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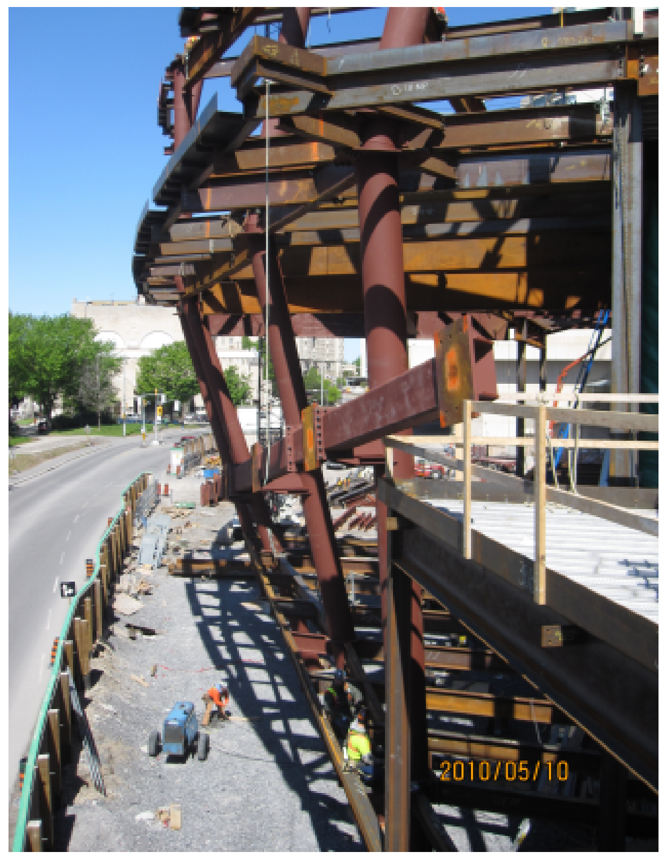
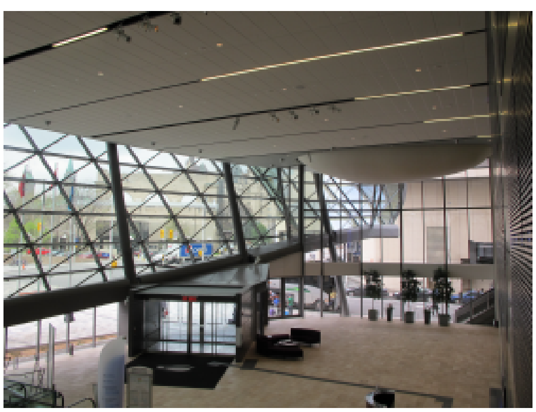
Ottawa Convention Centre

Building Structure





Adjeleian Allen Rubeli Limited
Consulting Engineers

May 8, 2012

Canadian Consulting Engineering Awards 2012

Ottawa Convention Centre – Building Structure
by
Adjeleian Allen Rubeli Limited

Project Summary

Structural Engineering of the Ottawa Convention Centre

Project Summary

Completed in April 2011, the $154 million Ottawa Convention Centre replaced the original, smaller and outdated, Congress Centre located at the same downtown location. The building structure design features innovation, complexity and sustainability and was constructed with minimal impact on the adjacent Rideau Centre and an operating parking garage below. The structure enhances the architectural iconic front façade of curved glass providing panoramic views of Parliament Hill and the Rideau Canal.

Project Highlights

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Structural Engineering of the Ottawa Convention Centre
Project Highlights

Introduction

The Ottawa Convention Centre, located in downtown Ottawa, replaces the original smaller convention facility on the same site. The new facility contains 4 levels of convention space, meeting rooms, a dining/ballroom, and support areas. The $154 million project was completed in early April of 2011.

The Ottawa Convention Centre is immediately adjacent to the Rideau Centre, a large retail complex, and a two level parking garage is located below the east portion of the new facility. Full operation of this parkade was required throughout the demolition of the previous convention facility and the construction of the new facility. 25 mm expansion joints separate the Rideau Centre from the Convention Centre.

The project procurement was by means of a design-build competition with an RFP that included a demonstration design of the building architecture, structure and mechanical/electrical systems. Adjeleian Allen Rubeli Ltd was on a team led by PCL Constructors Canada and bbb Architects Ottawa. This team was the successful proponent in response to the RFP. The building structure features innovative design, complexity in execution, and sustainability initiatives with an aggressive design and construction schedule.

Innovative Design

The RFP structural demonstration design featured a reinforced concrete design for all floors with a steel framed roof. The design included numerous column penetrations in the parking garage below and the use of the garage foundation walls as part of the seismic force resisting system. Numerous micro piles were required for the foundation of the new columns and existing south foundation wall The foundation system for the demonstration design resulted in a seismic site classification of “C”.

In consideration of cost, construction schedule, and minimizing the impact on the parking garage below, it was decided to offer a structural framing and foundation system dramatically different than the demonstration design presented in the RFP.

The first decision was to change the framing concept. The structure above level 2 was framed with structural steel. The level 3 floor, which contained the main conference hall, was framed with steel composite trusses with a span of 31m over the parking structure resulting in the creation of a single row of only 4 “super” columns within the parking garage.

The second decision was to create a seismic force resisting system (SFRS) founded on rock and determine the shear wave velocity of the rock. This decision led to a re-classification of the site to “A” with a significant reduction in seismic design forces. From level 2 to the main roof, the SFRS is comprised of structural steel brace frames located to line up with all 4 sides of the main conference hall. Below level 2, the SFRS is comprised of reinforced concrete shear walls founded on rock. The combination of the robust SFRS, the lighter structure, and the site classification “A”, minimized the seismic deformations to meet code separation requirements at the 25 mm expansion joints.

The selected structural system provided a bonus to the Client in the form of flexibility of the second floor meeting room area. With the clear span at level 2 in the area of the parking garage, a significant area could be configured as a column free secondary convention space, although moveable partitions were provided to allow for the option of smaller meeting rooms.

Complexity

The structural system has a new steel framed structure above level 2 and the west portion of level 2. The existing concrete structure at level 2 and below was retained, although at the west side of the building, portions of the concrete structure were altered and in other areas, new concrete framing was added.

The SFRS is a complex system with a mix of structural steel brace frames and reinforced concrete shear walls. The level 3 slab is concrete diaphragm transferring horizontal forces between these 2 systems within the SFRS. Extensive new seismic collector beams at level 2 transfer seismic forces from the concrete diaphragm slab to the shear walls.

Special design details were required for the south brace frame at level 2 above the parking garage below. This brace frame is a truss spanning 30.8 m while at the same time transferring horizontal seismic shear to the concrete diaphragm slab. At each panel point at the bottom of the truss, vertical steel brackets extend down below the truss bottom chord to engage horizontal concrete brackets with sliding bearing pads that permit the transfer of horizontal forces to the level 2 structure but not vertical forces.

The 25 mm expansion joints impacted the stiffness requirements of the steel brace frames, particularly torsion considerations. A three dimension analysis was carried out on the brace frames using ETABS and numerous adjustments to the bracing stiffness, with re-runs of the analysis, was required to ensure relatively uniform horizontal movements along the length of the expansion joints.

The brace frame on the east side of the conference hall had a dual function of resisting seismic loads as well as transferring gravity loads from the roof and the main conference hall to the super columns in the parking garage spaced at 18m. Furthermore, at the most southerly 18m bay, the bottom diagonal element of the truss had to be deleted due to a major access corridor and the south support column had to be sloped 5.4° in a north-south direction in order to clear an existing pile foundation in the garage at level 2. This column is founded on stiff glacial till about 1.7m above the bedrock level. The computer analysis model was adjusted to include a spring support of this column to model the foundation stiffness as all other columns are founded on rock.

