BAHEN CENTRE
UNIVERSITY OF TORONTO
TORONTO, ONTARIO

DIAMOND SCHMITT ARCHITECTS

Nathaniel Lloyd
B. Arch Candidate
University of Waterloo

BAHEN CENTRE
TORONTO, ONTARIO

QUICK FACTS

Building Name	Bahen Centre for Information Technology
City	Toronto, Ontario, Canada
Year of Construction	2001
Architect	AJ Diamond & Schmitt Architects
Consultants	Keen Engineering (mechanical), Allen Kani Associates (sustainable), Read Jones Christofferson (structural), Crossey Engineering (electrical)
Program	Faculty of Applied Science & Engineering; Faculty of Arts & Science

Gross Area	565,000 sq ft; 52,500 sq m
Owner/User Group	University of Toronto
Climate	Temperate, cold-humid
Site Conditions	Infill site
Aesthetics	Clean, institutional
Structural System	Concrete
Mechanical System	Heat exchanger for 92% of heat needs; energy consumption 60% of a conventional building; 5,000-ton chiller servicing surrounding buildings
Special Construction	Removal of site contaminants; encompasses existing buildings
Daylighting	Natural daylighting used throughout
Shading	Fixed brie de sole's
Acoustics	Perforated metal panels; wood panels; stucco; wood soffits above doors to counteract exposed concrete
Ventilation	Displacement ventilation from below raised floor
Adaptability	Removable drywall partitions on access flooring
User Controls	University of Toronto Automated Control System; operable windows & air diffusers
Estimated LEED rating	33 points – Silver Status
Budget	Building 88 million, underground 300 car parking structure 12 million
Cost of Constructions	100 million
Annual Maintenance	Not Established
Special Circumstances	Contaminated site required cleaning

INTRODUCTION

The Bahen Centre for Information and Technology is exemplary of sustainable design in Canada. The BCIT is a 400,000 square foot, eight level building made up of computer labs, classrooms, lecture theatres and offices which serve two university faculties and a barrage of industry related research institutes (Figure 1). This high tech building uses “echo-tech” solutions to exceed the ASHRAE 90.1 standard for energy efficiency by forty percent (40%). This significant accomplishment is achieved through many different design measures, all of which must accommodate the specific demands of the University of Toronto mechanical systems and the individual faculties and institutes.[1]

This building is particularly Canadian in the sense that it endures harsh winters and hot summers. The mechanical design employs the same techniques year-round; however it benefits most from its passive systems in the shoulder seasons. The building employs a high-tech/echo-tech approach that is partially passive in nature. The two dominant passive elements are its capacity to harness its thermal mass and its ability to deliver natural daylighting to virtually every space. Ironically, passive strategies do not come naturally to this building: in many cases passive elements are assisted by high-tech systems.

The vision of this building “is to bring together the Faculty of Applied Science and Engineering and the Faculty of Arts & Sciences in a multidisciplinary facility that accommodates teaching and research in computer science, electrical engineering, engineering science, mechanical and industrial engineering. The Centre also houses a variety of industry-related research institutes, including the Nortel Institute for Telecommunications, Bell University Research Labs, Computer Systems Research Group and Knowledge Media Design Institute.”[2]

Figure 1 (Above): The north-east corner of the Bahen Centre in winter. Figures 2 and 3 (Below): The central circulation atrium provides all floors with natural daylight.

