BC Place Revitalization

Project Highlights

BC Place Stadium is a 54,000 seat sports and entertainment centre, originally opened to the public in the early 1980s. Since that time, it has become a key public gathering place and part of the fabric of British Columbia. This facility was the host venue for the 2010 Winter Olympics and on average hosts more than 200 event days per year. These numerous and diverse events, include sporting events, banquets, trade shows, concerts, conventions, religious gatherings and celebrations all of which have their own unique facility requirements. With all this in mind, the BC Pavilion Corporation (PavCo) embarked upon a plan to revitalize its facilities to meet the future demands of a changing community and BC Place was a primary part of this process.

In October of 1982 the roof of BC Place Stadium was inflated covering the first domed stadium in Canada and one of only six in the world suitable for professional field sports. Today there are over twenty domed stadia in North America and almost half of these venues have retractable roofs. Many older stadia have been either abandoned by their anchor sports tenants or have been raised and replaced with new facilities. In early 2008 with the knowledge that the existing air supported fabric roof had reached the end of its usable life and the approach of the 2010 Winter Olympics PavCo determined that a revitalization of the stadium was needed to assure its utility, stature, and relevance in the decades to come. The early consideration was to demolish the existing stadium, sell the site for urban development and build a new facility. Due to land requirements the new facility would have to be developed at a suburban location which is the norm for these types of endeavors. GENIVAR and Geiger Engineers were engaged by PavCo in order to assist with this evaluation and to analyze the possibility of revitalizing the existing stadium. During this evaluation it was determined that the primary systems of the existing stadium were very serviceable with the notable exception of the air-supported roof. It was also determined that the existing stadium structural systems were suitable for upgrades required to replace the existing air-supported with a gravity supported roof. Moreover possibly the stadium's greatest asset, its urban location would have been lost had a new development been pursued. Furthermore it was determined that an equivalent new facility would have cost in excess of $1.0 billion dollars whereas revitalization including a new gravity supported roof was estimated to be less than half of the stadium replacement cost. Finally it was determined that the environmental cost of demolition of the existing structure and equipment along with associated dispersal of building elements to the landfill, along with the greenhouse gas production associated with both demolition and construction of a new stadium far exceeded the environmental cost of revitalization.

Having chosen the revitalization option the designers commenced the complex process of both designing the new roof and analyzing the existing facility to determine associated upgrades.

By replacing the existing air supported roof structure with a gravity supported roof structure the structural designers faced a significant task. The greatest attribute of the air supported roof, its unparalleled material efficiency and minimal mass, created the greatest challenge in its replacement. The existing air supported roof also incorporated a snow melt system intended to melt snow in winter so the roof and consequentially the support structure below was not designed to accommodate snow loading. In order to achieve a light-weight design a membrane roof supported on post-tensioned cable trusses was chosen. The cable truss system consists of 18 cable trusses having spans varying from 227 m to 186 m. the cable trusses are supported by 36 perimeter steel masts rising 47.5 m above the original roof's concrete ring beam. Stabilility of the entire system is provided by a continuous steel compression ring forming an approximate circle to the outside of the steel masts at 18 m above the original roof's concrete ring beam. This is balanced by a tension ring consisting of ten cables located in a two tier grouping which form an approximate circle to the inside of the steel masts at the base of mast level. The resulting cable truss system provides a flexible vertical and lateral load carrying system which gains its stability from the force couple of the opposing compression and tension rings. Despite this being a very efficient structural system it was determined that new static loads imposed on the base structure below were in the range of 18,000,000 kg of additional dead load and 7,000,000 kg of additional snow load. Complicating this was the fact that the existing stadium base structure had been designed with 54 racker frames supporting the bleachers, concourses and air-supported roof. Therefore a transfer girder was designed to be placed within the “U” shape of the original roof’s concrete ring beam. This transfer girder distributed loads from the 36 roof masts to the existing support system. Roof and base building engineers worked closely to determine demands on the existing structure and subsequent upgrade requirements which included reinforcement of numerous columns and a significant number of building foundations.

