals for environmental and social sustainability.

Portland, Maine employees Ian Johnson and Amanda Lehman fertilize a plant using compost generated from the office's food waste.

London office staffers show off their new organic and recycled-fiber socks, which they received as prizes for winning our 2013 Carbon Footprint Challenge.

"We aspire to be one of the most sustainable firms in the AEC world, both in the way we design our projects and how we operate as a responsible business. In embracing this challenge, we see an opportunity to lead by example."

Tom Scarangello
Chairman & CEO

Since establishing a corporate sustainability department in 2012, we have made substantial progress toward fully integrating sustainability into every aspect of the firm.

This year, we produced our first stand-alone sustainability report, an online document that details our goals and describes some of the ways we worked toward them in 2013, including:

- Strategic goals and targets for sustainability in building design, business operations and social responsibility. We're committed to achieving climate-neutral business operations by 2030.
- We are one of the few firms calculating the embodied energy and carbon in our projects, and we are using this data to meet the reporting requirements of the AIA 2030 Commitment.
- Greening office operations in accordance with our sustainable operations policy, which mandates LEED Gold or higher for new office space. In 2013, we sought LEED CI certification for four locations.
- Programs to engage, inspire and educate our employees, including a new employee benefit that provides paid time for volunteering.

See the complete sustainability report at
www.thorntontomasetti.com/about/corporate_sustainability

The report is also available in the Global Reporting Initiative's Sustainability Disclosure Database.

Scan code to download the complete sustainability report.

The Thornton Tomasetti Foundation

Board of Governors

Richard L. Tomasetti
Chairman

Joel S. Weinstein
Vice Chairman

Daniel A. Cuoco
Secretary

Jeffrey R. Schreier
Treasurer

Joseph Burns

Wayne Stocks

Activities Committee

Aaron Beebe

Rachel Jackson

Elisabeth Malsch

In 2013, the Thornton Tomasetti Foundation, an independent 501(c)3 nonprofit organization, distributed $75,000 in scholarships, charitable projects and other initiatives in support of its mission. Since its inception in 2008, it has distributed more than $500,000 in grants and scholarships to more than 20 organizations. See more at www.ThorntonTomasettiFoundation.org

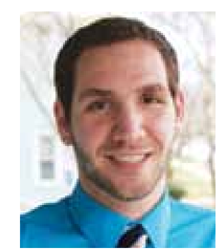
Highlights of commitments made in 2013:

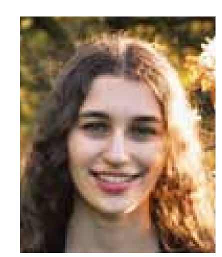
Bridges to Prosperity The Foundation provided $10,000 for construction of a much-needed footbridge in Tiraque, Bolivia, to be built with the help of the University of Michigan Bridges to Prosperity Chapter.

Education Grants A $5,000 grant to Lehigh University funded a student pursuing a Master of Engineering in Structural Engineering. At the University of Southern California's School of Architecture, another $5,000 grant is helping 10 doctoral students expand their research on the interface between building envelopes and building structure. We also provided a $5,000 grant to the New York City Urban Assembly, which runs education programs in 22 theme schools for 9,000 underserved children.

Scholarships Adam Bichir, Jingyu Lee and Francesca Renouard (pictured at left) were recipients of the second annual Thornton Tomasetti Foundation National Scholarship, which supports students interested in the integration of engineering and architecture. Each student received $10,000 to pursue master's degrees in structural engineering. The recipients are graduates of the University of Michigan, Illinois Institute of Technology and University of Washington, respectively.

Engineers Without Borders Our total support for Engineers Without Borders reached $100,000 with this year's donation of $25,000, which supports, in part, the Wichita State University EWB chapter's expansion of a rural school in Choestancia, Guatemala.





Richard Tomasetti with Professor Toby Cumberbatch and Cooper Union students. Our $12,000 grant supported the students' design and construction of sustainable disaster and refugee shelters in Ghana.

Our $10,000 grant to Bridges to Prosperity helped fund construction of a foot bridge in Bolivia to provide isolated communities access to healthcare, education and job opportunities.

Courtesy Bridges to Prosperity

A $5,000 grant supported the Build Change program, which trains vocational students in Indonesia in earthquake-resistant design and construction.

An additional $5,000 grant was made to Trilogy Publications for distributing Those Amazing Engineers to grade school children nationally. Our support to the publication now totals $15,000.

Integrated Practices

Building Structure
Our structural engineers collaborate with architects, owners and builders to design elegant solutions for projects of all sizes, types and levels of complexity. From designing the world's tallest buildings and longest spans, to engineering inventive small-scale "jewel-box" structures, we continually seek the best balance between the demands of form, function, sustainability, constructability, schedule and budget.

Construction Support Services
Integrating design and construction teams through the use of technology helps projects move smoothly from concept through completion. We develop project delivery strategies customized to each client's priorities. Our advanced project delivery and modeling services coordinate complete structures, using a single model to create design drawings and construction deliverables, from fabrication-ready models to shop drawings and sequencing plans. We provide erection and stability engineering, lift design, fixture design and equipment and logistics planning, as well as on- and off-site field engineering support.