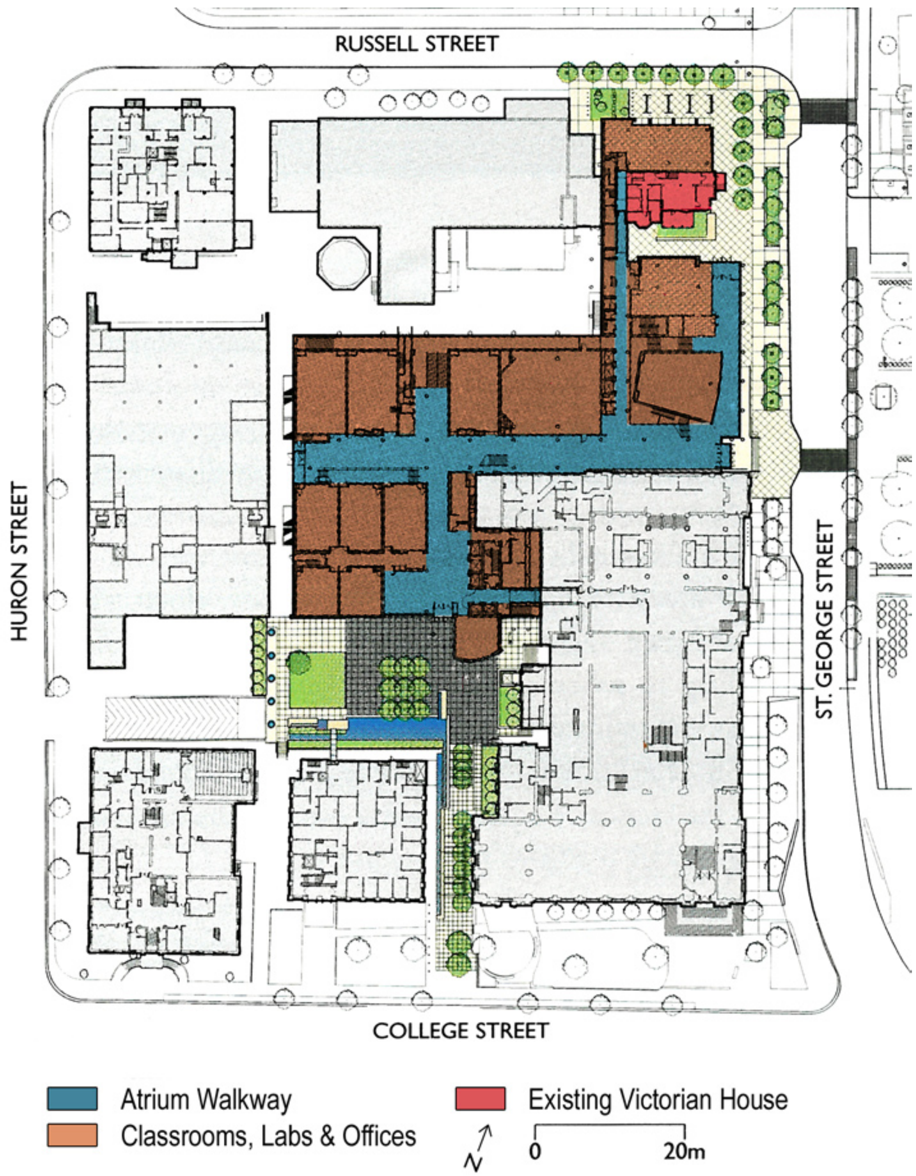


Figure 4: Site and Main Floor Plan of Bahen Centre

The BCIT was subject to a demanding schedule with construction starting only five months after the architects were chosen. An integrated design process was employed to ensure coordination between the consultants from the beginning, as there was not time to resolve problems later on. The driving genius behind the project was the client's willingness to accept sustainable technologies with a payback of less than seven years. This allowed the design team to use proven, yet unconventional, systems. The most significant aspects of this building are its ability to bring natural light into a large floor plate, its relationship to the site and university campus, and its energy efficient characteristics.

The aesthetic intentions in this design are to provide a non-cluttered and clean look while highlighting and attracting attention to certain architectural elements. The rainwater retention pond is a highly visible aesthetical element which raises awareness of the building's sustainable design. Throughout the entire building, however, there are many moments that attract awareness to unconventional elements.[3]

PROGRAM

The Bahen Centre is composed of three main elements: the Faculty of Applied Science & Engineering to the north, a central atrium, and the faculty of Arts and Science to the south (Figure 4: Main Floor Plan). The atrium provides a point of cohabitation between two faculties who have historically kept to themselves. This allows the "hardware people" to meet and mingle with the "software people." The programmatic elements are located to best suit the sustainable objectives and site requirements. For instance, the heat generating computer labs are located along the north façade – the coldest exposure of the building. To foster a relationship between the two faculties they share a number of elements; there are public study areas throughout the building as well as other more secluded study rooms. The classrooms are found off of the atrium and are shared by both faculties. The building also acts as an inner-node within the University of Toronto campus, generating cross traffic and activity from other buildings in the area.[4]

The program relates to the environmental strategies in that all spaces receive natural light. This is manifest in the open appearance of the offices due to glazing along the corridors. Even the guard rails are made of glass to permit unobstructed light to pass from the atrium into the different spaces.[5]

The environmental strategies used in the BCIT create a fresh appearance in the building. The glass, the access floor plenum, the stormwater system, and atrium are all prominent features. The atrium also serves a secondary role as a bridging element that links St. George Street to Huron Street. The only environmental aspect that could be viewed negatively is that the building takes longer to initially heat or cool than a conventional building.

