GeoConneXion
Magazine

September
Septembre
2008

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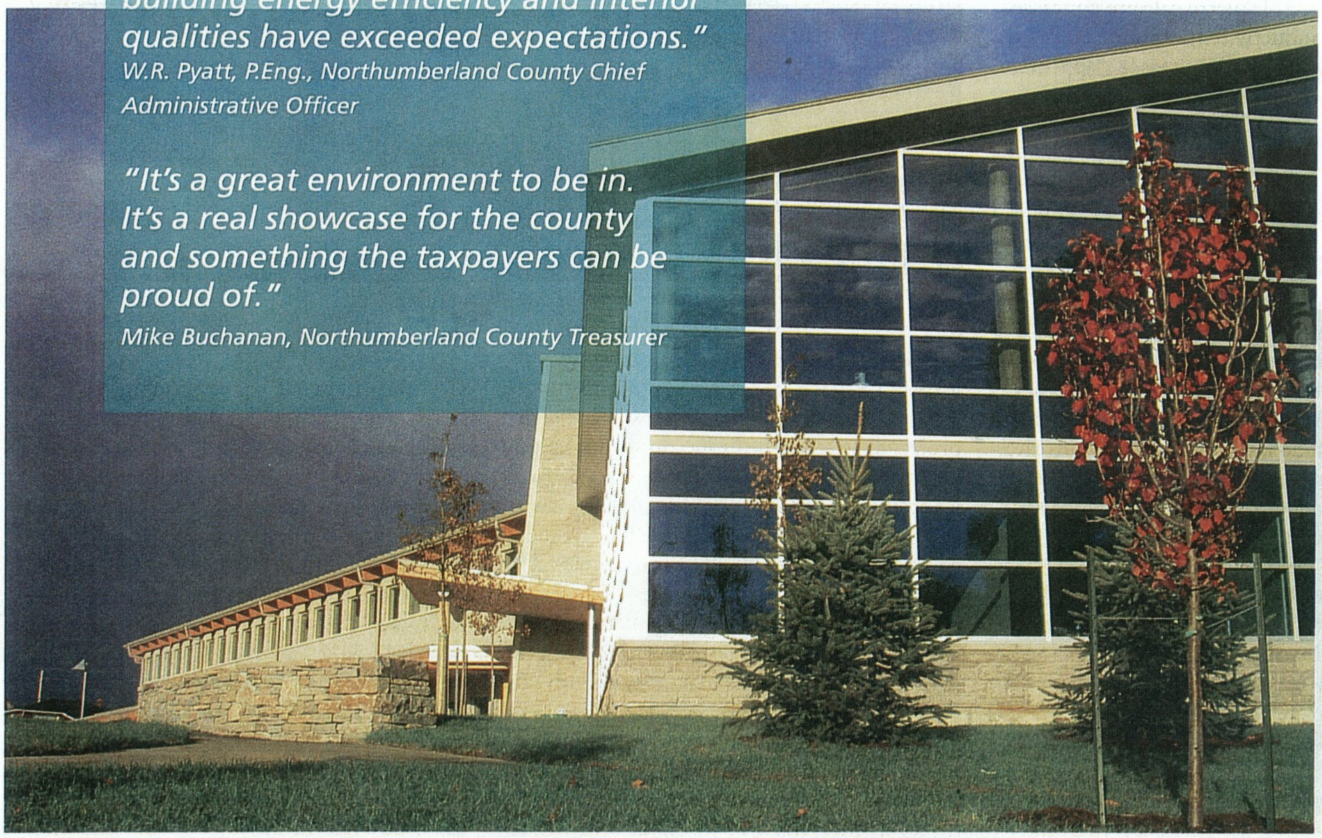
By
Ted Wilson*, OAA, LEED AP[1]

Northumberland County Headquarters

"The project has been in operation since November 2007. Systems commissioning is complete and the building energy efficiency and interior qualities have exceeded expectations."
W.R. Pyatt, P.Eng., Northumberland County Chief Administrative Officer

"It's a great environment to be in. It's a real showcase for the county and something the taxpayers can be proud of."
Mike Buchanan, Northumberland County Treasurer



Introduction

Totten Sims Hubicki Associates (TSH) was retained in 2006 by the County of Northumberland (Ontario) to study opportunities and constraints associated with expanding the existing headquarters facility in Cobourg for long term use by County operations. The study also considered the feasibility of locating a new facility at the nearby County Services Campus.