Steel columns located at the west perimeter are sloped to follow the general profile of the curved exterior glass wall . This geometry resulted in significant tension and compression forces at level 3, 4 and the roof with the change in the column slopes at each floor. These forces are transferred through the floor diaphragm to the steel brace frames. The distribution of these forces within the floor diaphragms was complex and required computer analysis to resolve.

The gravity loads of the curved exterior glass wall on the west elevation are supported on a series of HSS 508X305 beams which were labeled the “keel beam” due to its appearance as it is expressed architecturally. The keel beam is curved in two directions and is supported by means of horizontal HSS struts to the sloped columns. The loading on the beam and support struts was complex with numerous load combinations to consider and in some local areas, steel plates had to be added due to the high stress levels.

Sustainability Initiatives

The roof of the previous convention facility was framed with steel trusses spanning 54m. These steel trusses were salvaged and re-used for the roof of the new facility. The roof of the new Convention Centre has a span of 60.56m. The re-used trusses were centered on the span, located between new trusses, and cross trusses at each end transferred the re-used truss reactions to the new roof trusses.

Most of the existing concrete structure below level 2 was retained to be incorporated into the new facility notwithstanding the complexities that resulted with existing head room and the tie-in to new concrete framing.

Client Satisfaction

The new Ottawa Convention Centre was completed on schedule and within budget. In one year of operation, it has hosted 562 events including 40 national and international conventions. The economic impact is reported to be over $83 million with over 1,100 jobs created. Over the next 5 years, the economic impact is forecasted to generate $257 million in Ottawa. The facility received the Tourism Industry Association of Canada 2011 Award for New Business of the Year and the City of Ottawa awarded to the designers an Urban Design Award of Merit. The Client is very pleased with their successful new building.

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Full Project Description

Structural Engineering of the Ottawa Convention Centre

Project Description

Introduction

The Ottawa Convention Centre is located in downtown Ottawa overlooking the Rideau Canal UNESCO World Heritage Site and connected to both the Rideau Centre and Westin Hotel. The Convention Centre has a 30 m high by 100 m long glass façade with a view that includes the Rideau Canal, Parliament Hill, the National Arts Centre, Ottawa City Hall, the Ottawa and Provincial Court House, Confederation Park, the Conference Centre and the Chateau Laurier Hotel.

The Ottawa Congress Centre, the original building located at this site, was identified as being too small to stage large national & international events that would otherwise be attracted to the Nation's Capital. Events such as the NHL All-Star Weekend that was held at the newly completed complex in February 2012 less than a year after opening, could not have been held in the previous facility.

The building was financed partially by Canadian and Provincial Governments, along with the City of Ottawa and was completed on time and on budget for the April 2011 deadline.

The architectural expression played an important role in developing the structural framing of this facility. The architectural design is by bbb Architect Ottawa, with the design concept and vision by architect Richard Brisbon. The principal vision was to include a 100 metre curved glass elevation facing the canal. The building has been identified through the media as a crystalline building representing a Tulip on its side to reflect one of the most prominent and beautiful symbols of the City of Ottawa.

Figure 1: Completed Building

In April 2012 the Ottawa Convention Centre (OCC) celebrated its first year of operation. It has hosted 562 events, including 40 national and international conventions and the sold out NHL All-Star Weekend. The OCC has reportedly attracted close to 35,000 out-of-town delegates and exhibitors which has had a major economic impact in Ottawa, generating over $83 million with over 1,100 jobs in the first year. It has been reported that during the next five years 95 conventions have already been confirmed and the facility is forecasted to generate a minimum of $257 million in Ottawa.

The facility received the Tourism Industry Association of Canada (TIAC) 2011 award for new business of the year. This Award recognizes success, leadership and innovation in Canada's tourism industry and rewards those people, places, organization and events that have gone above and beyond to offer superior tourism experience to travellers in Canada.

The City of Ottawa has presented to the building designers their 2011 Award of Merit in the category of Urban Infill (mid- to high-rise).

The previous Ottawa Congress Centre, built in 1981-1883, was partially demolished. It was part of a 15 acre Rideau Centre development, consisting of a 1,020,000 ft^2 three level shopping centre, three theatre cinema, two level parking garage and the Westin Hotel. The structure of the previous Congress Centre was designed by Adjeleian and Associates.

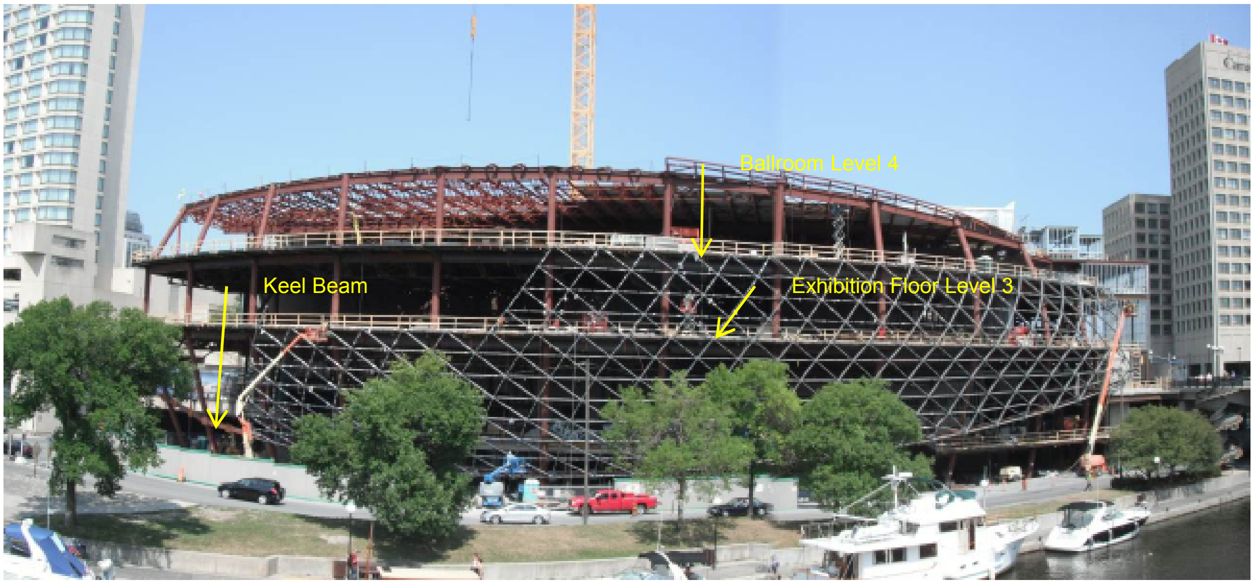


Figure 2: Structural Steel Nearing Completion

Figure 3 Demolition Complete Foundation below in progress

Facility Overview

The primary goal was to create a new facility that had a larger exhibition hall with pre-function areas, plus having the ability to accommodate numerous sets up options. Some key features of the project are as follows:

- The 100 m long by 30 m high west glass walls provide a naturally-lit interior to level 2 & 3 Pre-Function areas and to level 4, the Ballroom area, with a magnificent view of Parliament Hill and the Rideau Canal for the Users of the facility.

