2013 CANADIAN CONSULTING ENGINEERING AWARDS

THE EDMONTON CLINIC

Yolles, A CH2M Hill Company | DIALOG®

The Edmonton Clinic: Building a Foundation for Excellence in Health Care

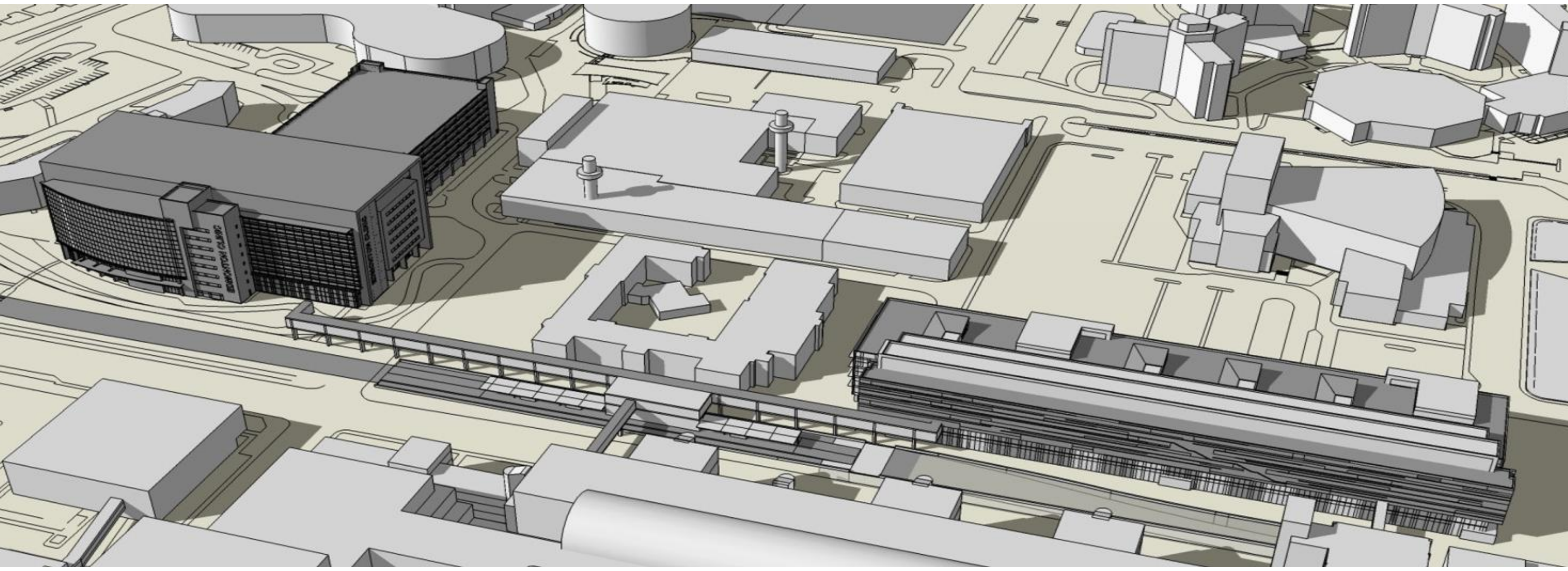
1. The Vision: A New Model for Care and Learning

In 2004, Alberta Health Services developed a vision statement to provide Albertans with ***"a leading, state-of-the-art enabler of integrated, patient-centred clinical care, education and research."*** To realize that vision, the Government of Alberta supported a partnership between Alberta Health Services and the University of Alberta for the construction of two new complementary clinics in the heart of the Health Sciences Campus at the University of Alberta: ***The Edmonton Clinic Health Academy*** and ***The Kaye Edmonton Clinic***.

The Health Academy primarily houses health sciences academic offices and classrooms, while the Kaye Edmonton Clinic is designed for the treatment of outpatients while providing educational opportunities for health sciences students. Though there are two separate buildings, together they form the overall Edmonton Clinic facility, which is very much a single project with one bold vision.