This latter location was selected for the new Northumberland County Headquarters as part of an integrated services campus which already includes a long term care facility operated by the County, an affordable housing community, a family and childrens' services centre and the community hospital.

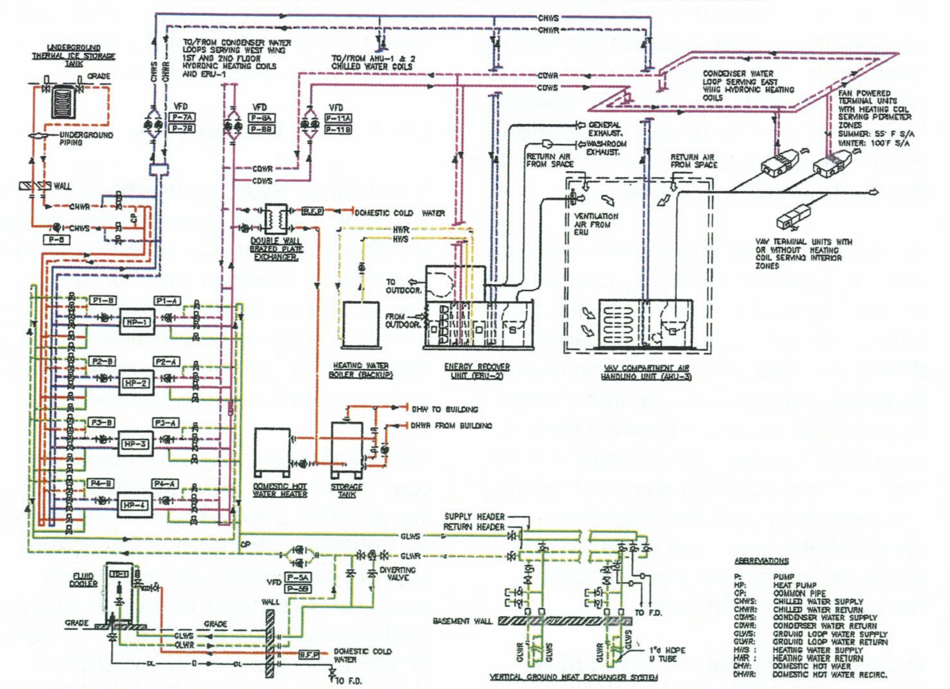
Architectural Design Brief

As the County seat the headquarters is designed to demonstrate the role public buildings can play in our communities as leaders in sustainable design. It is viewed not only as a functional facility providing services to the constituency. It also showcases the unique environmental and historic assets of Northumberland. Features of Northumberland such as dry stone walls and native plants have been gathered into the design. Sustainable design features also include a GSHP system which is also set up to allow for expansion to service other facilities as the campus continues to evolve.

The building includes 40,000 SF / 3,716 m^2 on two levels set into a hill so that the lower level of the building mass is able to benefit from the moderating effect of the surrounding earth on three sides. The cut-and-fill process that was used to position the building minimized the amount of material hauled away, reducing landfill burden and fuel consumed for trucking.

(*) Ted Wilson is a project architect with Totten Sims Hubicki Associates. TSH provides integrated A/E consulting services, focusing on design, project management and the development of long-term client relationships. With 340 personnel in nine Ontario locations including the Whitby head office, and an office in Calgary, TSH offers sustainable building solutions through tshgreensmart promoting the "soft path" – resource conservation and the integration of renewable energy technologies.

INTEGRATION OF HVAC SYSTEM WITH GEOTHERMAL ENERGY AND THERMAL ICE STORAGE



This disposition on the site allows for the south elevation to provide a strong civic presence to Elgin Street at Burnham Street, a "gateway" to the community as one arrives from the west. Pier elements have been introduced at the main entry and in the east elevation to add further moderating mass to the structure. The piers also buttress the Council Chamber which is wrapped in curtainwall to reflect the transparency of public process. To the north the lower pitched roof profile and clerestorys of the building complement the architecture of the long term care facility, formerly the site of the first County courthouse.

