# Going Geospatial

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## The National Geospatial-Intelligence Agency consolidates its resources into a new steel-framed facility on the outskirts of D.C.

**TO SAY THAT** the National Geospatial-Intelligence Agency (NGA) is interested in the big picture is quite the understatement.

The agency is the nation's primary source of geospatial intelligence—the collection and analysis of imagery and geospatial information that describes, assesses and visually depicts physical features and geographically referenced activities on earth—for the purposes of U.S. national security, defense and disaster relief.

In late 2011, NGA has moved into a new facility, the New Campus East, which consolidated six Washington-area sites into a single location at Fort Belvoir in Springfield, Va.; the project's origins are in the Base Realignment and Closure (BRAC) legislation that was passed in November of 2005. With a construction value of $1.4 billion, the new campus provides over 2.4 million sq. ft of facilities to accommodate 8,500 employees on a 130-acre site. Primary project components include a 2.2 million-sq.-ft, nine-story office building, a 145,000-sq.-ft technology center, a 105,000-sq.-ft central utility plant, a 5,200-car parking garage, a visitor control center and a vehicle inspection facility. (The project was one of this year's AISC IDEAS$^2$ Award winners; see the May issue.)

As with all BRAC projects, the NGA campus schedule was subject to a strict, non-negotiable completion and occupancy date. The size and complexity of the campus, combined with rigid constraints surrounding security and IT, demanded phased move-in requirements, which accelerated the required completion of core and shell construction.

The design team developed and assessed several ideas relative to the layout and character of the office component—e.g., mid-rise vs. high-rise, multi-building campus vs. single integrated facility, conventional box vs. more unique forms, etc. Driven by goals of an open, trusting and collaborative knowledge-based environment, the decision was made to house employees in a single Main Office Building (MOB). The building is comprised of two nine-story wings curving around a central, eight-story atrium that provides primary circulation and access to all the shared conference rooms and break areas, and serves as a crossroads and casual meeting space, encouraging interaction and collaboration among staff.

David Whitcomb

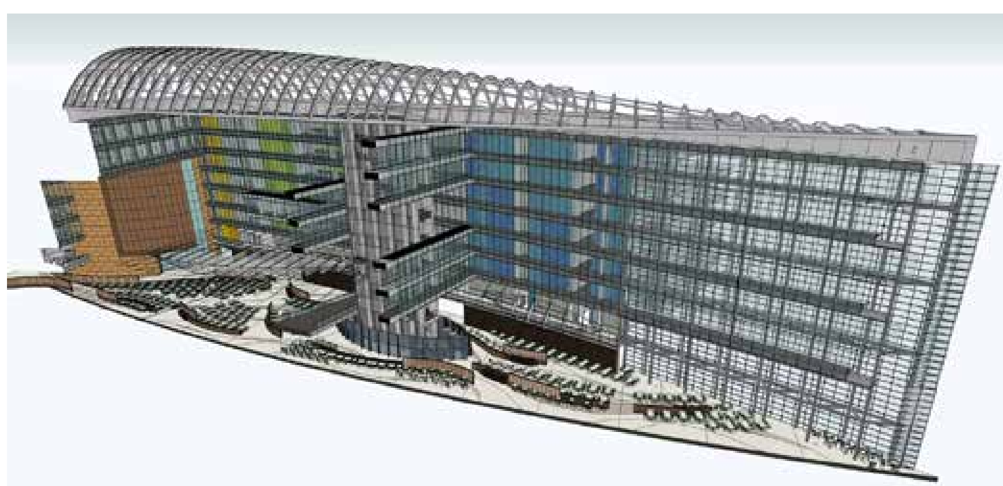
James West

▲ The eight-story atrium (inset).

▲ The NGA's new 2.2 million-sq.-ft, nine-story office building.

▲ HSS framing for the atrium.

▼ A cross section of the atrium.



