Gordie Howe International Bridge. Approach viaducts.

Puente Internacional Gordie Howe. Viaductos de aproximación

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RESUMEN

El puente International Gordie Howe cruza la frontera entre Canadá y Estados Unidos sobre el río Detroit. Está formado por un tramo atirantado y dos viaductos de aproximación: el del lado Canadá con 432 m de longitud y vanos de 56 m, y el estadounidense, con una longitud de 543 m y vanos de 73 m. Los tableros son de sección mixta, formados por vigas metálicas doble T y una losa de hormigón in situ. Parte del proyecto y toda la construcción estuvo condicionada en el lado canadiense por una subestación eléctrica, que estaba en las inmediaciones. Esto obligó a adoptar una serie de medidas para reducir los asientos, como emplear bloques de poliestireno expandido en los terraplenes de acceso al puente.

ABSTRACT

The Gordie Howe International Bridge crosses the border between Canada and the USA over the Detroit river. The GHIB is made up of a cable stayed section and two approach viaducts: the Canadian one is 432 m long with typical spans of 56 m long, and the US side, has a total length of 543 m and 73m-long typical spans. The superstructure is composite, with steel I beams and cast in place concrete deck. Part of the design and the whole construction was subjected to the presence of an electrical substation on the Canadian side. Some measurements had to be adopted to reduce settlements, like the use of expanded Polystyrene (EPS) lightweight fill, that was incorporated into the design of the approach embankments.

PALABRAS CLAVE: viaducto de aproximación, vigas metálicas doble T, relleno porexpán en terraplén.

KEYWORDS: approach viaduct, Hydro One, steel I beams, composite structure, EPS lightweight fill.

1. Preamble

The Gordie Howe International Bridge crosses the border between Canada and the USA over the Detroit river, connecting Windsor (Canada) and Detroit (USA). It is 2,5 km long and 37,5 m wide and features six lanes for traffic, one multipurpose trail for both pedestrian and bike traffic and two wide shoulders. The GHIB consists of a cable stayed section with spans of 38,5 – 60 – 258,5 – 853 – 253,5 – 60 – 38,5 m, and two approach viaducts that connect to the Ports of Entry in Windsor and Detroit. The Canadian viaduct is 432 m long with typical spans of 56 m long, while the US viaduct, slightly longer, measures 543 m in total length with typical spans of 73m. The superstructure is composite, consisting of steel girders and a cast in place concrete deck. The main span of the cable-stayed section, spanning 853 m, is the longest cable-stayed span in North America and the longest cable-stayed composite deck in the world.

The owner, the Windsor-Detroit Bridge Authority (WDBA), delivered the project through a public-private partnership (P3). Bridging North America (BNA), comprised of ACS Infrastructure, Fluor and Aecon, is responsible for designing, building, financing, operating and maintaining the infrastructure, which includes the bridge and the Canadian and US Ports of Entry. The design-build team was composed by Dragados Canada, Fluor and Aecon, with the design led by Aecom. The total investment reached $4.3 billion.

The bridge is named Gordie Howe in recognition of the legendary hockey player, born in Canada, who played for the Detroit Red Wings.

2. Description

The GHIB approach viaducts are designed as composite structures comprising structural steel and reinforced concrete.

Figure 1. Canadian approach viaduct

The Canadian section features nine spans, with individual lengths of up to 56 meters, resulting in an overall length of 432 meters. Similarly, the U.S. section consists of nine spans but achieves greater maximum lengths of up to 73 meters, totaling 543 meters. Both sections incorporate ten “I” steel girders per span, each 2.4 meters in height, supporting a deck width of 34.85 meters.

Figure 2. US approach viaduct

The vertical alignment of the viaducts includes a consistent gradient of 5% and a horizontal curvature radius of 400 meters. Superelevation varies linearly from 0% at the abutments to a maximum of 5% at mid-curve. The Canadian segment incorporates four expansion joints: one adjacent to the main bridge, one at the abutment, and two additional joints dividing the deck into three equal sections. The U.S. segment includes three expansion joints: one at the main bridge connection, one at the abutment, and one at mid-deck, dividing the deck into two equal parts.

