Galway Overpass: a Case Study in Bridge Superstructure Type Decision Making

Garrett Smith
Senior GeoStructural Engineer
Atlantic Industries Limited
Sackville, New Brunswick
gsmith@ail.ca

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Abstract

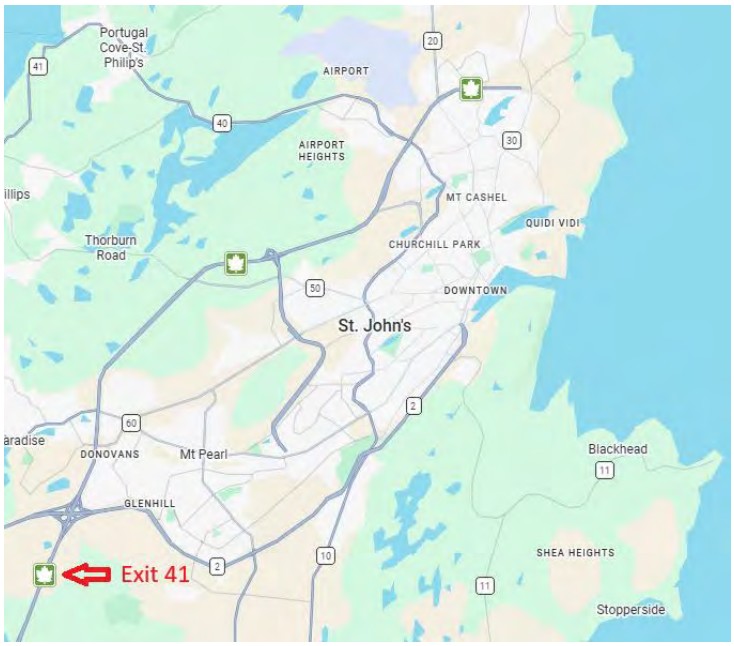
Many factors are involved in selecting the type of superstructure to be used for a crossing. Construction cost, lifecycle costs, durability, sustainability, environmental impact, and societal disruption are just some of the factors that an owner must consider when deciding which bridge superstructure type is most appropriate for their application. The bridge designer will need to consider bridge span, loading, in situ soil conditions, elevation difference between roadways and roadway geometry, among other factors, when deciding which bridge types are suitable for the application. A recently constructed overpass for the Trans Canada Highway located in Newfoundland will be presented as a case study exploring the process of how to select a superstructure type for a crossing to meet the needs of the owner and the designer. The presentation will cover how the durability and design needs of the crossing can be considered in a pre-tender phase to influence superstructure type selection. Additional information will be presented on how to incorporate sustainability concerns into the superstructure type selection including lifecycle assessments.

Introduction

As of 2022, Statistics Canada reports that Canada's inventory of publicly owned bridge and tunnel assets has nearly reached 84000 crossings. Local governments are responsible for managing 59.3% of these assets with provincial and federal governments managing 39.7% and 0.9% respectively (2025). Maintaining existing structures and commissioning new structures is a complex responsibility of all levels of government with the bulk of structures being under the purview of provincial and local governments. With limited resources at their disposal, it is tempting to streamline the bridge asset management decision making process as much as possible. However, by conducting an expanded analysis early in the process, additional design solutions can be considered which have the potential to improve the long-term performance of the crossing. One such expanded analysis was conducted by the Newfoundland and Labrador Department of Transportation and Infrastructure for a recently constructed crossing.

The crossing being studied is the exit 41 overpass located outside of St John's, Newfoundland. Beginning in the year 2013, planning of a new commercial development located between the Trans Canada Highway and Provincial route 2 took place. With the proposed development being bounded by two existing highways, crossings would be required to connect the development to existing roadways. The exit 41 overpass crosses the Trans Canada Highway and allows traffic exchange between the highway, the proposed development and local roads. The location of the crossing relative to Saint John's is shown in Figure 1. The crossing has the Trans Canada Highway traveling over Danny Drive. Danny Drive connects the eastbound and westbound access ramps to the Trans Canada Highway through a pair of roundabouts. The crossing allows for four lanes of traffic bounded by guardrails with service access available on both sides. The clearance box for the main traffic area was set as 14.7m wide by 5 m tall and the service roads each had a clearance box of 3 m wide by 2.7 m tall. The Trans Canada Highway at this location consists of a two lane eastbound lane separated from a two lane westbound lane by a median. The crossing must be able to support CL-625 loading as described in CSA S6 in addition to a heavy haul vehicle defined by the province [2019].