SITE

A parking lot between several existing buildings was chosen for the site of the Bahen Centre. The urban design resolution was based on realizing the full potential of the infill site. “The Bahen Centre is nestled – to the extent that a building of this scale can be said to nestle – among an eclectic collection of smaller existing buildings near the southwest corner of the campus: the Beaux Arts Koffler Centre for Student Services, the Fields Institute, the Faculty of Architecture, Landscape and Design at the corner of College and Huron Streets, an administration and services building on Huron, and the University’s central

Figure 5: The atrium circulation corridor is a meeting place between the two faculties.

Figure 6 (Above Left): The Victorian house is integrated into the design. Figure 7 (Above Right): The north facade of the Koffler Centre forms one side of the atrium. Figures 8 and 9 (Below): A computer model and actual photo of the tower element.

steam plant. In addition the Bahen Centre's construction involved the demolition of Victorian houses on St. George Street; public opposition resulted in the retention of the most historically significant of these, which further complicated the already constrained site (Figure 6). The house has been incorporated into the Bahen Centre, providing a unique identity within the complex for the Professional Experience Year Program."[6]

Special strategies also had to be implemented to clean contaminated soil on the site caused by a generator's fuel oil leak. Due to the intense construction schedule for the new building, this problem had to be dealt with in the fastest possible manner.

Because the BCIT is sited between an array of buildings, it is never possible to read the building as a whole. Instead, it presents itself through several distinct moments. The main entrance is along St. George Street, where the building presents a three-story podium in respect for the scale of the surrounding buildings and wraps around the historic Victorian house. From the podium, the building rises to five stories on the corner. The atrium inside the main entrance integrates the north façade of the Koffler Centre and continues west, anticipating a future interior connection to Huron Street (Figure 7). On College Street, a vista containing a water element leads the eye to an eight story cylindrical tower (Figures 8 and 9). This view of the tower is provided by a narrow service lane that provides pedestrian access to the building.[7] Walking towards the Bahen Centre tower, one is presented with a courtyard containing the rainwater demonstration elements and an entrance to the Fields Institute. As this is the south façade of the building, it has tightly spaced louvers attached to the exterior of the building with the actual façade set deep behind them to limit thermal gain from southern light.

The BCIT harnesses the full potential of its site. The building maximizes its area while taking advantage of waste heat from the University's steam plant chimneys; it integrates adjacent and existing buildings as in the case of the north façade of the Koffler Centre and the historical Victorian house, and creates an interior pedestrian corridor running east-west that links the diverse sides of its constrained site. The building also incorporates the site's stormwater as it is used as both an ecological demonstration project and an architectural focal point in the courtyard retention pond.

The success of this design is linked to both the specific elements of the site and the climate. Where it cannot gain shelter or use from the surrounding buildings, it employs elements to gain from the environment. The surrounding buildings have also gained environmental protection from the BCIT's presence: the Koffler Centre had the most to gain as two of its exterior facades were enclosed.

Figure 10 (Above): Interior partitions are low to allow light diffusion into spaces and moveable for increased flexibility. Figure 11 (Below): A glazed interior partition.

SUSTAINABLE DESIGN

Materials with the least environmental impact were chosen for the building. This means that, when possible, they were from a sustainable producer or manufacturer, a local source, contained low levels of embodied energy, were abuse resistant, or familiar to local contractors. Fly-ash was tested in the concrete as it has a low embodied energy, but due to uncertainties in the product and the demanding construction schedule, it was not used. On the other hand, the brick used for the building is over 90% silica fume – a waste product from mica mining with a very low embodied energy.