- The building extends over the street and sidewalk along the west and north sides of the building to various dimensions with the maximum extension being 14m.
- Level 3 was designed to have a multipurpose hall with an area of 5,200 m^2, with an additional 2,045 m^2 of pre-function space. The multipurpose hall has back of house service areas on both the east and south sides.
- Level 4 is designated as a Ballroom area having a floor area of 1,768 m^2. It was designed with full glass walls providing a view of Ottawa's landmarks. The space is marketed as "the premier gala event and banquet venue in the Capital".
- Levels 1 and 2 contain meeting rooms, with the rooms on level 2 being highly-configurable so that they can be setup to combine into larger rooms by means of the numerous moveable walls.
- The building's main entrance from Colonel By Drive at the north west corner, opens into an 11 m high space that connects to level 2 with both a curved ramp and escalators. Level 2 has interior connections to both the Rideau Centre shopping areas and the Westin Hotel.
- New connections were created at both the entrance level and B1 level for patrons to have direct access to the existing parking garage.
- The building has 17,840 m^2 of usable space.
- The main entrance east wall that encloses the exit stairs and elevator has a wood finish that extends from level 1 to 4. The wood used in creating this feature was century-old lumber reclaimed from the Ottawa River.

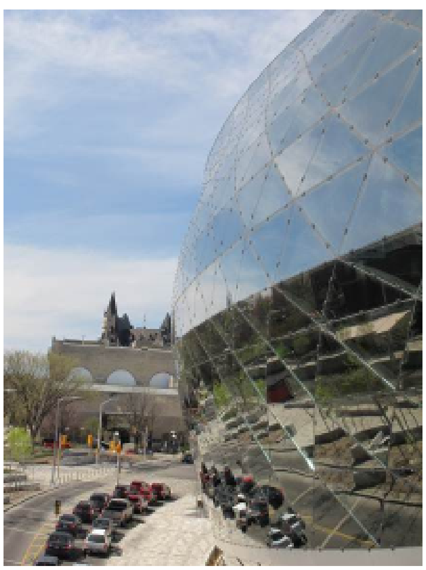



Figure 4: Completed building

Innovation Design

The project procurement was by means of a design-build competition with Adjeleian Allen Rubeli Ltd on the team that was led by PCL Constructors Canada and bbb Architects Ottawa Inc. The RFP that was used as a guide for the design-build competition included a demonstration design from the Owner, outlining a building architectural, structural and mechanical / electrical system concept.

Our team, being the successful proponent to the RFP, proceeded to the design development stage. During the Structural Development Design stage the framing and concepts were substantially changed from the structural framing and layout outline in the project RFP. The innovative changes, as listed below, provided the Owner with additional flexibility and reduced the cost and disruption to the existing occupied parking garage below.

The innovative structure framing is comprised of the following key features:

- The new structural framing above level 2 is structural steel in place of the reinforced concrete frame for level 3 as provided in the RFP demonstration design.
- The level 3 exhibition hall floor principle framing is comprised of long span composite trusses. At the east side of the hall, the trusses span 30.8 m from the west edge of the garage to a row of "super" columns located within the garage, thus eliminating the additional columns anticipated to be located at level 2 and within the garage under the demonstration design. Four of these "super" columns were located within the garage so as to ensure no loss of car parking spaces.