The key feature that distinguishes the Kaye Edmonton Clinic from a typical hospital is that it has no overnight beds: all patients at the Clinic are day patients not requiring acute care, separating them from the emergency and critical care patients across the street at the University of Alberta Hospital. This new approach - a first in Alberta - will provide levels of service and efficiency in delivering patient care greater than ever before.

To support the massive scale of this $900 million project and its ambitious schedule, structural engineers DIALOG, based in Edmonton, and Yolles, a CH2M Hill Company, based in Toronto, joined as equal partners to tackle the structural engineering challenges. Though a single project overall, the Kaye Edmonton Clinic and the Edmonton Clinic Health Academy have very different functions and priorities, leading the design team to develop different structural solutions.



Design rendering of The Kaye Edmonton Clinic (left) and the Edmonton Clinic Health Academy (right)

2. A New Paradigm in Health Sciences Education: The Edmonton Clinic Health Academy

Housing the faculties of Medicine and Dentistry, Nursing, Pharmacy, Rehabilitation Medicine, the School of Public Health and the Health Sciences Council, the Health Academy brings together health sciences professionals from diverse backgrounds to focus on health research, education, and training.

Operated by the University of Alberta, the Health Academy provides an environment that enables health professionals, students and researchers to share space, time, clients, and information to the benefit of clinical care, health education, and health research. This interdisciplinary and integrated "Made in Alberta" model of ambulatory care, teaching and research will facilitate the education of a new type of health professional by cultivating a culture of interdisciplinary practice and supporting a collaborative team approach focused around the patient.

With an area of over 52,000 square metres over six above-grade stories and one underground level, the Health Academy is nearly 200 metres in length. Located prominently at 114 Street and 87 Avenue in Edmonton, the Health Academy is situated along the Edmonton LRT and across the street from the University of Alberta Hospital and the Stollery Children's Hospital.

North Entrance, Edmonton Clinic Health Academy

2.1 CONCRETE OR STEEL: MAKING THE RIGHT CHOICE

A key decision that led to the success of Health Academy opening on time and on budget was the selection of structural steel as the material of choice for the building frame. Most large health facilities built in Edmonton over the last several decades have been cast-in-place concrete, so the proposal to use structural steel departed from the norm.

Operational Performance Factors	Design and Construction Factors
• Aesthetics	• Project delivery approach
• Storey heights	• Project schedule
• Wear and tear	• Construction cost
• Green design	• Cost escalation risk
• Fire protection	• Construction labour risk
• Noise and vibration	• Competitive bid process
• Adaptability to change	• Adaptability to changes on the fly

How did the team arrive at the decision to use structural steel? The structural engineers worked closely with the owners, the construction manager, and the rest of the design team to assess the options available for the structural framing system against fourteen performance factors shown in the table on the previous page (DiBattista, 2012).

Steel erection completed August 2009

Of these factors, two in particular tipped the balance from concrete to structural steel. During the schematic design process for the project in late 2007, it rapidly became apparent to the design and construction team that the only material that would meet the demands for the super-fast-tracked schedule would be structural steel. To meet the completion schedule of summer 2011, construction needed to start in March 2008. At the time of design in 2007-2008, the Alberta construction marketplace was superheated. Availability of local labour and materials was unpredictable, and costs in the local construction marketplace were escalating rapidly. Steel offered the ability to fabricate the structure wherever it was cost-effective to do so, not necessarily within the confines of the province.

From consideration of economics, the ability to advance construction quickly, and the availability of trades in the Alberta marketplace, the design team quickly identified structural steel with composite steel beams and girders as the best choice for the project. After examining many options for the structural framing system, the design team selected a typical bay size of 9 m by 7.5 m framed by composite steel beams and girders. Long-span 15 metre bays over classrooms in the lower levels were also best suited for structural steel rather than cast-in-place concrete.

