Thornton Tomasetti

Tall and Supertall

Cover: Kingdom Tower, Jeddah, Saudi Arabia © Adrian Smith + Gordon Gill Architecture

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Tall and Supertall

The New York Times Building, New York, N.Y.

Contents

Shanghai Tower, Shanghai, China, courtesy Gensler

Firm Profile

Thornton Tomasetti is a leader in engineering design, investigation and analysis, serving clients worldwide on projects of all sizes and complexity. Our projects include the tallest buildings and longest spans as well as complex special structures. We address the full life cycle of a structure through our integrated practices in building structure, building skin, building performance, construction support services, and property loss consulting.

Founded in 1956, today Thornton Tomasetti is a 550-person organization of engineers and architects collaborating from offices across the United States, and in Europe, Asia-Pacific and the Middle East.

We apply practical innovation to all our work to meet our clients' requirements for form, function, sustainability, schedule, constructability and budget. We combine the latest technological tools and processes with best practices learned from more than 50 years of experience. Our "multilingual" software proficiency aids effective communication and coordination across disciplines and time zones. With a highly collaborative approach to rapid design prototyping, we strive to realize our client's vision within budget and often on fast-track schedules. From the onset of the design process, we work closely with architects, contractors, consultants and user groups to facilitate efficient integration of architecture, structure, building services, infrastructure and sustainability criteria, to create buildings that positively affect their occupants, the community and the environment.

Integrated Practices

Our firm is organized into five integrated practice areas – building structure, building skin, building performance, construction support services, and property loss consulting – that are engeged globally in a wide range of market sectors.

Our Vision

We strive to reinvent how buildings are imagined – and built.

Building Structure

We collaborate with architects, owners and builders to achieve elegant structural solutions that meet the demands of challenging projects of all types and sizes, for new facilities as well as renovations and conversions. We understand the similarities and differences among building types – office towers and ballparks have both common and divergent design features – and the structural systems applicable to them. We focus on finding the optimal balance among multiple objectives: form, function, schedule, sustainability, constructability and budget.

Building Skin

Our expertise in skin and structural systems extends from applications of innovative materials and point-supported and cable-supported glass, which can provide signature architectural statements, to budget-friendly conventional curtain walls. The creative use of new materials and techniques, combined with our pragmatic approach of unifying structure and skin, offers our clients valuable opportunities to achieve solutions that are both striking and sustainable. We have extensive experience working directly with manufacturers worldwide on the design, engineering, testing and installation of a wide variety of systems, from unitized curtain walls and off-the-shelf aluminum stick systems to metal and glass cladding, point-supported glazing, steel-framed systems, grid shells, fabrics, and ethylene tetrafluoroethylene (ETFE) and Mylar films.

Building Performance

Building owners and managers have ever-increasing expectations for high performance in moisture management, thermal comfort and noise control, as well as in meeting challenges such as sustainability, force protection, and pre-event and post-event evaluation. We recommend maintenance regimes, guide owners through expansions, adaptive reuses, rehabilitations and repairs, and provide expert witness representation.

Building Skin – Model of the Federation Tower's steel and glass cap, Moscow, Russia.

Building Structure – 731 Lexington Avenue, New York, N.Y.

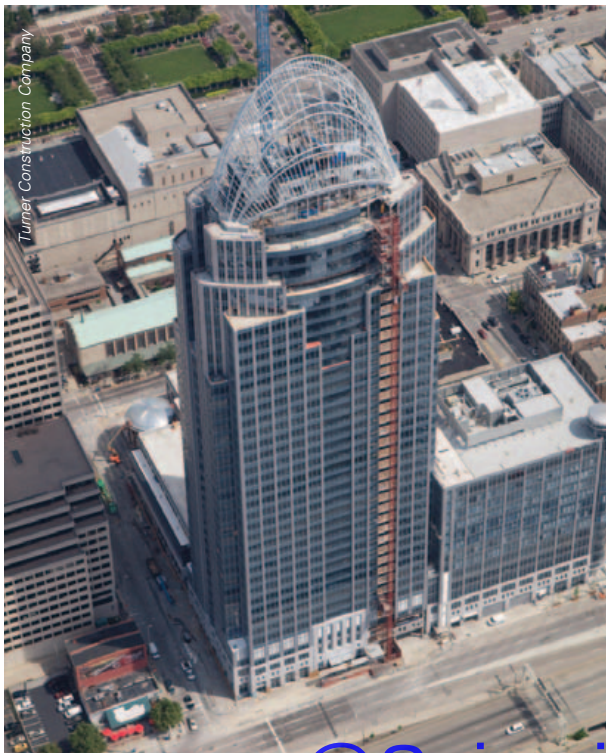
Building Performance – Chrysler Building restoration, New York, N.Y.

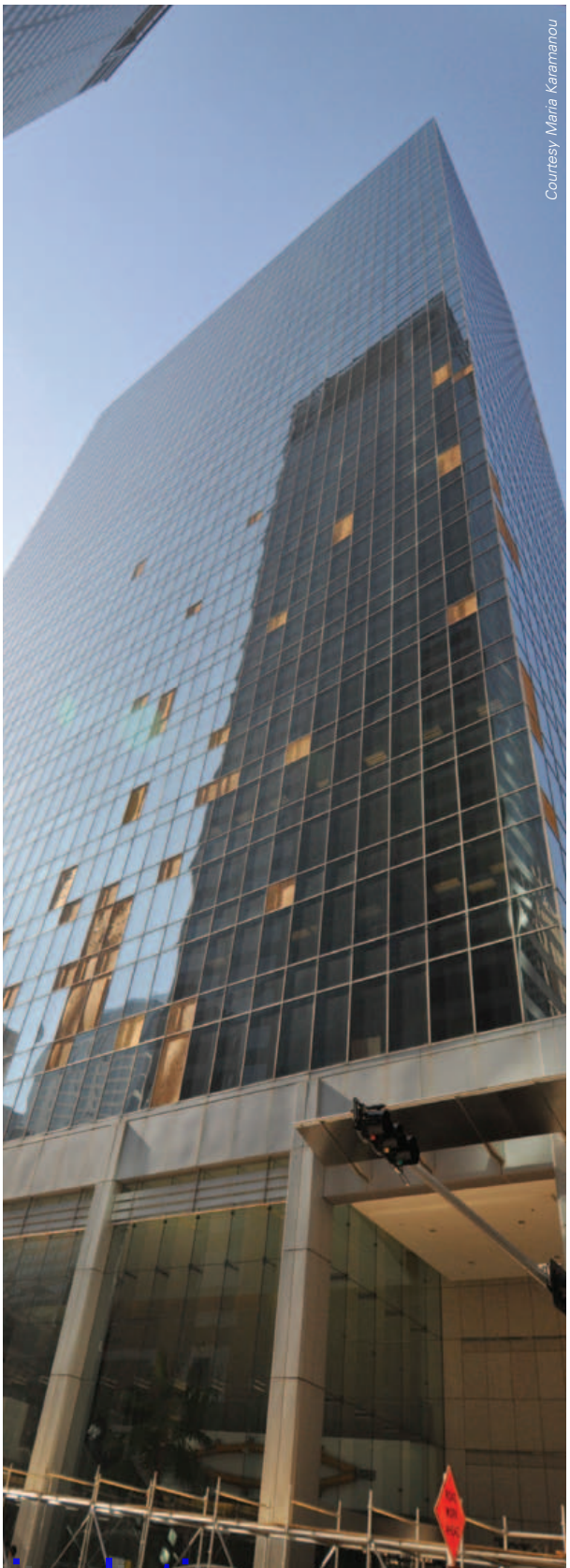
Property Loss Consulting

We assist insurance companies and their representative attorneys and adjusters in evaluating the scope and nature of losses related to natural and man-made events. We offer scope of damage determination, including cause and origin investigation, engineering, architectural and MEP evaluations, building code consulting and the handling of property claims related to LEED-certified properties. In many instances, after completing a cause and origin investigation, we provide expert reports and testimony. We also offer due diligence surveys to help evaluate and mitigate the nature and level of risk a catastrophic event could pose to specific structures or a portfolio of properties.

Construction Support Services

Working closely with developers, construction managers, fabricators, erectors, and general and specialty contractors, we move projects efficiently through concept, delivery, final completion and project close-out. Our services include project delivery strategy, design-build, steel detailing, precast modeling, cast-in-place modeling, building façade modeling, steel connection design and construction engineering for erection engineering and site logistics, stability engineering, and equipment and logistics. Our experienced engineering professionals provide early planning for Integrated Project Delivery (IPD) and design-build projects, as well as building information modeling (BIM) coordination and document services.


Turner Construction Company


Courtesy Maria Karamanou

Construction Support Services – Erection engineering for the "Queen City Square Tower's" tiara," Cincinnati, Ohio.

Property Loss Consulting – After Hurricane Ike in Houston, Texas.

Sustainability

200 5th Avenue, New York, N.Y.

In 2010, Thornton Tomasetti became the first engineering design firm to sign the AIA 2030 Commitment, a program that promotes the transition to carbon-neutral buildings by 2030. To meet this commitment, we are preparing a system that will enable us to quantify, track and reduce the embodied energy and carbon values of the structures we design.

This commitment aligns with our goal of delivering sustainable solutions for new construction and existing building projects of all sizes and in all market sectors.

Since the inception of the LEED rating system, we have contributed to the LEED certification of hundreds of projects.

Our sustainability consulting services, supported by our 170+ LEED-accredited professionals, include:

- sustainability strategy development
- administration of LEED or other environmental rating systems
- building performance audits
- building systems analysis and upgrades
- energy modeling and other advanced building simulations

As an international firm, we help clients address sustainability objectives for buildings in a wide range of climates. We design constructable, high-performance building envelopes that are responsive to the local climate and effectively support energy efficiency objectives.

Our structural designers contribute to the realization of sustainable buildings in many ways: specification of cement substitutes (fly ash, slag) and recycled steel; support for green roofs, cisterns and bio-retention systems; and the use of local materials to reduce transportation impacts. Efficient structural design also contributes to an overall reduction in building materials.

Safe and long-lasting tall and supertall buildings unavoidably incorporate substantial amounts of structural materials. When our engineers develop efficient structural systems and take embodied carbon impacts into account, we are able to make truly significant contributions to a project's overall sustainability.