The position of the building in the rise of land also affords the opportunity to provide at-grade barrier-free access to both the upper and lower levels. With access from Courthouse Road to both levels, parking and pedestrian flow can be organized so that programs and services frequented by the public are available at the main level (south side fronting Elgin) and staff – intensive operations accessible from the upper level parking. An internal elevator and stairs would also allow internal vertical movement.

The siting of the building also allowed for several mature trees to be retained and to provide shading for the Council Chamber. Other trees have been relocated to appropriate positions on site so as

to afford wind breaks and shading for adjacent outdoor areas.

The placement of new buildings on site also requires that stormwater quantity and quality be maintained to pre-development conditions. To this end, an extensive light weight planted roof has been placed on the south elevation canopies. Stormwater run-off is absorbed and reflection of the sun through upper level windows is reduced. The canopies and upper level roof overhangs are positioned to provide summer shading and allow for winter solar gain. The planting is also expected to extend the life of the roofing membrane and provide a colourful display of alpine meadow flowers for users to view from the second level of the building.

The rooting of the building in the hill rise up to the long term care facility affords the opportunity to share the moderating effect of the earth's constant temperature. By surrounding and directly moderating the building mass, radiant energy reduces the burden on the mechanical systems. The insulating performance of the envelope has also been increased to levels equivalent to 25% better than those set by the Model National Energy Code of Canada for Buildings.

The burden on the mechanical component is further lowered, assisting in reducing capital and long-term operating costs by approximately $15,000 per year.

We refer to the above approach as part of the "Soft Path" to sustainable building design. The Soft Path combines conservation with renewable energy technologies. The county headquarters charges down this path with a resource-conserving envelope assisted by the moderating effects of the earth utilizing the geo-thermal system.

Development of the geothermal system for the headquarters has been the primary goal of the current project. The next horizon will be to accommodate the long term care facility as its mechanical plant approaches the end of its useful life and opportunities to reduce operating costs with Soft Path technologies can be considered.

Within the building, heat exchangers transfer the geothermal sourced energy to a high volume, low velocity air system featuring heat recovery technology. Heat recovery wheels recycle heat prior to air being exhausted. Increased numbers of thermostat controls through the building allow for more adjustment of working environments by occupants. Lower velocity of air movement reduces drafts, noise and wear on mechanical system components which in turn reduces operating and maintenance costs.

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At the upper level of the building, the vaulted areas of the Council Chamber and west open office wing feature clerestory windows to naturally light the spaces. Trees, roof overhangs and orientation of the clerestorys to the north moderate the lighting effect and solar gain.

As external canopies are used to moderate the intake of incoming solar energy, so are windows positioned and provided with a low-emissivity coating, argon and tinting to reduce heat gain and glare. Building cross-sections are also designed to ensure all occupants have a view to a window. Daylighting is integrated to reduce the burden on electrical lighting and diffused to prevent high background light levels and glare for computer operators. Light fixtures feature indirect diffusion.

Together the above strategies have been combined through an integrated design process to provide a headquarters that speaks of the Northumberland as a leader in showcasing its natural resources and their management. It demonstrates that Northumberland County is committed to embarking on the Soft Path – the route that provides healthy, financially sound, resource efficient sites and buildings.

Mechanical Design Brief

Selecting an HVAC system for the building to be a leader in sustainable design and showcase the unique environmental and historic assets of Northumberland was a balance of many issues. High priority was given to sustainable design features including energy conservation and renewable energy technology.

Additional priorities were employee comfort as outlined in ANSI/ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, appropriate outside air ventilation levels for acceptable indoor air quality conforming to ANSI/ASHRAE Standard 62-2004, Ventilation for Acceptable Indoor Air Quality, and maintaining good humidity control within the building. Year-round indoor humidity control presented a large challenge when more than 7500 cfm of outside air is to be provided.

Based on goals of energy preservation, environmental protection and sustainable design, TSH recommended an integrated HVAC system with hybrid geothermal heat pump system and thermal energy storage as new infrastructure to serve the new headquarters building. It is designed to exceed the Model National Energy Code and ASHRAE 90.1.

The measures included in the design to meet this goal include:

1. Hybrid close loop parallel piped vertical heat exchanger system.
2. Water-to-water geothermal heat pump system
3. Thermal energy storage system
4. Domestic hot water preheat by waste heat
5. Energy recovery from exhaust air
6. Use of thermal mass and zone separation of perimeter and interior spaces
7. Variable air volume compartment air handling units
8. Variable frequency drive pumps
9. Efficient DDC control system
10. Efficient building envelope.

