MORRISON HERSHFIELD

# Cloudraker Skybridge and Raven's Eye Cliffwalk

**CANADIAN CONSULTING ENGINEERING AWARDS 2019**
Category B – Transportation

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## PROJECT HIGHLIGHTS

**Heart racing. Knees weak. Do it!**

Cross the 130 metre long, gently swaying, Cloudraker Skybridge, suspended between Whistler's Top of the World Summit and the West Ridge, to reach the Raven's Eye Cliffwalk ... a viewing platform more than 2100 metres above sea level. Anchored into the cliff wall, it appears to be hanging mid-air, with only metal grating and a few clouds separating the valley below! The view is spectacular ...

# CLOUDRAKER SKYBRIDGE AND RAVEN'S EYE CLIFFWALK

## PROJECT INFORMATION

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|---|---|
| Title | Cloudraker Skybridge and Raven's Eye Clliffwalk |
| Location: | Whistler, BC |
| Year Completed: | 2018 |
| To Be Entered in Category: | Category B – Transportation |
| Firm Name: | Morrison Hershfield |
| Firm Address: | Suite 300, 6807 Railway Street S.E.<br>Calgary, Alberta T2H 2V6<br>Canada |
| Role in the Project: | Lead Consultant, Bridge Design and Construction Engineering |
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## SUMMARY

Whistler Blackcomb wanted to expand its tourist infrastructure with a safe yet thrilling attraction. Morrison Hershfield designed a 130 m long, steel pedestrian suspension bridge and a 12.5 m cantilevered viewing platform to do just that. At over 2,100 m above sea level, the Skybridge is thought to be the highest pedestrian bridge in North America. Capable of year-round operation in extreme weather conditions, the structures provide an eco-tourism and economic boost to the resort.

Skybridge main cables were installed using a high-line, pulley and winch system

# Q.1
## INNOVATION

In Summer 2018, the new Top of the World Summit attractions at Whistler opened to the public. The Cloudraker Skybridge and Raven's Eye Cliffwalk are situated at an elevation of over 2100 metres and are believed to be the highest pedestrian structures in North America. These world-class feats of engineering and construction include a new 130 metre long, steel pedestrian suspension bridge leading to a cantilevered viewing platform, anchored into rock and projecting 12.5 metres out from the mountain's edge.

The successful delivery of this grand vision required a collaborative effort between Whistler Blackcomb (Owner) and the design-build team members. Axis Mountain Technical (Prime Contractor) assembled a team of experts, including Morrison Hershfield as the Lead Consultant responsible for overall Bridge Design and Construction Engineering.

Other key team members included Legacy Engineering (Pedestrian Suspension Bridge Specialist), Wyllie Norrish Rock Engineers (Geotechnical Engineer), Alpine Solutions Avalanche Services (Snow & Environmental Loading) and George Third & Son (Steel Fabricator).

### The Cloudraker Skybridge

The 130 m long Skybridge is a steel pedestrian suspension bridge supported and stabilized by four 48 mm diameter steel cables, each with an ultimate capacity of over 2250 kN. The cables are anchored to steel anchor plates tied to 14 – 44 mm Dywidag rock anchors, all embedded via 4 m x 7.5 m x 0.55 m cast-in-place reinforced concrete slabs. The rock anchors are drilled and grouted to the bedrock below with alternating depths of 6 m and 8m.

The geometry of the surrounding bedrock and desire to have pedestrians walk directly on to the bridge without stairs meant that the approach platforms could only be about 1 m above the abutment slabs. The cable anchorages were hidden below the approach platforms so they would not interfere with pedestrian access to the bridge and provide a cleaner appearance. Custom cable spelter connections and adjustable anchor plates were designed to minimize the anchorage length while providing as much adjustment length for the cables as possible. The design allowed for approximately 600 mm of adjustment for the cables at each end of the bridge.

The upper two cables were spaced at 1.8 m centre to centre and were 1.5 m above the lower two cables which were spaced at 1.2 m. This geometry

>> Rock Anchors and embeded cable anchor plates for the Skybridge west abutment slab.

created an inherently stable and self-righting structure. The wider top cables also allow for the deck panels to be placed from above and to sit on the lower cables. The lower cables had a pin-to-pin length of approximately 128 m and the upper cables had a pin-to-pin length of approximately 135 m.

The geometric configuration of the cables was the seed for the final geometry of the deck modules and the abutment headframes. The deck modules had sloped sidewalls to follow the cables. The abutment headframes were sloped so that the end saddles would align with the cable configuration (wider at the top and narrower at the bottom) and they were tilted back to 'bisect' the deflection angle of the cables as they were re-directed down to the anchor points. Balancing the angle on each side of the abutment headframe minimized the unbalanced loading on the headframe, allowing the cable to be as efficient as possible - a true 'form-follows-function' situation.