Thornton Tomasetti's business operations and practices reduce our environmental footprint by limiting our consumption of energy, water and natural resources and by reducing waste generation. We continually educate our employees about sustainability practices, and we strive to maintain a workplace in which the value we place on sustainability is reflected in our product as well as our day-to-day operations.

At Thornton Tomasetti we are certain that the building model of the future will be dramatically "greener" than that of the past – any other scenario is simply, well, unsustainable. We are firmly committed to playing a role in this transformation to a more sustainable built environment.

Inside the winter garden of the LEED Gold certified Comcast Center, Philadelphia, Pa.

Role in Tall Buildings

New Design

In recent years, supertall buildings have become more structurally challenging and visually exciting. Lateral accelerations on windy days and differential column shortening (post-construction creep and shrinkage) as height increases pose special challenges. Powerful computer programs now aid in geometric modeling and structural analysis. A broader understanding of wind and seismic loads and new architectural and structural materials, along with improved construction technologies, all facilitate the design process. This knowledge base – buttressed by our understanding of the interaction between structural system framing elements, building skin, and architectural and mechanical systems – is invaluable in providing designs that are safe, comfortable, economical, sustainable and constructable.

Feasibility Studies

There is no substitute for experience when an early decision is needed on concept feasibility. Evaluation must be based on a combination of extrapolations from completed designs of other high-rise buildings and computer models that condense structural details while preserving attributes essential to answering preliminary design questions. Our design professionals use both historical information and an analytical approach to develop the answers owners and design teams need to select an appropriate design course.

Peer Review

It takes a firm experienced in supertall building design to know whether a design proposed by another firm is appropriate. Our approach to peer review services applies the lessons learned during our work on both new building designs and existing building investigations. We know how to address conflicting design criteria when it is time to provide suggestions and observations as a peer reviewer. This experience means our comments focus on the realities of supertall buildings rather than hypothetical considerations.

Value Engineering

Design criteria and construction methodology are just two of the key components of supertall buildings that often require expert review and value engineering. Often local codes and practices, or construction materials and methods that are appropriate for projects of more conventional size, are applied to supertall designs for which they were never intended. We have experience around the world in helping reviewers understand and apply current international standards for these unique projects. We also assist contractors and developers by sharing best practices.

Chicago Spire, Chicago, Ill.

Project Delivery

Project Delivery Approach

From traditional design-bid-build, to fast-track, construction manager-at-risk (CMR), design-build and integrated project delivery (IPD): we've done them all. The collaborative approach we bring to all our work has been a critical factor in our success with newer project delivery methods like design-build and IPD. We strategically apply the benefits and best practices of new technology and processes to enhance traditionally delivered projects. We can also assist in the selection of the delivery process best suited for a specific project. Our experience across the project delivery spectrum, combined with a suite of innovative services and capabilities, helps us optimize the design and construction process for projects large and small.

Design-Build

Thornton Tomasetti has more than fifteen years of experience in design-build project delivery. Our successful track record includes projects across a wide range of market sectors: commercial, sports, residential, cultural, education, healthcare, aviation, retail and industrial. By combining design and construction into a single contract, all members of the team – architect, engineers, contractors and fabricators – work together from the start to improve coordination and constructability.

The enhanced collaboration that is integral to design-build results in fewer changes, reductions in field issues and shorter construction schedules. Modeling technology enables all project stakeholders to visualize the entire structure early on, optimizes the interplay between aesthetic and functional considerations, eliminates clashes between systems and facilitates accurate early material procurement.

Integrated Project Delivery

Thornton Tomasetti's collaborative approach and unique suite of services and capabilities are ideally suited to IPD. This delivery method contractually joins the owner, architect, contractor, engineers and key subcontractors to encourage members to work together for common ends. Creating a united team – sharing goals, incentives, risks and rewards – further improves efficiency and reduces waste to create a better process for all stakeholders. Expanding upon our experience in design-build, we are leading the way in developing IPD processes.

Project Delivery

Building Information Modeling (BIM)
A building information model is a digital 3D representation of a building that contains intelligent information and can serve as the final deliverable to the fabricator, contractor and other members of the project team. BIM has multiple benefits, including enhanced visualization, linked data sets, improved design team coordination, expedited quantity takeoffs, better scope definition and improved schedule. As industry leaders in this technology, we offer BIM services for any project and provide our models as deliverables to improve the project delivery process.

Advanced Detailing
We provide 3D detailing services for both steel and concrete, in which the model can be used as a construction document deliverable for projects large and small. These models save significant time for the design team and the contractor while more clearly defining the construction scope. The first phase of detailing is a member model with the main structural framing members, which can be used for accurate quantity takeoffs to create an advanced bill of materials, and is ready for use by the fabricator. The second phase adds steel connections or concrete reinforcement to the model. Shop drawings and additional material takeoffs, such as connection material quantities, bolt lists and rebar quantities, can be generated from this model. Our detailing services also include steel shop drawings.

BIM for Shanghai Tower, Shanghai China

Automation, Animations and Renderings
We continually develop and enhance proprietary customized software tools that automate processes to increase our efficiency and deliverable quality. We focus on automation of repetitive and otherwise time-consuming tasks in analysis, design and modeling. In-house routines provide interoperability between software packages, allowing optimal transfer of design information between BIM platforms, spreadsheets and structural analysis programs. This saves time and ensures the integrity of the structural design as it moves from one application to another. In addition, we use parametric modeling to define complex geometries mathematically to reduce their generation to a manageable set of parameters. This computational process enables a rapid yet thorough structural study and optimization process.

We provide rendering, animation and advanced graphics services, from simple geometric representations to advanced kinematic simulations (in which moving objects obey the rules of physics). Rendered and animated models help to clearly visualize both design and forensic issues. Animations and 3D renderings are inherently more understandable than traditional 2D drawings; with our custom tools, they can be generated quickly and linked to intelligent data to represent complex scenarios clearly and efficiently. In addition, our animations can include 4D (time) and 5D (cost) information to provide a more comprehensive overall representation of a project.

Erection Engineering and Site Logistics
Structural members and assemblies undergo different loading and support conditions during erection than in their completed state. Erection engineering addresses a structure in its incomplete state, including erection procedures, the adequacy of elements to serve as part of the completed building and the design of elements used as temporary erection aids. Our services include assistance in selecting construction equipment, determining construction sequencing, estimating manpower and establishing safety guidelines. We can also assist the structural steel erector in the development of lift plans and rigging.

Stability Engineering
All structures are subject to temporary forces during construction. Sometimes these forces can be resisted without

Erection Engineering – CONSOL Energy Center, Pittsburgh, Pa.

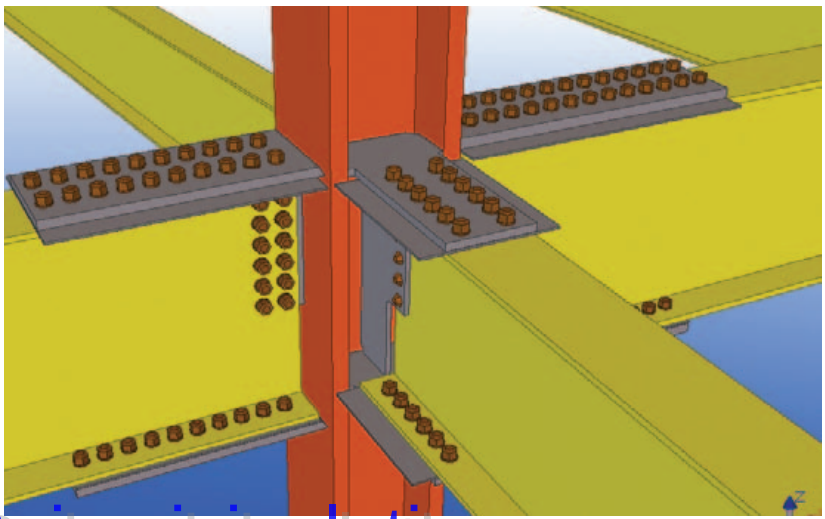
additional bracing, but temporary support is required. Thornton Tomasetti provides stability engineering for all aspects of construction, including long-span steel structures, larger concrete structures and substructures and sequencing of high-rise structures. These efforts are most often developed in collaboration with the installing contractor to develop a constructable and cost-effective solution.

Equipment and Logistics

We provide logistics, equipment and site planning services to general contractors, fabricators and erectors to assist in bringing a project from the planning stage to the construction phase. These include preliminary engineering checks for crane capacity and equipment selection, investigation of soil conditions and existing structures that will support equipment, and optimization of crane locations for construction sites where crane capacity may dictate the construction sequence.

Integrated Quality Assurance

Our commitment to quality is backed by our formal quality assurance/quality control program. Dedicated QA/QC managers assign new projects to experienced reviewers and track progress so reviews are carried out at appropriate intervals. Standardized checklists and sign-off procedures streamline the process and document program compliance.



Advanced detailing Tekla model, Yankee Stadium, New York, N.Y.

Building Information Modeling (BIM)

Our approach to building information modeling improves the design process for all members of the project team. Thornton Tomasetti design professionals are at the forefront of these technologies, lecturing about BIM at conferences worldwide, working with software manufacturers to improve programs, and writing our own scripts and routines to fill interoperability gaps. Our expertise in BIM is based on years of experience in a wide variety of project types, which has equipped us to provide efficient design, workflow and project delivery.

Benefits of BIM

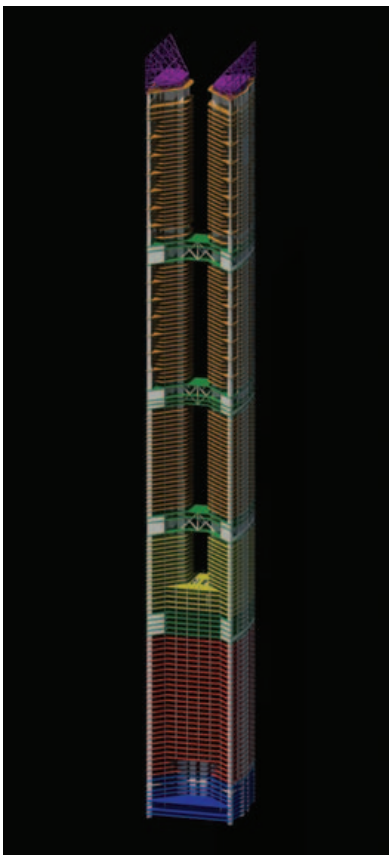
Effective development of BIM improves drafting efficiency, production drawing quality, design team coordination, visualization, client communications, interoperability and design flexibility. These benefits are evident in superior drawings, decreased production time and reduced costs. Downstream benefits include minimized schedule risk and reduced field problems. Finally, the "model as the deliverable" ensures that all team members have exactly the same data and can slice any sections they need. Delivering the model to the fabricator reduces fabrication time and removes any ambiguity, since the model can often be fed directly to CNC fabrication machines.