Building Skin
We apply expertise in systems and materials to integrate building skin and structural designs in new buildings, renovations and re-cladding projects. We provide façade consulting and engineering services to architects, building owners and developers; perform a suite of specialty analyses that solve complex design challenges, improve constructability, maximize energy efficiency and increase security; and offer a range of construction support consulting services to assist contractors during bidding, negotiation, value engineering, post-contract review and site supervision.

Building Sustainability
Our sustainability specialists collaborate with clients and project partners to integrate successful green solutions into the planning, design, construction and operation of buildings, reducing their environmental impact at every stage in their life cycle. We use whole-systems thinking and cutting-edge technological tools to develop innovative solutions that balance economic, social and environmental factors. Our experienced team offers sustainable design strategies, energy analysis, green building certification consulting, sustainability analysis and upgrades for existing structures, and education and training.

Building Performance
We assist property owners, managers and other stakeholders with technical support for existing structures through our renewal and forensics services. Our multidisciplinary professionals – structural engineers, architects and MEP engineers – assist with upgrades, repairs, expansions, adaptive reuses and historic preservation. We also evaluate losses in strength, functionality and value; perform materials testing and reliability and risk analyses; develop repair solutions; and provide expert opinion and litigation support.

Property Loss Consulting
We serve insurance companies, their representative attorneys and executive general adjusters by evaluating the scope and nature of losses related to natural and man-made events. Our areas of expertise include structural, architectural and MEP evaluation; scope of damage determination; cause and origin investigation; building code consulting; multihazard risk assessment and mitigation; expert witness testimony; and green claims consulting. Operating internationally, our multidisciplinary team provides critical information that helps our clients make informed decisions regarding property and casualty, construction defect, builders' risk, surety and liability claims.

Offices

Abu Dhabi, UAE
Beijing, China
Boston, Massachusetts
Chicago, Illinois
Christchurch, New Zealand
Dallas, Texas
Denver, Colorado
Dubai, UAE
Fort Lauderdale, Florida
Ho Chi Minh City, Vietnam
Hong Kong, China
Irvine, California
Kansas City, Missouri
London, United Kingdom
Los Angeles, California
Moscow, Russia
Mumbai, India
New York, New York
Newark, New Jersey
Philadelphia, Pennsylvania
Portland, Maine
San Diego, California
San Francisco, California
São Paulo, Brazil
Shanghai, China
Washington, D.C.

Board of Directors and Officers

Board of Directors

Thomas Z. Scarangello, P.E.
Chairman &
Chief Executive Officer

Robert P. DeScenza
P.E., LEED AP BD+C
President

Aine M. Brazil
P.E., LEED AP
Vice Chairman

Dennis C.K. Poon, P.E.
Vice Chairman

Joseph G. Burns
P.E., S.E., CEng, FAIA, RIBA, LEED AP
Managing Principal

Bruce Gibbons
P.E., S.E., CEng, LEED AP
Senior Principal

Steven Hofmeister
P.E., S.E., LEED AP
Senior Principal

Gary F. Panariello
Ph.D., P.E., S.E.
Managing Principal

Wayne Stocks
P.E., LEED AP BD+C
Managing Principal

Yi Zhu
Senior Principal

Founding Principals

Charles H. Thornton
Ph.D., P.E., NAE, Hon. AIA

Richard L. Tomasetti
P.E., NAE, Hon. AIA

Practice Leaders

Building Structure
Robert Sinn
P.E., S.E., LEED AP BD+C
Principal

Construction Support Services
Darren Hartman
P.E., LEED AP BD+C
Principal

Building Skin
Sergio De Gaetano
Dott. Ing., CEng, MICE
Vice President

Building Sustainability
Gunnar Hubbard
AIA, LEED Fellow
Principal

Building Performance/Forensics
John Abruzzo, P.E., LEED AP
Senior Principal

Building Performance/Renewal
Gary Mancini, P.E., LEED AP BD+C
Senior Principal

Property Loss Consulting
Charles Meade
Principal

Regional Leaders

East U.S.
Michael Squarzini
P.E., LEED AP
Senior Principal

Mid-Atlantic and South U.S.
Wayne Stocks
P.E., LEED AP BD+C
Managing Principal

Midwest U.S.
Steven Hofmeister
P.E., S.E., LEED AP
Senior Principal

West U.S.
Bruce Gibbons
P.E., S.E., CEng, LEED AP
Senior Principal

Europe, Middle East, India, Brazil
Joseph G. Burns
P.E., S.E., CEng, FAIA, RIBA, LEED AP
Managing Principal

Pacific Rim
Yi Zhu
Senior Principal

Global Support

Amy Hattan, LEED GA
Corporate Sustainability Officer

Robert Honig
General Counsel

Ed Kasparek
Director of Business Development

Jim Kent
Chief Marketing & Communications Officer

Leigh Mires
Chief Learning Officer

Steve Ross
Chief Information Officer

Cover and text paper:
Reincarnation – 100% PCW

RECYCLED
Paper made from recycled material
FSC® C002684

Russell Design NYC www.russelldesign.com

www.ThorntonTomasetti.com