Every effort was made to keep the embodied energy in the building to a minimum. For instance, it was decided that fabricated moveable partitions had

Figures 12 - 15 (Clockwise from Upper Left): Different facade treatments correspond to their exposure. Photos are west, north, south, and detail of the south louver system.

much more embodied energy from their extensive manufacturing process than drywall partitions, so drywall was used instead. Foreseeing that the layouts likely would not change for at least thirty years, it is possible that the fabricated partitions would be obsolete by the time modifications were needed anyway. The carpets used are also modular so if an area deteriorates or is stained it can be replaced as needed. The carpet modules are less than one square meter in size.[8]

Overall, the building impacts its surroundings in a positive manner. It provides no additional stormwater load, reduces heat island effects, links to surrounding buildings while providing them with climatic shelter, and creates pleasant courtyard spaces. It also utilizes low-flow bathroom fixtures to reduce potable water consumption while also using native planting species in the landscaping to reduce maintenance and the need for irrigation water.

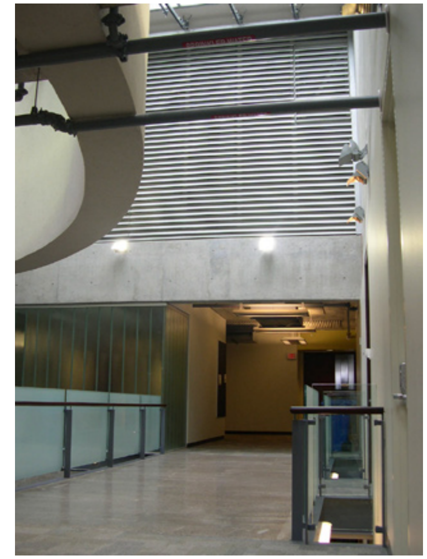
ENVIRONMENTAL CONTROLS

Shading of direct sunlight takes place on all façades via louvers oriented to best suit their exposure (Figures 12 - 15). Daylighting is brought into the building through atria and is allowed to pass through objects that are typically opaque, but in the BCIT are made of glass. All regularly occupied space receives daylighting either from an exterior window or from glazing into the atria.[9]

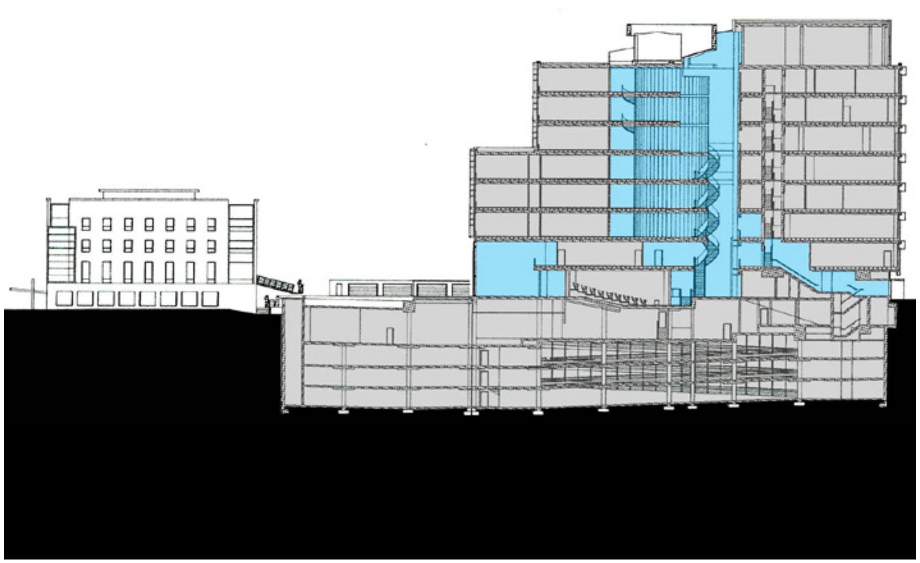
Ventilation occurs through a raised floor system in which air is displaced from the floor plenum and naturally rises to the return air, which is located at a high level. This system provides an improved indoor air quality due to the characteristics of displacement air circulation. This displacement air system is also installed in the high occupancy raked auditoriums on the ground floor. Mechanical air handling systems have been combined in a header arrangement to provide complete operational flexibility and nine stages of air capacity for optimum efficiency. Much of the return air is through the top of the atrium, allowing for natural, passive assistance of mechanical systems in certain conditions through the stack effect (Figures 16 - 18).[10]