On the sixth floor, west-facing clerestory glazing allows sunshine to spill through two atria and two light wells all the way down to the third floor. The atria feature unique architecturally exposed steel stairs that cross diagonally from floor to floor, and exposed steel Macalloy main building bracing is featured along the west wall.

North atrium, Edmonton Clinic Health Academy

The high recycled content of structural steel also made it a natural choice for its contribution to environmental sustainability. The Edmonton Clinic Health Academy is currently on track to receive a LEED® Silver rating from the Canada Green Building Council.

The primary structural steel design was completed and issued for bid in April 2008, three months before completion of the Design Development stage of the project. Later, as more detailed architectural design information became available, other steel components such as stairs and cladding support were detailed. Structural steel erection began in February 2009. Despite the challenges of beginning erection in winter, the team was able to top off the steelwork on August 28, 2009, ahead of the U of A's tight schedule by two weeks.

Today, the Health Academy stands complete with more than 3,300 tons of structural steel in place. The design and construction team's choice of structural steel allowed this massive, $425 million super-fast-tracked project to be constructed on time and on budget for its 2011 opening.

"Structural steel was absolutely the right way to go," says Lou Zoldan, Project Manager for the Edmonton Clinic Health Academy, about the structural engineering team's decision to recommend steel. ***"It met our needs for cost, efficiency and schedule. The whole team did a great job. The fabricator and erector were highly skilled and very dedicated to quality and the meeting the schedule demands."***

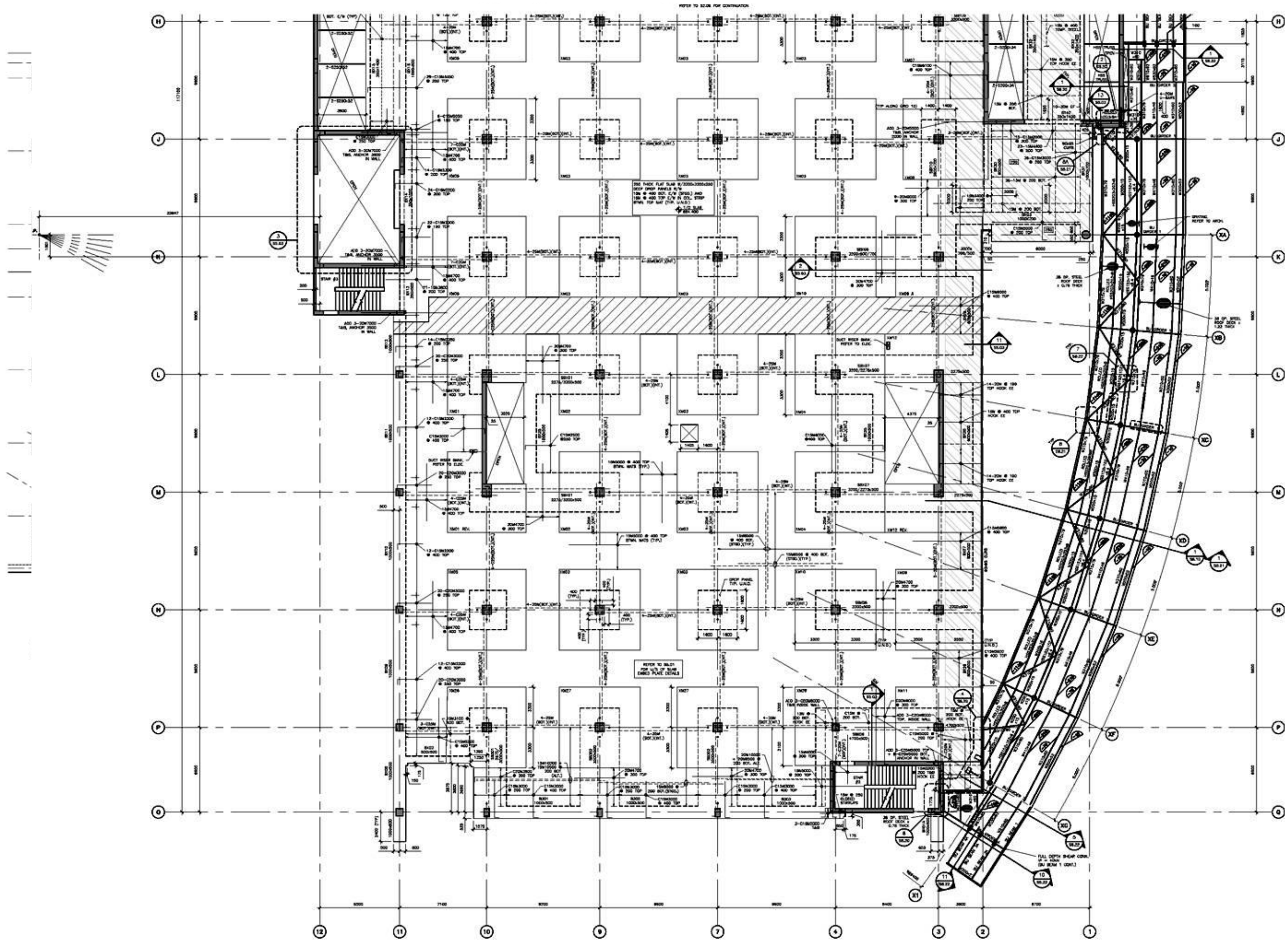
3. Delivering Patient Care: The Kaye Edmonton Clinic