## Structural System Selection

For the MOB's structural system, selection criteria were similar to the usual metrics and pro-con assessments: cost, constructability, ability to meet schedule, flexibility and performance related to project-specific requirements. Key criteria and constraints that affected typical bay-framing options and solutions were identified early in the process and included:

- ➤ 100 psf design live loading (mandated by NGA)
- ➤ Design for "electronic office" vibration criteria in accordance with AISC guidelines
- ➤ An open environment, with minimum column spacing on the order of 30 ft to 35 ft

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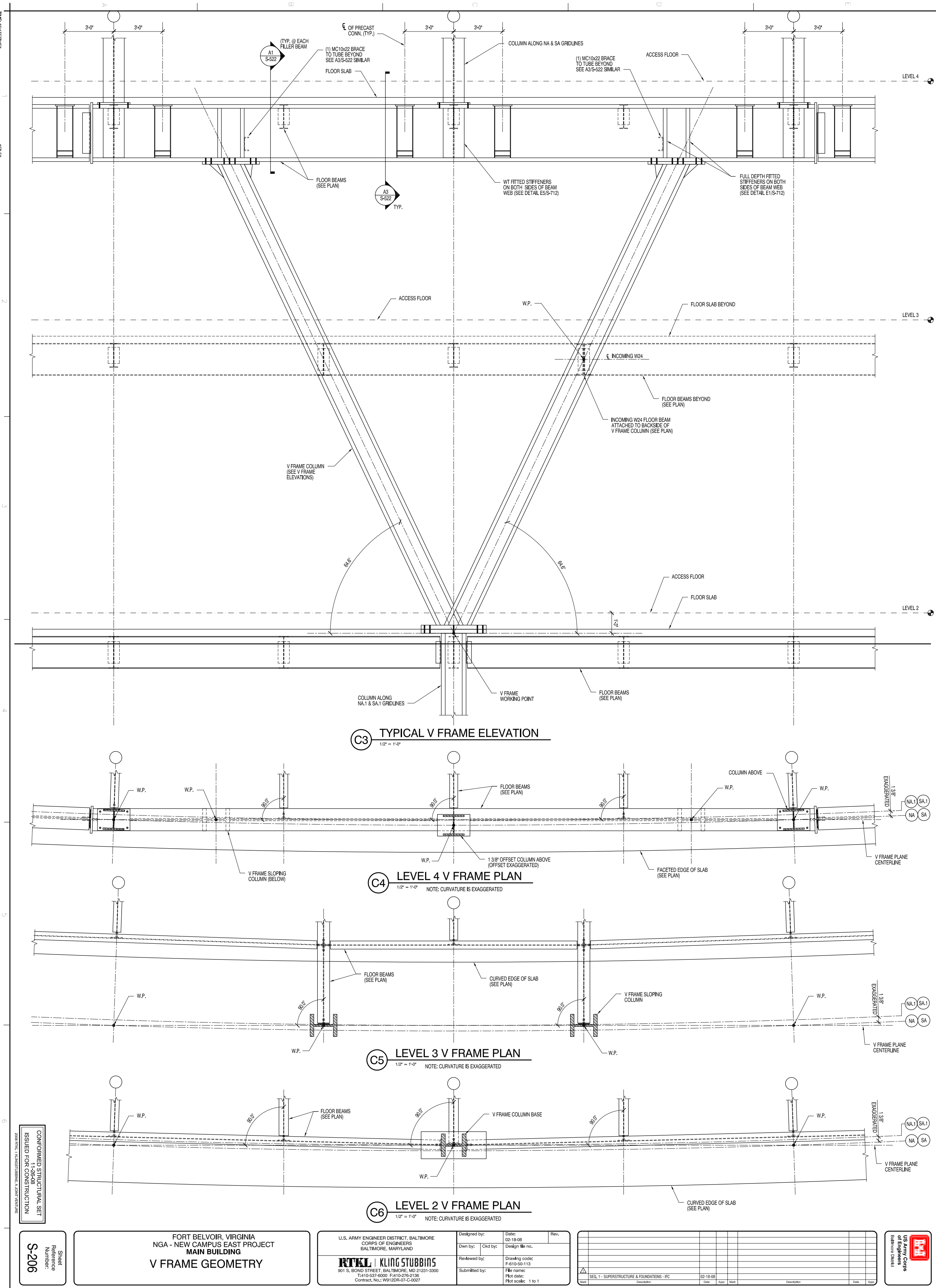