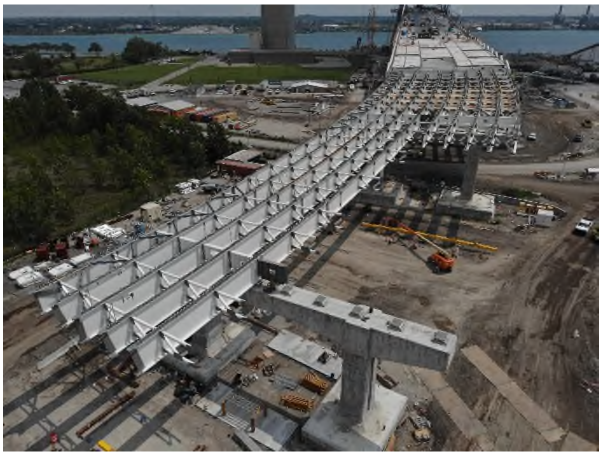

Figure 3. Steel structure

The majority of the piers have independent pile caps for each column, although there are some of them in which the pile cap is unique for both of them. The foundation design employs driven steel piles for both sections, terminating at geotechnical refusal. The Canadian foundation utilizes 406 mm diameter steel pipe piles with 15.8 mm wall thickness (between 13 and 23 piles per column), while the U.S. segment employs HP 410 x 181 steel H-piles. In the Canadian segment, the upper six meters of the piles, with a minimum of three meters below the water table, are encased in concrete to meet the 125-year durability requirement. The encasement was over-drilled by an additional 300 mm to flush contaminants effectively and ensure a clean bonding surface for the concrete. The piles are filled with sand to the bottom of encasement elevation and filled with concrete above. Concrete within the encasement was placed using the tremie method, ensuring continuous placement and minimizing segregation or contamination, particularly in challenging subsurface conditions.

An overflow volume equivalent to 300 mm of encasement depth was included to account for impurities at the base, ensuring that only clean, high-quality concrete remained within the structural section.

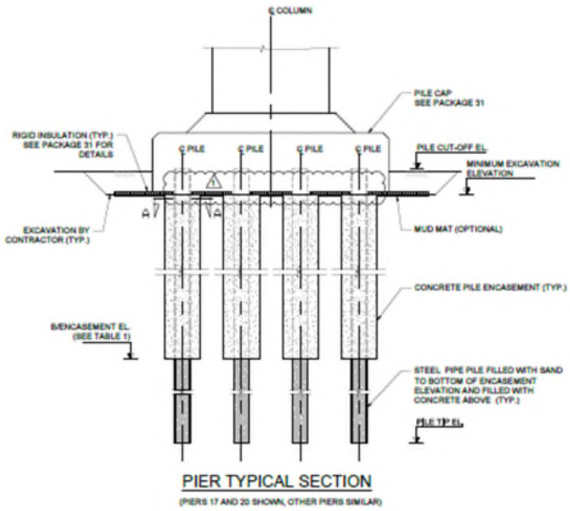

Figure 4. Canadian pile encasement

By contrast, in the US section, H-piles are encased in concrete as well, but in addition they kept in place the steel casing.

The viaduct substructures for both the Canadian and U.S. segments share a standardized design, incorporating reinforced concrete elements with consistent geometric profiles. The pile caps are rectangular in section, providing robust support for the columns. The columns themselves are of rectangular cross-section, optimized for axial load transfer and lateral stability. The pier caps are rectangular in section and are sloped to match the gradient of the deck, ensuring seamless integration with the superstructure and effective distribution of loads. This uniform design approach facilitates constructability and ensures structural continuity across both segments.

Figure 5. Viaduct substructure

2.1. Ground-level walls and their purpose.

The Ground-level walls are a security feature of the bridge. It's purpose is to provide protection from Truck vehicle-borne and Car vehicle-borne improvised explosive devices. The Ground-Level walls are designed to stop a large truck travelling at speed and striking the wall at a ninety degree angle. They are also designed to shield the bridge from the energy from an explosive device located within the stopped truck.

The Security Requirements of the project require that each of the piers and the underside of the bridge deck are protected from impact.

Figure 6. Ground level wall.

3. Erection

Upon completion of the substructures, the installation of steel I-girders was executed using different methodologies for each segment. On the Canadian side, the girders were pre-assembled on the ground into pairs for each full span. This approach provided enhanced stability during installation and additional strength and rigidity to the structure once installed. The pre-assembly method eliminated the need for temporary assembly towers and supporting brackets, simplifying the installation process. This efficiency reduced the labor hours required for constructing the steel superstructure and significantly shortened the project schedule. The paired girders were installed using tandem lifts, employing two cranes to ensure precise placement.