Housing diagnostic imaging, an outpatients collection lab, surgical clinics, transplant clinics, the Glen Sather Sports Medicine Clinic, and Stollery Hospital clinical services, the Kaye Edmonton Clinic will be more welcoming and patient-friendly than traditional hospitals. The Kaye has a footprint of approximately 7000 m^2, comprising of one basement level and seven floors above ground plus a two-storey penthouse, for a total floor area of 60 000 m^2. The majority of the structure consists of two-way concrete slabs with drop panels, typically spanning 9.6 m in both directions. The penthouse roof is a steel structure. Concrete shear walls resist the lateral loads. The exterior wall cladding is a combination of lightweight curtain wall and precast concrete panels. The most prominent architectural features of the Kaye is a curving, eight-storey glazed atrium wall on its east elevation. To the west, the building is serviced by a new, 1,200-stall, five storey parkade and underground loading dock.

View from the southeast, Edmonton Clinic South

The atrium wall accentuates the main entry and the public functions of the Kaye, which are accessed from the east side of the building. An open volume of over 10 000 m^3 behind the atrium wall provides the public functions with views towards southeast Edmonton and allows for natural light to penetrate deep into the building.

The curved atrium wall is 37 m high, has an arc length of 60 m, and a radius of 89.4 m. To create the open atrium space, the wall spans from the third level (where an exterior canopy acts as a horizontal wall support) to the roof, a height of nearly 30 m. From the ground floor to the third level, a conventional curtain wall system is used. Above the third floor, clamped point-supported glazing spans between curved HSS203x203 girts with a vertical spacing of 2.2 m. In turn, the girts are supported at every 7.8 m by round HSS356 columns that carry the atrium roof and act as the compression member of a double-cable truss system.