Efficiency and Quality

A building information model can be used to generate accurate construction documents, eliminating much of the tedious 2D drafting process and reducing human error. Sections are cut directly from the building information model and updated seamlessly, saving time and ensuring accuracy and consistency within a set of drawings.

Courtesy Aedas

We worked with Aedas on a design competition for a 350-meter tower that relies on a variable pattern of spiraling ribbons for structural support. We developed a model using Grasshopper (a Rhino plug-in) that allowed us to work collaboratively with the architects to easily explore a variety of options within pre-established functional parameters.



Incheon 151, Incheon, South Korea

Improved Coordination
BIM enhances coordination among disciplines and allows for better communication with the project owner. All disciplines benefit from the coordination and clash checking available through BIM. Ongoing coordination with other disciplines throughout the design process reduces time-consuming redesign, which helps to keep projects on time and within budget.

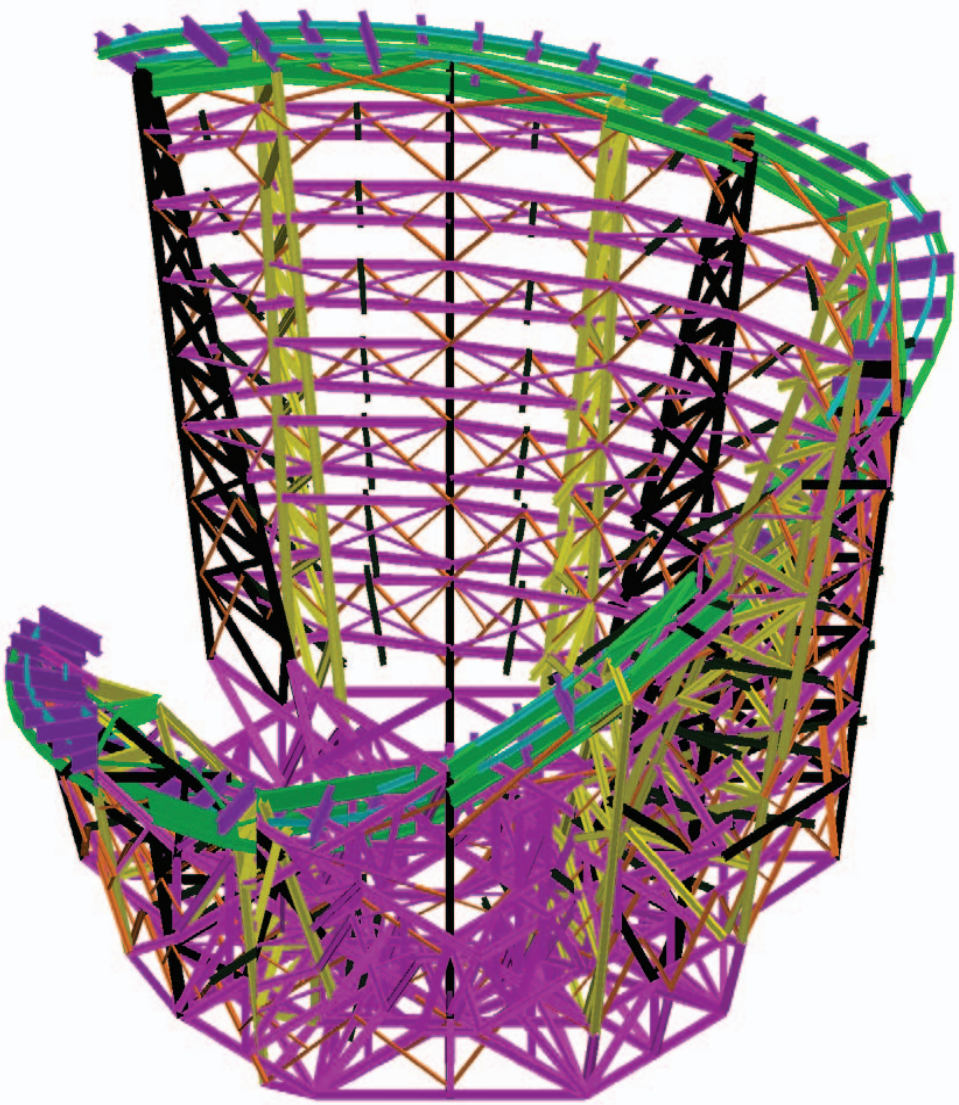
Superior Visualization and Communication
We use BIM to create 3D images and renderings that can clearly communicate design issues and are easier to understand than 2D drawings. Animations and fly-throughs can be created quickly and frequently to illustrate complex concepts.

Increased Design Flexibility
BIM offers a robust set of tools and methods to modify designs. Parametric models can rapidly generate reports and studies. Because modifications are automatically reflected throughout project documents, parametrics also allow us to apply last-minute design changes easily and accurately.

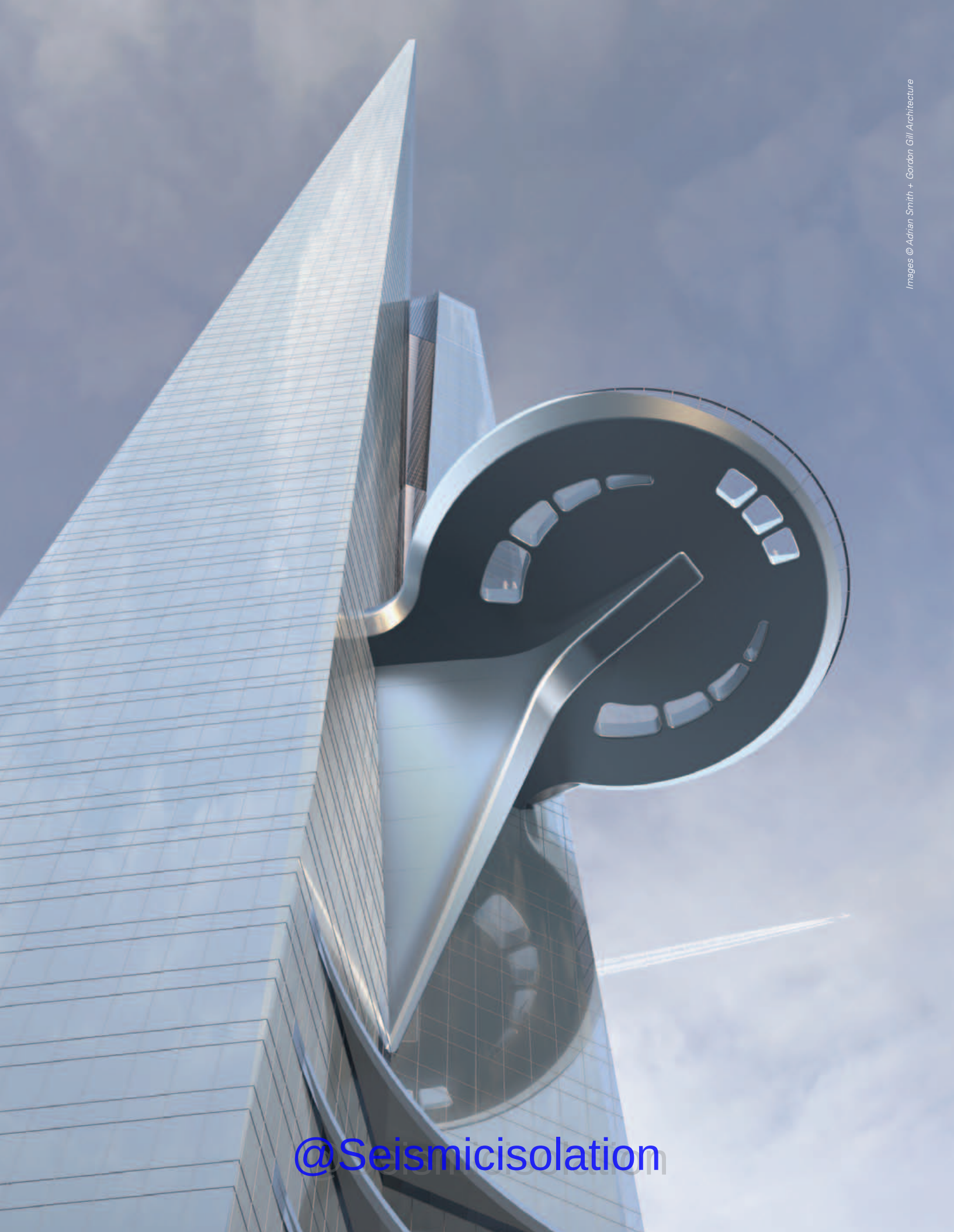
Interoperability and Automation
We use a variety of software for BIM, structural analysis, design and documentation, and we consider ourselves "multilingual." To address current shortcomings of intelligent interoperability between the IFC and CIS/2 formats, our advanced automation team creates custom in-house translators and interoperability scripts that assist design teams by enabling a more efficient workflow for all.

Our automation team creates these translators and scripts using an application programming interface to share intelligent BIM information between software programs such as Revit Structure, Tekla, AutoCAD, Catia, SAP, ETABS, Grasshopper, Rhino, Advance Concrete and others. Our automation staff can quickly write custom translators for job-specific problems to accelerate workflow and production. These translators save time and address many of the problems that arise in the absence of an industry standard BIM format.

Master Modeler and BIM Assistance
We often lead the BIM implementation on a project, working as the master modeler to integrate inputs from all disciplines. In addition, we provide training and full-time assistance to design team members who have not participated in a BIM project before. We can adapt our BIM standards for each project and share them with the team. Our BIM processes and standard libraries include the setup of live shared models across multiple locations to speed implementation. Our goal is to help all design team members realize the efficiencies offered by BIM.



