CHANGES IN BRIDGE ENGINEERING, AND
A NEW BRIDGE OVER A UNESCO WORLD HERITAGE SITE

William Victor Anderson, P.Eng., Executive Vice President, Delcan

Sylvain Montminy, P.Eng., Division Manager, Delcan

Abdol Nouraeyan, P.Eng., Program Manager, City of Ottawa

Marcel Delph, P.Eng., Senior Project Manager, City of Ottawa

Paper prepared for presentation

at the

STRUCTURES: BRIDGES IN A CLIMATE OF CHANGE

Session

of the 2009 Annual Conference of the

Transportation Association of Canada

Vancouver, British Columbia

ABSTRACT

Some 35 years ago the St. Patrick Street Bridge over the Rideau River in the City of Ottawa was replaced. It was proposed that the new bridge be an arch bridge, replacing the existing functionally obsolete multi-span concrete arch which had been at the site since the 1920s, but respectful of the heritage of the site and the crossing. However, in the then-prevailing climate of bridge design, a more conventional post-tensioned concrete multi-span slab bridge was selected for design, and it was constructed in 1975. It might be described as functional but perhaps uninspiring.

Since then the steel box girder Hunt Club Bridge has been constructed over the Rideau River, and the Cummings Bridge has been rehabilitated, amongst other bridge works over the river. Similarly the Bank Street Arch Bridge and the Plaza Bridge over the Rideau Canal have been restored. As well, in the intervening years the Rideau Canal has now been designated as a UNESCO World Heritage Site, and is on the National Register of Historic Sites in Canada.

It is now proposed that another new bridge over the Rideau River and Rideau Canal be constructed near the south limit of the City. The development of this project to include a beautiful new Rideau Arch Bridge spanning the river (and the canal which at this location joins the river) offers the opportunity of examining the significant changes which the bridge design and engineering process has undergone since 1975. The new bridge is considered to have the potential to be a gateway to Ottawa, and a landmark in the National Capital Region. In addition, the new bridge design respects the fact that this is a UNESCO World Heritage Site on a beautiful reach of the river and the canal.

Beyond that however, it is our goal to so design the bridge so that it has a strong net positive environmental effect on the site. This can arise if the engineering design of the bridge itself can create a bridge which offers a strong positive social and cultural benefit, not only from the perspective of several modes of transportation but also from the intrinsic artistic character of the bridge.

This paper follows the evolution of the changes in bridge engineering exemplified by the St. Patrick Street Bridge of 1975, to the current artistic and environmentally-positive approach to bridge engineering built into the proposed new Rideau Arch Bridge, which is intended to inspire the passers-by and contribute in a beneficial way to the City of Ottawa.

CHANGES IN BRIDGE ENGINEERING, AND A NEW BRIDGE OVER A UNESCO WORLD HERITAGE SITE

Bridge engineering has a long and honourable history dating back to such landmark structures as the Anui Arch Bridge in China (also known as the Zhaozhou Bridge), which was constructed in 591 to 599 AD, and the Alcántara over the Tagus River in Spain constructed by the Romans in 104 to 106 AD. These bridges remain in service today as a testimony to the skills of the designers and builders, and to their mastery of the art and science of bridge engineering design and construction. These bridges also have considerable and well-recognized merit from artistic and aesthetic perspectives and they can, we believe, be considered to add positively to the environments in which they are found. They are, in fact, the most interesting and noteworthy elements of those environments. We will return to this idea at the end of this paper.