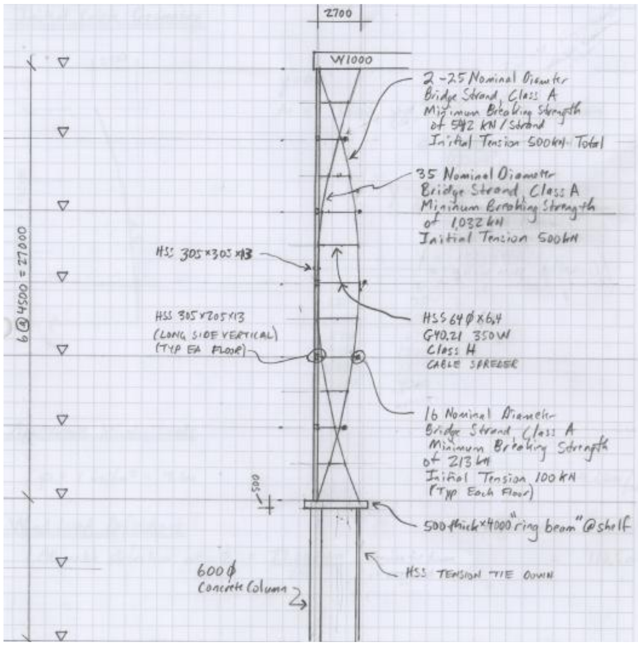
Partial Third Floor Structural Plan, the Kaye Edmonton Clinic

3.1 LET THERE BE LIGHT: DESIGN OF THE ATRIUM

In the conceptual design stage for the atrium, the structural and architectural teams collaborated closely to develop a structural system that is light and elegant in appearance, integrating the mechanical systems that are used to provide heating and cooling.

Cable truss systems are often used to support feature glazing walls for buildings. Typically, these systems span two or three floor levels, with the cables anchored at the top and bottom by relatively rigid structural members. Inspired by the light appearance of these systems, the structural engineering team conducted an extensive literature review on cable trusses but were unable to find any precedents for a cable truss system of the size and complexity proposed for the Kaye atrium wall.

The structural team used the procedures presented by Irvine (1981) on cable trusses for roof systems to develop a conceptual design for the cladding support system. The initial conceptual sketch of bow-shaped trusses that have vertical chords constructed from continuous pretensioned cables, from which the final design evolved, is illustrated on the following page. The cables ideally follow a parabolic shape, are anchored at the top and bottom and have horizontal spacers (spreader posts). The spreader posts extend to the columns that support the roof and glazing at the edge of the atrium. In addition to roof vertical loads and lateral wind loads on the glazing, the columns transfer the anchor forces between the ends of the cable trusses, introducing compression into the columns.



Early concept sketch for cable trusses

Under lateral wind loads, the tension in one of the vertical cables increases while the tension in the other cable decreases. In order to avoid loss of effective flexural stiffness of the system, both cables are pretensioned so that neither cable goes slack under service load combinations. However, excessive pretensioning forces must be avoided as it is expensive to resist large anchor forces at the ends of the cable trusses and it is often difficult to jack the cables to achieve large pretensioning forces. Thus the selection of an appropriate initial cable pretensioning force is a critical aspect of the design process.

The concept study of the cable trusses considered a simplified planar model, assuming no horizontal or vertical movements of the supports and no out-of-plane contribution of other structural elements. However, a more sophisticated structural model was also required to account for horizontal and vertical flexibility of the top and bottom cable supports, for arching action of the curved girt system, and for lateral flexibility of the horizontal supports at the top and bottom of the cable trusses. Consideration must also be given to the out-of-plane behaviour of the cable truss system.

In the end, DIALOG's design of the cable truss system, using non-linear geometric analyses, resulted in stainless steel truss cables with a diameter of 40 mm.

Details about the complex and highly technical design process for the cable trusses cannot be documented in detail in this award submission, and the process has been published in the proceedings of the 3rd International Structural Specialty Conference of the Canadian Society for Civil Engineering (Josi et al., 2012).

3.2 MAKING IT REAL: CONSTRUCTION OF THE ATRIUM CABLE TRUSSES

Architecturally exposed cable truss systems are often one-of-a-kind prototypes in which the clevises, cable anchorages, and other components are proprietary products. In order to provide open competition amongst qualified bidders, certain aspects of the cable truss system could not be specified in detail during the design phase of the project. The participation of a delegated design professional engineer (DDE) retained by the contractor for the cable truss system was also necessary.