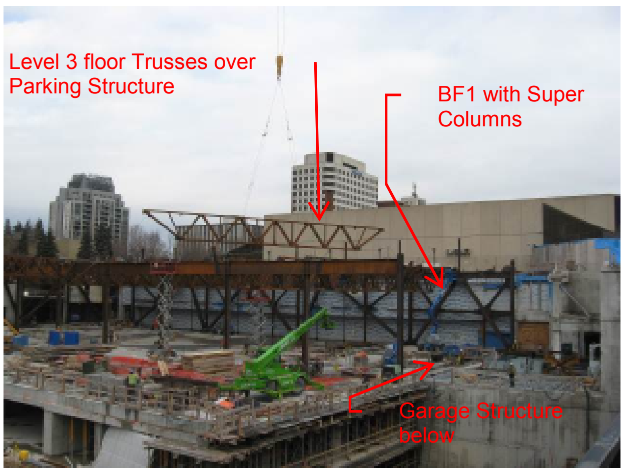


Figure 5: Level 3 Steel Erection

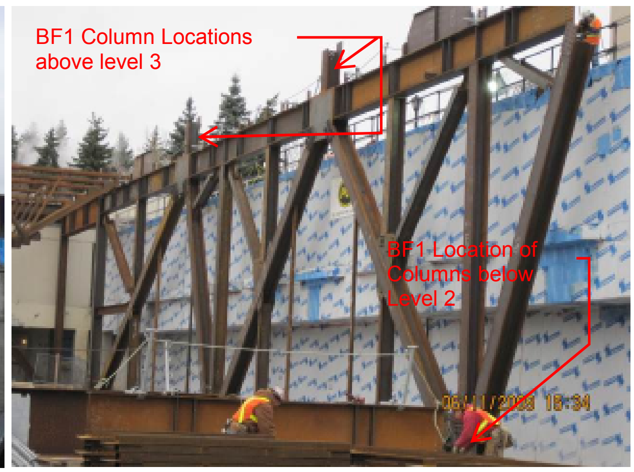


Figure 6 BF1 at level 2


Figure 7: Engineer Comparing Size of BF1 Connections to Self

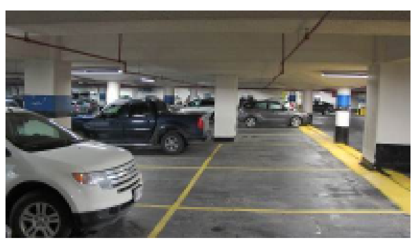
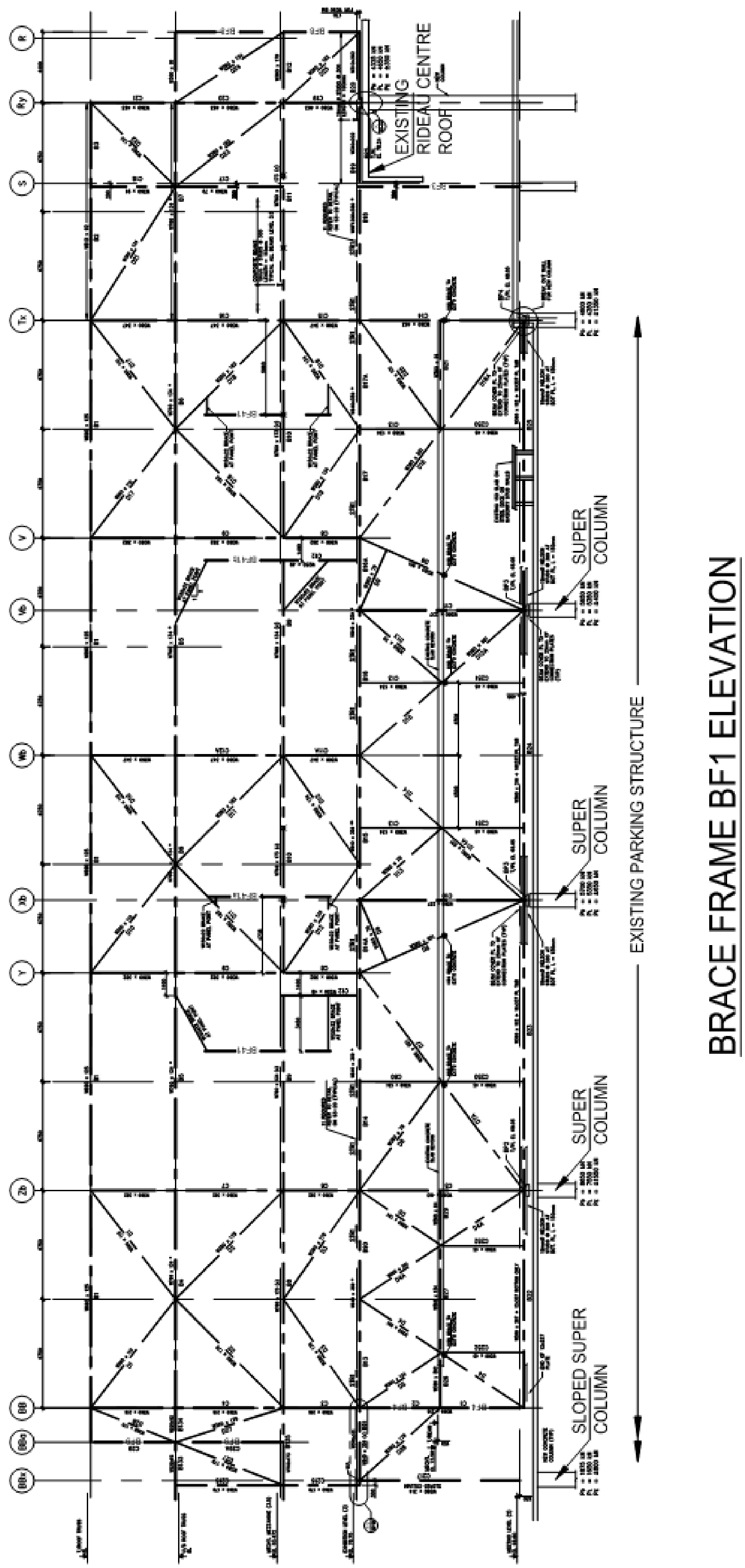
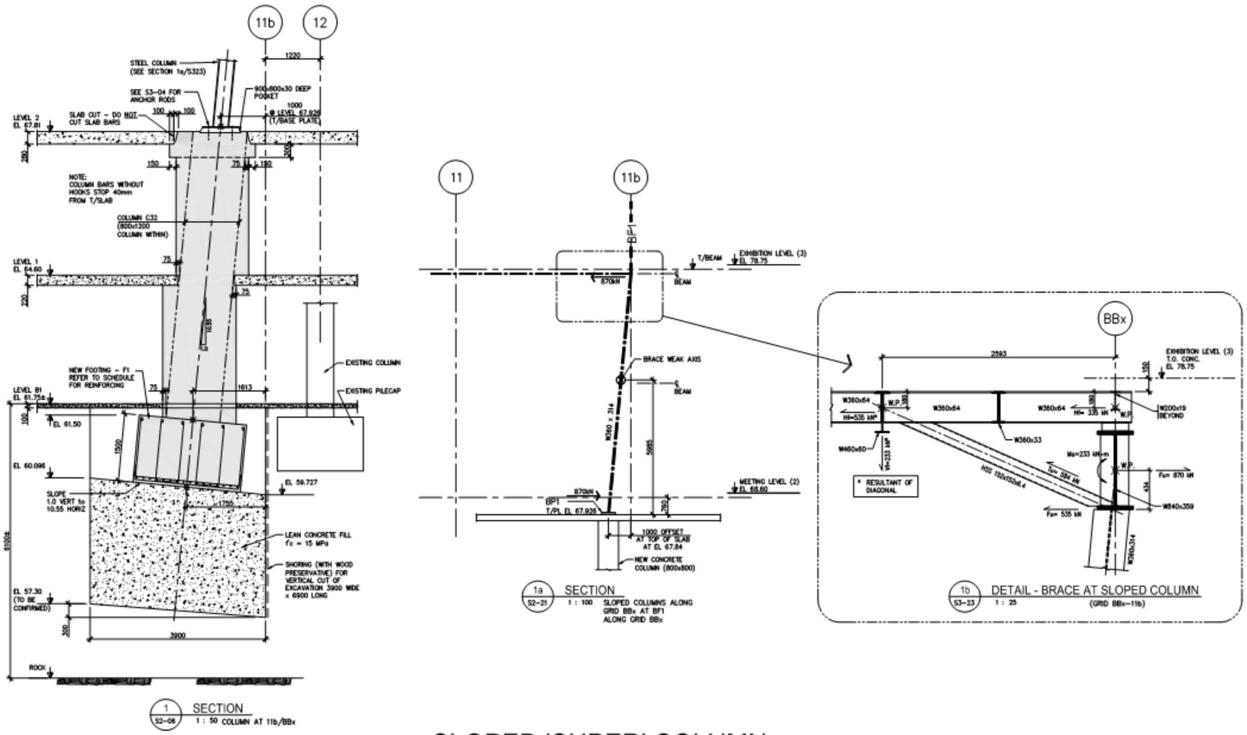


Figure 8: BF 1 Super Column in Existing Parking Garage


Figure 9: Hand Excavation in Existing Parking Garage

- With the selection of the structural system for the floor of level 3, the Client was provided with complete flexibility at the level 2 in the size and number of meeting rooms. The use of moveable partition walls on the east portion of level 2 allows the option of the Client to create secondary exhibition spaces with a clear span width of 30 m; an achievement not attainable with the RFP demonstration design.
- Except for most southerly column, the "super" columns were all founded on spread footings bearing on rock.


EXISTING RIDEAU CENTRE ROOF
SUPER COLUMN
SUPER COLUMN
SUPER COLUMN
SLOPED SUPER COLUMN
EXISTING PARKING STRUCTURE
BRACE FRAME BF1 ELEVATION



SLOPED 'SUPER' COLUMN
AT EXISTING GARAGE

- These new footings were at varying levels due to the profile of the bedrock. The depth of excavation was up to 5 m below the lowest level of the existing parking garage. Due to the restrictive access within the garage, this excavation required local shoring with hand excavation.
- The most southerly "super" column was angled in an east-west direction in order to clear an existing column and its pile foundation and, due to constructability issues, its footing was founded on dense glacial till located 1.7 m above the rock surface. The foundation stiffness differential between this footing on till and the other footings on rock was taken into account in the dynamic analysis of the structure.
- The seismic force resisting system (SFRS) was founded on rock. With the foundations on rock, it was decided to carry out a geotechnical evaluation of the site classification for the seismic design. Site testing was undertaken by the Paterson Group, geotechnical engineers, who determined that the foundation system was Site Class A. This change in soil classification from Site Class C , as provided in the RFP demonstration design, enabled a significant reduction in the seismic design forces.
- In reducing the penetrations into the parking garage and not using the south foundation wall, founded on piles, as part of the SFRS, we were able to utilize a concrete shear wall system developed below level 2 in which all shear walls, designated as part of the SFRS, were founded directly on sound bedrock. This concept allowed for the elimination of the anticipated costly strengthening of the existing garage with micro-piles.
- Seismic design controlled the design of the lateral force resisting system, requiring special attention to severely limit side sway due to the 25 mm width of the expansion joints, located where the portion of the existing Congress Centre that was retained, was adjacent to the Rideau Centre and the Mackenzie King Bridge. A limited ductility Seismic force resisting system of concentric brace frames, with a combination of chevron and non-chevron braces, was selected for the SFRS above level 2. These brace frames are located in all four walls of the exhibition

hall. Below level 2, reinforced concrete with moderately ductile shear walls were selected. The new concrete north-south shear wall system consisted of placing a new concrete wall on the exterior side of the existing west parking garage wall that resulted in a composite concrete shear wall, combining the new with old. The east-west shear wall system consisted of five walls. The north wall was a composite shear wall, again combining a new concrete wall with the existing wall of the parking garage. The other four shear walls were located from the foundation up to level 2. The appropriate R_d and R_o values for this system are 2.0 and 1.3 respectively. This seismic force resisting system resulted in sideway calculations for seismic motion indicating an "elastic" deflection of 5 mm at level 2 which, when increased to take into account inelastic action, is 13 mm which was within the limits of the existing expansion joint restrictions.