Shanghai Tower, Shanghai, China



Images © Adrian Smith + Gordon Gill Architecture

Owner
Kingdom Holding Company

Developer
Jeddah Economic Company

Architects
Adrian Smith + Gordon Gill Architecture

Contractor
Saudi Binladin Group

Total Area
530,000 m² / 5.7 million sf

Height
+1,000 m

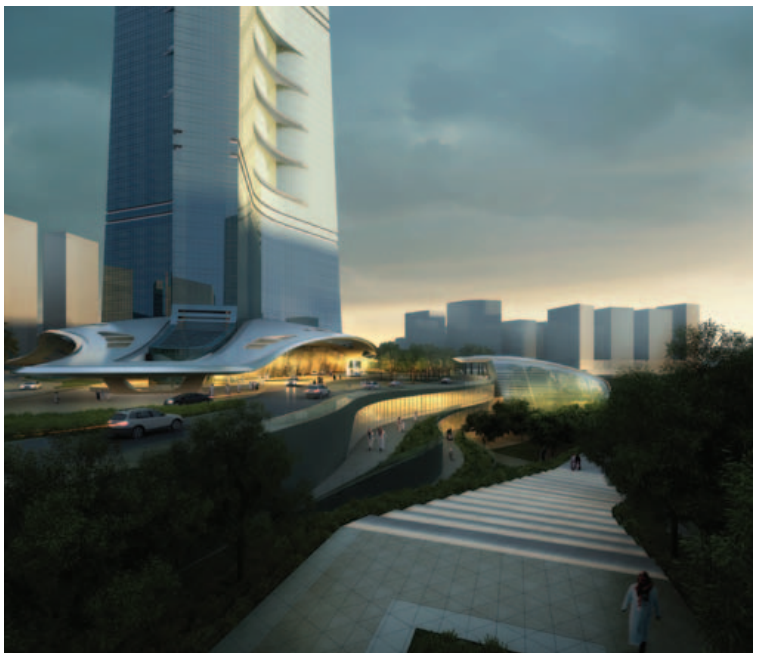
Kingdom Tower

Jeddah, Saudi Arabia

We are providing structural design services for Kingdom Tower, the centerpiece of the new 23-million-square-meter urban development known as Kingdom City. Upon completion, the tower will be the world's tallest building at +1,000 meters.

With a total construction area of 530,000 square meters, the mixed-use building will house an opulent hotel, luxury condominiums, serviced apartments, office space and the world's highest observation deck. A high-performance exterior wall system will minimize energy consumption by reducing thermal loads. In addition, each of the tower's three sides will feature a series of notches that create pockets of shadow, shielding areas of the building from the sun and providing outdoor terraces with stunning views of Jeddah and the Red Sea.

The design of Kingdom Tower's structural system is based on stringent performance criteria for supertall structures, utilizing both international performance standards and regional building codes. Key challenges of the project include establishing wind loads appropriate for the location and height of the building, producing a building form that minimizes the impact of wind loading while optimizing the structural system, design of the slender spire elements, and the design of a foundation system capable of supporting the loads induced by the heavily loaded structure while mitigating differential settlement.



Taipei 101

Taipei, Taiwan

Taipei 101 features a 508-meter tower with a unique profile, a five-level deep basement and a surrounding six-story retail structure. The building is designed to open upwards, representing a blossoming flower that signifies financial richness and everlasting vitality in the Chinese culture. Repeated references to the number eight also reflect local traditions. The architecture of the building relies upon the concept of inwardly slanted segments. When used in conjunction with energy conserving, transparent glass materials and innovative lighting design, the tower is crystal-clear and elegant. The building ranked officially as the world's tallest from 2004 until 2010.

The tapering walls result in most of the building's floor plans ranging from 2,000 to 2,500 square meters (21,500 to 27,000 square feet), with some as small as 47 square meters (506 square feet) above the main roof. The tower was designed to withstand typhoon winds and seismic activity. The structure includes a tuned mass damper suspended in the upper floors to offset movement caused by wind gusts. The tower is equipped with ultra-fast elevators, taking only 39 seconds to reach the observatory on the 89th floor.

Our services were engaged by C.Y. Lee and Partners to provide concept and preliminary designs, and to review the final structural design by the local engineer of record. We also responded to questions from the architect and advised the architect and owners during construction.

Owner
Taipei Financial Center Corporation

Architect
C.Y. Lee and Partners

General Contractor
KTRT Joint Venture

Completion Date
2004

Construction Cost
$1.7 billion U.S.

Total Area
204,388 m² / 2,200,000 sf

Number of Stories
101

Height
508 m / 1,667 ft

Awards
2004 Grand Award, Popular Science

Outstanding Project Award, National Council of Structural Engineers Associations, Excellence in Structural Engineering Awards, 2005

Diamond Award for Engineering Excellence, ACEC New York, 2006

Courtesy C.Y. Lee and Partners


Dugald MacKay Photo
@Seismicisolation

Petronas Towers
Kuala Lumpur City Centre (KLCC)

Kuala Lumpur, Malaysia

We provided structural design for two slender towers, the world's tallest buildings from 1999 until 2004, that soar 452 meters (1,483 feet) above Kuala Lumpur. Their dramatic design is enhanced by a sky bridge at floors 41 and 42 that connects the towers and creates a visual gateway to a major public park. The sky bridge was designed with slender structural members rather than heavy trusses to be compatible with the architecture of the buildings and was constructed more than 150 meters above street level. It accommodates independent movement of the towers as they sway with wind loads. The KLCC complex also includes a 5,143-car under-ground garage, a seven-story retail facility and an acoustically isolated 864-seat concert hall that spans over the entryway to the towers and retail areas.

Owner
KLCC (Holdings) Sdn. Bhd.

Architect
Pelli Clarke Pelli Architects with Adamson Associates

Completion Date
1999

Construction Cost
$1 billion U.S.

Total Area
306,580 m² / 3.3 million sf

Number of Stories
88

Height
452 m / 1,483 ft

Awards
The Aga Khan Award for Architecture 2004

Images courtesy Michael Goodman


@Seismicisolation

Photos: David Sundberg/Esto

The New York Times Building

New York, New York

Owner
The New York Times Company

Architect
Renzo Piano Building Workshop
FXFowle Architects

Developer
Forest City Ratner Co.

General Contractor - Core and Shell
AMEC Construction Mgmt. Inc.

General Contractor - Interiors
Turner Construction

Completion Date
2007

Construction Cost
$650 million

Total Area
157,935 m² / 1.7 million sf

Number of Stories
52

Height
319 m / 1,046 ft

Awards
Award of Excellence, AIA New York State Institute Honors, 2009

2008 Best Building Award – Americas, CTBUH

Diamond Award – Structural Systems, ACEC New York, 2008

2007 Project of the Year, New York Construction

The New York Times Building is a 52-story high-rise office tower of lightness and transparency topped by a mast that disappears into the sky. Contributing to this vision is an elegant structural steel exoskeleton that is integrated into the architectural design and a glass and ceramic curtain wall design that admits abundant natural light to the building on all floors.

The exposed structural steel provided several challenges for our design team, such as complying with the city's fire and building codes, detailing the steel to achieve aesthetic elegance, and designing for forces and movements caused by temperature differentials.

Adding to the building's appealing façade are thin, horizontal ceramic rods placed on a steel framework 18 inches in front of the low-emissivity glass. The first of its kind in the United States, this curtain wall design acts as 'sunscreen' and helps to reduce the heating and cooling requirements while the rods reflect the changing colors of the sky.

Shanghai Tower

Shanghai, China

We provided structural engineering design and building skin peer review services for this project, another of the world's most distinctive and innovative high-rise buildings. At 632 meters, Shanghai Tower is the world's third tallest building under construction. The 580,000-square-meter development will feature class-A office space, retail levels, a luxury hotel and cultural venues. Below-grade levels will provide parking and connec-tions to the Shanghai Metro.

We engineered a simple, safe and cost-effective structural system that enables a creative architectural form. The exterior of the tower – a twisting triangular surface that tapers as it rises – is wrapped around an inner concrete structure composed of nine stacked cylinders. An efficient design of super-columns with outrigger trusses derives stiffness from the concrete inner building, forming an effective system for resisting wind and seismic loads. We developed a unique support system for the twisting curtain wall that employs hanger rods supported at mechanical levels, horizontal girts, braces and cross-braces at each level. We also performed a peer review of the outer skin of the tower.

The design incorporates the latest sustainable technologies, including renewable-energy-generating wind turbines and solar panels, to achieve a low carbon footprint. The project will seek certification from the China Green Building Council (in association with the USGBC) as a LEED Project.