Figure 1 Alcántara Bridge over the Tagus River

Background

Over the centuries, the requirements for durable and functional bridges were often met most successfully by the use of techniques very similar to those used in ancient bridges. For example, stone arch structures have been constructed over the millennia.
With the coming of the industrial revolution in Britain, the exclusive use of stone for durable bridges and of timber for less durable bridges was augmented by new materials including iron in

the 18th century, and steel and Portland Cement concrete in the 19th century. In the 20th century, the use of high-strength steel for pre-stressing and post-tensioning was introduced. These materials remain today the principal materials used in significant and durable bridge construction. At the same time, the processes and regulatory requirements, which bridge engineering design and construction projects must deal with, has also changed significantly. No doubt, the Roman designer of the Tagus River Bridge had to go through an approvals process and to deal with cost considerations, organizational issues, and so on. Thomas Telford, the first President of the Institution of Civil Engineers in London, and the father of modern civil engineering in Britain, sometimes had trouble getting his bills paid and complained of having to go out personally to seek payment, a process sometimes involving cold and uncomfortable rides in horse-drawn coaches. Consulting engineers even now still have such issues from time-to-time, even if horse-drawn coaches are no longer to be found. So, there are many elements of bridge design and construction works which have been constant, we can reasonably assume, since the inception of efforts to construct significant, permanent, durable bridge works.

Another apparent constant throughout history is that bridge designers often made attempts to construct bridges which were not only durable, safe and practical, but which also had some element of beauty or aesthetic built into their fabric. Sometimes this arose as a result of a very clear application of engineering design principles, as in the case of the bridges of Robert Maillart in Switzerland, and sometimes it occurred as a combination of bridge engineering and decoration as in the case of the Pont Alexandre III in Paris. There are, of course, many exceptions where, for one reason or another, the bridge designers either did not try or were not allowed to incorporate aesthetic appeal into their bridges.

Figure 2 Pont Alexandre III in Paris

The Climate of Change in Canada

With this history as background, over the years there has been a gradually evolving climate of change enveloping the design and construction of bridges in Canada. There are many examples of this but, in order to illustrate the key issues, we refer in this paper to four projects in some detail, which cover the most recent 35 years of bridge design. These include:

- The Cummings Bridge.
- The St. Patrick Street Bridge.
- The Hunt Club Bridge (now called the Michael J.E. Sheflin Bridge).
- The Strandherd-Armstrong Bridge.

All of these bridges cross the Rideau River in the City of Ottawa.

The paper refers also parenthetically to a number of other bridges from the population which crosses the Rideau River and/or the Rideau Canal in Ottawa, such as :

- The Plaza Bridge.
- The Bank Street Bridge.
- The Heron Road Bridge.
- The Bytown Bridges

Figure 3 Bank Street Bridge

The recently evolving climate of bridge engineering design and construction can be illustrated by reference to this suite of historical and modern bridge projects.

The key changes that have taken place, in our view, over these years include the following:

- A period in time, now past, where there was a willingness to construct in the urban environment bridges which were best suited to highways.
- A renewed interest in the value of heritage considerations, and what is called in French the "patrimonie" of the country and, in this case, of the City.
- A willingness to consider re-creating the past in some special instances where this is appropriate.
- A more significant willingness to consider rehabilitation rather than replacement even where rehabilitation is a very significant undertaking compared to bridge replacement.
- A new awareness of the value of good, integral bridge engineering aesthetics.
- A clear recognition that good aesthetics cannot be glued onto a bridge by engineers or architects, but must be built into the fabric of the bridge.
- A willingness to allow architects and artists to participate on bridge design teams in some capacity.
- A recognition of the significant social and cultural benefits which can accrue from a properly-engineered bridge which has superior aesthetics and appeal.
- A recognition of the role of life-cycle costing in the selection of appropriate details.
- The effect of the Environmental Assessment Acts.
- The effects of changing technology and the availability of computers.

All of these are political and socio-economic or technical features of the overall climate in which bridge engineering has been conducted for the past few decades in Canada. The issue of climate change as understood in the literal sense, is not examined here as it has really no effect on a major bridge over the Rideau River as far was can be determined with current data, and it did not figure in the selection of the bridge or in its design.

Perhaps all of this will point the way to the future, although no doubt it holds many surprises for bridge engineering designers and constructors.