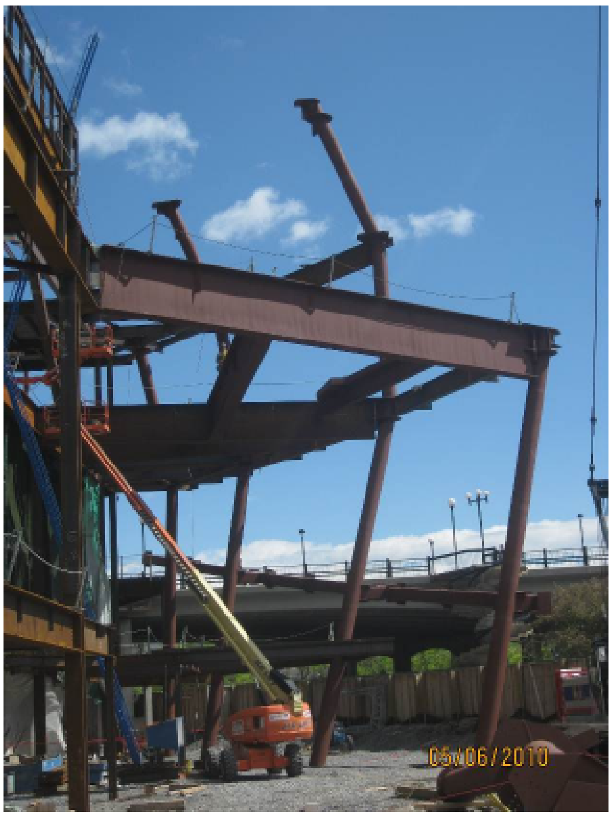
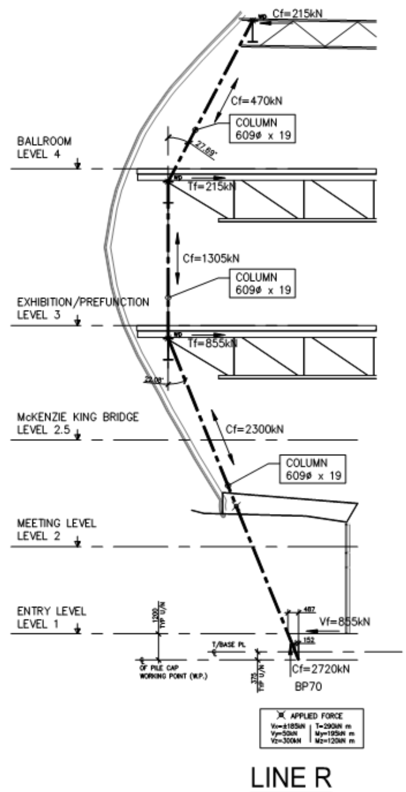
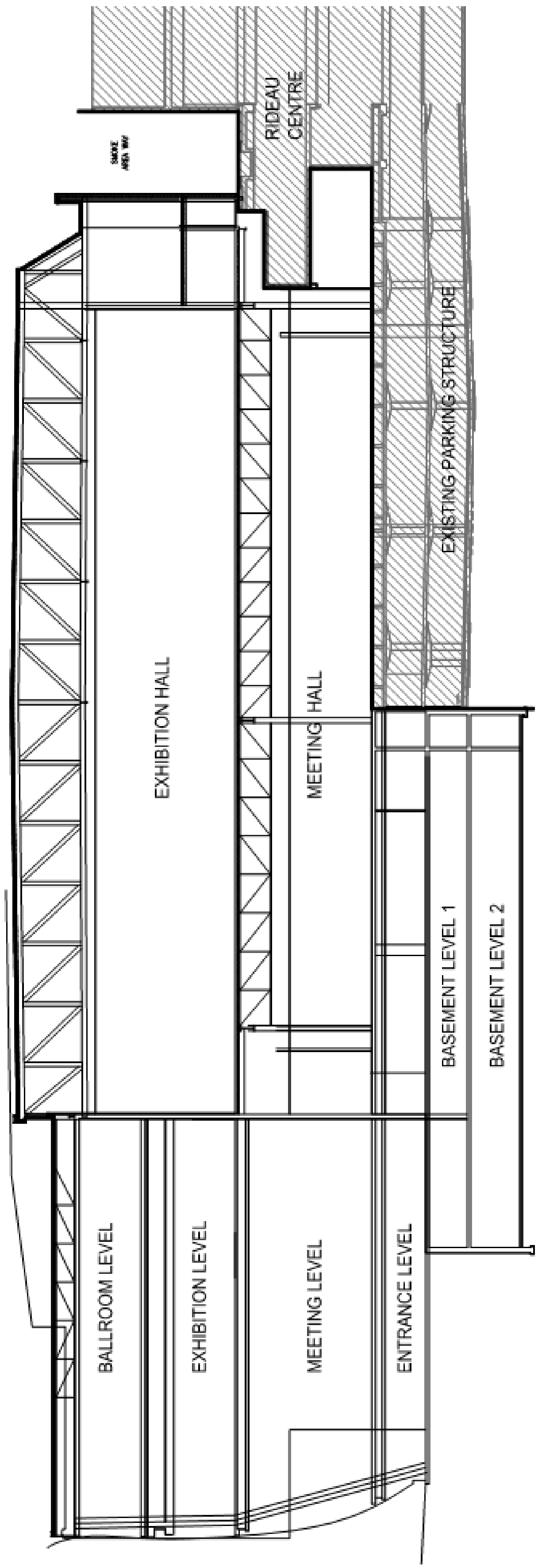


Figure 10: Level 3 Pre-Function Sloped Columns





BUILDING CROSS-SECTION

Complexity

The Ottawa Convention Centre was built over a portion of the parking garage for the Rideau Centre. The Rideau Centre and parking garage were designated to remain fully operational during construction; this required an engineering assessment when contemplating which portions of the original Congress Centre could remain. We needed to ensure that when cutting and temporarily supporting the portions to be retained that the supports were located so as to not obstruct or affect the occupancy of the areas designated to remain open.

The existing parking garage includes stairs that exit through the original Congress Centre building that was being demolished. The stairs had to be demolished and rebuilt while the Rideau Centre remained open during construction.

The Original Congress Centre also supports a bridge link to the Westin Hotel, crossing over Daily Avenue and passing under the Rideau Centre development, which remained in place during construction and was maintained as a link to the hotel with the completed structure.

The remaining portions of the existing building above level 2 required temporary lateral supports within the Convention Centre site. These supports were required until the new building was installed and the concrete structure was connected to the new steel framing.

The new building structure is a combination of reinforced concrete and structural steel. The building structure can be identified as three areas, consisting of the Exhibition Hall, Pre-Function area with Front Façade and the Service Areas to the South and East side of the new Hall.

The building structure's sesmic load resisting system (SFRS) is provided by steel brace frames above level 2 and reinforced concrete shear walls from foundations on rock up to level 2. An existing concrete slab at level 2 is reinforced with collector beams and edge chords to act as a diaphragm linking the concrete shear walls to the steel brace frames. The lateral thrusts due to the sloped columns at the west edge of the project at level 3 and 4 and the transfer mechanism of these forces to the steel brace frames adds to the complexity of the SFRS.

The sequence of construction was designed and scheduled for the box of the Exhibition Hall to be completed first in order to support the erection of the sloped structural steel of the front façade. The site was restrictive for access due to its downtown location. The site also required that the front Pre-Function section of the building be scheduled to follow the Exhibition Hall.

The south Service area was required to be partially demolished down to rock in order to provide the framing for the five elevators and the cistern used to collect the rainwater from the roof. The structural framing was considered traditional concrete below level 2, with traditional structural steel framing above.