A greater technical challenge for the structural engineers was the lateral load analysis associated with the revitalized stadium. Complicating this analysis were the inherent characteristics of the base building structure and new roof structure. The new roof structure is a relatively flexible structure with a fundamental period (period of vibration in an earthquake) of approximately 2 seconds whereas the base building is somewhat stiffer with a period of approximately 0.6 seconds. To determine lateral demands on both the new roof and on the base building the design team developed a computer model of the base building structure, the roof structure and the intermediate transfer structure between the two systems. These models were then combined into an over model of the combined structure and extensive analyses were undertaken to calculate member structural demands in this highly complex and indeterminate system. Based on the noted analyses, vertical eccentrically braced frames were incorporated into the roof structure and the top level of the existing shear walls in the existing base building were replaced with buckling reduced braces in order to limit the magnitude of seismic forces transmitted to the new roof structure.

Along with the structural upgrades noted a full revitalization of the building mechanical and electrical systems was undertaken. Of significant impact on the mechanical ventilation systems was the change from the pressurized conditions associated with the air-supported roof to the atmospheric pressure environment of the revitalized facility. This involved decommissioning and redeployment of numerous pressurization fans. The snow melt system associated with the air-supported roof was also decommissioned. All of these modifications resulted in significant savings in energy costs for the owner. Electrically a full evaluation of existing electrical systems was undertaken and significant upgrades were undertaken with a view towards modernization and ultimately energy savings.

A further significant consideration for the ownership and consultant group was the schedule and timing of the required upgrades. With BC Place scheduled to be one of the primary hosting venues for the 2010 Winter Olympics and with less than two years until that event it was determined to split the project into two phases. The first of these phases was to undertake interior upgrades to public spaces within the stadium and undertake as many structural upgrades as possible in the available schedule. This was followed by the approximately six month Olympic black out period. Once this was complete the stadium was handed back to PavCo and the second phase of construction commenced. This phase involved demolition of the existing roof, installation of the new roof and numerous changes to entrances and back of house areas of the stadium, and was completed in approximately 18 months.

Having completed the revitalization program, the stadium is now ready to continue to be a key public gathering place for British Columbians and its iconic shape will continue to define Vancouver’s skyline.

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New Application of Existing Techniques / Originality / Innovation

The revitalization of BC Place Stadium posed a number of significant challenges to the engineering team and represented a number of technical achievements. One of the greatest achievements was the design and construction of the largest cable supported, retractable membrane roof structures in the world and the first of its kind in North America. The structural concept for the roof had previously been used for several stadia in Europe but had not previously been incorporated into a roof of this scale both from a size perspective and from a loading perspective. This achievement was complicated by the significant challenge of the placement of the new cable supported roof structure on a base building which had not been originally designed for a gravity roof system. This represented both the demand capacity challenge of the new increased gravity loads to be imposed on the existing building structure as well as the geometric challenge of the idealized circular shape of the new roof's structure on the elongated flat oval shape of the existing stadium structure. Lateral load analysis of the new roof structure also represented a significant challenge to the design team. An advanced dynamic model of the existing stadium structure and the new roof structure was required in order to determine interaction between the stiff base structure and somewhat flexible new roof structure in order to determine member demands both in the existing base structure and in the new roof. This required individual development of the base building structure model, the roof structure model and the intermediate transfer structure model and consolidation of these into a total building model. This consolidated model was then utilized to analyze the total stadium structure both through the time steps of construction and through the range of loading conditions anticipated for the completed facility.