That DDE was responsible for the detailed design of the truss system and the components used by the contractor, the methods of construction, and ultimately the overall performance of the cable trusses as a system in the context of the design requirements given in the contract documents.

Working together closely, DIALOG as the Engineer of Record (EOR) and Erdevicki Structural Engineering as the DDE developed a jacking system using the top distributing beam to introduce the required pretension force into the cables. The DDE proposed to detach the top distributing beam from the roof beam and to use it as a tensioning yoke. High-strength threaded rods 36 mm in diameter connect the distributing beam to the roof beam, stabilized laterally by shear tabs. Through the design collaboration, the design cable pretension at lock-off was increased in order to prevent the complete slackening of either cable at ultimate loads, improving the overall behaviour of the system.

Concurrently with these design optimizations, the geometry and details of the cable connections were developed and custom produced by the contractor. Prior to full production of the parts, mock-ups were fabricated and accepted by the EOR and the architect. In addition, the mock-ups served as test specimens. These tests confirmed that the prototypes also met the structural design requirements.

3.3 THE TEAMWORK: ERECTION AND CABLE TENSIONING

Erection of the main steel structure (canopy truss, columns, girts, and roof beams) was the responsibility of the steel fabricator. The erection and tensioning of the cable trusses themselves (cables and spreader posts) were the responsibility of the glazing subcontractor. During the design optimization of the cable truss system, the EOR and the DDE involved the steel fabricator in order to integrate efficiently the changes to the top and bottom beams. Close collaboration between the fabricator and the engineers during this phase led the glazing contractor to subcontract the erection of the cable trusses to the steel fabricator.

The cables were prestretched in the factory to attain a consistent stiffness and shipped in segments to the construction site. The trusses were assembled on the ground to ascertain that the desired overall cable geometry was met. The locations of the clamps were marked on the cables, which are fixed to the spreader posts and act as deviation to give the main cables the required quasi-parabolic shape.

The cables were then disassembled, the top distributing beam was then lowered to the ground floor, and the top two cable segments attached to the beam.

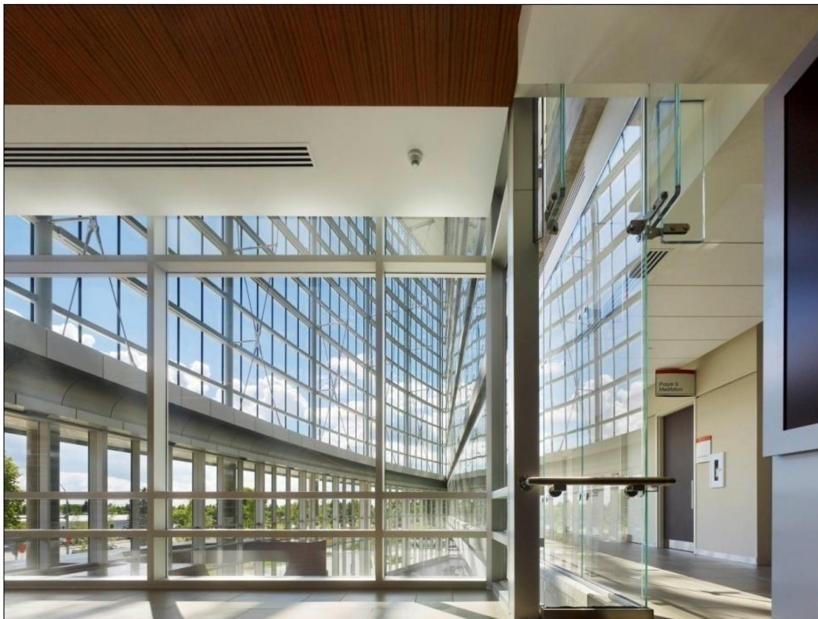
Next, the distributing beam was hoisted so that the cross-over plates could be attached from the ground. This sequence of hoisting the beam and assembling the cables piece by piece from the ground was continued until the last segment was in place. The beam was then hoisted to the top and loosely attached to the roof beam. The ends of the cables were connected to the bottom beam. The cables were now ready for pretensioning.

