Steel framing provides the structure for the ornamental stairs and bridges that span across the skylit central atrium.

Can a building's structure enhance the human interactions that occur within and communicate its *raison d'être* to those outside its walls? These are the ideas that shaped the design of Building 201 at the Johns Hopkins University Applied Physics Laboratory (APL) in Laurel, Maryland, the nation's largest University Affiliated Research Center. The result is an innovative structure that promotes collaboration and embraces the sense of the unknown inherent to revolutionary scientific research.

A Revolutionary Workplace for Scientific Discovery

Building 201 serves as the flagship facility for the Research and Exploratory Development Department (REDD) at APL, a multidisciplinary group of researchers whose work in hard science, engineering, and advanced fabrication drives groundbreaking discoveries at the Laboratory. Innovation at REDD is powered by teams of scientists and engineers drawn from across a broad spectrum of disciplines. Consequently, promoting collaboration and physical connection throughout the 263,000-square-foot building was the primary design objective. Because REDD is mission-focused, its needs for specialized laboratories, manufacturing facilities, and offices are continually evolving. In response to these challenges, CannonDesign and APL created a building that promotes collaboration, provides for maximum future flexibility, and reflects the critical research that occurs within.

Supporting the Mission

The structural design of Building 201 supports the core functions of scientific discovery, which depends on partnership, cross-disciplinary collaboration, and efficiency. Research and fabrication facilities occupy an L-shaped wing along the south and west sides of the

STRUCTURE AS A STATEMENT

Johns Hopkins University Applied Physics Laboratory Building 201 *By John Roach, P.E.*

The "flying" fourth floor, supported by concrete-filled HSS columns and cantilevered plate girders, is perched 45 feet above the entrance plaza.

building, while offices, dry labs, and conference rooms are housed in separate wings along the north and east. At the center of the complex is a five-story atrium, which connects each of these intertwined zones.

To accommodate constantly evolving research needs, laboratory and office spaces are based on the Universal Grid, a structural configuration consisting of 31.5-foot square bays that can be subdivided into 10.5-foot planning modules for nearly unlimited flexibility. With a floor-to-floor height of 15 feet, a two-way concrete flat slab was selected for the structural system of both the laboratory and office wings, which maximized the available overhead space for the intense concentration of mechanical, electrical, and plumbing systems serving the area.

APL required that each floor's long-term live load deflection not exceed L/480 and established stringent Vibration Criteria (VC) for all lab spaces. To meet these requirements, CannonDesign structural engineers used RAM Concept to design a 14-inch-thick reinforced concrete slab in both the laboratory and office wings, which allows the latter to be quickly converted into research space as future needs dictate. Vibration consultant Colin Gordon Associates (CGA) used proprietary finite element modeling software to validate the design

OF PURPOSE

for both VC-A and VC-B performance, which correspond to acceleration limits of 2000 μ-in/s and 1000 μ-in/s, respectively.

At the east wing, multi-bay conference rooms, closely spaced stair and mechanical shafts, and a two-story auditorium made reinforced concrete construction impractical. Instead, a steel frame structure is used throughout this five-story section of the building, separated from the concrete portion by an expansion joint to accommodate differential movement. Three, five-foot-deep steel transfer girders, each weighing 20,000 pounds, span 60 feet across the auditorium. The design approach of varying the structural system according to programmatic requirements helped reduce costs and maximize constructability.

Bridging the Divide

The heart of Building 201 is a five-story skylit atrium that links each part of the complex and emphasizes the role of structure in making unique connections between spaces and people. On each floor along the south side of the atrium, the two-way slab cantilevers 10 feet into the open volume, providing a path for circulation and a "gallery corridor" that offers views into the laboratory spaces. Seven bridges span the width of the atrium from the gallery corridor to the north wing to promote cross-disciplinary collaboration and encourage informal encounters.

Several structural challenges added complexity to the bridge design. First, each bridge is skewed relative to the Universal Grid structure, resulting in spans that exceed 40 feet. Additionally, five ornamental stairs that connect the bridges to one another are oriented at severe angles, which adds complexity to their support conditions. Finally, the south end of each bridge begins at the tip of the cantilevered gallery corridor, while the north supports occur at a building expansion joint.