The Skybridge has 101 removable steel deck modules (1.25 m segments) to allow for decommissioning and maintenance in the off-season. The deck modules have a 1.2 m clear deck width with open grate steel decking and steel wire mesh railings. Each deck module has two rigid transverse frames made from C100x11 (4" deep) channel sections that help maintain the cable geometry. The lower two cables sit in saddles attached to the bottom of the frames and the upper two cables are attached to the frames with U-bolts. To install the deck modules, the module is lowered on to the bottom two cables and seated in the saddles. Then the U-bolts are used to secure the upper cables to the deck module. There is a 20 mm gap between deck modules, and once installed, the deck modules are essentially fixed to the cables.

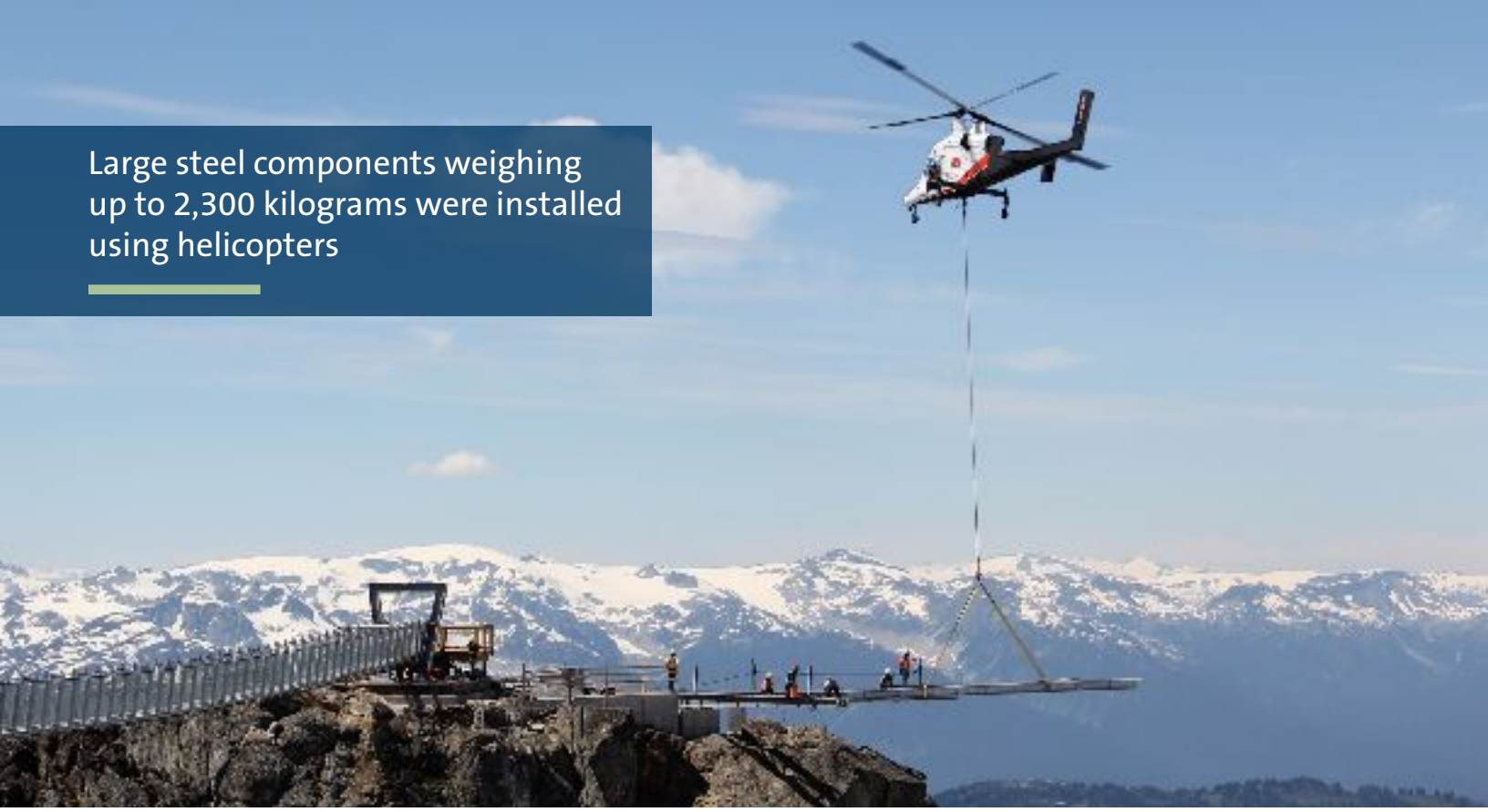
All steel bridge components were galvanized, and a timber approach platform was constructed at each end.