Figure 1 Location of Exit 41 Overpass relative to Saint John's, Newfoundland



Presented with all of the site constraints and conditions, the owner conducted feasibility and predesign studies to evaluate which types of bridge superstructures would be possible for the crossing. The owners identified which criteria were important to evaluate the behaviour of structure. By expanding the breadth of options considered and investing more effort early in the decision-making process, the owner was able to select a structure type that best met their needs.

Feasibility Study

The feasibility study identified seven potential structure types for the crossing. The structure types are summarized in Table 1. Buried structures were considered in both steel and concrete. Concrete prestressed girders and built-up steel plate girders were considered. The girder bridge options were studied in two configurations, a longer span with a 1.5:1 stable slope abutments and a shorter span with mechanically stabilized earth (MSE) wall abutments. Both of the girder options were possible with integral or semi-integral abutments. Lastly, a hollow core slab was considered with a span similar to the shorter girder bridge option.

Table 1 Summary of feasibility options

Structure Option	Material	Span (m)	End Treatment	Feasibility	Recommended for use
Buried	Concrete	25.6	MSE wall	Not feasible	No
Buried	Steel	25.6	MSE wall	Feasible	Yes
Girder	Concrete	27.5	MSE wall	Feasible	Yes
Girder	Steel	27.5	MSE wall	Feasible	Yes
Girder	Concrete	34.0	Open slopes	Feasible	No
Girder	Steel	34.0	Open slopes	Feasible	No

Hollow core slab	Concrete	27.5	MSE wall	Not feasible	No

The concrete buried bridge was deemed unfeasible based on the span to rise ratio of the crossing. The ratio of the span to rise of the structure is set for concrete buried structures. For a concrete buried structure to be considered for the crossing, the span would need to be decreased, or the rise would need to be increased which was not possible. Steel buried metal structures are more flexible in their span to rise ratios and so an option for the crossing was feasible using a shorter rise. All of the girder options could feasibly be used for the crossing with the longer span options requiring larger girder designs. The hollow core slab option was possible with CL-625 loading but the heavy loading renders the design unfeasible. Additionally, concerns were raised about the deflection of a hollow core slab at this span.

The five feasible options then advanced to a predesign comparison phase. Of the five options, the longer span steel girder and concrete girder options were not recommended for use. The simplicity of using sloped abutments did not outweigh the cost and complexity of the longer span. Preliminary designs were then presented for the three options being investigated. In preparing the designs, all three options were designed to CSA S6-19 and Newfoundland and Labrador Department of Transportation's (NLDTI) Highway Specifications Book [2025].

Live loading for the crossing is as previously described in the introduction. Structures were designed for ultimate, serviceability and fatigue limit states. All loading relating to temperature changes, wind, ice and seismic events are as per CSA S6-19. Geotechnical investigations suggested bedrock was located 2 m to 4 m below existing grade on the Trans Canada Highway. All three options would require bedrock blasting. Trans Canada Highway speeds were designed to be 110 km/h while Danny Drive was designed for 60 km/h. TL-5 concrete crash barriers were required on all crossings. All structures would require a detour of the existing Trans Canada Highway during construction. For the girder bridge options, a 225 mm thick cast-in-place concrete deck was required while the buried bridge does not require a concrete deck. The three options all required a 110 mm thick asphalt layer overlaying a waterproofing membrane.

Accounting for these design inputs, preliminary designs for the buried steel arch, the built-up steel plate girder and prestressed concrete girder design were prepared. The buried steel arch was designed using a deeper corrugation steel plate as defined in CSA G401 (2024). Thanks to the in-situ bedrock, the buried steel arch design was able to be placed on shallow footings. The top of the buried steel arch was located 1.4 m to 2.1 m below the Trans Canada Highway and 6.1 m above Danny Drive. For the girder bridge options, both designs were possible with integral or semi-integral abutment design. Options for a prestressed concrete girder with integral abutment and a built-up steel plate girder with integral abutment were developed to compare the performance of concrete girder vs. steel girder. An additional design was prepared for a prestressed concrete girder design with semi-integral abutments to allow for a comparison between the different abutment types.

Design Comparison

With preliminary designs completed for the four options, the owner was able to begin comparison between the options. The categories for comparison were: capital cost, durability/life cycle cost, constructability, project schedule, geotechnical, inspection requirements, impacts to the traveling public, impact on surrounding lands, expandability, aesthetics and overall risk. The four options were

ranked in these 11 categories and each of the categories had a weight assigned to it. Using the category rankings and weighting, the owner was able to determine which of the four options would provide the best performance for the crossing.