Developer
The Shanghai Tower Construction and Development Company

Architect
Gensler

Completion Date
2014

Total Area
580,000 m² / 6.2 million sf

Height
632 m / 2,074 ft

Courtesy Howe Keen Foong/Gensler

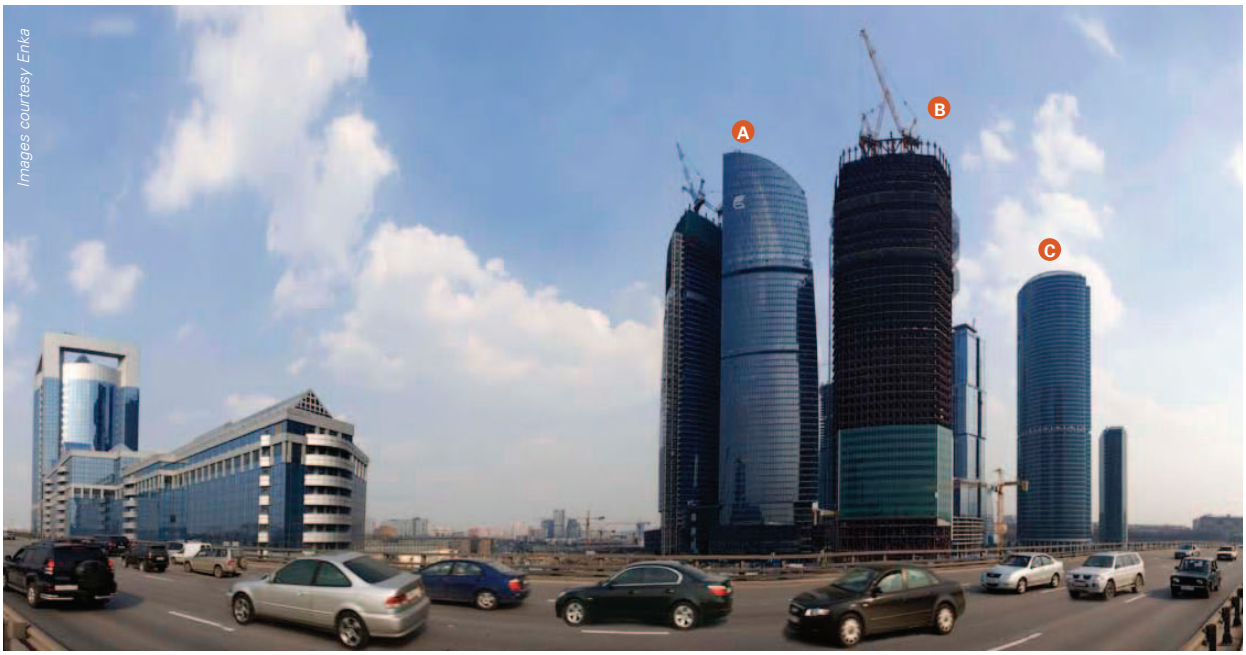
Courtesy Gensler


Courtesy Gensler
@Seismicisolation

Moscow International Business Center

Moscow, Russia

Thornton Tomasetti is providing structural engineering services for three major projects in the new Moscow International Business Center. These include Federation Tower for the Mirax Group, Eurasia Tower for Eurasia IPG and Naberezhnaya Tower for the Enka Development Group.



Moscow International Business Center. A: Federation Tower B: Eurasia Tower C: Naberezhnaya Tower

Owner
Mirax Group, Moscow

Architect
NPS Tchoban Voss

Completion Date
2012

Total Area
325,160m² / 3.5 million sf

Number of Stories
East Tower: 96
West Tower: 64

Awards
Prix d'Excellence, Office Category
Winner, International Real Estate Federation (FIABCI), 2009

Federation Tower

Moscow, Russia

Rising 365 meters, the 93-story Federation Tower complex provides accommodation for class-A offices, a five-star hotel and luxury apartments. It is the centerpiece of the new development.

Adjacent to the 96-story East Tower is its 64-story partner, the West Tower. A 448-meter stiletto-like, glass-clad elevator mast and spire visually unites these two sail-shaped buildings. Connecting the two towers and the mast are pedestrian bridges at the 33rd and 61st floors and the observation platform at the 87th floor. Federation Tower is the first project in Russia to utilize super high-strength concrete technology. Three levels of steel outrigger truss systems, placed at the bridge levels, distribute gravity and wind loads between the core and perimeter framing. The project design incorporates modern require- ments for occupant safety in supertall structures.

In addition to structural engineering services, Thornton Tomasetti also provided building skin consulting services and specialty glass and steel design. We have used computational geometry and building information modeling to develop innovative and efficient designs for the tower caps, integrating the structure with architectural elements, maintenance requirements and mechanical functions.


Courtesy Mirax Group

Eurasia Tower

Moscow, Russia

We provided complete structural engineering services for this 72-story, two-million-square-foot commercial and residential development. The project includes a five-level underground parking garage and concourse that connects to a central core with a shopping mall, entertainment facilities and a transportation center. The 300-meter (1,000-foot) tall building is the first high-rise in Russia to use a structural system of com- posite "steel/concrete" core and deck floors with steel exterior columns.

Owner
Eurasia IPG, Moscow

Design Architect
Swanke Hayden Connell

General Designer
Gorproekt, LLP

Completion Date
2012

Total Area
185,806 m² / 2 million sf

Number of Stories
72

Height
300 m / 1,000 ft

Owner
Enka Development Group

Architect/Contractor
Enka Construction Corp.

Completion Date
2008

Total Area
111,483 m² / 1.2 million sf

Number of Stories
66

Height
240 m / 790 ft

Naberezhnaya Tower

Moscow, Russia

Located on Lot 10 of the Moscow International Business Center, this prominent 66-story highrise is a part of the Enka Commercial Complex, featuring a five-story underground garage and concourse level connected to the central core and its shopping malls and transportation center. Two levels of steel outrigger trusses, placed at the mid-height and at the top of the tower distribute gravity and wind loads within this composite structure. We provided structural analysis and design through design development phase (project phase) and worked closely with local regulatory agencies to assist the client in conforming to Russian norms and regulations.

New Ring of Moscow

Moscow, Russia

Thornton Tomasetti is participating in the 15-year high-rise residential development program, New Ring of Moscow, initiated by the City of Moscow to replace residential buildings built in the 1950s and 1960s. About 60 high-rise complexes are to be constructed, creating a ring of modern and comfortable structures equipped with convenient shopping, parking garages and parks. Green building technology will be integral to the building systems and materials.

We are providing complete structural engineering services, including the project phase (SD and DD) and working documents phase (CD and shop drawings), for three projects. Project Lublino comprises 1.9 million square feet and 42 stories, project Crystal will be 1.4 million square feet and 45 stories tall, and project Marino will be 1.3 million square feet and 51 stories tall.The main construction material is high-strength reinforced concrete. 3D Advance Concrete software was applied in the working documents phase.

Owner
New Ring of Moscow/Moscapstroy

Project Manager
Interstroi

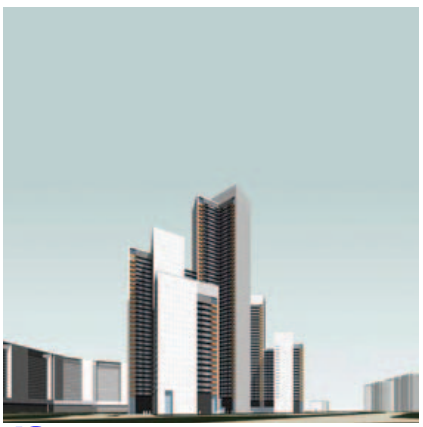
Architect
Swanke Hayden Connell Architects

Completion Date
2014

Total Area
464,515 m² / 5 million sf

Number of Stories
Lublino: 42
Crystal: 45
Marino: 51

Lublino



Crystal (above) and Marino

Owner

The Hattat Group

Architect

Hema Industry / Dome Architects

Total Area

161,000 m² / 1.7 million sf

Height

289 m / 949 ft

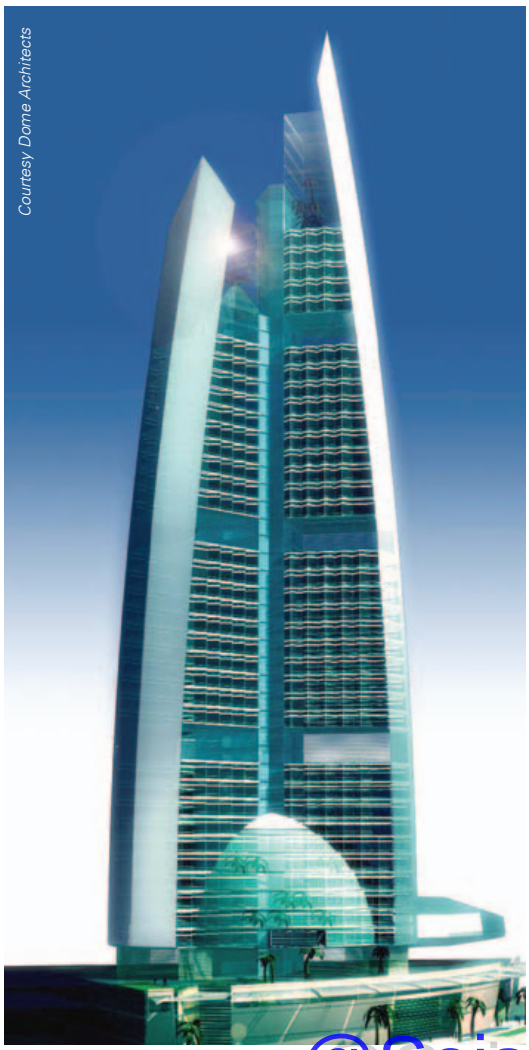
Diamond of Istanbul

Istanbul, Turkey

Our engineers provided structural design and seismic analysis for the Diamond of Istanbul, a 289-meter mixed-use tower that upon completion will be the tallest building in Turkey. The tower will include office space, apartments and a luxury hotel above a podium structure, with a retail mall and eight levels of below-grade parking.

Because the site is only 24 kilometers (15 miles) from the main Marmara fault – part of the North Anatolian fault system – the tower was designed to withstand severe seismic forces. A "Y" shaped plan, with a reinforced concrete core and secondary steel moment frames along each wing, provides lateral force resistance.

While the building was designed using conventional code-based methods, our engineers also performed a non-linear time history (NLTH) analysis to assess how the structure would perform during a seismic event. Our team applied simulated earthquakes, based on raw data provided by Turkish seismic experts, to our 3D model of the structure. When results showed that the tower would perform well, the owner proposed adding ten stories. We then embarked on a second phase of NLTH analysis to assess the impact of those additional levels on the structure and worked with the local Engineer of Record to implement the necessary design changes. Our application of performance-based design methods allowed the owner to maximize the real estate potential of the site.



Courtesy Dome Architects

Plaza 66

Shanghai, China

Plaza 66 consists of two towers, retail space on a five-story podium and three levels of below-grade parking. A special feature of the first tower is the great height that is accomplished on a small footprint. The concrete tower soars 288 meters (945 feet) above the city featuring a narrow irregular-shaped lantern on the rooftop.

As structural engineer, one of our challenges was the skylight roof design that covers the seven-story atrium in the retail podium. The oval-shaped atrium roof is approximately 200 feet by 125 feet. The cross sections of its members vary along the span, as do the cross sections of its supporting columns, resulting in a visually dynamic but technically challenging atrium.

The 48-story second tower was also built on a small footprint. The concrete tower was complicated by lateral stability concerns, poor site soil, seismic considerations, high water table, limitations of locally available building materials, and construction between new and existing buildings.

Our engineers developed a functional and economical structural system that could be built using local labor and materials almost exclusively.

