Simmons Hall, MIT

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Introduction

Massachusetts Institute of Technology was founded in 1861 'for the purpose of instituting and maintaining a society of arts, a museum of arts, and a school of industrial science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures, and commerce'. MIT's commitment to innovation has led to many scientific breakthroughs and technological advances; 57 past and current members of the MIT community have won a Nobel Prize. A massive renewal programme, the 'Evolving MIT Campus' initiative, is under way to add 'nearly a million state-of-the-art square feet' to the campus. MIT's President, Charles M (Chuck) Vest, describes the programme as 'a mega-scale interdisciplinary research project… In the Institute's long tradition of innovation, I see our building programme as one of MIT's great inventions'.

Out of over a dozen individual projects, the first to be completed is Simmons Hall, a student residence. Its programme called for 350 beds with amenities including a dining hall, study areas, fitness centre, theatre, and café. The term 'open' is dominating the community-wide planning process, and for this student residence planners desired a welcoming building, open to light and air, with spaces designed to encourage intermingling between residents who, before Simmons Hall, occupied isolated off-campus apartments.

In early 1999 MIT appointed Steven Holl Architects to design the building. It would be the cornerstone in a masterplan developed earlier by Holl for a strip of new buildings lining Vassar Street on the campus. Holl's planning vision encouraged multiple penetrations along the strip to maintain views from an open urban green space to the north and to prevent the row of buildings from forming a barrier wall. Holl invited Arup to join the team; Arup New York would assume responsibility for the schematic and design development phases. Work would be transferred to the Boston-based associate architect, Perry Dean Rogers & Partners, with Arup's Boston office handling the construction documentation and construction administration.

Throughout the project, the design team had to balance the client's various interests and concerns. President Chuck Vest desired a landmark building in terms of sustainability and architecture. MIT's project management team had a clear mission to deliver the project on budget and on time.

The facilities group, responsible for MIT's heating and cooling plant, appreciated the sustainability goals but needed assurance that residents would be comfortable. Members of MIT's Building Technology Faculty required proof that the building's daring design would be successful and a symbol of pride for the Institute.

1. Close-up of the south façade, showing the operable windows in use by students in summer.

Steven Holl Architects envisioned the building as a 'sponge' with pores or openings. In early meetings, the architects and engineers actually handled sea sponges to explore how their order might be applied in some way in the design.

2. Early model, showing the 'porous sponge' concept and internal atria.

The concept

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It became a mantra to allow penetration of light and air into the heart of the building via a double approach: through elevations that consist of a porous grillage, and by embedding irregular and amorphous 'natural' open volumes to puncture and animate the repetitive floor plan of double-loaded dormitory corridors.

Simmons Hall is a narrow, 385ft (117.3m) long, 10-storey structure of 195 000ft^2 (18 100m^2) gross area, where main entrances, view corridors, and outdoor terraces provide large openings. Small openings are in the form or more than 3000 operable windows – an unusual nine windows per single-occupancy student room. Larger windows correspond to common areas. Five curvilinear atria flow through the building's otherwise Cartesian grid. The 'porous' concept embraces programming and planning goals while allowing airflows and views over the nearby Charles River.

In the plan that emerged, architecture, structure, and building systems developed as an integrated whole. The exterior walls, designed by project structural engineer Guy Nordenson and Associates, are in a unique system dubbed *PerfCon* - prefabricated, perforated, reinforced concrete panels. The 2ft (610mm) square perforations house the operable windows. Each perforation's 18in (457mm) depth allows for low winter light to enter, while shading the rooms from the high summer rays.

Mechanical design

Simmons Hall presented a rare opportunity for Arup in the North Eastern USA. With 3000+ operable windows, inherent sun shading, concrete's stabilizing thermal mass, and the fact that student rooms would be less occupied during the summer months, the mechanical engineers were determined that their systems should be as economical as possible.