In this building both passive and active strategies are employed. Solar heat gain is reduced through passive means like the extensive use of louvers and high performance glass which help the building stay cool. The building's thermal mass – its concrete structure – serves two additional functions: it is the interior ceiling finish in many spaces, and also the second side of the mechanical ducting of the building in conjunction with the raised floor plenum. Unfortunately, the thermal mass is not purged of excess heat at night during the summer through passive means – a sustainable strategy overlooked by the U of T Automated Control System. Daylighting through exterior and atrium facing windows provides much of the required light, dramatically reducing the amount of energy required to light the building. The ventilation is also partially passively managed in the sense that it utilizes the displacement principle to get the air from floor to ceiling in office, classroom, and laboratory spaces, and then the stack-effect principle to get to the return air to the top of the atrium to be vented. At certain times of the year ventilation could happen naturally with the windows open throughout the offices and the air return vent at the top of the atrium open. However, once again the U of T Automated Control System does not account for this possibility. It is feasible to run the building manually to exploit these passive principles, but it was not part of the commissioning of the building and no one currently holds that responsibility.

The BCIT is adaptable in many ways. First, it is designed to adapt to changes in the surrounding buildings. When the university offices to the west are



Figures 16 (Above Left): Air is drawn up the atrium using the stack effect. Figure 17 (Above Right): Vents at the top of the atrium. Figure 18 (Below): Diffusers are integrated into the floors slabs along the atrium walkways to aid in air circulation.



Figures 19 (Above): East-west section through the Bahen Centre atrium space.
Figure 20 (Below): North-south section through the atrium corridor.

redeveloped, the two buildings will link at the atrium to provide sheltered passage from St. George Street to Huron Street (Figure 19 and 20). The atrium itself is highly adaptable, capable of functioning as a quiet study area or the location of a noisy event. The floor plans are also highly adaptable; the drywall partitions sit *on* the raised flooring to allow for easy alterations.

Acoustical control was a concern because of the large amount of exposed concrete in the building. In the office areas wood panels with absorptive backing are used in the soffits above the doors. In the classrooms and labs sound absorptive panels are hung from the concrete ceiling, while in other areas stucco is used to absorb sound. In the atrium, perforated metal panels are used on the underside of the stairs, while large wooden screens with absorptive backing line the north side of the space. A corrugated pattern can be found in the concrete on the ceilings of the main corridors; this is primarily for the orientation of building users, however, it also has a positive acoustical affect.[11]

Because the building is run by the aging University of Toronto Automated Control System, the level of direct user control is minimal. The building could be run much more aggressively, but currently the university is not prepared to invest in a control system capable of doing that. Thermostatically, each room and exposure is individually and automatically controlled to minimize energy use, while a secondary hot water overhead radiant panel heating system is installed to offset heat loss and increase thermal comfort. If an individual wishes to change their environment, it is not possible to change the thermostat. However, it is possible to open a window or adjust the air diffusers in the raised flooring. Despite these drawbacks, occupants have the opportunity to participate in energy consumption reduction by using the operable windows for ventilation and accepting a broader range of temperatures and humidity conditions.[12] More public awareness of these sustainable concepts will benefit society and particularly the younger generation, which will be an active participant in conserving natural resources in the future.

CONSTRUCTION

The Bahen Centre incorporates a highly insulated wall system with high performance glazing. On the north façade, glazing is kept to a minimum while on the other façades it is used extensively with louvers. Almost all of the glazing is PPG Solarban 60 SolarControl Low-E glass with the high-end performance characteristics (Table 1).

The building envelope uses a glazing system to minimize cooling and maximize daylighting. This was achieved using the Light to Solar Gain (LSG) coefficient to find a balance between cooling requirements and lighting needs. The LSG of 1.86 means that almost twice as much visible light enters the building as solar energy – the level being derived from the visible transmittance of the glass divided by the solar heat gain coefficient.

With the exception of the louvers and the atrium, all the technology used in the Bahen Centre can be found in a conventional building. The building envelope is greatly enhanced by the louvers; they reduce the cooling load by 100 tons, resulting in an $800,000 capital costs savings and a $60,000 annual electricity reduction.[13] The atrium greatly enhances the mechanical system as it is utilized as part of the return air system. In a conventional building, a similar system without the atrium would require much more extensive ductwork. Instead, the atrium allows for the natural stack effect to do some of the work.

Table 1: PPG Solarban 60 SolarControl Low-E Glazing Performance Characteristics

Transmittance	UV 14%	Visible 69%	Solar Energy 32%
Reflectance of Visible Light	UV 12%		Solar Energy 28%
Imperial U-Value	0.29		
Metric K-Value	1.64		
Shading Coefficient	0.44		
Solar Heat Gain Coefficient	0.37		
Light to Solar Gain (LSG)	1.86		
The skylights are also 55% fritted to reduce solar heat gain			

Figure 21 (Below): Detail of the Solarban Glazing at the main entrance of the building.