St. Patrick Street Bridge

By way of illustrating some of these points, we start with the St. Patrick Street Bridge. It is currently a multi-span, cast-in-place, post-tensioned concrete bridge derived from the highway bridge technology brought to Ontario by the Ministry of Transportation of Ontario in the 1960s from Germany. It is a sleek, shallow, smooth structure, supported on four reinforced concrete piers founded in the river. The bridge was designed and certified by Vic Anderson. The bridge was built to replace a multi-span, cast-in-place, reinforced concrete arch structure, which dated from the 1920s and which, in turn, replaced a previously-existing structure. So, it is interesting to note that our original recommendation in the 1970s was that a concrete arch structure be constructed at this site. This was intended to pay some tribute to the previously-existing bridges on the site and to enhance the environment with an aesthetically-pleasing structure, which would not alter the overall neighbourhood aesthetic.

The arch bridge schemes considered for the replacement of the 1920s St. Patrick Street Bridge included replacement essentially in kind by open spandrel concrete arches and the construction of a faux stone arch structure, constructed in concrete of course, but echoing other stone arches in the area including the Chaudière arches on the Ottawa River. In retrospect, this faux arch was probably not particularly suitable but it did have (admittedly tenuous) links to the history of bridge construction in the Ottawa area and a quiet, peaceful demeanour overall compared to the sharp-edged, post-tensioned concrete bridge, which ultimately was built.

In the event, however, the time was not right for such a recommendation. Other schemes which were considered included precast pre-stressed concrete girders, which were deemed to be too utilitarian in appearance; and steel box girders, which would have been more practical than post-tensioned concrete but which the owner did not wish to adopt.

Steel box girders and post-tensioned concrete slab bridges were ultimately short-listed, with the post-tensioned concrete bridge being selected by the owner for implementation. This created a bridge design which required a very significant intrusion into the Rideau River to enable not only the construction of the piers, but also the supporting of the concrete deck on falsework. While the effect on the hydraulics of the river was an obvious consideration, issues such as fish habitat were not at that time, and the bridge was constructed by the use of earth cofferdams, and such measures as falsework supported on timber on the riverbed. While this created some adventures during construction, and included some risks which had to be carefully controlled, the bridge proved to be constructible and it has served well for more than 30 years. It seems likely, however, that no such bridge will be built in the Rideau River again.

Figure 4 St. Patrick Street Bridge

There was however a glimmer of the future on the St Patrick Street Bridge as, while it was designed to carry 6 lanes of traffic, it has never done so. Instead 2 traffic lanes were given over to bicycles. In addition, attractive decorative low level lighting was provided to the bridge. This however proved to be too attractive and too low, as soon the local youths were wearing the decorative amber-tinted lighting globes around town, as they made handy space helmets. After some attempts to maintain the lighting, it was in due course removed, a victim of vandalism.

Heron Road Bridge

The Heron Road Bridge is an example of a high level concrete girder bridge comparable to the Hunt Club Bridge (see below) in scale and height. This bridge was constructed in 1970. Unfortunately, part of it collapsed during construction. The collapse was caused by a failure of high scaffolding, which supported the bridge during the pouring of concrete in the bridge superstructure. In the current climate, such a structure would almost never be built. Instead, in all probability, long span steel would be used to effect the crossing, or a technique such as segmental concrete, or long span concrete girders, might be adopted. Arch schemes might also be considered.

This bridge, like St Patrick Street Bridge, reflected the ethos of the time as to bridge selection, namely an interest in aesthetics tempered by an emphasis on modernity as then perceived, as reflected in fairly sleek, linear, smooth, unadorned and rather conservative designs. Ideas such as the use of arches, while considered at some length, were ultimately set aside for more simple linear structural forms. As well, environmental considerations (such as fish habitat and spawning, tree conservation and the like) were not considered explicitly, and the effects on the social and cultural environment were not given high priority.

Figure 5 Heron Road Bridge

Hunt Club Bridge

In the 1980s, steel box girders were adopted for the next bridge over the Rideau River, which was the Hunt Club Bridge. This is a high level, graceful, haunched steel box girder structure. It can be seen that it is an advance in thinking in some respects in the context of this river. For example, it spans completely over the river with a 100m clear span so that construction could be accomplished without any permanent or temporary interference with the river. This quelled some concerns with regard to the natural environment. Its curvilinear soffit echoes the curves of some of the more graceful structures on the Rideau system, including Bank Street Bridge, which, in our view, is an iconic bridge on the Rideau Canal.