Owner
Hang Lung Realty

Architect
Kohn Pedersen Fox Associates PC

Completion Date
Tower I: 2001
Tower II: 2006

Construction Cost
$400 million U.S.

Total Area
213,729m² / 2,300,000 sf

Height
Tower I: 288 m / 945 ft
Tower II: 228 m / 749 ft

Number of Stories
Tower I: 66 plus 10-level lantern
Tower II: 48

Retail podium skylight roof

Courtesy Philip Gostelow

We've the Zenith

Busan, South Korea

The tallest residential tower in Asia topped out in early 2011, rising above the waterfront of South Korea's second-largest city, Busan. At 80 stories and 984 feet (300 meters), the tallest of the three towers in We've the Zenith forms the centerpiece of a 4.1-million-square-foot development, which also includes a retail podium and six below-grade levels for retail, parking and mechanical facilities.

Exposure to typhoons has been the biggest engineering challenge in the design of We've the Zenith. The team designed these structures to withstand sustained winds of 90 mph and gusts to 105 mph. The towers present a smooth, rounded face to the wind, which makes them more aerodynamic, and reduces wind loads. Also helping improve stability and comfort for occupants is the very wide stance, with an aspect ratio of nearly 1:7. The efficient design of the core wall, which is butterfly-shaped in cross section, maximizes building stiffness while minimizing the amount of material used in construction.

Owner
Doosan Construction and Engineering

Architect
DeStefano + Partners

Completion Date
2012

Total Area
378,500 m² / 4.1 million sf

Number of Stories
70 and 80

Height
300 m / 984 ft

Courtesy Doosan Construction and Engineering

Owner
American International Group
The Seoul Metropolitan Government

Developer/Project Manager
AIG Global Real Estate

Architect
Arquitectonica

Construction
GS Construction, POSCO Construction

Completion Date
2013

Construction Cost
$1.6 billion U.S.

Total Area
509,524 m² / 5,480,000 sf

Height
Tower One: 186 m / 610 ft
Tower Two: 176 m / 577 ft
Tower Three: 279 m / 915 ft

International Finance Center (IFC) Seoul

Seoul, South Korea

IFC Seoul is a mixed-use development with three class-A office buildings, a five-star hotel and below-grade retail and parking. The 509,524-square-meter complex was designed to achieve environmental sustainability, with rainwater harvesting systems and integrated photovoltaic panels supporting the project goal of LEED Silver certification.

The three steel-framed commercial towers – at 52, 32 and 29 stories – have reinforced concrete core walls with outrigger trusses at mechanical levels. This structural system provides large column-free tenant spaces. Three-meter ceilings, raised access flooring and expansive lobbies rising 11.1 meters (36 feet) tall enhance tenant appeal.

The 38-story hotel, framed in reinforced concrete, encompasses 446 guest rooms, a fitness center, conference facilities, a ballroom, and dining and retail venues. Solar panels on the rooftop and on the building's south-facing façade will provide electricity for hot water and lighting.

The development sits atop a seven-level basement structure consisting of reinforced concrete, bound by a slurry wall. The below-grade area houses four levels of parking and a three-story luxury mall with a glass pavilion extending above ground to let in natural light.


Courtesy Arquitectonica


Courtesy GS Construction

Kohinoor Square

Mumbai, India

We provided structural engineering design and building skin consulting services for a pair of commercial towers at Kohinoor Square. The larger of the two, at 50 stories, will be among India's tallest office buildings.

Kohinoor means "mountain of light," and is also the name of one of the world's largest diamonds. While the gleaming, slope-sided towers were designed to evoke the facets of cut diamonds, the specific shape and structure of the towers were based on extensive wind load studies. The structure comprises a concrete core and post-tensioned concrete slab and spandrel beams. The façades consist of faceted unitized aluminum curtain walls with provisions for double façades on portions of each tower. The towers are linked by a podium with a façade of custom point-supported glazing on specialty steel trusses.

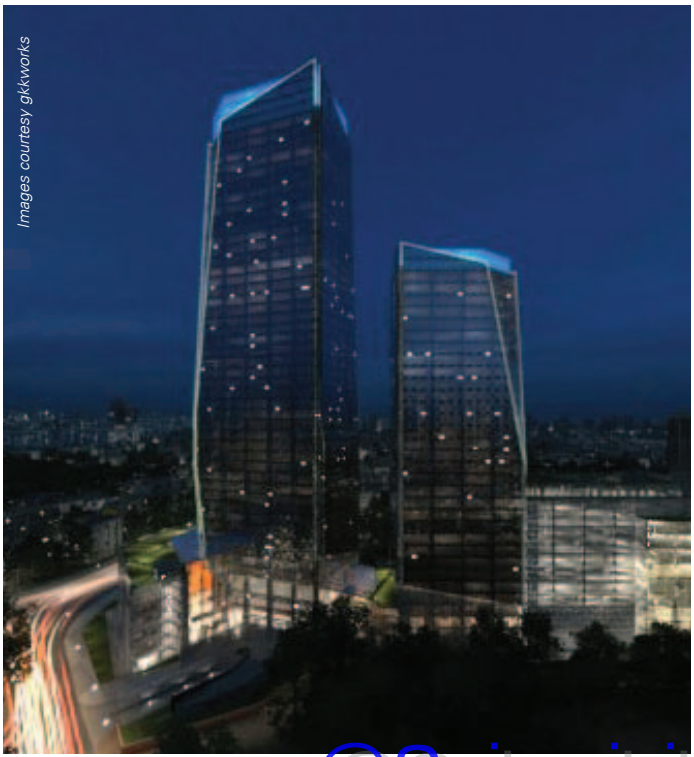
This project is achieving technological breakthroughs for Indian construction practices in structural design, life safety code concepts and sustainability, with LEED Gold certification – part of the Indian

Owner
Kohinoor CTNL Infra Company Ltd.

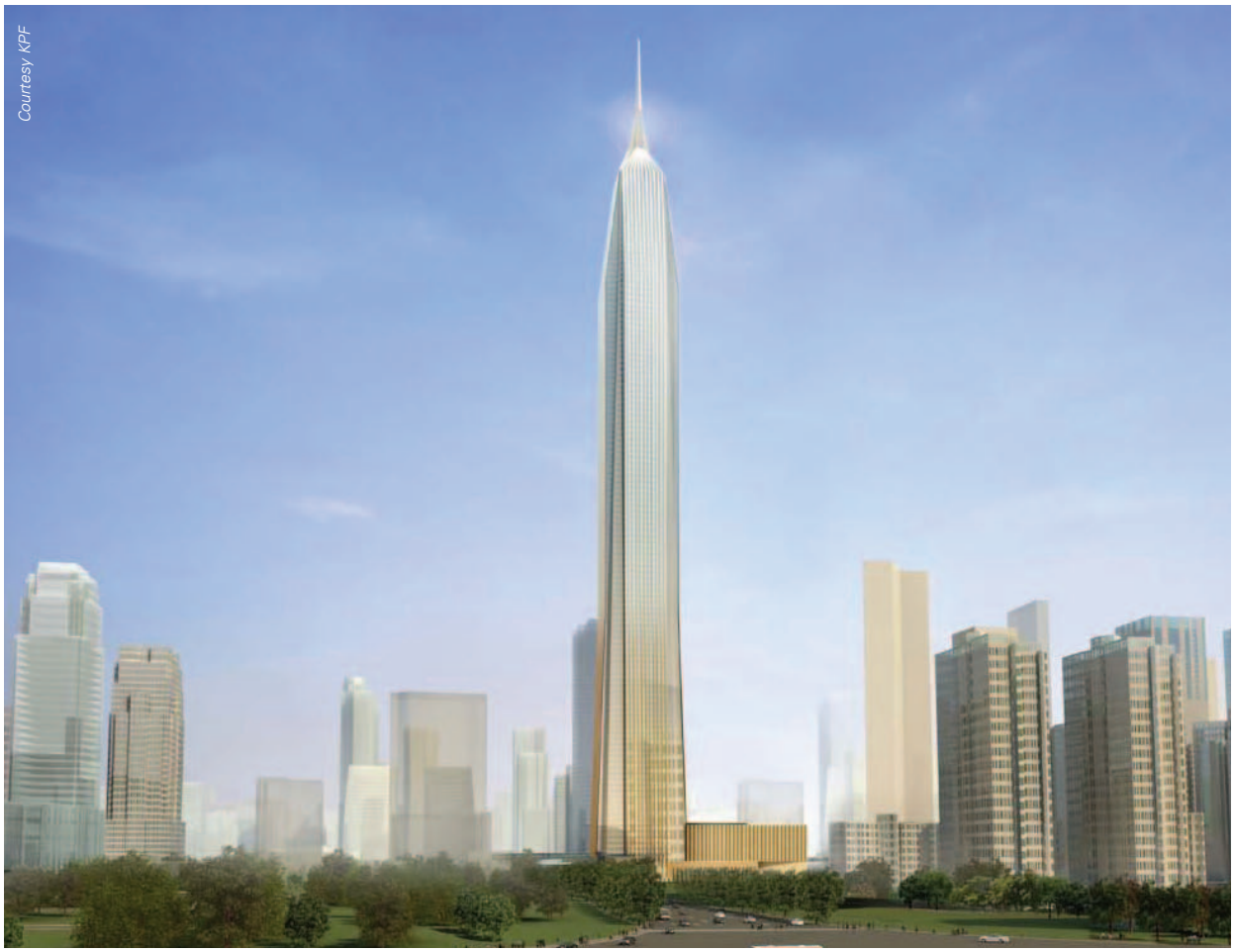
Architect
gkkworks / SSA

Contractor
Larsen & Toubro Limited

Completion Date
2012



Images courtesy gkkworks


Courtesy KPF

Owner
China Ping An Life Insurance Company

Architect
Kohn Pedersen Fox Associates

Completion Date
2014

Construction Cost
$678 million U.S.

Height
648 m / 2,126 ft

Total Area
468,600 m² / 5 million sf

Ping An International Finance Center

Shenzhen, China

Our engineering team used performance based design (PBD) methodologies to design this new office tower, set to be the tallest in China at 648 meters. Because supertall structures behave differently than the shorter buildings that are the basis for standard building codes, PBD – where advanced analysis technology allows engineers to design a structure according to how it reacts to various conditions – allows our designers to create buildings that maximize both safety and efficiency. The selected structural system consists of a concrete core with steel outriggers connecting to eight super-columns. The project also includes a 90,000-square-meter basement with parking and an 11-story steel-framed podium with a conference center, high-end shopping arcades, restaurants and rooftop cafés.