Capital costs were prepared for all four options with the assistance of contractors and suppliers. The capital costs consider any aspects of the designs that would differ between the options. The lowest cost option was found to be the buried steel arch. The largest factors in this were the cost of girders vs. the steel plates and the cost of the shallow foundations for the buried steel arch vs. the deep foundation required for the abutments of the girder bridges. Between the three girder options, the semi-integral abutment was found to have a higher capital cost than the fully integral abutment.

Life cycle cost information came from the owner's experience in maintaining comparable bridges in their inventory. Information on durability primarily came from published standards such as the American Association of State Highway and Transportation Officials Load and Resistance Factor Design Bridge Design Specifications (AASHTO LRFDBDS) (2024). The semi-integral abutment was found to be the costliest options, primarily due to the introduction of bearings into the design. Bearing maintenance and replacement represents a large cost over the life of a structure and buried metal arch and integral abutment girder designs are able to eliminate the need for bearings. When comparing the three remaining options, the buried metal arch was deemed better than girder bridges as there are no flanges or ledge to accumulate debris or provide bird roost. The concrete girder option was considered better than either of the steel options as there were no concerns with corrosion, galvanizing loss or recoating of steel over the design life. Ultimately, the buried steel arch and concrete girder option had comparable life cycle costs.

The buried steel arch was found to be the option with the best constructability. The precast concrete girders were notably heavier than any other option and would require larger cranes to position on site. Steel plate girders have lateral instability during construction, prior to the concrete deck being cast which necessitates more construction bracing. With the steel metal arch, it was noted that the initial rings would be more difficult but the remainder of the structure would be easier to erect than any of the girder options.

The semi-integral abutment was the worst option when considering project schedule. The larger abutments lead to longer construction times as compared to the integral abutment options. When comparing the remaining girder options, the concrete option was preferred over the steel option based on the concrete fabrication facility being closer to site than the steel fabricator. While the concrete girders can also be sourced closer to site than the buried steel arch plates, the time to construct the buried metal arch was much shorter. The speed of construction outweighed the travel distance to site and the buried metal arch was found to work best within the project schedule.

When considering the geotechnical impacts of the four options, the buried steel arch was the clear winner as it was the only option that did not require piles. While all of the options required removing bedrock, the buried steel arch needed less bedrock removed than the three girder options. It was determined that it would be feasible to install piles on the site however, there would be additional complications for the construction and the design caused by the bedrock. Between the three girder bridge option, the semi-integral option had more complications caused to its abutments than the fully integral options

The steel girder option was found to be the most onerous option to inspect. The need to inspect the coating of the steel girders made it much more time consuming than the concrete girders or the galvanized buried steel arch plates. Between the two concrete girder options, the semi-integral abutment option was more difficult for inspection due to the girders being supported on bearings. The buried steel arch option is readily inspectable from the inside of the structure however the soil side of plates is not inspectable. The exterior soffits and end treatments of the plates are also easily inspected. The inspection requirements for the buried steel arch and the concrete girder with integral abutments are different but the overall effort for both were deemed similar.

All four options had minimal impacts to the traveling public and were ranked the same. For all options during construction, long term detours were required. The detour maintained all lanes of travel with minor impact on travel speed. Each option would have required temporary lane closures at different points during their construction but the overall impacts of the closure for the different options were similar. After construction was completed, the buried steel arch option provides a seamless driving experience on the Trans Canada Highway while Danny Drive would be darker and more tunnel like. For the girder bridge options, Danny Drive would have been brighter as there is a gap between the two structures. However, this same gap would require additional higher guardrails on the bridges and a change to the shoulder width which changes the driving experience for the Trans Canada Highway.

Overall, the impact on surrounding lands was low for all options. None of the options had an impact on existing land ownership since the footprint of all options would fit on land the owner already controlled. The buried metal arch has the largest footprint of the four options. Vertical clearance for Danny Drive was also slightly less for the buried steel arch option than for the girder options. It was also noted that the road profile for Danny Drive for all four options could be better optimized once an option as chosen and the project advanced to the design phase. No watercourses were located near the structure and the crossing is being constructed under an existing section of the Trans Canada Highway so the environmental impact is expected to be low.

While the crossing is currently only designed for two lanes of travel in either direction on the Trans Canada Highway, the owner wanted to factor the ability to expand the road width in the future into their decision-making process. The soil steel arch is the least expandable of the four options. It is possible to add more rings to the structure to expand its length, however, to do so would require removing and replacing the entire MSE wall end treatment at a high cost. For the three girder options, it is possible to extend the width of the bridge by adding more girders without impacting the MSE walls. The process of expanding the semi-integral abutment option would be more complicated than expanding a fully integral abutment option. The narrower vertical clearance on the buried steel arch also limits the expandability of Danny Drive in the future. All three girder options were ranked equally and the buried steel arch was the least desirable.