The construction of the Hunt Club Bridge also made use of the waterway in an optimum fashion in that large steel sections were brought to the site by water from Montreal, through the lock system on the Rideau Canal, and then lifted into position at the bridge site. This is in contrast to the St. Patrick Street Bridge, where the water was a considerable difficulty for construction of both substructures and superstructure. Hunt Club Bridge is derived from conventional highway bridge technology but it was carefully thought through in order to fit well with the site, and with pleasing aesthetics overall given its considerable scale and substantial depth of construction.

Figure 6 Hunt Club Bridge

Plaza Bridge

Whereas the 1920s spandrel arch St. Patrick Street Bridge had been demolished in order to make way for a new modern structure in the 1970s, by the 1980s, the climate had evolved whereby much more consideration was given to the possibility of ridge rehabilitation rather than bridge replacement, even when very little of the original structure might remain when the rehabilitation was complete. This technique was used in the restoration of the Plaza Bridge in downtown Ottawa adjacent to Parliament Hill and crossing the Rideau Canal just above the flight of locks at the Ottawa River.

While consideration was given to replacement of this bridge, and substantive schemes were developed for such work, bridge rehabilitation was ultimately adopted, partly with a view to the heritage and historical value of the old Plaza Bridge. A lot of care was taken with the associated architectural features and landscaping, and the result is a very pleasing completed project compatible with nearby historic structures such as the Parliament Buildings and the Chateau Laurier, as well as with the overall aesthetic of the Rideau Canal including the retention of the curvilinear soffit of the bridge where it crosses the canal.

Cummings Bridge

Similar considerations led to the 1990s rehabilitation of the Cummings Bridge, a reinforced concrete spandrel arch. Very little of the original structure was, in fact, retained during the rehabilitation as a result of the very poor condition of the bridge, but the arches remain in service and the bridge, as reconstructed, restored this fundamentally elegant bridge crossing to its original appearance. Considerable efforts were made with such features as handrails and lighting to ensure a thoughtful restoration. One can imagine the tremendous difference had, for example, a precast concrete girder bridge been constructed at this site. No doubt, such a precast concrete girder bridge would have been less expensive in terms of capital cost, but it would have been much more expensive in terms of social and cultural effect as a very negative and brutal intrusion upon the urban landscape. In the past 40 years, such intrusions have become virtually unthinkable, fortunately.

Figure 7 Cummings Bridge

Bytown Bridges

That is not say that precast, pre-stressed concrete has no place in the urban context, or even on the Rideau River. In fact, it has been used in this century at the Bytown Bridges just above Rideau Falls, where it was desired that a minimalist, very low level structure be replaced by a new similarly low profile, low impact structure. Here, the road profile precluded many options and the desire to subdue the crossing rather than make it a feature was a design parameter. This arose from the fact that the bridge is nearby to the Prime Minister's residence and to Rideau Hall, the Governor General's residence, and was part of a contiguous ceremonial route on Sussex Drive. The bridge was subservient to these features and the focus was on the bridge roadway and sidewalk surfaces and ancillary features, not on the superstructure itself.

Figure 8 Bytown Bridges

Strandherd Armstrong Bridge over a UNESCO World Heritage Site

All of this history came to bear on the process by which the Strandherd Armstrong Bridge over the Rideau Canal and River was developed.

It was appreciated very early that this was a bridge on a special waterway and accordingly the Owner, the City of Ottawa, commissioned the definition of aesthetic design criteria for the crossing. This work was carried out by DTAH Architects. The DTAH aesthetic guidelines are summarized briefly as follows:

- Distinctive new bridge in a spectacular, natural setting.
- Respectful and sensitive to Rideau.