TYPICAL V FRAME ELEVATION
1/2" = 1'-0"
LEVEL 4
LEVEL 3
LEVEL 2
3'-0"
℄ OF PRECAST CONN. (TYP.)
(TYP. @ EACH FILLER BEAM
(1) MC10x22 BRACE TO TUBE BEYOND SEE A3/S-522 SIMILAR
FLOOR SLAB
COLUMN ALONG NA & SA GRIDLINES
ACCESS FLOOR
FLOOR BEAMS (SEE PLAN)
WT FITTED STIFFENERS ON BOTH SIDES OF BEAM WEB (SEE DETAIL E5/S-712)
FULL DEPTH FITTED STIFFENERS ON BOTH SIDES OF BEAM WEB (SEE DETAIL E1/S-712)
TYP.
W.P.
FLOOR SLAB BEYOND
℄ INCOMING W24
FLOOR BEAMS BEYOND (SEE PLAN)
INCOMING W24 FLOOR BEAM ATTACHED TO BACKSIDE OF V FRAME COLUMN (SEE PLAN)
V FRAME COLUMN (SEE V FRAME ELEVATIONS)
64.6°
1'-3"
COLUMN ALONG NA.1 & SA.1 GRIDLINES
V FRAME WORKING POINT
LEVEL 4 V FRAME PLAN
1/2" = 1'-0"
NOTE: CURVATURE IS EXAGGERATED
COLUMN ABOVE
90.0°
1 3/8" EXAGGERATED
V FRAME SLOPING COLUMN (BELOW)
1 3/8" OFFSET COLUMN ABOVE (OFFSET EXAGGERATED)
FACETED EDGE OF SLAB (SEE PLAN)
V FRAME PLANE CENTERLINE
LEVEL 3 V FRAME PLAN
CURVED EDGE OF SLAB (SEE PLAN)
V FRAME SLOPING COLUMN
LEVEL 2 V FRAME PLAN
V FRAME COLUMN BASE
CONFORMED STRUCTURAL SET 11-26-08 ISSUED FOR CONSTRUCTION
Sheet Reference Number:
S-206
FORT BELVOIR, VIRGINIA
NGA - NEW CAMPUS EAST PROJECT
MAIN BUILDING
V FRAME GEOMETRY
U.S. ARMY ENGINEER DISTRICT, BALTIMORE
CORPS OF ENGINEERS
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Contract, No.: W912DR-07-C-0027
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Date: 02-18-08
Rev.
Dwn by:
Ckd by:
Design file no.
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Drawing code: F-610-50-113
Submitted by:
File name:
Plot date:
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SEQ. 1 - SUPERSTRUCTURE & FOUNDATIONS - IFC
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Mark
Description
Date
Appr.
US Army Corps of Engineers
Baltimore District


▲ The roof of the atrium during construction.

◄ Typical V frame elevation and level plans.

▲ NGA's New Campus East consolidates six Washington-area sites into a single location at Fort Belvoir in Springfield, Va.

- ➤ Flexible construction to accommodate changes—during construction due to the fast-track process, as well as post-occupancy during the life of the facility
- ➤ Antiterrorism and Force Protection (ATFP) criteria, specifically UFC 4-023-03 (*Design of Buildings to Resist Progressive Collapse*), which dictates floor and roof uplift load requirements for all horizontal framing

Based on the selected building form, plan dimensions and preliminary floor plan layouts, the design team quickly developed a short list of viable typical bay sizes for further study. Three bay geometries—30 ft×30 ft, 30 ft×40 ft and 40 ft×40 ft—were assessed for both structural steel and cast-in-place concrete options. Steel-framed system studies included alternate filler beam spacing and various slab-on-metal deck sandwich characteristics. Concrete-framed studies looked at two-way flat slab systems as well as one-way beam-and-slab construction, with an option to use post-tensioned beams at the 40-ft spans (despite the negative ATFP-related aspects of post-tensioned construction); the 30-ft×30-ft bay was eventually dropped from consideration due to space planning concerns.

In order to advance the design to meet schedule demands, fundamental decisions such as structural framing selection were made far in advance of selection of the construction manager. The design team engaged an independent cost consultant to provide structural framing costs as well as costs and comparisons for other systems and trades affected by the structure. The cost analyses accounted for total building effects due to structural system differences, including sprinklers, fireproofing, lighting, ceilings and floor and column finishes, as well as façade costs due to depth of structure.