Project Objectives, Solutions & Achievements

In October of 1982, the roof of BC Place Stadium was inflated covering the first domed stadium in Canada. The stadium was the first of many developments that transformed the east end of Vancouver's False Creek basin. In subsequent decades, as the stadium was knitted into the city's urban fabric, the demands, norms and needs of the events and users of the stadium evolved. The state-of-the art in sport venues and user expectations changed dramatically. When BC Place opened it was one of only six domed stadia in the world suitable for professional field sports, all of which were in North America. Today, while the building type is still quite unique, there are twenty some domed stadia in North America and others in Japan and Europe. Almost half of these venues have retractable roofs. Many older stadia for professional sports in North America, domed and open, have been either abandoned by their anchor sport tenants or have been raised and replaced with new facilities. BC Place held its own hosting in excess of 200 event days a year and providing a home for BC Lions football. However, as the limit of the expected service life of the air-supported roof's fabric was approaching and the world's attention was about to be focused on the facility for the 2010 Olympic Winter Games, it became clear to its owners - BC Pavilion Corporation (PavCo) - that a revitalization of the stadium was needed to assure its utility, stature, and relevance in the decades to come. While consideration was given to construction of a new stadium, the primary systems of the existing stadium were found to be very serviceable and sound with the notable exception of the air-supported roof. Moreover possibly the venue's greatest asset, its urban location, would likely have been lost had a new development been pursued. Finally, revitalization of the existing facility was clearly seen to be both economically and environmentally superior to new construction.

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Interior View

Exterior View

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In revitalizing the stadium, PavCo sought to strengthen the spectator experience, reduce energy use, create a "high-energy" atmosphere for events, and resolve operating shortcomings of the air-supported roof, while reinforcing the presence of the building in the cityscape. These goals drove the design of the new roof and overall revitalization of the existing facility.

Replacement of the roof with a non air-supported system to eliminate energy costs and operational constraints was a significant challenge. Air-supported structures are unique in their material efficiency in covering very long spans and their first cost economy was key in emergence of domed stadia as a building type. Despite its efficiency this design does have some significant shortcomings and unique vulnerabilities that guided the design team away from an air-supported concept. The greatest attribute of the air-supported roof, its unparalleled material efficiency and minimal mass, created the greatest challenge in its replacement. Mindful of the need to minimize the weight of the new roof, a sweeping new design of a membrane clad post-tensioned radial cable truss was devised. The new roof designed by Geiger Engineers in association with Schlaich Bergermann and Partner is the most visible manifestation of the revitalized facility, dramatically enhancing the stadium interior, especially for field sports. The new roof covers 40,000 m^2 with a retractable center of nominally 7,500 m^2. The primary structure of the roof is all exterior; in essence the roof "floats" over a large clerestory creating a new open airy interior. Daylighting is enhanced by the use of translucent membranes for all roof cladding.

Eliminating the snow melt system required a design that could support approximately 7,000,000 kg of snow on clear spans of 227 and 186 m in addition to the roof's self weight. To achieve this in a light-weight design, the primary structure consists of a series of 18 radial cable truss structures, post-tensioned within a new circumferential steel compression ring and opposing cable tension ring. The upper radial suspension cables supporting the membrane roof hanger cables are supported by 36 perimeter steel masts rising 47.5 meters above the original roof's concrete ring beam. The masts in turn are supported on circumferentially guided slide and rotation bearings placed on a new reinforced concrete girder in the channel cross-section of the original roof's precast concrete compression ring. The new concrete girder in the existing precast ring beam was necessary since the original building structure consisted of 54 radial frames supporting the seating bowl, concourses and precast compression ring. This resulted in the 36 mast structures being supported at varying distances from the existing 54 frame columns. This roof design not only kept the weight of the new structure down, but the re-use of the existing ring beam and support structure below minimized the impact to the interior concourses below the roof level.

The roof masts are prominently featured exterior to the stadium as is the new compression ring, providing a new iconic appearance for the stadium. Below the roof eave is 12.5m clearstory façade clad in ETFE (Ethylene tetrafluoroethylene) membrane, a clear fluorocarbon film. This is the first use of this material in Canada and its selection was in keeping with an open and light-weight design concept that dramatically increases the natural lighting in the building. The fixed portion of the roof is a PTFE (polytetrafluoroethylene)-coated fiberglass tensioned membrane similar to the material of the original air-supported roof, in keeping with the most beneficial features of the original roof design. As the fabric is no longer pneumatically supported, the new roof membrane is supported on steel tube arched purlins carried by the primary cable truss.