Using Arup's in-house E+TA software, the team conducted computer simulations to maximize the benefits of natural ventilation. Thermal analysis models took in all scenarios, including the fact that since each student room has nine operable windows, opening high and low windows can take advantage of the natural rise of warm air within the high-ceilinged rooms. Student rooms were designed with exposed concrete to keep the cooling load as low as possible. Models considered how the thermal lag of the concrete structure stabilizes interior temperatures.

The team first studied a natural ventilation scheme for one side of the building, with windows open but doors to the corridor closed. Using a design air temperature of 90˚F (32˚C) and humidity level of 50% RH, natural ventilation did not bring conditions in the student rooms within the zone defined in ASHRAE *Standard 55*[1]. However, these initial studies proved promising for a cross-ventilation scheme. This brought temperatures and humidity levels into acceptable ranges, but cross-ventilation could not comply with fire codes. Though it was ruled out for the entire building, Arup and MIT designed a section of four rooms to simulate cross-ventilation's potential.

The added benefits of cross-ventilation in these test rooms can be monitored and documented by MIT's Building Engineering Department. Such research may lead to code-acceptable strategies for cross-ventilating high-rise residences.

Arup saw the opportunity to introduce an innovative 'mixed mode' system derived from concepts used in Europe. 'Mixed mode' is a hybrid arrangement that combines the mechanical cooling effects of a low-volume ducted air-conditioning system with the natural ventilation effects of opening windows. (In the USA, one reaps the benefits of such a system when one walks past the open doors of an air-conditioned storefront on a hot day.)

When MIT accepted Arup's idea, the Institute paved the way for Simmons Hall to be one of the first major buildings in the USA to use this system.

3. Computer visualization of an atrium.

4. South façade of Simmons Hall under construction.

During summer, students are encouraged to control natural ventilation using windows and blinds. $50ft^3$ ($1.42m^3$) per minute per person, or 2AC/h (air changes per hour) of pre-cooled outdoor air is ducted directly to each room. In spring and autumn, the system can operate at varying supply conditions depending on inside and outside temperatures. In the winter, the system delivers 2AC/h pre-heated fresh air (at room temperature or a little higher depending on internal conditions) to student rooms. This guarantees high levels of air quality and eliminates the need to open windows for fresh air. The system combines with a low-temperature hot water radiator system that is the primary source of controllable heat to the student room. The quantity of conditioned air normally required by a space is reduced from 4-6AC/h to 2AC/h. Energy modelling conducted on Visual DOE Software shows 20% estimated annual energy consumption savings compared to an identical building with conventional HVAC systems, and 40% savings compared to the average energy consumption of this building type in the North Eastern USA.

The long, narrow Simmons Hall structure is divided into three sections ('towers'). With horizontal distribution extremely limited by the architectural requirement for high-ceilinged corridors, nearly all distribution occurs through carefully co-ordinated vertical risers. Arup designed an air-handling unit (AHU), one to be mounted on the roof of each of the three towers.

Outdoor air (pre-cooled and dehumidified in the summer to 65°F/18.3°C) is ducted from the AHU through risers adjacent to each bathroom extract - the only available vertical riser space.

Pre-cooled air is ducted to each room via insulated sheet metal risers and branch ducting just as with conventional air-conditioning infrastructure, but significantly smaller.

The mixed mode system offers inherent maintenance advantages. Three AHUs require considerably less maintenance than the 250 fan coil units in a traditional air-conditioning scheme.

5. One of the atria, extending up through four storeys to the skylight.

Residents have likened living in Simmons Hall to living in a piece of art... it is also a work of science to be studied and advanced in the future.

In student rooms, the risk of condensate drain overflow and the presence of movable components susceptible to tampering are eliminated. Also, there is no requirement for maintenance staff to access student rooms during summer months. Automatic seasonal changeover is initiated by a combination of internal and external temperature sensors. 16 temperature and 16 humidity sensors are located throughout the building.

When averaged, the sensors provide a general indication of building conditions to allow some optimization of the supply air temperature and humidity.