King Abdullah Financial District

Riyadh, Saudi Arabia

We provided structural and building skin design to Henning Larsen Architects for several tower projects in the new King Abdullah Financial District.

Crystal Towers will serve as the district's main financial center. The complex is split into two towers of 135 meters and 95 meters, linked by a 70-meter elevated podium bridge that forms a gateway to the development.

The Gem Building consists of two mid-rise reinforced concrete office and residential towers that link to two "Gem" structures, which are composed of a two-story steel frame structure and a concrete shell forming a single crystalline roof over a double-height retail space at ground level.

Villas in the Sky is a 33-story tower with 12 levels of residential units above 13 floors of office space. The building is crowned by a "sky gym," spa and roof terrace.

Our engineers used BIM on these projects to speed analysis of complex building geometries, increase design flexibility, improve coordination among design team members and simplify clash detection and resolution. The use of BIM also allowed easy generation of 3D visualizations of the structure that made for more effective client presentations. Both Crystal Towers and Villas in the Sky received awards recognizing the project team's innovative use of BIM from Bentley Systems, a leading software designer.

Owner
The Public Pensions Agency

Developer
Rayadah Investment Company

Architect
Henning Larsen Architects

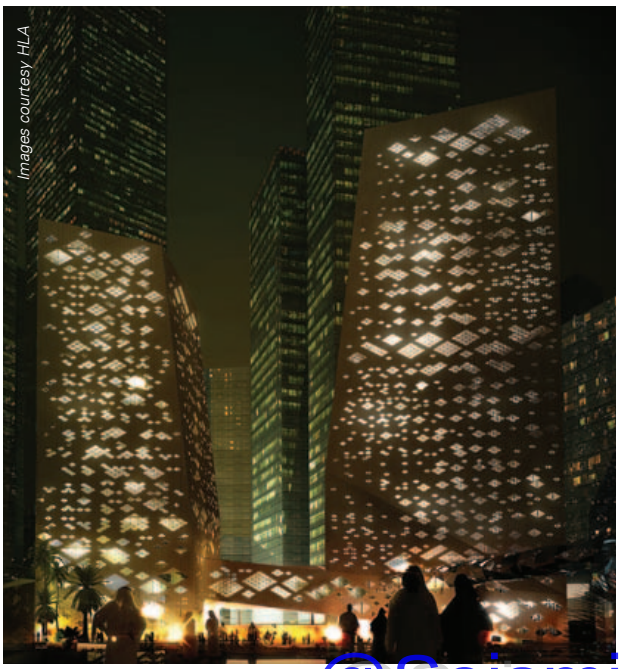
General Contractor
Saudi Binladin Group

Completion Date
2011

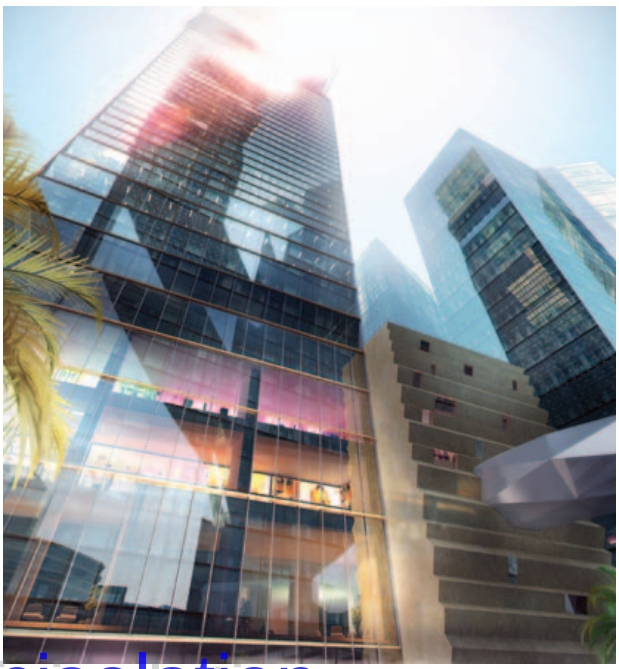
Total Area
1.6 million m² / 17.2 million sf

Awards
Crystal Towers: Be Inspired Award for Innovation in Building, Bentley Systems, 2010

Villas in the Sky: Be Inspired Award for Innovation in Generative Design, Bentley Systems, 2010



Crystal Towers



Villas in the Sky

Owner
Crescent

Architect
Heerim Architects & Planners

Completion Date
2012

Total Area
Tower 1: 56,522 m² / 608,340 sf
Tower 2: 45,464 m² / 489,370 sf

Number of Stories
Tower 1: 46
Tower 2: 37

Crescent Tower

Baku, Azerbaijan

We provided structural and parametric building skin design services through design development for these iconic residential towers on a hillside overlooking the Caspian Sea. To resist extreme winds (Baku means "windy city") and severe seismic forces, we designed a dual system: a special reinforced concrete (RC) shear wall and a special RC moment frame. The structural floor system combines a two-way 200-millimeter slab and RC beams. The curved towers have special requirements for façade panelization that allows the use of flat quadrangle unitized façade systems. Parametric modeling allowed us to determine the optimal façade unit geometry, thereby reducing fabrication and erection costs.


@Seismicisolation

Comcast Center

Philadelphia, Pennsylvania

Owner
Liberty Property Trust

Architect
Robert A.M. Stern Architects

Environmental Consultants
Atelier Ten

Completion Date
2007

Construction Cost
$352 million

Total Area
125,400 m² / 1.35 million sf

Number of Stories
57

Height
297 m / 975 ft

Awards
Diamond Award for Engineering Excellence, ACEC New York, 2010

Best in the Nation, Office Building Category, McGraw-Hill Construction's Best of the Best Awards, 2008

Best Commercial Project, General Building Contractors Association's Construction Excellence Awards, 2008

Best of 2008 Overall Project of the Year, Mid-Atlantic Construction, 2008

Award of Excellence, The Americas, Urban Land Institute, 2009

At just under 1,000 feet, the LEED CS Gold certified Comcast Center is not only the tallest building between New York and Chicago, it also reflects engineering and design lessons Thornton Tomasetti learned after leading the assessment of the 9/11 collapse of the World Trade Center towers.

Elevators, sprinklers, communications systems and stairwells are encased in a massive concrete core that stretches the full height of the building. Stairwells are 10 inches wider than code to allow for easier evacuation. And because the building footprint is small and the core relatively slim, the exterior walls are thicker than usual - 54 inches thick up to the 20th floor - to minimize flexing due to wind stress.

In addition to integrating new safety designs, the building has expansive open public spaces that needed to be designed without columns. A nine-story glass winter garden leads to a three-story lobby and atrium that is a 90-foot column-free span. In addition, a tuned liquid-column mass damper - a 300,000-gallon reservoir of water - is installed near the top of the building to increase the occupant comfort by limiting movement of the building from wind.

One Broadway Plaza

Santa Ana, California

At 491 feet above grade, One Broadway Plaza will be the tallest building in Orange County, California. We are providing structural design for this 37-story office tower, which is located in a high seismic zone. Early in the design process, our engineers performed a detailed seismic study resulting in the selection of a dual system consisting of a high-strength concrete core and a steel special moment frame perimeter. This system economically satisfies stringent code requirements while maximizing usable floor space.

Owner
Caribou Industries

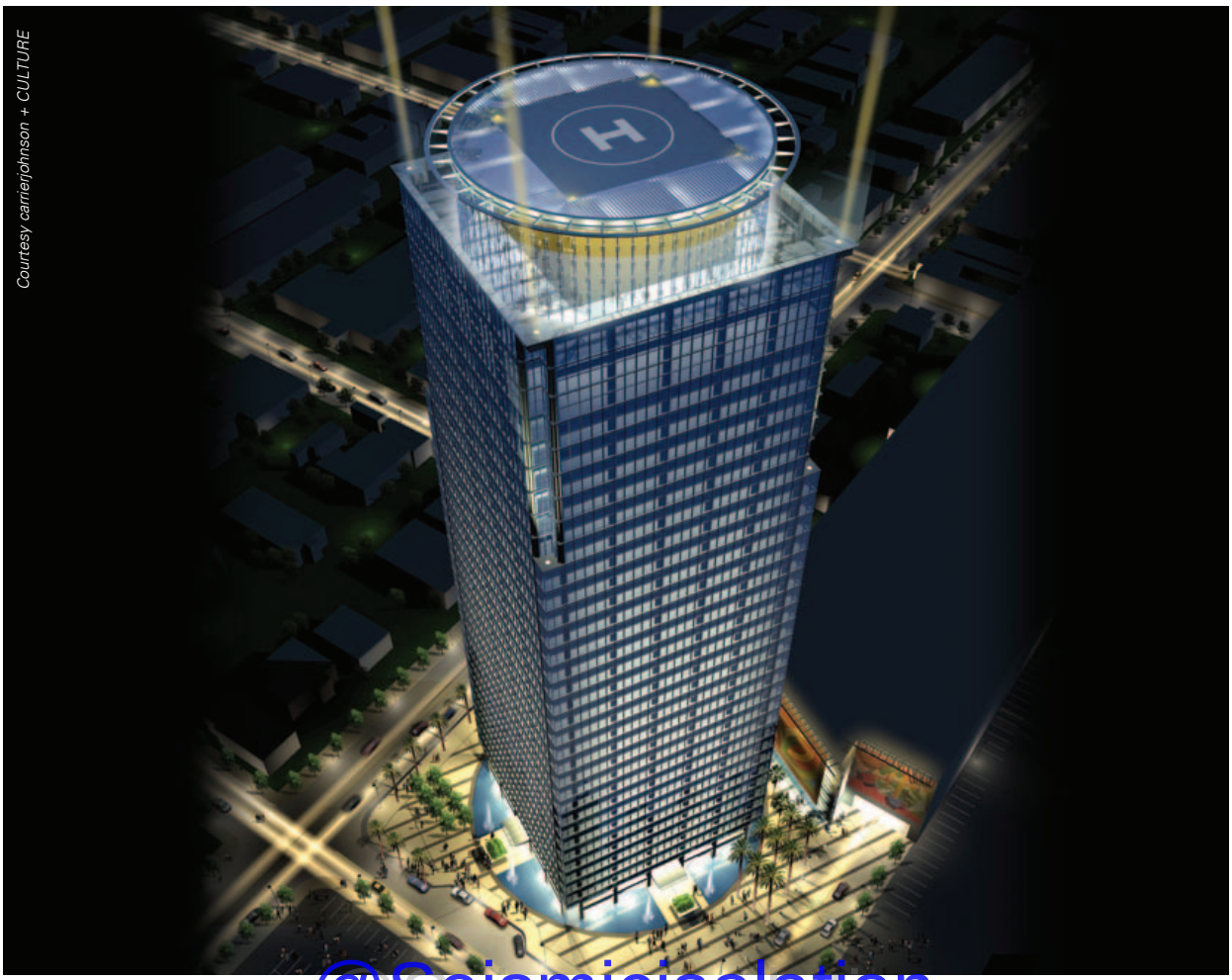
Architect
carrierjohnson + CULTURE

General Contractor
Hensel Phelps Construction Company

Completion Date
2013

Total Area
61,316 m² / 660,000 sf

Number of Stories
37



Courtesy carrierjohnson + CULTURE

Owner
Federation of Korean industries (FKI)