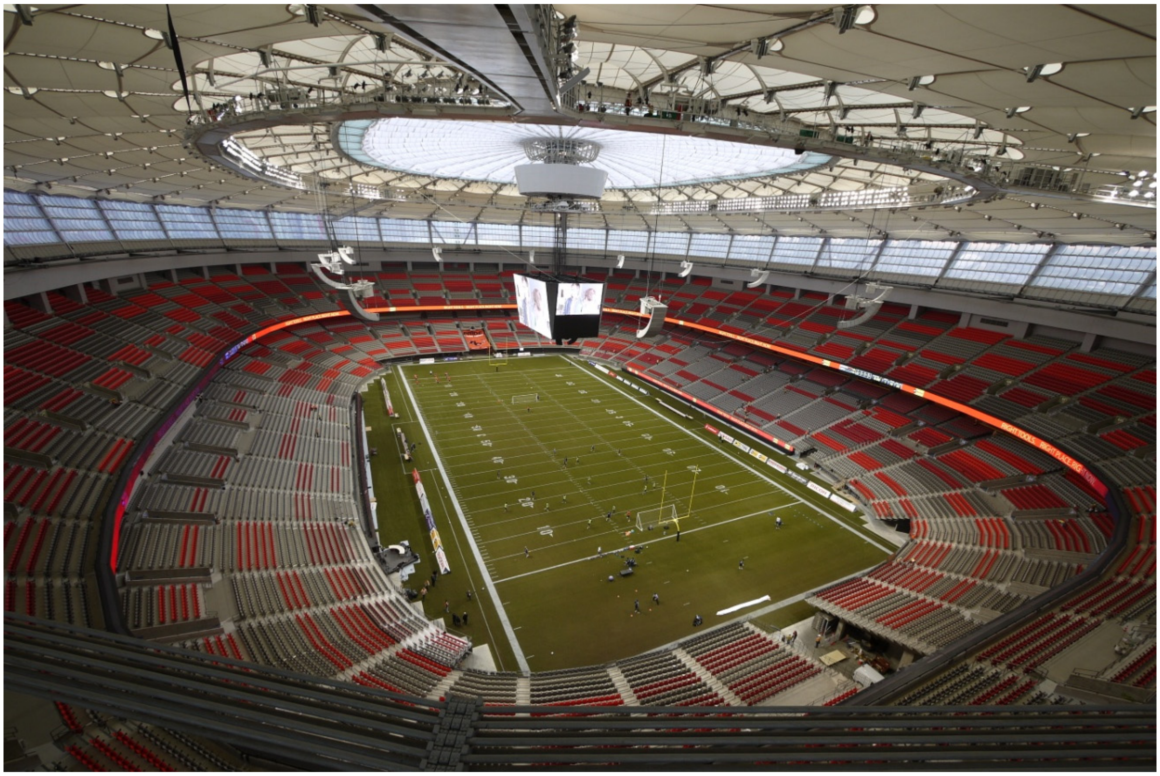
Mindful of the requirement to re-design the stadium to host MLS soccer in addition to CFL football, the roof structure was also designed to suit an event in which only the lower bowl is occupied.

GENIVAR GEIGER ENGINEERS

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA
ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS | CANADA

CANADIAN CONSULTING engineer

BC Place Revitalization



Roof

LED Lights on Building Fascia. Photo by Michael Elkan

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To scale the "house" for Whitecaps soccer a unique screening system was developed which creates a canopy over the lower seating bowl. The system of fabric panels is deployed from rollers integrated into the LED ribbon board supports at the leading edge of the upper seating deck. The canopy screens are suspended from the roof with and tensioned by the rollers. Incorporation of the "soccer curtain" into the stadium re-design was a key feature of welcoming additional sports leagues and community events to the facility with minimal alteration of the structure below.