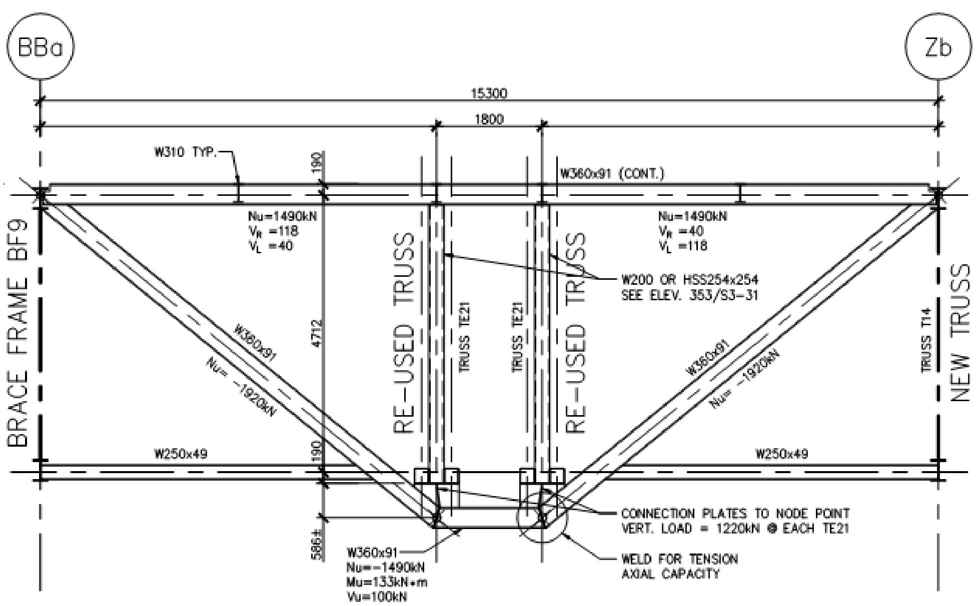
Exhibition Hall Framing System

Exhibition Hall Roof:

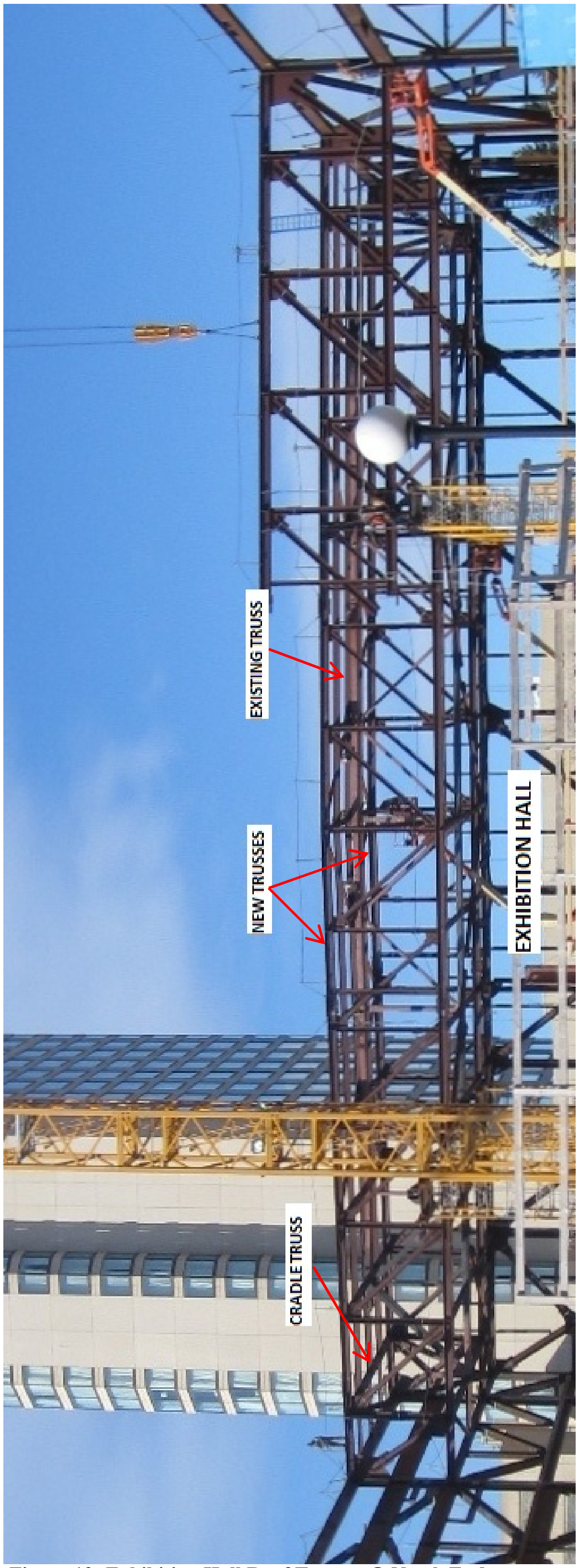
- The new roof was designed with new trusses that were placed at 13.5 m centres and cantilevers over the east brace frame, BF1, for a distance of 8.2 m to the east face of the building. Located over the Rideau Centre footprint, the cantilevered portion of the trusses is located directly over a mechanical mezzanine, supporting mechanical equipment. At the edge of the roof cantilever is a large snow collector that reduces snow drifting onto the existing Rideau Centre roof below.
- The new 60.56 m long roof trusses share the roof load with the re-used roof trussed from the original Congress Centre as part of the sustainability initiative. The re-used trusses, only 54 m in length, were shorter than the clear span of the new roof. The seven re-used trusses required supports, cradle trusses, to transfer the reaction to the adjacent new trusses. The new cradle trusses were located to transfer the original bottom chord supported trusses to the new trusses. The cradle trusses typically span between new the trusses at 13.5 m centre and support one re-used truss. This truss spacing resulting in a 6.75 m space to be framed with light structural steel

framing and diagonal bracing. At the south end of the building the spacing of the new trusses resulted in the cradle trusses supporting two of the re-used trusses.

Figure 11: Roof Cradle Truss Supporting Existing



ELEVATION - TRUSS T32



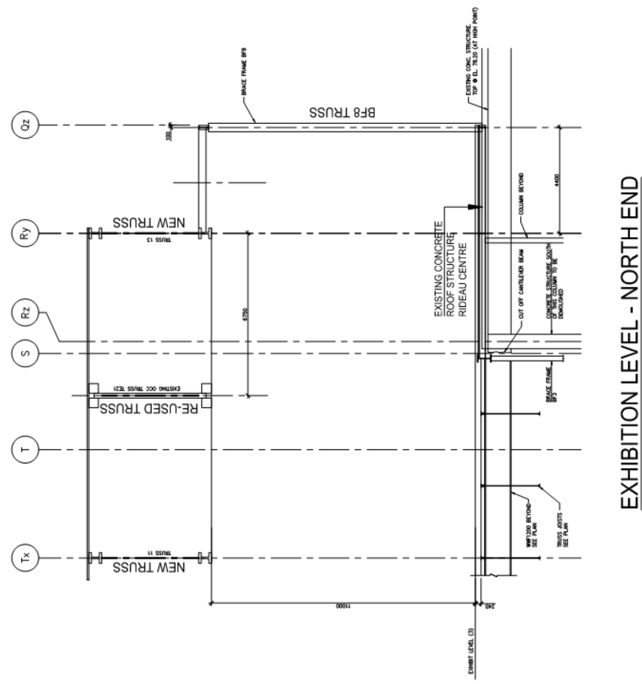
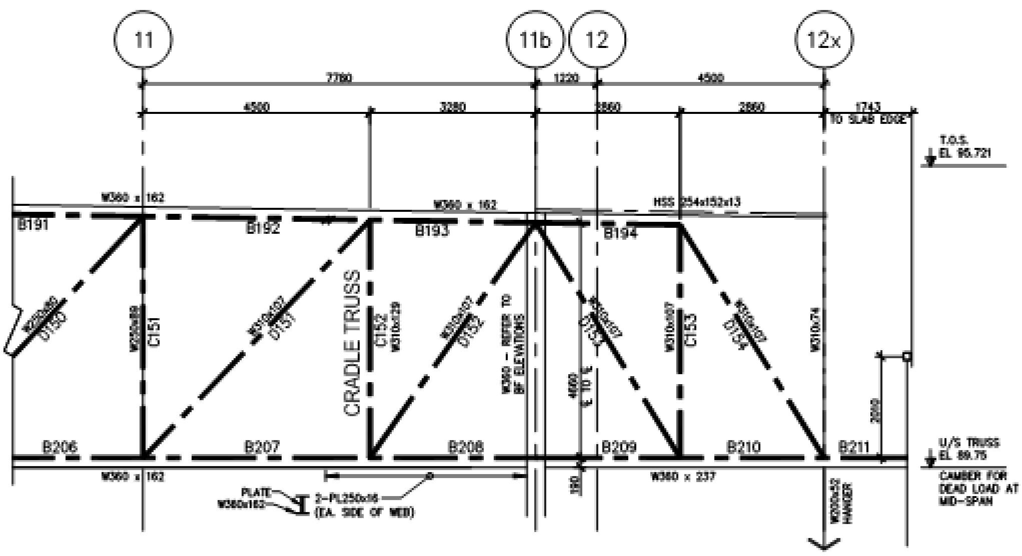