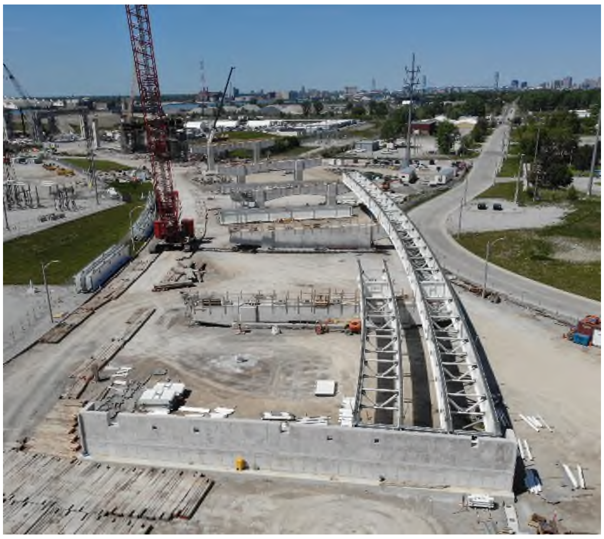

Figure 7. Canadian viaduct erection

Conversely, the U.S. segment followed a conventional installation method, utilizing assembly towers and brackets suspended from the pier caps. Individual girders were installed one by one, which required additional temporary supports but adhered to established practices.

Figure 8. US viaduct erection

3.1. The concrete deck.

After girder placement, the deck slabs were cast in place, completing the composite structural system. Conventional hanging stick forms were employed for slab construction, ensuring accurate geometry and structural integrity.

The Project Agreement specified unacceptable Materials/Systems for the bridge approaches, including stay-in-place formwork.

As a result, this refrained the use of left in place Formwork and precast panels which would have had many advantages if were acceptable such as increased strength and faster construction. Traditional formwork was opted for to satisfy the Project Agreement.

3.1.1. The Bidwell works

A Bidwell was used for placing the concrete deck overlay and concrete at both Approach decks. The use of the bidwell machine has many benefits. The bidwell is capable of levelling and smoothening the surface to the required grade. The bidwell has a tool called a “screed” that moves along the surface of the concrete to remove any excess. The bidwell is also meant to reach very wide areas of desired concrete placement, which means more area is covered more efficiently. The use of bidwell machines is common in North America for large scale projects such as bridges and highways. Bid-Well is an American company which is not yet readily available in Europe, however other types of concrete placement and finishing machines are used. Additionally, many European projects may not require the scale of a bidwell machine and projects may be within the boundaries of restricted spaces.

Figure 9. Bidwell works

4. Special conditions on the site

Hydro One, a very important medium voltage electrical substation, is located just by the Canadian approach viaduct. This had important implications in both the design and erection of this section of the bridge.

4.1. Hydro one and its impact on the project

No permanent works were permitted to be constructed within or beneath the utility owners' easement crossing the Canadian Bridge right-of-way. Subsurface wet and dry utilities required protection from the imposed loads of heavy construction equipment, including cranes, compactors, and trucks. To proceed with construction activities, coordination with utility owners was essential. The Project Agreement (PA) stipulated that the geotechnical design and subsequent construction must account for the presence of utilities and structures existing at the site as of the commencement date. These elements, deemed intolerant to movement or settlement, were required to remain stable throughout the works.

The Construction Joint Venture (BNA) conducted a comprehensive analysis to identify overlap zones between approach structures and utility corridors, incorporating the clearance requirements provided by utility owners. Approved construction techniques were developed and implemented to ensure compliance and maintain the integrity of the utilities and surrounding structures.

4.2. Geotechnical Instrumentation and Monitoring Plan

The foundation design and geotechnical engineering included the development of a Geotechnical Instrumentation and Monitoring Plan for the Main Bridge that addresses the requirements outlined in the Project Agreement. GIMP is required for the protection of the existing adjacent utilities and structures and for maintaining the stability of retaining structures. Geotechnical instruments monitor the magnitude and distribution of deformation and vibration in the soil and on existing structures and utilities.

Any type of construction activity grading will induce settlement of the soft native clay foundation. The clay will experience lateral deformation due to fill placement and pile driving activities. Construction operations such as pile driving will also induce vibrations. Geotechnical instruments are required to monitor the magnitude and distribution of deformation and vibration in the soil and on existing structures and utilities. Monitoring was also used to confirm design assumptions related to embankment/wall stability and settlement rates, and allow construction operations to be adjusted, as required.

Geotechnical instruments are specified to monitor the magnitude and distribution of ground movement within the anticipated zone of influence of construction. This includes settlement in the area of the grade raise, lateral movements immediately behind high fill slopes, lateral movement behind and in front of the retaining structures and settlement of the existing utilities on the site. In addition, instrumentation is considered to measure the pore pressure of the soft clay soils within the area.

4.3. Mandatory use of crane mats

The use of combined dunnage, comprising timber crane mats and steel plates, was deemed essential to safeguard adjacent utilities and structures and to ensure the stability of retaining structures under the imposed loads of cranes during bridge superstructure installation.