Aesthetic Aspects

Externally the new roof profile has created a presence which will become instantly recognizable around the world as Vancouver. The new profile along with lighting of the roof and façade has resulted in countless possibilities to animate the stadium creating a vibrant presence not only from near proximity but on the horizon.

Internally the new roof along with lighting of the roof along with new video displays both in the stadium bowl and on the stadium concourses has created a new and lively environment for events and patrons. The new ring of mechanical louvers and operable roof has also allowed the possibility of an open air venue with associated spectator experience.

Complexity

The project presented some unprecedented challenges for the designers and builders. The roof structure is unique in North America and the largest of its type in the world. No other domed stadium has replaced its roof with an entirely new and different roof structure. In addition to the ambitious design requirements, a challenging project schedule required the phasing of construction to meet a very public timetable.

Pushing the envelope of design, an innovative, retractable portion crowns the new roof and allows BC Place the option of operating as an open-air venue. The retractable roof is a pneumatic tensile structure of fluoropolymer coated woven PTFE fabric. The space between two layers is pressurized to create cushions that span between the radial cables. Pressure in the cushions is automatically modulated in response to roof load. The roof is opened by evacuating the cushions and contracting the membrane into the center gondola of the roof above the new centre-hung video scoreboard.

Despite its very efficient design the new roof imposed significantly higher vertical loads on the existing stadium base structure. This included not only the previously noted additional 7,000,000 kg snow load but also an additional 18,000,000 of roof structure dead load. Accompanying lateral wind and seismic loads also imposed significantly increased demands on the stadium base structure than had initially been designed for. In order to determine these effects a full analysis of the upgraded structure was required. This involved close cooperation between the roof designers, on two continents, and the base building engineers in order to develop the complex model required to determine these vertical and lateral effects. Determination of lateral effects was complicated by the significantly different characteristics and behavior of the new roof and existing base building under loading. The roof is a relatively flexible and indeterminate type of structure while the base building is much stiffer. A significant amount of analysis and expertise was required in order to determine interaction of the two systems and associated structural demands under earthquake loading. As a result of this analysis it was decided to incorporate the use of eccentrically braced frames for lateral stability of the roof itself and to replace the top level of existing concrete shear walls with buckling reduced braces in the base structure in order to limit earthquake loading transmitted to the roof structure. This analysis also allowed the engineers to design very precise upgrades to the base structure thereby reducing disruption and costs of the upgrades.

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Terry Fox Plaza and New Entrances

Exterior View

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Phased construction that required intermediate structural and mechanical modifications to the existing building leading up to the 2010 Olympic Games was vital to ensuring the project's successful completion on time. First phase construction was performed while the building remained in use. This necessitated redesign of the roof snow melt distribution system to allow construction of the new roof's transfer girder in the existing ring beam, which had also served as the primary plenum for the snow melt system. Additional enhancements to the supporting superstructure, including the foundations, were mindful of the existing equipment and operations of the facility as the work was completed while the building remained a pressure vessel. This included constructing caissons below grade atop the existing foundations to avoid extensive excavation, and the use of tremie concrete techniques alleviated the need to pump water in locations where the foundations were below the water table. Designing for a temporary, pre-Olympic phase of the building considerably reduced the subsequent construction period during which the use of the venue was lost with minimum impact on the operations of the building.

Complicating the mechanical system analysis and upgrade design was the significant change in operating environment. This was a result of changing from the pressurized environment required by the air supported roof to the atmospheric pressure environment of the new roof. While this has allowed the stadium to open itself to its surroundings, it also resulted in significant changes in mechanical ventilation requirements. Significant fan capacity which had been required to keep the interior of the building pressurized was no longer required. This allowed redeployment of portions of the fan capacity to other tasks such as strictly ventilation and dedication of a portion of the fan capacity to pressurization of exit ramps under fire conditions.