Figure 12: Exhibition Hall Roof Trusses @ North End

Figure 13: East Truss Cantilever



TRUSS T13 - EAST END

- The north-east corner required the cantilever roof trusses to support both the mechanical mezzanine and the level 3 washroom areas by means of steel hangers, as no supports below for the corner were possible due to the location of the Rideau Centre shops below.

East Wall of Exhibition Hall BF1:

- New concrete columns supporting BF1 extend from level 2 to the foundation. Of these columns, four "super" columns were located to pass through the existing two levels of the parking garage.
- The steel support framing on the roof at 13.5 m on centre does not align with the new concrete columns located to suit the existing parking layout. BF1 includes framing to transfer from the 13.5 grid above to the 18 m grid in the garage.
- New footings required up to 5 m of excavation below the lowest parking garage floor. The excavation was restricted to hand excavations as the parking garage remained fully operational with limited allowance for taking parking areas and restriction on clearance. The excavation required full shoring of the area.
- The "super" columns were located at 18 m on centre and designed to support both seismic forces and gravity loads from the new Exhibition Hall floor and roof.
- The south design of the "super" column was complicated by the 2nd floor clearance required for a major access from the loading dock and an existing below grade pile cap interference. This south column of the brace system was changed during the design stage to suit the clearance and conflict issues. The bottom chord and lower diagonal of the truss was deleted at this location and the column sloped perpendicular to BF1 5.6° from level 3 down to the footing level. The design of the seismic force resisting system was adjusted with the footing designed as a spring support column, to take into account the bearing of this column on glacial till 1.7 m above bedrock.
- The east end of BF1 cantilevers at level 3 to support the building's north brace frame.

West Wall of Exhibition Hall BF6:

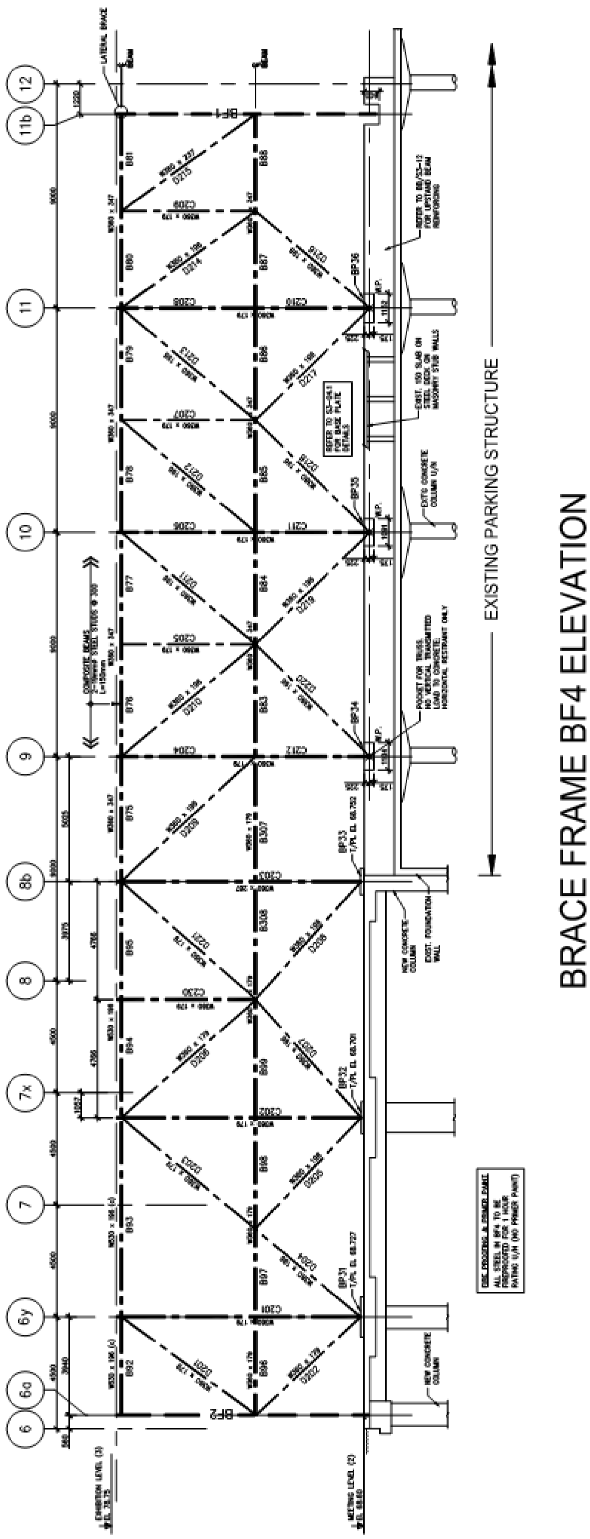
- The west brace frame support columns close in alignment with the west foundation wall of the original building. New concrete columns were added to support the columns of BF6. A reinforced concrete beam at level 2, at the underside of BF6, transfers the seismic shears to the concrete diaphragm slab at level 2.
- The west brace frame cantilevers at level 3 to support the building's north brace frame that is 4.5 m off the last column line, similar to the east wall of the Exhibition Hall brace frame.