Atria and corridors share generally the same mechanical approach as student rooms. In the summer, mixed mode supply outlets at the base of the atria supplement natural ventilation. Corridors are naturally ventilated in the summer. In the winter, heated air is supplied into the top of the atria from the mixed mode AHUs. Supplementary hot water heaters service the body of the atria voids. In the corridors, the air from the atria's mixed mode supply is drawn along the corridors by the bathroom extract systems. During the spring and autumn, air at outdoor temperature is supplied into the atria and corridors as in winter and is combined with natural ventilation as needed.

Electrical design

Sustainable mechanical and lighting systems have reduced the overall connected building electrical load. Arup's electrical design was driven by both architectural intent and the high standards of MIT, whose central utility plant supplies Simmons Hall's electricity. The Hall takes two 13.8kV supplies into a double-ended switchgear arrangement. While the latter is more typical for a data centre than a residence, MIT has safeguards so that if one transformer is lost the other provides redundancy for life safety systems. From the switchgear, six busway risers - two for each of the three towers - distribute power vertically throughout the building; all primary distribution is vertical to accommodate high-ceilinged corridors. Of the six busway risers, three are normal risers and three are emergency risers. Arup's design includes two generators, another unusual choice for a student residence. MIT requires one generator solely for the building and one for the fire pump, which at Simmons Hall is part of a multiple set of pumps in the campus loop.

Arup designed a high-end analogue addressable system with full voice evacuation for fire safety. Engineers went to unusual lengths to ensure that the system and speaker placement met the world standard Speech Intelligibility Index (STI) method of measurement.

Arup has since worked with the National Fire Protection Association to include IEC 60849 'Sound systems for emergency purposes' in NFPA 72, the national fire alarm code; Simmons Hall was one of the earliest projects to meet this stringent requirement.

Plumbing design

Due to the urban setting, engineers were restricted with stormwater run-off and needed to limit the discharge rate to the sewer during heavy rainfalls. Normally, an underground retention tank meets this limitation, but Arup utilized flow-controlled roof drains that use a trapezoidal weir configuration to govern the flow rate from the roof - which depends upon the depth of the water on the roof.

Sprinkler protection

Simmons Hall is classified as 'high-rise', requiring higher residual pressures for the standpipe system than a low-rise structure. Sprinkler protection in the atria required a series of creative solutions.

At the atria's glass doors and windows, sprinkler water curtains were provided to ensure a two-hour fire rating of the glass. Within each atrium's walls, piping is routed in PVC - an unusual choice that enabled the piping to bend with the undulating walls, in turn requiring fewer swing joints. Additionally, since sprinkler heads are concealed within the irregular curves of the walls, their exact distribution needed to be carefully addressed.

Since there are typically no ceilings in the student rooms, the building is almost entirely protected by sidewall and extended coverage sidewall sprinklers.

In the congested basement service corridor, fire protection mains could not be located where standard seismic bracing could be used. This required specially-engineered seismic bracing for the fire protection systems throughout the 350ft (107m) length of the basement service corridor.

Fire

In the spirit of MIT's 'interdisciplinary research project', Arup performed early CFD smoke control studies for the atria that pierce the building. The team sought a fire-engineered solution that would allow corridors to be open to the atria, but all strategies other than the code-compliant approach proved too difficult or costly to implement. The most effective way to control smoke was to provide fire doors on hold-opens rather than active mechanical smoke control.

Communications

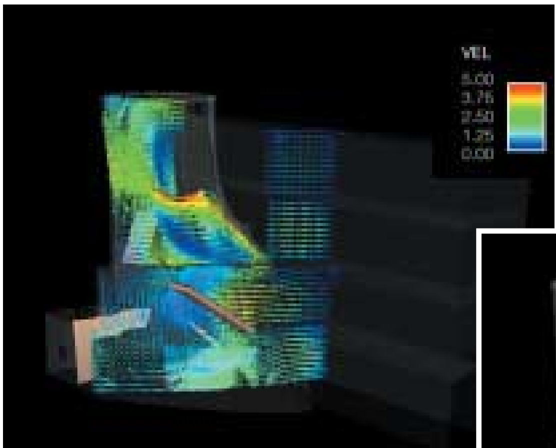
MIT and its students are demanding users of information technology and telecommunications (IT&T). Integrating IT&T infrastructure (rooms, routes and risers) seamlessly, transparently, into the facility, Arup provided support for high bandwidth digital communications in student rooms and common areas; wireless infrastructure to support mobile communications; and support for kiosks facilitating Internet access by students and guests.