Improving the spectator experience for such a large venue required a comprehensive design of the mechanical and electrical systems. The new roof system incorporates integral building services for lighting, sound, and HVAC. The cable truss roof supports 320 metric tonnes at the centre node; including the centre node connection (126 tonnes with cable connection fittings), the retractable roof receptacle, and the centre hung video board and its hoist. Suspended catwalks support event and house lighting, radiant heating for the seating, broadband wireless transmitting antenna, as well as hoists for the new sound system speaker arrays. The unique optical properties of ETFE are exploited in the façade by an integral digitally controlled LED lighting system allowing the entire façade to be animated in multicolour lighting. Combined with the LED exterior architectural lighting, the entire new roof can be lighted in a dazzling array of animated colour.

Environmental Impact

Prior to proceeding with upgrades to the existing stadium, the other competing option was to demolish the existing stadium and develop a new stadium in order to allow the existing stadium lands to be redeveloped. Three very important aspects of the upgrade option were superior to the redevelopment option. First was the environmental cost of demolition of the existing structure and equipment along with associated dispersal of existing building elements, many of which would likely have been destined for a landfill. Compounding this was the environmental cost of greenhouse gas production associated with building a new stadium. The second aspect was the location of the existing stadium at the transportation hub of the Greater Vancouver region. This includes Skytrain, Seabus, Canada Line and West Coast Express as well as the existing roadway infrastructure. Finally, the stadium upgrade eliminated the need for pressurization of the building, and it incorporated new LED lighting technology, both of which contributed to a significant reduction in energy consumption.

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New Entrance

Column Upgrade – Level 3

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Social and Economic Benefits

From an economic perspective it was determined that redevelopment of the existing stadium was significantly more cost effective than developing a new facility able to host the same range of multipurpose events. Adding to this was the fact that upgrading the existing stadium would continue to take advantage of the existing regional transportation infrastructure rather than requiring new infrastructure to be built to service a new suburban location. Cost of the stadium replacement option was estimated to be in excess of $1.0 Billion with the redevelopment option being less than half.

Adding to this was a continuous value analysis approach which was taken during design and construction. The intent of this was to utilize and upgrade existing building components and systems to the maximum extent in order to capitalize on their value and minimize costs. This not only applied to mechanical and electrical systems but also influenced the selection of the new roof structure. The chosen structure allowed for the complete change from an air supported to gravity supported structure with relatively minor upgrades to the existing stadium structure.

BC Place is an iconic Vancouver facility which has become a centerpiece for not only sporting activities but also numerous other community events. By refurbishing and upgrading the existing facility it will continue to fill this role and with the new operating environment provided by the new roof its place in the community and in attracting a diversified range of events to Vancouver will be enhanced. Not to be overlooked the new roof has allowed the existing facility to open to and embrace the surrounding urban neighborhood creating a more inviting presence to the community.

Meeting and Exceeding Owner's / Client's Needs

The entire project schedule for this undertaking consisted of three distinct phases which covered a period of 4 ½ years. The first phase began in early 2008 and included the initial feasibility phase where the upgrade concept was fully analyzed for viability from and engineering perspective and an economic perspective. Once the concept had been proven design of phase one commenced. This included upgrades to the interior public spaces within the stadium to prepare for the 2010 Winter Olympic functions. The first phase also included a significant amount of structural upgrades to the existing building structure in order to minimize the schedule for the post Olympic phase two construction. All of these upgrades were staged and undertaken within the operating stadium in order to minimize impact on the owner's significant event schedule. Phase one activities were completed in early November of 2009 to allow the handover of the stadium to the Vancouver Organizing Committee for the 2010 Winter Olympics. This allowed for a significant amount of planning and event upgrading to occur prior to the Winter Olympics in February of 2010. Subsequent to the Olympics and the removal of associated temporary installations the stadium was handed back to the owner and phase two construction began in April of 2010. This phase of construction required the closure of the stadium in order to allow decommissioning of the existing air supported roof and construction of the new cable supported roof. All of these activities were undertaken within the existing stadium footprint and surrounding stadium property. This tightly controlled sight allowed this significant construction project to occur with minimal disruption to surrounding streets and property. Concurrent with the roof construction a significant number of additional stadium upgrades were designed and constructed. This included upgrades to existing ramps, upgrades to entrances, three new entrance structures and miscellaneous