CannonDesign evaluated several alternatives for the bridge construction, including cast-in-place concrete, prestressed concrete, and steel framing. The limitations of cast-in-place concrete became evident early in the process due to the span-to-depth ratio that would have been required to limit deflection. Furthermore, site-cast concrete would have required the construction of multistory formwork and scaffolding, which was both impractical and detrimental to the construction schedule. The alternative of using site-cast prestressed concrete slabs would eliminate the challenges posed by deflection and formwork, but craning the 80,000-pound slabs into the center of the building was determined to be impractical. This left steel framing as the most viable alternative.

The cantilevered slab of the gallery corridor is interrupted by each bridge structure so that each span begins at the first interior line of columns. Each bridge girder bears in a shear wall pocket or on a W12x72 beam encased in concrete, rather than a structural concrete beam, to simplify the connections at this end and minimize structural depth. At the north expansion joint, each bridge girder bears on a polytetrafluoroethylene (PTFE) pad supported by a concrete corbel.

The design team used both RAM Structural System and RISA 3D to analyze the steel bridge and stair structures. Due to the complex configuration of the stairs and bridges and the location of the expansion joint, careful consideration of construction sequencing was necessary

Concrete and steel are interwoven throughout Building 201 to maximize each material's structural efficiency.

to minimize the impact of differential deflections between floors and across the width of each bridge. The stair and footbridge provisions of the American Institute of Steel Construction's (AISC) Design Guide 11, *Vibrations of Steel Framed Structures Due to Human Activity*, provided initial vibration design criteria, which was further refined by finite element analysis. Heavy W14 girders with a composite slab were used to satisfy these requirements while holding the structural depth to only 22 inches.

Telling a Story Through Structure

Alluding to the transparency and objectivity that drives the process of scientific discovery, architecturally exposed structural steel and concrete are prominently featured throughout the building. At the atrium, these materials are intertwined with one another in the same way that individuals and building functions blend together in the same space. At the perimeter, five-story monolithic shear walls with a board-formed finish visually anchor this vast open space. Self-consolidating concrete (SCC) was used in each wall to preserve the grain and texture of the wood formwork.

The defining feature of Building 201 is the "flying" fourth floor at the north wing. Here, the lower three floors of the structure end at an outdoor courtyard while the fourth level transitions from concrete to steel framing and continues another 150 feet. This upper floor is supported by seven, asymmetrically arranged, three-story columns that serve as a physical metaphor for the core mission of the REDD team at APL: bringing together diverse teams for one common purpose.

While the building's interior embodies transparency through structural expression, the flying fourth floor serves as a counterpoint by instead emphasizing mystery. When viewed from below, the structure seems to float in space. The steel columns, which appear impossibly slender, are composite HSS sections filled with reinforced, 10,000 psi SCC to maintain a less than 50% demand-capacity ratio. The underside of the flying fourth floor features a mirror-like stainless steel surface. To someone looking up from the ground, the reflected columns appear to extend infinitely through the building itself.

Seven five-foot-deep steel plate girders span between the columns, concealed behind the mirrored surface. Weighing nearly 50,000 pounds, the girders cantilever up to 27 feet to the west and 15

Highly textured, board-formed concrete shear walls are prominently featured throughout the completed structure.

feet to the north and south, enhancing the perception that the fourth floor is floating in space above the courtyard. Their concealment, together with the mirrored surface above the columns, creates a skewed perspective of reality that alludes to REDD's ethos: to see what everyone has seen and to think what no one has thought.

To capture the compound deflections of the multidirectional cantilever framing, the design team used RISA 3D to model and analyze the floor structure. Because this portion of the structure lacks its own lateral force-resisting system, both the steel framing and the composite slab diaphragm are designed to independently transfer wind and seismic loads into the north wing shear walls. Steel framing at the roof level is augmented by in-plane bracing, and spandrel beams serve as chord elements. These beams are encased within the SCC shear walls to provide load transfer, with headed studs welded to the steel engaging the vertical wall reinforcing.

Building for the Future

APL Building 201 is a landmark facility that will accelerate discoveries by promoting collaboration within the scientific workplace. Therefore, it is fitting that close collaboration between its architects, engineers, and APL leadership drove this revolutionary design. Critical to this process and the successful completion of Building 201 is an appreciation that structure can shape human interaction and tell the story of a building and its purpose in subtle but important ways. In this way, Building 201 will provide APL with one more tool as it carries out its mission to solve the most complex technical, engineering, and scientific challenges facing the nation.▪

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