## The Raven's Eye Cliffwalk

The Raven's Eye Cliffwalk is a 12.5 metre long, cantilevered viewing platform. It is supported on four tapered steel beams ranging from 600 mm (24") deep at the abutment to 400 mm (16") deep at the cantilevered end. The beams are connected in pairs, and the two pairs are oriented at 45 degrees to each other to create a 'pie-shaped' configuration with a 12.5 m bridge spanning between the cantilevered ends of the main beams.

The main beams are restrained by a vertical tension anchor foundation at the abutment end and a compression bearing foundation approximately 2.5 m (8 feet) from the tension foundation. The compression foundation is doweled into bedrock using reinforcing steel, and the tension foundation is anchored to the bedrock with six vertical 44 mm Dywidag rock anchors, drilled and grouted to the bedrock below with alternating depths of 6 m and 8 m.

At 2,100 metres above sea level, these are believed to be the highest pedestrian structures in North America.



Large steel components weighing up to 2,300 kilograms were installed using helicopters

The decking and side rails on the Cliffwalk were designed to match the geometry, appearance and detailing on the Skybridge. The clear walkway on the cantilevered segments is 1.2 m, and the width of the end bridge varies down to 600 mm at the midspan to provide some additional excitement. The structure is designed to be fully loaded, but it was intentionally allowed to have a certain level of 'bounce' to it. A keen observer may notice that the overall shape of the Cliffwalk is similar to the shape of the abutment headframes on the Skybridge – in keeping with the owner's desire for an aesthetically pleasing attraction.

## Innovative Design & Construction

### Many non-traditional and innovative approaches were used in developing solutions for this project.

No sway cables were used to stabilize the bridge. A self-stabilizing four cable system was implemented, along with open mesh decking and side rails for wind damping and desired aesthetics. There is a contingency to install sway cables in the future if needed, however so far, the bridge has behaved well with only a gentle rocking behavior in the wind.

Initial project timelines did not allow for the custom order of specialized bridge strands, so the design team utilized available wire-rope type cables. A cable testing program was developed and implemented to determine the cable stiffness properties and to provide some assurance on the anchorage capacity.

The Skybridge abutment headframes and the Cliffwalk main beams and end frame were too heavy to haul and manipulate on site without damaging the landscape and fragile vegetation. Each component weighed up to 2,300 kg, so they were flown into place with a helicopter. The large components were pre-assembled in the fabrication shop to ensure that there would be no misalignments during the critical helicopter installation. The five main steel beams of the Cliffwalk were installed by helicopter in approximately five hours.

The ability to efficiently remove and reinstall the deck modules was a design innovation to mitigate risk. There is some uncertainty regarding the effectiveness of snow removal operations in the winter, and Whistler Blackcomb does not want to impact skiers and snowboarders descending under the Skybridge. Panels were designed to sit on the lower two cables while being installed and removed, and a special cart was designed to run along the main cables to assist in the installation and removal of the deck panels as well as clearing the snow and ice build-up on the cables .

# Q.2
## COMPLEXITY

### Significant logistical and technical challenges were overcome to deliver the owner's vision.

The site was remote, with extreme environmental exposure and limited construction access. Early season construction access drove through a vertical snow cut over 30 feet deep! Delicate alpine vegetation required that the area used for bridge foundations and construction laydown be kept as small as possible to maximize preservation.

Rock anchorage into the fractured bedrock was also unpredictable. Abutment locations were carefully selected, and still one rock anchor required over 70 bags of grout due to it intersecting a seam in the bedrock!

Tight timelines drove the selection of cables and other design and fabrication decisions. Wire rope was selected over specialized bridge strand due to availability. A minimal cable sag was required to satisfy accessibility on to the structure (<10% grade) which also necessitated high cable tensions. A cable testing program was implemented to determine cable stiffness properties and provide assurance on the anchorage capacity of the components. Cable properties were input back into a 3D model to determine cable forces and deformations which was critical as there was only 600 mm of adjustment length for the cables during installation and they had to be pre-cut to length before being brought to site. The cables were successfully installed with final adjustments of less than 200 mm required at only one end of the bridge.

Large components were designed to be light enough for helicopter installation and detailed to be quickly bolted together while the helicopter was hovering.