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additional surrounding plaza and interior back of house area upgrades. Since the stadium plays such a significant role in the community and in order to minimize disruption to the owner's business and activity plan this work was all undertaken in a period of approximately 18 months to allow the scheduled reopening of the facility in September of 2011.

As a result of the aggressive schedule, as well as close cooperation between owner, designers and contractors BC place was reopened to the public as a virtually new world class facility both on time and on budget and in the process was also the focus of global attention as host facility for the 2010 Winter Olympics.

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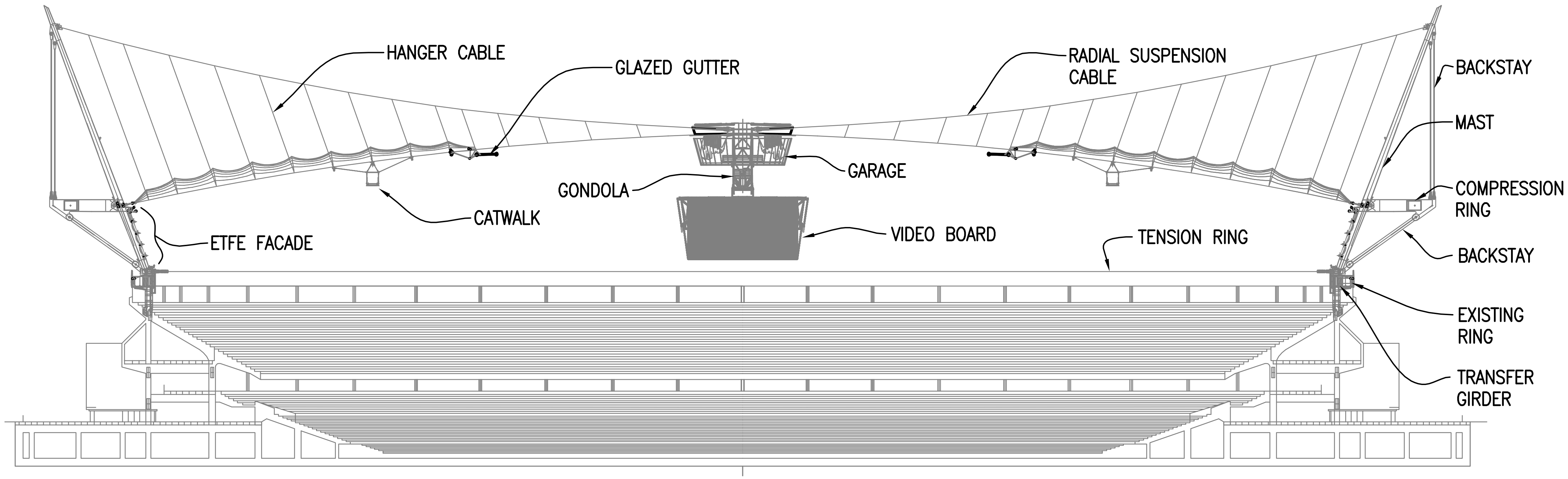