The pricing studies revealed that steel framing system costs were less than concrete framing options for both of the remaining bay sizes (total costs included the effects of pro-concrete attributes related to some finishes as well as benefits due to floor-to-floor height reduction). For the steel framing systems, the 40-ft×40-ft bay was more costly than the 30-ft×40-ft bay; the benefits of fewer steel pieces to fabricate and erect were offset by the weight increase of the 40-ft-long girders. In addition to structural system studies, extensive interior spatial studies were conducted to assess workspace options and related pros, cons and cost impact. Despite the slight overall building shell savings that the smaller bay offered, the 40-ft×40-ft module provided workspace and furniture efficiencies as well as a more flexible layout for future renovations, and was eventually selected as the typical framing module for the MOB.

In addition to the favorable cost study results, the schedule demands also strongly favored steel framing. In fact, it was clear that the only way to meet the strict end dates would be a very aggressive fast-track design and steel procurement process to facilitate early erection and completion of a steel-framed building. In addition, the lighter weight led to substantial savings in foundation costs and the lighter building mass also generates lower seismic forces in lateral frame components and affected foundations. Also, the ATFP-related uplift loading requirements for all floor and roof framing are mass-based and would have led to substantial premiums for concrete construction to accommodate load reversals. Plus, steel responded well to the various curved geometry, multi-story floor segments spanning across the atrium and the general complexity of a number of other atypical framing conditions.

## On the Fast Track

The NGA campus project was procured via an integrated design-bid-build (IDBB) process managed by the U.S. Army Corps of Engineers (USACE) Baltimore District branch. Detailed discussions between USACE and the construction manager—a joint venture between Clark Construction and Balfour Beatty (CBB)—led to a fast-track design and delivery schedule consisting of nine phased primary steel procurement packages (sequences 1 through 9). Design content for each sequence extended from foundation to roof level, following defined plan limits; the design packages were issued starting with sequence 1 in February of 2008 and ending with sequence 9 that July. On average, this equated to one sequence, representing about 250,000 sq. ft, being issued every two to three weeks. In addition to the primary procurement packages for typical steel framing, non-domestic jumbo shapes (totaling more than 2,500 tons) required separate earlier submissions due to longer lead time requirements.

The overall fast-track design and steel procurement effort could only be successful to the extent that it was supported by an accelerated submittal and approval process. According to

▲ The main office building uses 23,000 tons of structural steel.

▲ A base for one of the V columns.

Rob Rutherford, vice president of NGA's steel fabricator, SteelFab, the success of the submittal process was the key factor to the overall success of the project.

"Our detailer was submitting nearly 800 tons each week for approval, and the design and construction team was able to match that pace with review and comments," he said. "The direct communication among team members during the process helped eliminate major surprises and further strengthened the collaborative environment."

SteelFab used three plants to fabricate 23,000 tons of structural steel for the MOB. Erection on sequence 1 started in September of 2008 and the final sequence was completed in April of 2010. Six separate cranes were used on a phased-in basis to erect the nearly quarter-mile-long building. Steel erection manpower peaked at over 140 ironworkers spread across multiple areas of the building, and a vacant warehouse on-site was used to control an inventory of more than 850,000 bolts.

## A New Look

The chosen typical bay size of 40 ft×40 ft incorporated filler beams spaced at 13 ft, 4 in. on center and employed W18×50 beams at the third points and a W24×84 girder, with 3-in., 19-gage composite metal deck and 3¼-in. lightweight concrete topping. The typical framing also included bottom flange bracing of filler beams to address ATFP-related uplift forces. Original cost studies favored this solution over a quarter-point filler beam option due to lower overall steel weight and fewer pieces to fabricate and erect. The initial studies concluded that the higher cost of the 3-in. deck and additional concrete would be offset by the steel savings.

With SteelFab and CBB coming on board following the initial selection of the typical bay framing size, the design team took a fresh look at the framing. Due to the tremendous project size, they recognized that even nominal efficiencies would translate into sizable savings. Upon reexamination and assessment, it was determined that the premium for 3-in. composite deck was more substantial than initially believed, and bottom flange bracing costs were also higher than original estimates had accounted for. As such, the bay framing was reconfigured such that beams were placed at quarter points at 10 ft on center, and bottom flange bracing was eliminated by using the AISC continuous torsional brace procedure—albeit at the expense of a heavier section. And the composite metal deck was reduced from 3 in. to 2 in. deep. Although overall steel weight was increased, this holistic approach produced substantial total steel and project savings.