- Scenic, natural and cultural heritage context.
- Look and feel special, not just another highway bridge.
- Pleasing to the eye by day and night, close and from a distance.
- Bridge should exhibit landmark quality.
- Harmonious with natural setting.
- Respond to history of engineering innovation and evolution of high quality bridge design on the Rideau Canal, yet be an expression of its own time.
- Support a safe, enjoyable and memorable experience on and under bridge.
- Enable visual compatibility with future adjacent LRT bridge.
- Piers not permitted within river.
- Abutments should not interrupt existing shoreline.
- Locate utilities in concealed locations.
- Form of structure an honest expression of its function.
- Size and shape of structural elements appropriate for structural task.
- Architectural expression and detailing of its time.
- Appropriate materials for their function to express inherent nature.
- Simplicity of form, not monotonous.
- Economy in design.
- Minimum number of components.
- Minimum dimensions.
- Clean, uncluttered lines.
- In scale with surroundings.
- Good proportional relationships amongst bridge components.
- Minimize visual impact of structure.
- Maximize transparency and lightness through the structure.
- Provide harmony and visual balance using order, symmetry, and rhythm.
- No visual confusion.
- Structure symmetrical about central axis provides a natural balance.
- Rhythm and visual flow provide contrast and complexity to relieve monotony.
- Consider manipulating solid and void to allow play of light and shadow.
- Surface texture to provide visual interest.
- Colour to help integrate bridge into surroundings or focus eye.
- Bridge to be visually pleasing decades after construction.
- Avoid extremes of current fashion or overtly historisist references.
- Quality and durability of base materials.
- Good design and detailing.
- Regular maintenance procedures.
- Achieve landmark quality.
- Review previous bridge crossings and incorporate references in the new bridge if appropriate.
- Go beyond typical highway bridge structural type with regard to aesthetics and structure.
- Review design of previous bridge crossings
- Consider introducing local stone, steel, and wood.
- High-quality materials and premium appearance.
- Protect against adverse environmental effects.
- Minimize maintenance.
- Rigorous and consistent approach to details and connections.
- Introduce texture and colour and visual interest.

- Opportunities for users to learn about Rideau Canal.
- Interpretative signage.
- Public art.
- Consider views of the bridge and from the bridge.
- Use continuous open metal railings.
- Consider use of stainless steel, aluminum or premium custom-colour paint finish over steel for railings.
- Enhance design of barriers between pedestrian and traffic.
- Lower-height concrete inner barrier with metal railing instead of full-height concrete barrier.
- Custom design metal railings instead of chain link fence.
- Enhance barrier wall terminations.
- Provide good, high-quality lighting.
- Above-deck pedestrian scale lighting.
- Minimize number of pole systems by integrating support for lighting and pedestrian scale lighting, if possible.
- Sufficient accent lighting to enhance night time illumination of bridge.
- Minimize exposed area of abutment faces to decrease visual weight.
- Increase sense of integrating with the topography.
- Incorporate textural effects in poured-in-place concrete or accent with stone.
- Convenient and accessible pedestrian movements.
- Landscaping to reinforce naturalness of setting.
- Naturalize planning approaches and embankments.
- Naturalize slope treatment under bridge such as selected river stone laid into concrete.

As one can see, these were very comprehensive, and very much more detailed and formal than the criteria used in the 1970s, which were undocumented essentially.

In addition, many ideas were received from the distinguished members of the National Capital Commission Advisory Committee on Planning, Design and Realty. For example, these included:

- Recognize the historic context of the Rideau Canal.
- Refer to how the design for the bridge is true to the intentions of the aesthetics guidelines developed by DTAH.
- Design should enhance the experience of the Rideau Canal from a heritage waterway system perspective, both approaching and leaving it.
- Imperative that bridge be sensitively integrated into the site context.
- Reduce the bridge’s visual impact.
- Keep the structure as light and transparent as possible.
- Avoid heaviness.
- Break down the scale of the bridge.
- Seek to achieve a delicate rather than a massive structure.
- Ensure a positive experience under the bridge for pedestrians and boaters by day and by night.
- Note that colour will contribute to the experience.
- Great degree of openness should be achieved.
- Explore ways for natural light to penetrate the structure.
- Possible gateway to the National Capital.
- It should be perceived as an “urban marker”.