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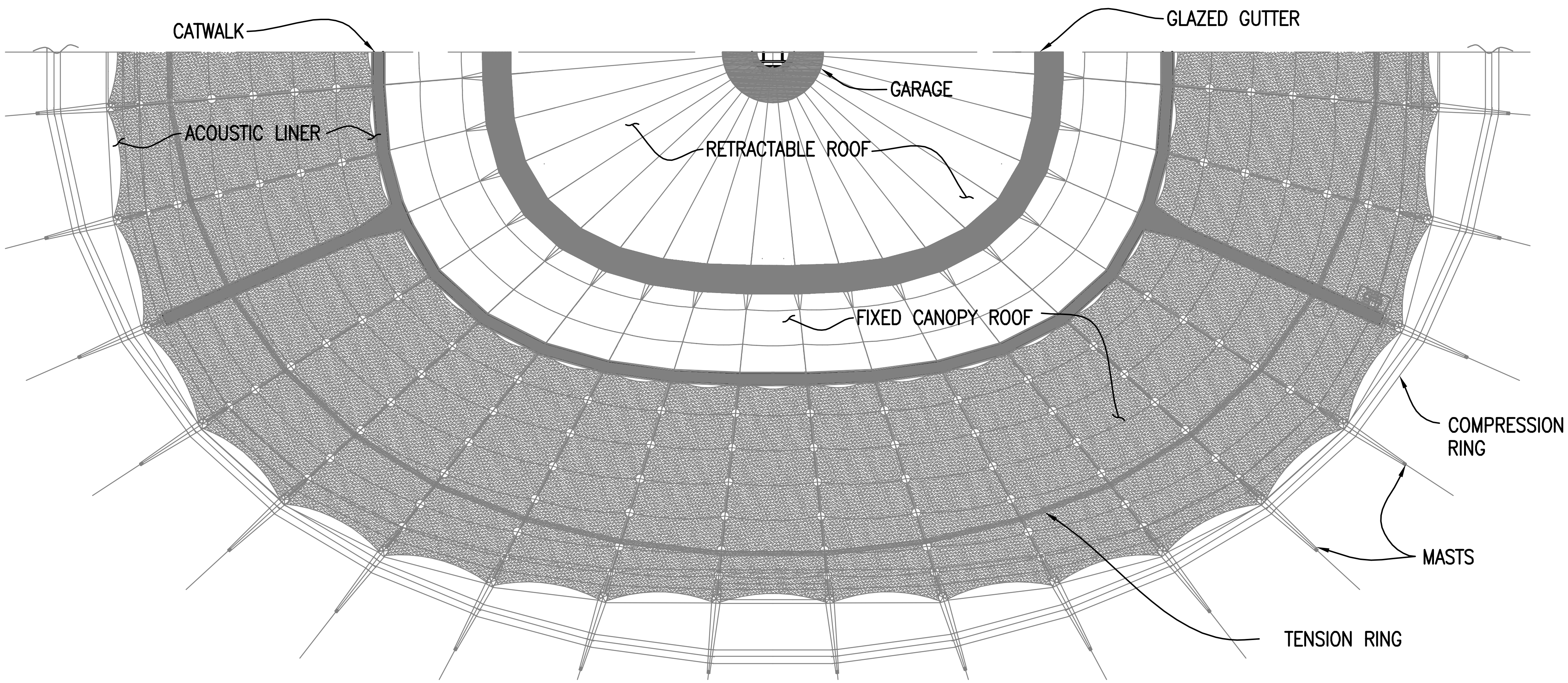

PARTIAL PLAN (REFLECTED CEILING)

GENIVAR
1985 WEST BROADWAY, SUITE 200
VANCOUVER (BRITISH COLUMBIA)
CANADA V6J 4Y3
PHONE: 604-736-5421 FAX: 604-736-1519
WWW.GENIVAR.COM

GEIGER ENGINEERS

PROJECT:

ISSUED FOR – REVISION:

IS	RE	DATE	DESCRIPTION
0		2012/02/07	

PROJECT NO:

DATE: 2012/02/07

ORIGINAL SCALE: N.T.S.

DESIGNED BY: A. PATTERSON

DRAWN BY: JG.

CHECKED BY: G. HUBICK

DISCIPLINE: STRUCTURAL

TITLE:

BC PLACE REVITALIZATION

SHEET NUMBER:

SHEET #: 1 OF 1

REV #: 0

XREF

STAMP