# Q.3
## SOCIAL AND ECONOMIC BENEFITS

The addition of the Skybridge and Cliffwalk to the Top of the Word Summit has attracted a whole new set of visitors to the peak of Whistler Mountain – not just skiers and mountain bikers. It offers an accessible "WOW" experience that is awe-inspiring and thrilling - yet low-risk - to a wider range of guests, particularly families.

The Skybridge and Cliffwalk broaden the appeal of Whistler Blackcomb, adding diversification to the resort's tourist infrastructure, with year-round possibilities.

Workers bolt and brace the main structural components of the Raven's Eye Cliffwalk

The new attraction is a boost to tourism at Whistler and the surrounding areas, and is already welcoming visitors from around the world. It has helped solidify Whistler's position as one of the world's leading four season mountain resorts, for play, work and investment.

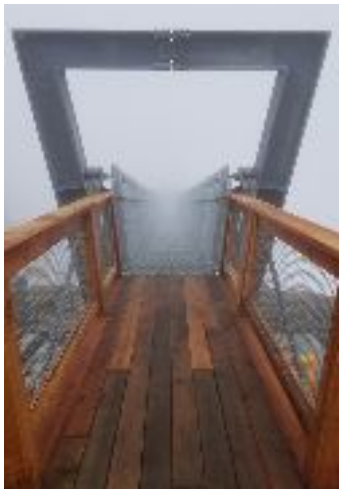
The structures provide a route around the summit of Whistler Mountain with a trail connecting from the far side of the bridge back around to the Peak chair lift. This provides for stunning views of the structures and surrounding mountains as well as of the lichens and wildlife occupying the mountaintop.

The attraction has a clean and sturdy appearance up close, yet slender and thrilling from a distance. Already a popular spot for photographers, the Skybridge is quickly becoming one of the most highly photographed pedestrian bridges in the world ... only a few months after opening. Visitors can enjoy 360° views of the Coast Mountains, with the Cliffwalk platforms providing views of the Whistler Valley and across to Blackcomb Mountain, as well as the famous Black Tusk peak.

## Q.4

## ENVIRONMENTAL BENEFITS

Whistler Blackcomb is known for its commitment to sustainability. This impacts all activities taking place at the resort, including new development, expansions and renovations. The design and construction of the Skybridge and Cliffwalk were respectful of the natural environment, and efforts were taken to minimize and mitigate any potential impacts on the surroundings. The goal was to create an impressive yet unimposing set of structures that fit the landscape to the greatest extent possible, without detracting from it.



To maintain the rugged, organic appearance of the landscape, natural materials were integrated into the bridge and platform design where feasible. Large components were fabricated off-site and set into place using a helicopter, helping to minimize physical damage to the terrain. Steel components were designed to be hot dip galvanized and field assembled with bolts for durability. There was no field drilling or welding.

The bridge and platform foundations were kept as small as possible and the construction laydown area was compact to maximize preservation of the very delicate lichen and moss that grows in this extreme alpine environment. The time to establish some of these species can be hundreds of years and measures were taken to minimize damage so that future generations can enjoy the varied colours that decorate the landscape.

Exceptional collaboration was needed to achieve the owner's vision

The Cloudraker Skybridge is quickly becoming one of the most photographed bridges in Canada

It is hoped that the spectacular experience offered by Skybridge and Cliffwalk will allow visitors to immerse themselves into the vast beauty of the natural landscape, heightening awareness of the intrinsic value of nature and inspiring more environmentally conscious behavior.

## Q.5

## Meeting Owner's Needs

Whistler Blackcomb's goal was to create a thrilling adventure that would attract summer visitors without impacting winter operations. Exceptional collaboration and technical innovation played an important role in overcoming significant challenges to achieve the owner's vision.

Whistler Blackcomb required that the Skybridge and viewing platform be aesthetically pleasing and functional year-round. Both structures are designed to operate in some of the most extreme weather conditions in North America. The structures were detailed to mitigate wind effects, facilitate snow removal, and maintain durability from guests in ski-boots.

To make the bridge accessible to as many guests as possible, it was desired to keep the initial slope onto the Skybridge to 10% or less. This required the bridge to be designed for a very low sag and a correspondingly high level of tension. To complicate matters, the west abutment is 4 m lower than the east abutment. The final design achieved a maximum initial slope on the bridge of less than 10% and a sag of approximately 2.15 m (when empty).

In Summer 2018, the new Top of the World Summit attractions at Whistler opened to the public. The attraction has been very well received in its first season of operation, garnering a significant amount of attention at home and abroad, and the Skybridge is quickly becoming one of the most photographed bridges in Canada!

The bridge was constructed on-budget, and it is safe to say that the final product exceeded the owner's expectations.

Morrison Hershfield