- Design to be a distinct and cohesive object with the ability to astonish and inspire viewers “in the round”.
- Design to reflect importance and location of the larger context (i.e., the Rideau Canal navigable waterway from Kingston to Ottawa).
- Refine and harmonize design details of bridge.
- Achieve a unique ensemble and character for the bridge, rather than an assembly of separate parts.
- Keep lighting levels as low as possible.
- Quality and quantity of night light to be handled sensitively.
- Design pedestrian pathway noting it will be seen from afar.
- Pedestrian pathway should be a fine experience for pedestrians, so bridge should provide a secure and dynamic crossing.
- Use wood and texture for the pedestrian pathway, recommended to create a slower ambiance on the bridge.
- Protect pedestrians from adverse climatic conditions including water and slush spray and from snowplow clearing and ensuing accumulation.
- If colours are too light, bridge could appear to be constructed of concrete and its width could be further emphasized.
- Important for the width of the bridge to be reduced visually.
- Use of Rideau Canal system’s existing palate of materials, finishes and colours thought to be good design direction.
- Materials that reflect the light or the effect of light on the water’s surface should be used wherever possible
- Landscaping to be coherent with water and pathways; no afterthoughts.
- Landscaping to evolve with the area around it from a more naturalistic approach to one reflecting the urbanization of its setting.
- Strong, calm, natural re-vegetated setting recommended.
- Slope under the bridge could reflect the Canadian Shield.
- Design overall to enhance the experience of being associated with water.

As bridge design engineers we tried to absorb and synthesize all of this information. We were particularly struck by the idea that the bridge be a distinct and cohesive object with the ability to astonish and inspire viewers “in the round”, while at the same time we were very alert to the fact that the bridge had to be compatible with the fact that this bridge was to cross a World Heritage Site which was also on the National Register of Historic Sites. In addition we had a very interesting population of bridges already on the river and canal systems, and our own history of bridge design and construction works on these waterways.

It is often suggested that bridges should “blend with the environment” which, in fact, they almost never do. The only bridges which really blend with the environment are very small, insignificant bridges that are made of natural materials such as stone and possibly wood. The more common construction materials for modern bridges cannot really blend with the environment for bridges of any scale. The Strandherd Armstrong Bridge over the Rideau River, with a span of about 125 m and a basic width of some 40 m, cannot blend with the natural environment riverscape and treed lands which exist there. Instead, our goal was to enhance the environment, creating a bridge which is respectful of the river, and which is deemed to be a feature of particular significance and beauty. For such a wide bridge with a relatively short length, this is a fairly daunting task which requires some creativity.

So we were determined to produce a bridge project which was deemed to have a net positive environmental effect, rather than struggling to mitigate negative effects. The key to this was to introduce features that enhanced the social and cultural environment substantially. An example of this is the Humber River Arch Bridge in Toronto, where the bridge successfully changed the environment for the good, specifically from a cultural and social perspective.

All of this came together to produce a unique new bridge design for this crossing.

This process has been led by the owner of the project, the City of Ottawa. Delcan is the Bridge Designer, and Delcan's team includes DTAH architects and a number of specialist consultants including for example for lighting. Traditionally engineers and architects have not had the smoothest of relationships on bridge projects, as engineers are trained to design bridges, whereas architects generally are not. Nevertheless, architects can bring some interesting insights to a bridge project such as this one, and we have found the working relationship to be positive and beneficial. All of the basic ideas for the bridge were developed by Delcan; but the refinement of these ideas, and the testing of them against alternatives, was greatly assisted by the architects. It is this process of fun collaboration which has in the case of this project, contributed so much to a design scheme which has met with great enthusiasm on the part of the stakeholders and the public.

There are occasions when a star architect is retained on a sole source basis to provide a bridge architectural design which essentially bears that individual's imprint and which, indeed, is the architect's signature. Such undertakings result in bridges which can be very spectacular and which comprise a personal statement, sometimes divorced from the context of the site. These projects may be intended, in fact, to dramatically alter the characteristics of a site and become the dominant feature in the environment.