Design of the vertical ground loop heat exchanger was highly complex, and was further complicated by the variety of geological formations and properties that can affect thermal performance. Proper identification of materials, moisture content, and water movement was required. To determine the type of soil/rock at the proposed building site, a test borehole with a depth of 400 feet / 120 m was drilled north of the proposed building location and an in-situ thermal conductivity test was performed to collect data for the study, design and optimization of the ground heat exchanger.

After a thorough study of the thermal conductivity test results, the building cooling and heating load and the available land area for geothermal heat exchanger, a total of 36 U-loop boreholes with depths of 350 feet / 107 m, 20 feet / 6 m apart were drilled north of the building. It would accommodate a high density polyethylene (HDPE, SDR11) parallel-piped vertical heat exchanger system for transferring building heat to ground in summer and extracting heat from the ground in winter. The boreholes were filled with thermally enhanced grout from bottom to the top to prevent potential downward leakage of contamination from surface water and migration between aquifer or ground water as well as providing thermal contact between the pipes and the surrounding earth.

To balance the heating and cooling loads of the ground heat exchanger, reduce the number of boreholes and limit the long-term temperature increase of the ground, a fluid cooler was installed parallel to the ground heat exchanger. The fluid cooler provides supplemental heat rejection only when required or to trim ground heat exchanger temperature during off-peak hours when the electricity rate is low. It enhances the performance of the ground heat exchanger in the long term.

A hybrid geothermal heat pump system has some advantages over a full ground-coupled heat pump system. Hybrid systems can reduce the first cost of a geothermal installation since the closed-loop fluid cooler capacity is less expensive than the same heat rejection capacity in a closed-loop ground-coupled grid. Additionally, a hybrid system typically is designed to meet a building's peak heating load with the ground-coupled loop heat extraction peak requirements. This eliminates a supplemental heat-source boiler from the system. The advantage of a low pumping energy, closed-loop system also is attainable with the hybrid system using a fluid cooler.

Geothermal heat pump system is the heart of this integrated system. By nature, water-to-water geothermal heat pump system produces both warm and chilled fluid whenever the compressor is in operation. The geothermal heat pump system is highly efficient, because it uses the earth as a heat source that is free and infinitely renewable.

The county building geothermal heat pump system can move 3 to 5 times more energy to or from the building than the energy required to operate the system. The system allows energy that is not required in some areas of the building (cooling load) to be moved and used in areas that do require energy (heating load), so the ground heat exchanger is not used as heat source for the heat pump system. These concepts have a significant effect on energy savings and greatly enhance the efficiency of the system as well.

The system is also environmentally friendly because greenhouse gas emissions from the building are significantly reduced with the integrated system. Less energy is used by the system because of simultaneous heating and cooling. When fewer kilowatt-hours are used, less greenhouse gases are emitted at
the generating stations.

Soft energy path design will also facilitate the integration of a thermal ice storage system with the geothermal heat pump system. The geothermal heat pump system is capable of producing low temperature chilled water for ice making during off-peak hours when the electricity rate is low and the building is in unoccupied mode. One or two heat pumps will run to produce chilled water for ice making. The ice will be stored in an underground ice storage tank outside the building, which can be used to cool the building during peak times the following day. During peak cooling periods, only a circulating pump is needed to provide chilled water for cooling equipment.

Integration of the geothermal heat pump system/ thermal energy storage tank systems reduces the capital cost, energy costs, operating and maintenance costs, and environmental impact of the building.

To maximize the heat recovery from waste heat generated when the system is in air conditioning mode a double wall brazed plate heat exchanger is installed to pre-heat domestic hot water.

To maintain indoor air quality of the building at an acceptable level as per requirements of applicable codes such as the OBC and ASHRAE 62-2004 a significant amount of outdoor air needs to be introduced to the building and exhausted to maintain the comfort level of building occupants. This air needs to be heated and humidified during winter and cooled and dehumidified during summer.
Without efficient energy recovery equipment, all the energy will be wasted through exhaust air. To capture this wasted energy and use it to pre-heat or pre-cool the incoming outdoor air, two custom designed VAV energy recovery units were installed in the building, one for the west wing and one for the east wing (post-disaster command centre). The units are furnished with high efficiency desiccant wheels, condenser

water coils, heating water coils (backup) and chilled water coils. Three (3) custom made VAV compartment air handling units complete with chilled water cooling coils, in conjunction with two (2) VAV custom made energy recovery units are coupled with the integrated geothermal heat pump and ice storage system. Together they deliver conditioned air to each space within the building via VAV terminal boxes and fan powered terminal boxes complete with condenser water reheat coils.

