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Case Study

GSA

Footfall Vibration

Frick Chemistry Laboratory, Princeton University

Founded in 1746 as the College of New Jersey, Princeton University is the fifth oldest higher education body in the USA, and one of the eight universities that form the Ivy League. The primacy of chemistry in its research agenda is equally historic.

The previous Frick Chemistry Laboratory was completed in 1929 with funds from a bequest of the 1919 will of the industrialist Henry Clay Frick. By the early 2000s it had become the oldest functioning chemistry facility in any US academic institution, with cramped spaces and ageing infrastructure, and the need for a replacement was increasingly obvious. Princeton selected Hopkins Architects to design a new building, as part of a strategy to attract leading research chemists. Hopkins collaborated with Payette Associates, a Boston architectural firm with prior experience on the Princeton campus, and Arup worked with both firms throughout the life of the project, providing structural, mechanical, electrical, plumbing, fire protection, façades, and telecommunications engineering, plus consulting services in acoustics and vibration, artificial lighting and day lighting, and sustainability. The old Frick Laboratory is being decommissioned, and a study is under way to decide its future use.

Building overview

At 265,000 ft2 (24,620 m2), the $280M Frick Chemistry Laboratory is the second-largest academic building on the Princeton campus, designed to house up to 360 researchers. Overall it comprises two four-storey wings, one for laboratories and the other for offices, separated by a 27 ft (8.2 m) wide, 75 ft (22.9 m) tall glass-roofed atrium running the length of the building.

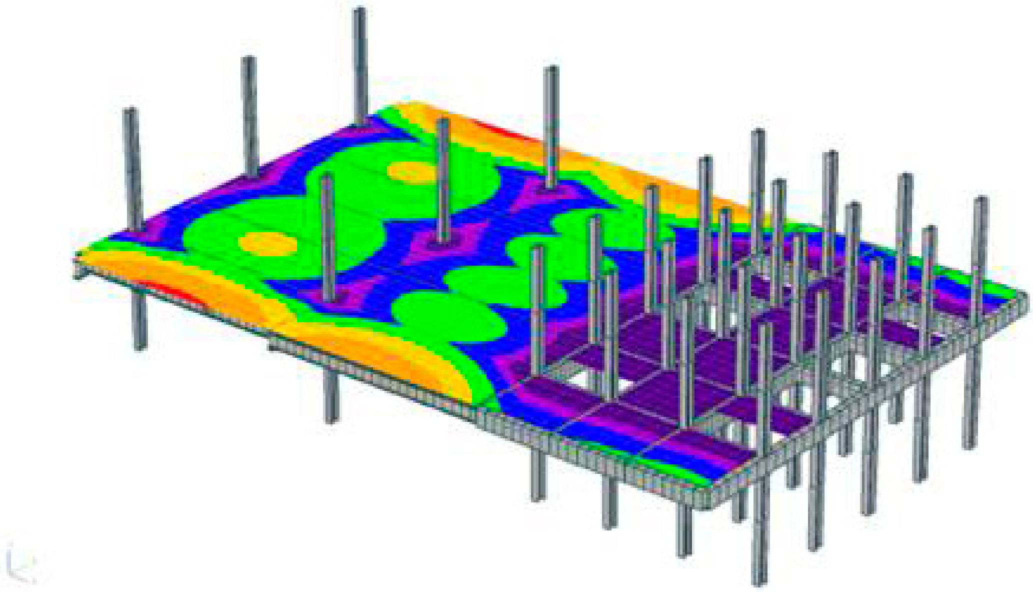
The office wing houses 30 faculty members and 30 staff, while the larger laboratory wing can accommodate up to 300 graduate students, post-doctorate, and research staff on the upper floors, with laboratory space for hundreds of undergraduates on the ground floor. A basement level contains a 260-seat auditorium and vibration-sensitive research equipment.

Research continually evolves, so the building was designed to support flexibility of use. Future revisions to the space will be achieved more easily, since the infrastructure was designed to be fully modular and easily accessible. The Chemistry Department was clearly looking to the future, since at the completion of construction documentation, only about half the spaces had named research occupants. The remainder of the building was to be fitted out for the specific research needs of subsequently recruited faculty members.

The Laboratory Wing

A constant theme throughout the design of the laboratories is modularity, allowing for changes to the building systems to accommodate a range of research as the space requires.

Vibration was a major structural design criterion in the research laboratories, where experiments are conducted using microscopes, lasers, and other sensitive equipment. Each unique laboratory was categorised according to its tolerance to vibration, which helped to define the best locations for sensitive and ultra-sensitive equipment. Some, such as the electron microscopes and NMR imaging devices, require vibration levels many orders of magnitude below the threshold of human perception. These were segregated to the basement, where extremely low floor vibration levels could be provided.



The 21 ft x 31 ft 6 in (6.4 m x 9.6 m) column grid on which the building is structured allows a variety of floor loading. As this tends to be less stiff than smaller spans, the team developed a series of vibration models to calculate floor movements under various footfall inputs, leading to a cost-optimised design by identifying areas of acceptably higher and low vibration levels that met the University's criteria for the laboratories. The areas near columns are stiffer and can be used to support more sensitive equipment, while corridors and cantilevered areas were designated for non-critical use, where these limits could be exceeded. The increased mass of the floor sections in the middle bays of the building evened out the stiffness throughout the floor framing and created an efficient structural system for the layout and performance criteria.

Some columns were placed in-board of the façade by 10 ft 6 in (3.2 m), with the edge zones of the floor plates devoted to non-instrumented space. Vibration up to 16,000 µin/sec is permitted in these cantilevered "ghost" corridors along the building's perimeter, compared with 2000 µin/sec maximum within the laboratory spaces. Cantilevered glass half-bays, 10 ft 6 in (3.2 m) long, create the appearance of a slender colonnade, while the façade is simultaneously used to reduce vibration.

Conclusion

Close collaboration between the acoustic, structural and mechanical engineers resulted in a design that meets the client's background airborne noise and vibration criteria for each of the building's occupied spaces. Particularly with the highly sensitive NMR laboratory, the effort was focused on achieving mechanical and structural systems performance at the desired acoustic level within the architectural framework of this complicated building.

Construction of the new Frick Chemistry Laboratory began in autumn 2007 and building occupation commenced in selected areas in July 2010 as soon as the building Temporary Certificate of Occupation was granted. The dedication by Princeton University followed at the beginning of April 2011.

The multidisciplinary design contribution to the building's engineering fulfils several challenging goals. First and foremost was the University's need for a world-class chemistry research and teaching facility for the 21st century, along with the desire to exemplify the campus sustainability goals. A safe, modular, reliable design for the future was created through close collaboration between all the design team members, and contributed to the achievement of the University's goals.

One of the recently recruited researchers proclaimed that it is "the best building for academic chemistry in the country, if not the world". As department Chair David MacMillan puts it, the building "is a dream come true".

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