Figure 22 (Above): The water retention pond, seen here in winter, integrates storm-water management with aesthetics. Figure 23 (Below): The floor diffuser is one of the only visible signs of the ventilation system below the walking surface.

INTEGRATION OF SYSTEMS

The building systems in the Bahen Centre interact, share space, and are integrated with one another. In the integrated design process a “capital cost transfer strategy” was put in place which meant that capital costs saved due to reducing mechanical systems could be used to pay for integrated passive solutions. The design team also maximized duel purpose equipment, such as return air fans that can run for smoke exhaust under a fire/smoke mode. The raised access floor is exemplary of an integrated system; it acts as an air plenum, a flexible space for data, telecommunication, and electrical services, an extra zone for structural system expansion, and a practical module for the carpet system.[14] The BCIT is also integrated into the urban fabric by its close proximity to two subway stops, its underground tunnel system, and at grade through a pedestrian path linking to surrounding buildings and courtyard spaces. In doing so, it underscores the building’s importance to the university campus and the larger urban fabric it connects to.

Despite the overall excellence in the integration of its systems, there are several minor redundancies in the building. First, a portion of the 5,000 tonne chiller remains inactive until future campus buildings are constructed requiring its use. Second, natural ventilation in the shoulder seasons is entirely possible, however due to the automated system the building continues to run its mechanical fans during these times of the year. The building design also accommodates future technology through the raised access floor; however wireless technology may eventually render this system redundant.

COSTING

The hard economic up-front costs in the Bahen Centre have been justified through the quantifiable operation and maintenance savings in the long run. The University of Toronto will accept higher capital costs if the payback period is less than five years, but will consider payback times up to seven years.[15] The social cost of this building in regards to user comfort is minimal. In many ways user comfort is enhanced due to personal control over lighting, operable windows and air diffusers. The maintenance costs of this building are extremely low as it has a high level of daylighting, uses a heat exchanger to extract 92% of its heating needs from the chimney, uses louvers to reduce its cooling requirement, and partially uses passive ventilation. The key economic decisions were to meet the site requirements, the budget, and the schedule. The cost of the sustainable building systems balanced out to match those of conventional building systems while creating dramatic long term savings. The rainwater reclamation system and the green roof are not expected to pay for themselves, however: they were designed as demonstration projects the university wanted to showcase in the building. To help off-set design costs, a financial incentive from CBIP was awarded as a result of the buildings high energy performance.[16]

LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN

The BCIT is capable of obtaining a LEED Silver rating with a score of 33 points. The building rates well in the Sustainable Sites categories because it is an urban infill project located on a formerly contaminated site. It also obtains points for its location close to public transportation lines and stormwater management strategies. The BCIT only loses one point in the Water Efficiency categories. Ironically, this is because of its low use of water for landscaping and irrigation;

LEED GREEN BUILDING RATING SYSTEM 2.1

Project Checklist	
Sustainable Sites	**8**/14 Possible Points
Water Efficiency	**4**/5 Possible Points
Energy & Atmosphere	**7**/17 Possible Points
Materials & Resources	**4**/13 Possible Points
Indoor Environment Quality	**10**/15 Possible Points
Innovation & Design Process	**0**/5 Possible Points
Project Totals	**33**/69 Possible Points
Bahen Centre Result	**Silver Status**

Figure 24 (Below): Computer model of the south-west corner, courtesy of the architect.