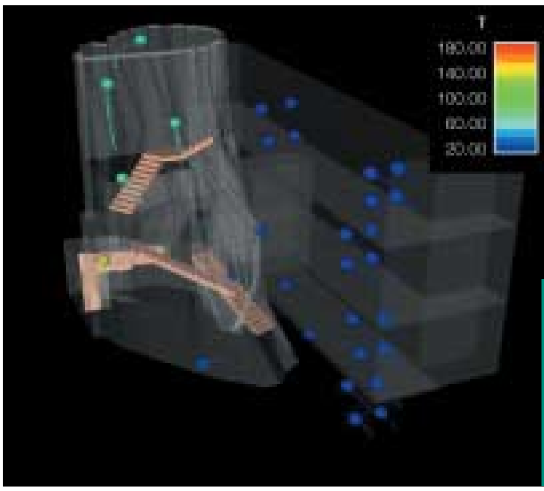
Awards

American Institute of Architects (AIA)

2002 New York Design Award and 2003 National Design Award

2000 Progressive Architecture Award





6 & 7 left. CFD models of velocity and temperature showed that, in principle, smoke could be extracted from the atria, limiting its flow from an atrium fire into the corridors. However, various constraints including getting supply air to the base of each internal atrium necessitated a code-compliant solution.

Conclusion

Rarely in professional life are engineers granted the opportunity to innovate on such a large scale as in Simmons Hall. MIT asked its designers to improve social and aesthetic qualities of the urban landscape and to do so by promoting sustainable solutions for the future.

Since the building opened in August 2002, residents have likened living in Simmons Hall to living in a piece of art.

This building, where architecture, structure, and building systems impart one harmonious sustainable answer, is also a work of science to be studied and advanced in the future.

Reference

(1) AMERICAN SOCIETY OF HEATING REFRIGERATION AND AIR CONDITIONING ENGINEERS. ANSI/ASHRAE 55-1992. Thermal environmental conditions for human occupancy. ASHRAE, 1992.

8. Ground floor stairway.

Credits

Client:
Massachusetts Institute of Technology

Architect:
Steven Holl Architects

Associate architect:
Perry Dean Rogers & Partners Architects

MEP, fire, acoustics and communications engineers:
Arup Bill Ahearn, Jack Aroush, Aitor Arregui, Julian Astbury, Tom Beaudoin, John Boehs, Irina Bulbin, Danny Chan, Dale Cibene, Bernard Conroy, Steven Davidson, Gavin Davies, John Elissa, Gillian Gardiner, Gabriel Guilliams, Dennis Hromin, Carey Jones, Rebecca Kennedy, Lui King, Leroy Le-Lacheur, Susan Leven, Diego Lozano, Al Lyons, Anthony Goulding, Tom Grimard, Chris Marrion, Andy Passingham, David Powell, Mircea Preda, Ashok Raiji, Mahadev Raman, Joel Ramos, Anatoliy Shleygar, Peng Si, William Stevenson, Akiko Tanikawa, Nigel Tonks, Steve Walker, Mark Walsh-Cooke, Alex Yaroslaviskiy

Design structural engineer:
Guy Nordenson and Associates

Structural engineer of record:
Simpson Gumpertz & Heger Inc

Construction manager:
Daniel O'Connell's Sons, Inc

Illustrations:
1, 4, 5, 8, 9: Andy Ryan
2, 3, 6, 7: Arup

9. View from the south east of Simmons Hall at night.