An advanced high efficiency Facility Management System (FMS) controls and monitors the operation of mechanical systems throughout the building via DDC systems.

The integrated geothermal heat pump system with thermal energy storage is also designed to accommodate future requirements of neighboring facilities that will tie in with the headquarters. This may include a seniors' centre and an emergency medical services building. Aging mechanical systems in these adjacent facilities will be able to be replaced and tied in as they reach the end of their life cycle.

Achievements

The County is saving 30 – 50 % of the costs of running a conventional building (this is an estimate, as the building has not been in use for a full year). The project was delivered at budget, and met the deadlines of an aggressive time schedule.

This project used an integrated design process to ensure that all engineering and technical disciplines and the concerns of stakeholders were taken into account.

The headquarters is currently generating local and international interest. It will be featured as a learning centre for the application of sustainable design technologies in communities at the World Sustainable Buildings Conference SB08 in Melbourne, Australia in September 2008.

As background to our sustainable design approach to projects, TSH references LEED (Leadership in Energy and Environmental Design) measures. LEED is an internationally recognized system developed to integrate efforts of owners, users, designers and builders realize healthy, resource-efficient, cost-effective buildings.

Sustainable Site

- Minimize site impacts such as removal of trees, changes to the extent of site impermeability, and the creation of heat islands
- Design parking areas and driveways to minimize paved surfaces (non-permeable areas)
- Planting of mixed deciduous and coniferous trees to the south and west to control exposure to prevailing winds and solar heat gain in summer; enable the facility to take advantage of this source of energy primarily from the fall to spring equinoxes
- Extend roof overhangs in combination with the building orientation to reduce summer solar gain and capture winter sun as a passive heat source

Water Efficiency

- Use of water conserving toilet fixtures
- Use of native plant materials to eliminate the need for irrigation
- Extensive use of native planting and natural conditions to maximize the amount of storm water allowed to naturally percolate into the ground on site

Energy and Atmosphere

- Integration of alternative energy technologies including geothermal heating / cooling
- The two-level concept provides barrier-free access to each level from the exterior; this reduces the burden on the elevator and helps to save in energy and operating costs; use of stairs will also increase fitness of occupants
- Consider the lower level as a component of the mechanical system – lower level cool air is circulated through the building – this is a form of radiant cooling
- Consider the inherent energy conservation benefits of the existing lower level sharing the moderating effect of the surrounding earth
- Integrate heat recovery to ensure required fresh air changes for occupants and the recycling of heat energy

Materials and Resources

- Use cut and fill approach for building siting – reduced fill having to be hauled from site
- Envelope components high-mas concrete and masonry and increased insulation, high performance windows, planted shade canopies and light-coloured roofing with low albedo finish – medium to light tone offering the maximum degree of UV reflectance in the Southern Ontario region to minimize heat island effect
- Engineered wood structure – enables the use of wood manufacturing by-product to be diverted from the waste stream and featured as part of the interior environment – an excellent way to feature the Northumberland Forest – the material also does not require finishing – reducing costs and eliminating VOC's
- Recycled material for carpeting
- Use of ceramic tile to increase finish durability, reduce maintenance and add to building mass for radiant energy retention

Healthy Interior Environment

- Open concept work stations – the greatest operating cost saving potential is derived from the improved health and enhanced community spirit of working teams. An open concept work environment enables:
  - air flows at slower rates in larger volumes – spaces become ducts, eliminating sheet metal costs, and the unseen build-up of dusts, organisms and moulds that traditionally have contributed to Sick Building Syndrome – air distribution motors are reduced in size and work less – larger volumes of air distributed above occupant working levels to enable air to be heated and cooled to a lesser extent, again reducing the burden on mechanical systems
  - daylighting or views to the exterior for all work stations

The key to success is integration – *the sum of measures is greater than individual initiatives!*