Aesthetically, each option had their strong points and weak points but the steel girder option had a slight advantage over the other options. The steel girder bridge was shorter overall than either concrete option giving it a sleeker, less bulky profile. The buried steel arch was noted to have a more aesthetic appearance while on the Trans Canada Highway than the girder options, but the aesthetics while on Danny Drive were worse. Driving on Danny Drive, the user would be in a darker environment and there would also be the formation of white rust on the surface of the galvanized steel. The semi-integral abutment girder bridge was not remarkably aesthetically different to users of the crossing.

The overall risk category attempts to capture all elements of risk associated with the construction and final use of the crossing. The concrete girders had smallest amount of risk associated with material procurement as the girders could be manufacturing in province while the steel arch plates and the steel girders would need to be sourced from out of province. Construction risk was found to be lowest for the buried steel arch option. All other options require bridge contractors to install whereas the buried steel arch can be constructed using less specialized contractors. A negative of the gap between the girder bridges that was identified at this phase is the that the gap will allow snow to accumulate on Danny Drive. The buried steel arch option would prevent snow accumulation on Danny Drive. The lower vertical clearance and curve shape increased the risk of vehicle collisions with the buried steel arches when compared to the girder options. The buried steel arch is a newer and less widely adopted technology with only one other example in Newfoundland and Labrador. The one example of the buried steel arch also had a significantly shorter span of 13.5 m as opposed to the 26.5 m of the crossing under consideration.

Final Design Analysis

After conducting the design comparison, each option was ranked from 1 to 4 in the 11 categories of evaluation with 1 being the best and 4 being the worst. Each option in a category was ranked independently with multiple rankings being possible (i.e. if all options were considered equally, they would all be ranked 1). Each category had a weight associated with it between 0 and 1 with the sum of all weights being equal to 1. The value of the weights was decided by the owner based on their needs and the needs of the site. For a given design option, the ranking in each category and the weight in each category were multiplied together and the value for each category was added together. In this system, the lower the value obtained, the higher ranking the option was. The final rankings for the options were as follows:

- Option 1, Buried Steel Arch: 1.07 (most preferred option)
- Option 2, Prestressed Concrete Girder with Integral Abutments: 1.56
- Option 3, Steel Plate Girder with Integral Abutments: 3.05
- Option 4, Prestressed Concrete Girder with Semi-Integral Abutments: 3.4 (least preferred option)

The buried steel arch was found to be the preferred option with a ranked score of 1.07. This option was chosen for the structure and the project moved into a detailed design phase. In the detailed design phase, the main structural elements of the design were finalized and additional design elements were added to the structure to further improve durability. Erection of the steel arch rings began in September 2023 and was completed in 12 days. Placing of the soil around the structure and construction of the MSE walls took an additional month to complete. Road paving and site preparation was completed the following spring and both roadways were open to the public in summer 2024. Figure *2* shows the as constructed condition of the crossing looking along Danny Drive.

Figure 2 Final construction of the buried steel arch option



Conclusion

After receiving an initial design for a girder bridge crossing, the Newfoundland and Labrador Department of Transportation and Infrastructure expanded their preliminary investigation to include other bridge superstructure types. The investigation considered alternate girder configurations, hollow core slab decks and buried arches. This wide field of options was winnowed down based on the feasibility of whether a design could possibly be undertaken using the bridge superstructure type. The second round of analysis took the feasible options and compared them across 11 categories, ranking each option. The ranking exercise found that a prestressed concrete girder design with fully integral abutments was the best of the girder option but that the buried steel arch design bested all the girder options. Ultimately the buried steel arch option was constructed beginning in fall of 2023 with the structure opening for use in summer of 2024. This process of analysis highlighted several takeaways for bridge owners:

- Including a wider variety of bridge superstructure types at the tendering phase can result in a design that better meets the needs of the owner.
- Conducting a wider analysis early in the process will slow down the project initially as more options need to be considered. However, by spending more efforts engineering early on, later engineering, construction and maintenance effort can be saved.
- Different bridge superstructure types interact with their local environment in unique ways which will change the analysis from site to site. In this situation, the bedrock being close to the surface meant the buried steel arch could make of use shallow footings which saved time, cost and complication when compared to piled foundations for the girder options.
- Setting up evaluation categories and weightings prior to receiving tenders allows for more holistic design factors such as sustainability, life cycle costing and impact on local lands to be considered in the decision-making process.

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