Hydraulic jacks were used at the roof level to displace the top beam upward. Load cells provided measurements of the pretension forces in real time. The pretensioning was carried out in several steps: jacks were reset in order not to run out of stroke, bolts at the cable clamp locations were retorqued to prevent slip of the cables, and the geometry of the cable truss system was checked at predefined load increments to confirm the anticipated behaviour of the system. Once the load cell readings confirmed that the required tension in the cables was achieved, the hoisting beam was "locked in".

The spreader posts could only be attached to the columns when the steel temperature was between 15˚C and 25˚C. Larger deviations from the target temperature of 20˚C might have lead to unwanted cable force changes.

Although the physical work was carried out directly by the fabricator's erection crew, the pretensioning of the cables was a team effort. The initial procedure was defined by the DDE. Under his supervision, the procedure was continually refined and improved during the pretensioning phase with the input of the erectors, the construction manager and the EOR.

The splendour of the atrium wall, the elegance of the cable truss system and the grace of the details are an inspiration to the entire design and construction team. Our hope is that this elegance helps bring happiness to the generations of patients, staff, and the public who will use the Kaye Edmonton Clinic. The authors believe that such accomplishments can only be achieved through teamwork, bringing together all stakeholders and treating each partner with respect. The Kaye Edmonton Clinic atrium wall is a success story of collaboration between client, architect, structural engineer of record, delegated design engineer, construction manager, glazing subcontractor, and steel fabricator and erector.



4. The Achievement: Engineering Effectiveness and Architectural Elegance

After over six years of planning, designing, drawing, optimizing, fabricating, and erecting, The Edmonton Clinic is quickly becoming a focal point in the heart of the University of Alberta Health Sciences campus. Meeting the schedule and the $900 million budget with engineering effectiveness and architectural elegance, the structural systems for The Edmonton Clinic are truly helping to achieve the vision to be ***"a leading, state-of-the-art enabler of integrated, patient centered clinical care, education and research."***

References

- DiBattista, J.D. 2012. "Concrete or Steel? Considerations for the Edmonton Clinic," Canadian Institute for Steel Construction, The Steel Workshop, Calgary, AB.
- Josi, G., Montgomery, C.J., DiBattista, J., Anderson, G., and Erdevicki, D. 2012. "Design and Construction of a 30-Metre-High Glazing Wall Supported by Cable Trusses," Canadian Society for Civil Engineering, 3rd International Structural Specialty Conference, Edmonton, STR-1135.
- Irvine, M. 1981. Cable Structures. Dover Publications, Inc., New York, NY, USA.

Team Credits

Role	Kaye Edmonton Clinic	Edmonton Clinic Health Academy
Client	**Alberta Health Services**	**University of Alberta**
Client Project Manager	**Alberta Infrastructure**	**University of Alberta Project Management Office**
Architecture and Prime Consultant	**DIALOG** **RTKL**	**HOK** **Stantec Architecture**
Structural Engineering	**DIALOG** **Yolles a CH2M HILL Company**	**Yolles / DIALOG Joint Venture**
MHealth Academynical Engineering	**DIALOG** **MMM Group**	**Hemisphere Engineering Inc.**
Electrical Engineering	**DIALOG** **MMM Group**	**Stantec**
Interior Design	**RTKL** **DIALOG**	**HOK** **Stantec Architecture**
Landscape Architecture	**ISL Engineering and Land Services** **DIALOG**	**ISL Engineering and Land Services** **DIALOG**
Construction Manager	**PCL Construction Management Inc.**	**PCL Construction Management Inc.**
Structural Steel Fabrication	**Waiward Steel Fabricators**	**Structal**
Glazing Systems	**Specialty Glazing Systems** **Stella Custom Glass Hardware Inc.** **Erdevicki Structural Engineering**	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