Architect
Adrian Smith + Gordon Gill Architecture

Contractor
Hyundai Construction

Completion Date
2013

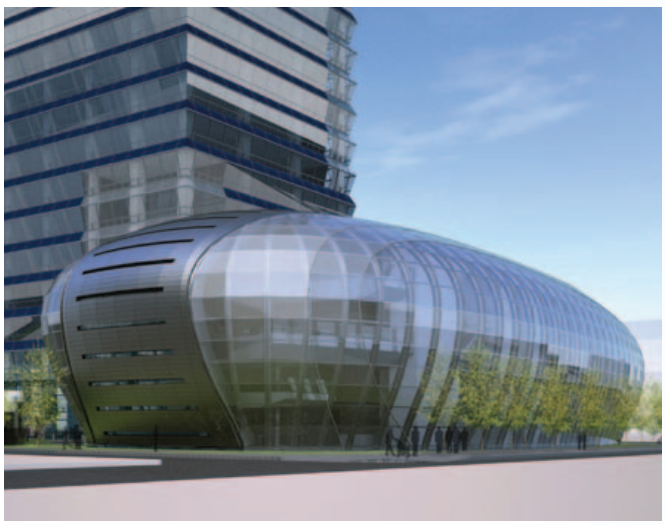
Total Area
Tower: 170,000 m² / 1,829,865 sf
Conference Center: 6,000 m² / 64,583 sf

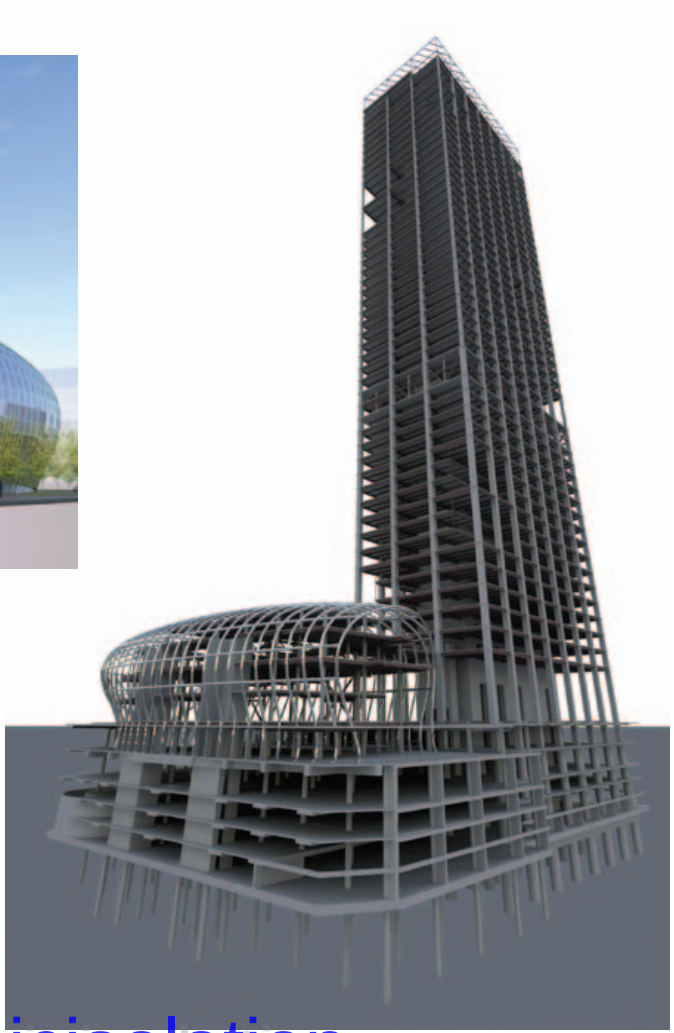
Height
245 m / 804 ft

Federation of Korean Industries Headquarters Building

Seoul, South Korea

We performed schematic structural design for this 245-meter commercial tower. Our team designed a structural system consisting of a reinforced concrete core and composite columns, augmented by steel outrigger trusses and perimeter steel belt trusses. Revit and Tekla modeling applications were used to document the design. The tower's furrowed exterior wall provides optimal placement for spandrel-mounted photovoltaic panels and plays a key role in disrupting the formation of wind vortices. An adjacent three-level conference center will occupy an ornamental egg-shaped structure. Our building skin experts designed and detailed its glazing system using Gehry Technologies' Digital Project. The team employed parametric shape optimization techniques to develop a rationalized geometry that accommodates glass panel attachment on its curved exterior.





Wuhan Greenland Center

Wuhan, China

We are providing structural design and building skin services for this 119-story tower, to consist of office space, luxury apartments, a five-star hotel and a penthouse-level private club. The 606-meter structure will be the third tallest building in China and the fourth tallest in the world. Because the building exceeds the China building code's height limits, engineers are using performance-based design methods to efficiently satisfy seismic requirements set by an expert review panel.

The building's structure uses a core, floor system and columns of composite concrete, which provides multiple benefits. Concrete with embedded steel provides superior strength and ductility while improving cost-effectiveness, since East Asia concrete prices are much lower than steel.

The tower's tripod plan and rounded form were selected to reduce wind resistance and the formation of vortices that cause uncomfortable motion in tall buildings. The tapered structure reduces the forces at the top of the building, resulting in reduced overall wind forces and overturning moments. The aerodynamic performance achieved by this configuration allows designers to minimize the amount of structural material used in construction, reducing costs and environment impacts of the building.

Building skin services included parametric modeling, analysis, and re-construction of the building skin surfaces in order to develop practical curtain wall solutions for the warped geometries.

Owner
Greenland Group

Architect
Adrian Smith + Gordon Gill Architecture

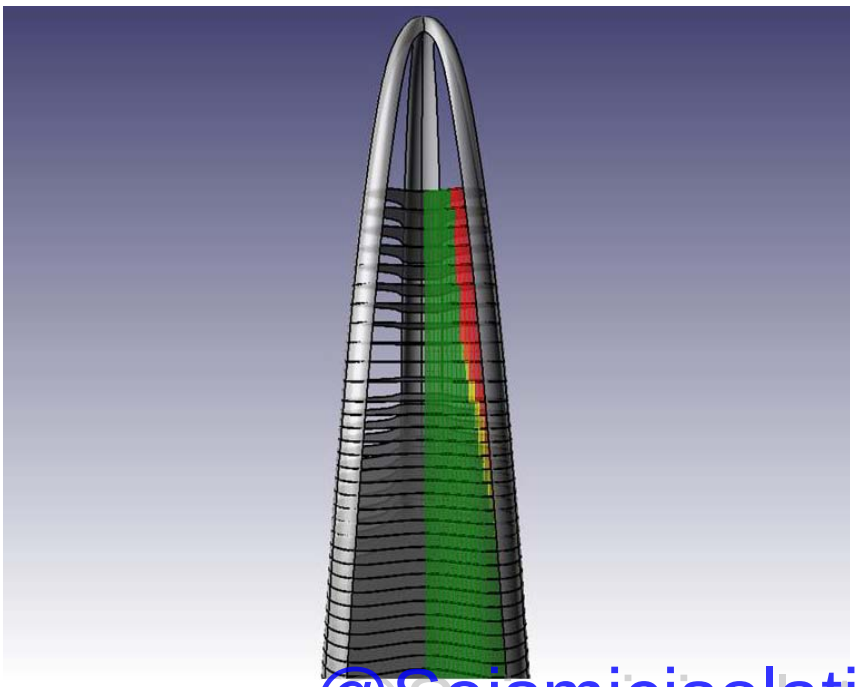
Completion Date
2017

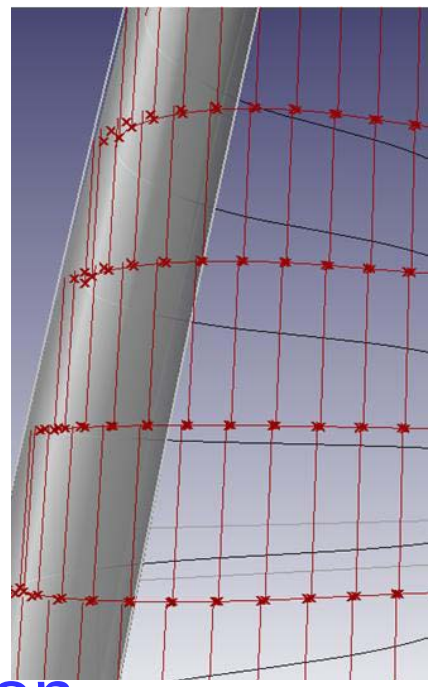
Construction Cost
$4.5 billion U.S.

Total Area
303,955 m² / 3.3 million sf

Number of Stories
119

Height
606m / 1,988 ft





Images © Adrian Smith + Gordon Gill Architecture

Taipei 101, Taipei, Taiwan, courtesy C.Y. Lee and Partners

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