Geotechnical analysis confirmed the necessity of this dunnage configuration to effectively distribute surcharge loads safely and uniformly. This arrangement ensures that the bearing capacity of the underlying soils is adequate and that the imposed loads on existing utilities remain within allowable limits.

Additionally, to maintain the structural integrity and functionality of the underlying utilities, Bridging North America (BNA) utilized crane mats to mitigate vibrations and minimize potential settlement. The deployment of crane mats facilitated the even distribution of crane loads, thereby reducing the risk of localized overstress and ensuring the protection of underground infrastructure

4.4. Use of EPS blocks

Expanded Polystyrene (EPS) lightweight fill was incorporated into the design of the approach embankments behind retaining walls to achieve the required grade raise while minimizing the impact on underlying soft cohesive soils. By significantly reducing the applied loads and limiting stress increases on these materials, EPS helps to mitigate potential settlement or damage risks to nearby sensitive utilities. This approach provides an efficient and effective alternative to traditional soil fills in areas where settlement control is critical.

Figure 10. EPS lightweight fill

It should be noted that the work on the construction of the embankment, including earthworks, drainage system deployment, laying of specialized liners and EPS fill, followed by the construction of a distribution slab over the EPS and laying of granular fill, was carried out with constant dewatering of the entire area in three stages, over the course of a year.

5. Changes made to the original design

5.1. The change from H piles to pipe piles in the foundations

The original design of the pier foundations considered six piling options, including: 1-meter diameter drilled shafts, Driven precast concrete piles (610 x 610 mm), and Several H-Pile configurations with varying cross sections. After a thorough cost analysis and review of installation methodologies, H-Piles (410 x 181 mm) were initially selected as the preferred solution for supporting the approach bridge structure.

However, during subsequent evaluations with a preferred subcontractor, a steel pipe pile alternative (406 mm diameter, 15.875 mm wall thickness) was proposed. This alternative was validated based on structural equivalency in axial compression, ensuring that the pipe piles could meet or exceed the load-bearing capacity of the original H-Piles. The advantages of this alternative are described here:

5.1.1. Key Drivers for Design Modification

Artesian Groundwater Mitigation:

Pipe piles demonstrated superior performance in addressing artesian groundwater challenges compared to H-Piles. Their design minimized risks related to water infiltration and facilitated better encasement practices.

Concrete Encapsulation Concerns:

The original H-Pile design posed challenges in achieving consistent concrete encasement, particularly around the pile flanges. Pipe piles, with their uniform circular geometry, simplified concrete placement, ensuring full and consistent coverage within the encasement.

Cost Savings:

The proposed pipe pile solution offered a cost-effective alternative compared to other methods while maintaining the necessary structural and geotechnical performance criteria.

The round geometry of pipe piles enhanced constructability, reduced risks of incomplete encasement, and improved the overall durability and structural integrity of the foundation system.

Design Enhancements and *Durability* Measures to ensure durability and mitigate contamination risks during pile installation and encasement, the following measures were integrated into the design.

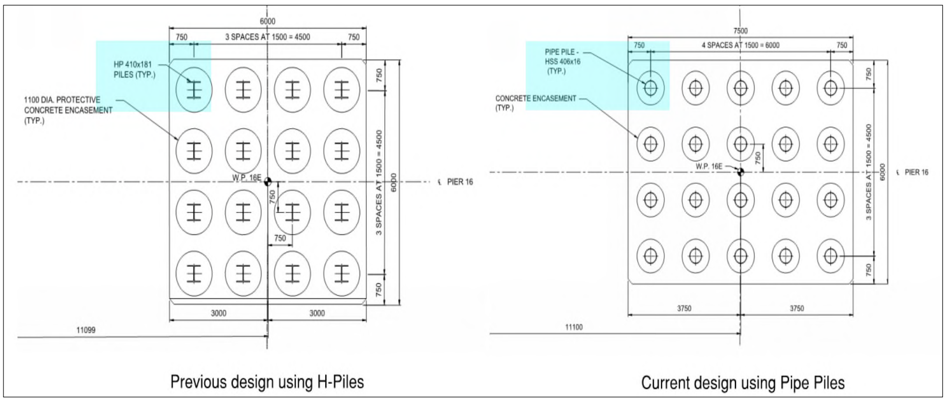

Figure 11. Initial Design and Alternative solution

5.2. The old change from concrete girders to steel girders.

BNA identified concerns with the original design using concrete girders such as torsion and girders buckling during post-tensioning and erection operation.

Due to a 130 imperial ton weight limit for shipping, this was a limiting factor for the length of the segments (38.5m). This resulted in 1 or 2 splices per girder, leading to additional transportation costs and 56% more splicing to be done on the project site.