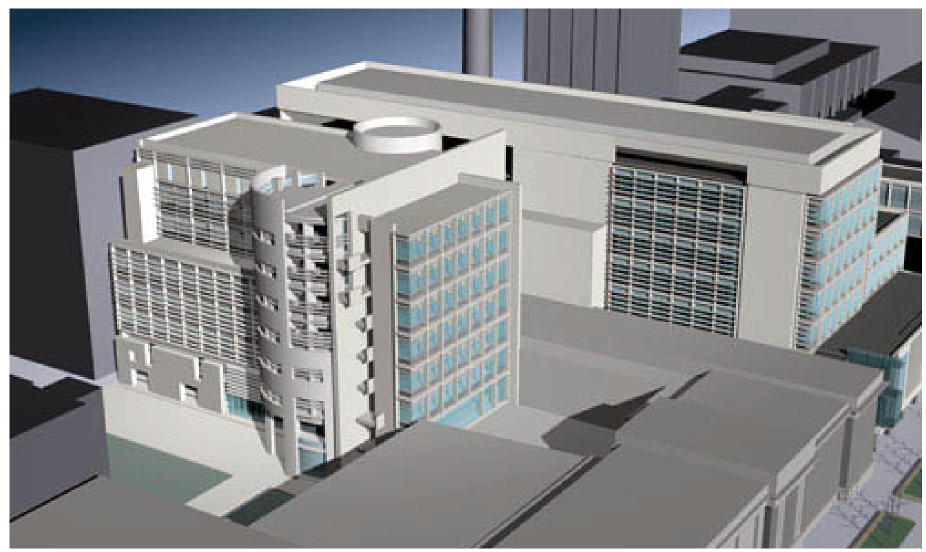


Figure 25 (Above): Detail of the north-east corner of the Bahen Centre.

however, only because it has very little actual landscaping to be watered or maintained.

Although the Bahen Centre out performs the MNECB by 53% and the LEED standard of ASHRAE 90.1 by 40%, in the Energy and Atmosphere section the building rates poorly. Only one additional point is earned in the section for the use of the University's steam plant's waste heat energy. Otherwise, considerations for the use of renewable energy sources, such as photovoltaic panels on the extensive southern façade to harness solar energy, or additional commissioning and maintenance were omitted due to either oversight or time constraints. The same is true of the building's performance in the Materials and resources category; the BCIT receives only a few points for construction waste management, resource reuse from incorporating adjacent buildings, and the use of locally manufactured materials. Despite this, the Centre rates best in the Indoor Environment Quality section. The design team placed much emphasis on indoor air quality, thermal comfort, and daylighting, resulting in a high standard of interior space.

CONCLUSION

Many insights can be gained from this building, the biggest being that sustainable design can happen at any scale; the Bahen Centre is undoubtedly the largest "green" building in Canada. Other insights include the use of previously overlooked, unique energy sources, the efficiency of external louvers to help mitigate solar gain, the cost effectiveness of green design that doesn't necessarily take more time to develop, and the necessity of an integrated approach to building systems in order to create a successful sustainable project. Through the integration of systems, a building and its systems appear seamless – a benefit in terms of aesthetics and sustainable strategies.

In conclusion, the University of Toronto has proven itself to be forward thinking: as an institution with over 175 years of experience they know the cost of building upkeep and maintenance, and today they are choosing to design sustainable buildings for the benefit of generations to come.

BIBLIOGRAPHY

Publications

1. Canadian Architect, January 2003. "Green Giant." Marco Polo

Internet

1. Diamond Schmitt Architects. Source: *http://diamondschmitt.com/gallery/sketchbooks/bahen3.html*
2. Dynamic Graphics Project. Source: *http://www.dgp.toronto.edu/*
3. Trane HVAC Systems. Source: http://www.trane.com/commercial/library/vol30_4/
4. University of Toronto News. «University opens doors to state-of-the-art information technology centre." Source: http://newsandevents.utoronto.ca/bin3/021001a.asp

Personal Interviews

1. David Dow, Project Director, Diamond Schmitt Architects, Toronto, Ontario
2. Tom Pratt, Project Manager, Diamond Schmitt Architects, Toronto, Ontatio

ENDNOTES

1. Canadian Architect, January 2003.
2. Canadian Architect, January 2003.
3. David Dow
4. Tom Pratt
5. David Dow
6. Canadian Architect, January 2003.
7. Canadian Architect, January 2003.
8. David Dow
9. David Dow
10. David Dow
11. David Dow
12. David Dow
13. Canadian Architect, January 2003.
14. David Dow
15. Tom Pratt
16. Tom Pratt

IMAGE CREDIT

1. Diamond Schmitt Architects: Figures 2, 4, 8, 19, 20 and 24

2. Dynamic Graphics Project Website: Figures 3, 9, 11, 16, 25, Title page and Quick Facts page.

3. Nathaniel Lloyd: Figures 1, 5, 6, 7, 10, 12, 13, 14, 15, 17, 18, 21, 22 and 23.

A special thank you to Diamond Schmitt Architects for their help and willingness to supply information and images.