## Signature V

The final framing scheme of NGA office building incorporates a number of unique, custom-designed steel assemblies and systems, many of which contribute to the overall aesthetic of the building. For example, exterior columns are transferred at level 4 to the project's signature "V" columns, which extend from levels 2 to 4. These V columns, typically comprised of W14×370 members, are spaced at 40 ft on center and topped by continuous level 4 transfer girders, which support vertical columns above. The exterior frames and V columns participate in the lateral load resisting system and also accommodate alternate load path design as required by ATFP criteria.

A two-story-tall Vierendeel truss between levels 7 and 9 spans 125 ft across the atrium, supporting large floor areas with sweeping views of the atrium below. Due to crane constraints, the truss was erected in two sections and spliced at the verticals above the "middle" chord. The design accounted for temporary loading conditions on the single-story truss, including staged loading, incremental deflection and rotation-thrust effects at truss ends.

The west end of the atrium is enclosed by a 135-ft-tall by 140-ft-wide steel space frame structure, faced with a curtain wall that provides generous natural interior lighting as well as excellent views to the wooded site outside the building. The frame is comprised of round HSS16X0.625 members constructed to project-specific AESS criteria and incorporates pedestrian bridges for atrium crossing at several levels. The space frame supports atrium roof loads as well as wind loads, spanning horizontally and distributing lateral loads to floor diaphragms at either end. The design required all HSS members to be joined by full penetration joints while still maintaining the complex geometry and AESS

James West

▲ The project was designed to meet Antiterrorism and Force Protection (ATFP) progressive collapse criteria.

▲ Lifting one of the Vierendeel trusses.

requirements, and new proprietary welding and weld inspection procedures were developed to accomplish these connections.

Lateral loads due to wind, seismic and blast forces are resisted by concentric and eccentric steel braced frames located at interior core walls as well as the perimeter V columns. Wind loading governs the overall lateral design due to the relatively tall floor-to-floor heights, lighter building mass resulting from the steel framing and the favorable Seismic Design Category of A. Large shear forces are transferred from the braced frames through the level 4 diaphragms to the perimeter V columns due to their substantial stiffness. Expansion joints divide the building footprint into four separate structures, each with independent lateral load resisting systems, and joint designs accommodate potential out-of-phase movement in both orthogonal directions.

The atrium is covered by an ETFE (ethylene tetrafluoroethylene) fabric roof, supported by steel arches spaced at 10 ft on center. The fabric is lightweight and provides excellent light-emitting and aesthetic characteristics and, due to ATFP balanced design requirements, it also provides favorable blast-related effects by minimizing loads applied to the supporting structure as compared to a more rigid skylight system. The arch spans vary along the atrium length and the maximum span is 125 ft; all the arches are 18-in.×12-in. tube shapes comprised of welded plates. (Although 18-in.×12-in. HSS were available, SteelFab elected to fabricate built-up sections due to concerns with the rolling process and potential deformations, as well as ability to maintain a consistent arch radius after rolling and erection.) To weld the arches, SteelFab built a custom sub-arc welding machine that rotated each arch section in order to maintain a flat weld position throughout the length of the section. Opposite sides of the atrium are typically separated by an expansion joint at floor levels. At the roof level, there are no expansion joints at the arch ends. The system design accounts for lateral loading and thermal effects of differential movement and load transfer through the arch ties.

The project design complies with ATFP progressive collapse criteria in accordance with UFC 4-023-03. This document requires the structure to remain stable when any single exterior vertical load-carrying member is removed—i.e., the Alternate Path Method—and these criteria apply to any and all vertical columns as well as the two-story-tall V columns. Numerous structural studies and options were developed to meet the ATFP criteria, and the final design involves a dual-level transfer system incorporating large girders at the fourth and roof levels. Columns removed above level 4 lead to loads being suspended from the roof girder, and removal of a V column leads to loads above being shared between transfer girders at the fourth and roof levels. The project design also incorporates uplift loads on floor and roof slabs as well as tie force requirements (also mandated by the UFC 4-023-03 criteria).

Considering the 2.2 million-sq.-ft size, 23,000 tons of structural steel and a super-fast-track design and construction process, NGA's new office building headquarters project is impressive based on those merits alone. And broader success for the entire project team stems from completion of a challenging project that met both budget and schedule demands, as well as high compliments from NGA leaders and staff on their new home. MSC

*Structural director Bill Gillespie and project manager Steve Favieri served as KlingStubbins' structural team leaders for the project and provided editorial input for this article.*

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