Alternate girder splices could lead to the misalignment of the girder cambers, diaphragm connections, precast deck and overall superstructure tolerances.

Post-tensioned girder assembly onsite would need to be subjected to different tolerances than those fabricated in the shop.

When concrete girders are lifted, they would need to be checked based on Mast Paper on Lateral Stability of Prestressed Girders. Eccentricity in the PT alignment would need to be considered together with stresses from lifting. The tolerances would then need to be checked for the girders' final condition.

To address these concerns, the decision was made to switch from prestressed concrete girders to curved steel girders.

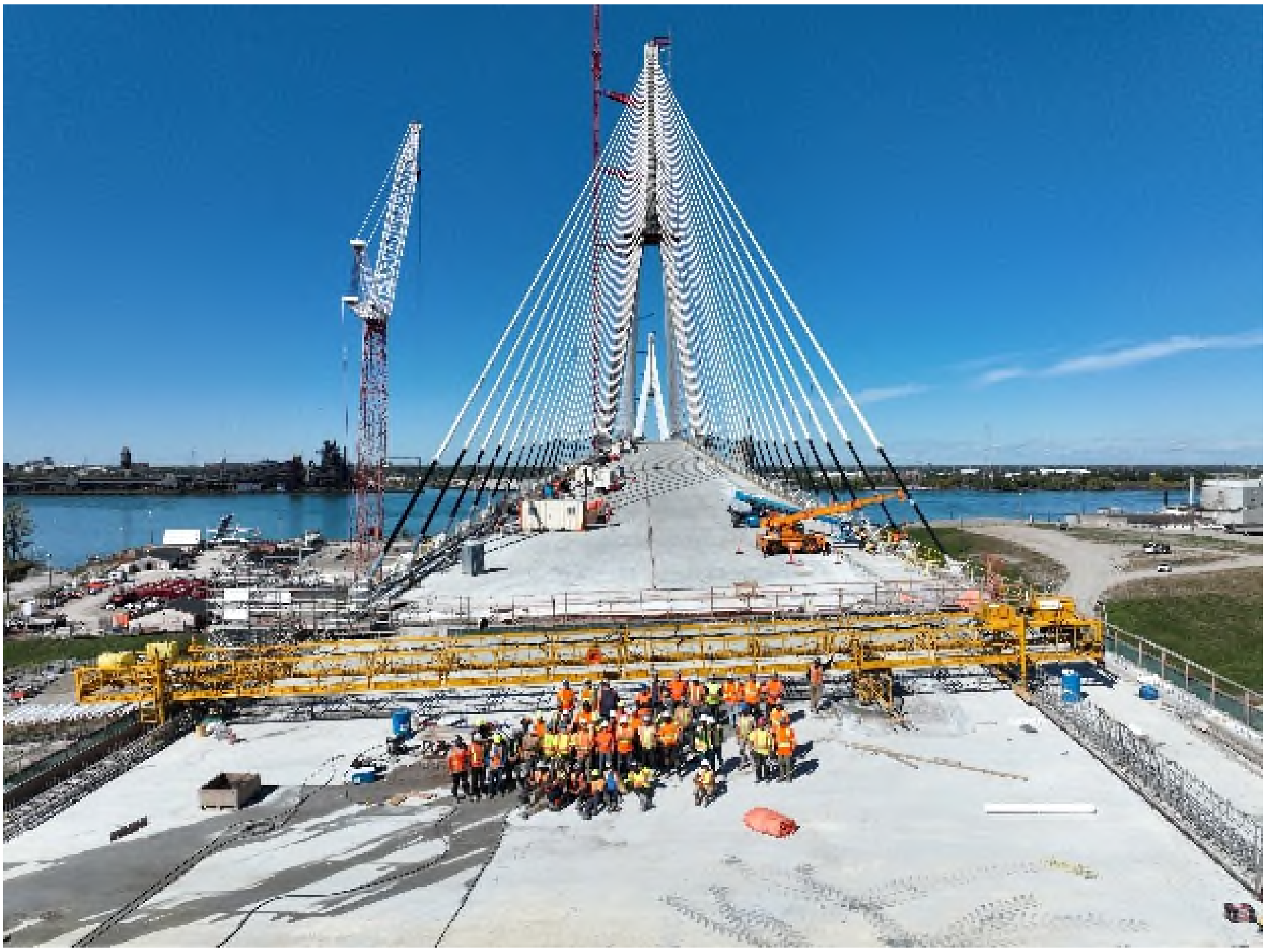

Figure 12. Erection team at Canadian approach

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