North Wall of Exhibition Hall BF1 and BF8:

- The north brace frame of the building at level 3 is located 4.5 m north of the supports below level 3, as framing could not pass through the occupied Rideau Centre below.
- The north brace frame is a brace frame truss that supports the level 3 floor located 550 mm above the Rideau Centre roof slab as well as the roof over the Exhibition Hall. The resulting clearance from the underside of the steel framing to the top of the existing concrete roof restricted the depth for the of steel and floor slab of the level 3 floor. The 11 m deep truss spanning 60.56 m from the east to west walls of hall framing was designed with W360x237 as a bottom chord. This assembly resulted in 85 mm clearance above the Rideau Centre roof. To counter the truss deflections, the ends of the frames along the east and west hall walls were constructed with a 10 mm at the end of the cantilevers. The truss was built with a 30 mm camber, providing for a total dead load deflection of 40 mm.
- Horizontal base shears of truss BF8 are transferred laterally at level 3 to BF1

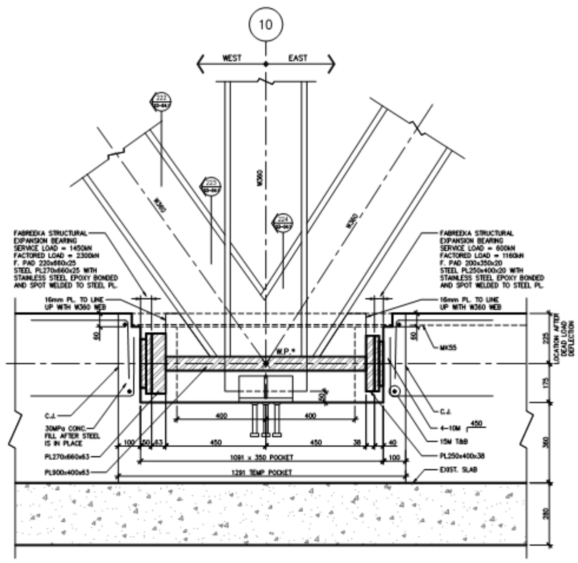
South Wall of Exhibition Hall BF4 & BF9:

- The south brace frame of the exhibition hall was unable to be located to align with the walls brace frame level 3 due to the restriction of the level 2 access from the loading dock. A horizontal transfer of shears from BF9 to BF4 was required at level 3.



- The south brace frame below level 3, aligns with the existing parking garage columns, which were assessed to be inadequate to support the new framing. To eliminate reinforcing of the existing structure, the portion of the brace frame over the garage was designed as a vertical load carring truss. Similar to the Exhibition Hall floor trusses, the brace frame is designed as a truss that spans the 30.8 m from the line of "super" columns to the column line added at the west side of the parking garage. The truss depth was from level 2 to 3 and was part of the seismic force resisting system that transfers the horizontal forces to the concrete diaphragm slab at level 2. The horizontal bearing support was a sliding bearing which allowed horizontal loads in either direction to be transferred from the brace frame to the existing diaphragm concrete slab, but permitted the truss to deflect vertically without transferring vertical loads to the level 3 slab.

Figure 14: BF4 Vertical Slip Joint at Horizontal Concrete Drag Beam



EXISTING PARKING STRUCTURE
BF4 - VERTICAL SLIP JOINT

Pre-Function Area and Front Façade:

- The Pre-Function areas on levels 1 and 2 provide an iconic large grand entrance for the facility.
- Vibration of the floor slab at the level 3 and 4 including the exhibition Hall on level 3 were designed to meet vibration requirements for ballroom dancing. This was achieved with composite trusses, beams and deck. The 240 mm thick composite slab had sufficient mass to reduce acceleration due to floor vibration to acceptable levels. Dynamic analysis of the floor system was carried out to confirm vibration natural frequencies of the floor system in the determination of acceleration values.
- The composite slab, 165 concrete on 75 steel deck, was also reinforced with top and bottom reinforcing to facilitate the large concentrated point loads anticipated during events. These slabs also acted as large diaphragms as part of the seismic force resisting system.
- The sloped columns supporting the front façade of curved glass resulted in high floor reaction forces to level 3 and 4: primarily tension at level 3 and compression at level 4. Special slab reinforcing combined with diagonal in plain bracing transfers these lateral reaction forces through the level 3 diaphragm to brace frames at the exhibition hall

- The curved glass façade gravity loads are supported at the bottom with a steel structure support beam. During design and construction the support beam was referred to as the "keel beam" due to its appearance at the base of the glass wall. The keel beam geometry resulted in two directional curves with the connection to the column varying at every location. The keel beam is fully supported from the sloped columns, except where it projects approximately 14m beyond the face of the building at the north end, where it is supported by diagonal hanger struts from the level 3 floor framing.

Figure 15: Sloped Columns @ Keel Beam Level

Figure 16: Sloped Column Compression Strut

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Figure 17: Front Façade Support Structure


Figure 18: Glass Wall Connection to Keel Beam

- The curved glass façade was designed by Novum Structures with six degrees of freedom, with 34 fixed connections for gravity loads on the keel beam. With Novum Structures providing the load cases, which consisted of 44 load combinations, Adjeleian Allen Rubeli used this data to design the keel beam. The keel beam became more complex when the north sloped column was deleted for architectural and road clearance reasons. This resulted in steel plating of the HSS keel beam to accommodate the increased stress levels.

- The front face of the building is supported by outward sloping 609 mm Ø circular tube steel columns that is supported by a piled concrete structure below the level 1 entry level slab. All columns are located sloping outward off the foundation system with up to level 3.

- Each column changes direction at levels 3 and 4 with the direction change being a combination of either vertical or inward sloping above level 3.

- The glass façade is supported laterally for horizontal loads at each floor slab and at the roof. With the façade designed with no expansion joints along its 100 m length, the 54 node point connections to the base building required movement in all directions except at discrete points at mid-point of the glass wall The movement and forces were all identified by Novum Structures from numerous scenarios resulting from temperature, floor usage, seismic, wind and roof snow loading. These façade forces were transferred to the horizontal floor and roof systems and from there transferred to the brace frame.

Figure 19: North Keel beam Extension

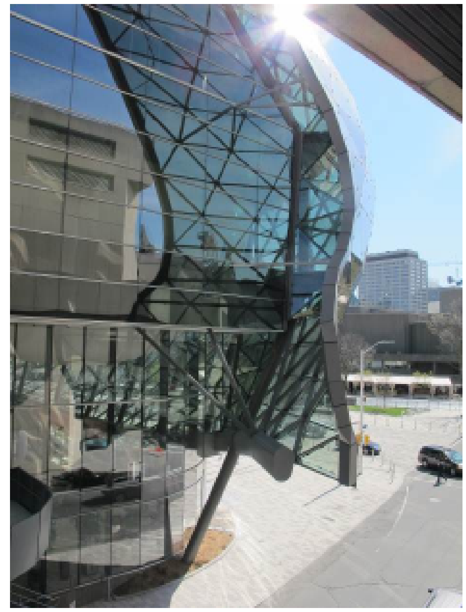

Figure 20: North Keel beam Extension

- Concrete shear walls at and below level 2 extended down to rock with anchors installed into the rock. The concrete walls were all incorporated into the existing slabs and walls outside the existing parking garage within the original Congress Centre building. For the walls outside the parking garage footprint, an extensive seismic collector system was developed within the existing level 2 floor system, that drags seismic forces from the level 2 diaphragm to the shear walls.

Sustainability Initiatives

The project was mandated to achieve and received the LEED (Leadership in Energy and Environmental Design) Silver Certification. This required the structural design to maintain and re-use portions of the existing building, resulting in a design that incorporated and salvaged various structural elements of the building.

- The seven roof trusses of the existing hall were salvaged for re-use in the new roof.
- The existing level 2 concrete structure over the parking garage was fully maintained.
- The concrete structure west of the garage below level 2 was generally maintained except where new shear wall systems, columns, four public elevators and four new service elevators were installed.
- The loading dock located under the Mackenzie King Bridge, on the south side of the facility was retained but altered with new column supports which were installed to suit the revised and additional truck bays and to increase the size of the loading dock.

Figure 21: Selective Demolition

Figure 22: South New Elevators

- A cistern was added to collect rainwater from the roof to be used for grey water within the facility. This cistern was relocated on numerous occasions during the design with the final location being underground in the loading dock.
- Demolition was undertaken as per LEED guidelines. This required demolished materials, where possible, to be diverted from the landfill. The concrete structural elements were crushed when removed, with the reinforcing steel separated out on site. The on-site sorting of demolished material was typically undertaken prior to the material being taken off site.