Another somewhat diametrically opposite approach is to attempt to blend the bridge in with the environment. This is sometimes put forward as a goal, the idea being that the bridge should be low-key in the context of the environment and effectively rather unobtrusive. This rarely works. Sometimes combinations of these approaches are used, depending upon the environment context.

There is a considerable range of bridge types which were considered for this site.

Obviously some bridge types lend themselves to one or the other approach, or to some median approach. For example, a suspension bridge such as Golden Gate is the dominant feature of the landscape, whereas, the typical highway overpass is something which does not excite wonder or comment.

We comment here on the various bridge types which were considered at the Strandherd Armstrong Bridge site over the Rideau River very briefly as follows:

- The most fundamental bridge type is probably the **slab bridge**. In their ancient configuration, these bridges were known in Britain, for example, as clapper bridges, and they comprised stone slabs sitting on stone piers. These slabs would span a few feet. Modern slab bridges can attain considerable spans and, for example, the St. Patrick Street Bridge over the Rideau River is effectively a slab bridge; in that case, a prestressed, cast-in-place, voided continuous concrete slab. Such bridges are more typically used as motorway overpasses. They tend to have clean, sharp lines and are capable of curvilinear alignments.

- **Open girder bridges** can attain greater spans than slab bridges and they include a variety of configurations such as precast, prestressed trapezoidal concrete girders; precast, prestressed concrete I-girders; structural steel I-girders; structural steel trapezoidal box girders; and various other configurations generally including a concrete deck for conventional bridges. The Highway 416 Rideau River Bridges are examples of such structures.

- **Closed concrete box girders** are an option compatible with intermediate to longer spans. They are generally associated with highway interchange designs.

- **Closed steel box girders** are an option which is compatible with relatively long spans with or without cable supports. Such bridges include orthotropic steel decks and, while they are relatively costly, they may have some advantages in terms of durability.

- **Truss bridges** are used for relatively small span bridges up to very large spans. Such bridges are rarely built now for various reasons including cost, maintenance issues, and perceived issues with regard to aesthetics. Truss bridges can be considered to harken back to an earlier era in bridge-building. The Alexandra Bridge over the Ottawa River is an example of a truss bridge. Truss bridges come in various configurations including deck trusses, through trusses, cantilever trusses, and so on. Such bridges are now relatively rarely built.

- **Arch bridges** are another age-old structural configuration and, indeed, even nature constructs arch bridges as in the southwestern United States desert country where there are many natural arches. Arches can be constructed in stone, concrete, or steel, or combinations of these materials, and there are many beautiful arch bridges in the world. They may be deck arches, through arches, or hybrid combinations and they are capable of spans over 500 metres.

- **Space frames** are sometimes used to architectural advantage and provide a wide range of structural possibilities. The Mimico Creek Footbridge is essentially a space frame including an inclined arch element.

- **Extradosed bridges** are a relatively recent invention comprising an amalgam of girder and cable-stayed bridge technologies. Very few of these exist but they are, nevertheless, a well-proven option for relatively modest span structures which might be spanned by girders or by cable-stayed configurations but which are best and most economically spanned by a combination or hybrid structure called an extradosed bridge.

- **Cable-stayed bridges** are an economical form of construction for relatively long spans but they can be used for intermediate spans as well, and they lend themselves to many elegant, airy and imaginative configurations. Depending upon the cable spacing and configuration, these can result in minimum depth structures over very considerable spans up to over 1000 metres.

- **Suspension bridges** are the kings of the bridge engineering world and they are applied to the longest spans in the world. The current longest clear span suspension bridge is 1991 m between towers. At the same time, suspension bridge technology is applied to relatively short span bridges including, in particular, footbridges, but it can also be adapted with reasonable economy to relatively short span vehicular bridges if, for example, a single suspension cable is used. Such configurations are relatively rare but could be considered.

All these bridge configurations were considered here although some of them were deemed to be less desirable than others based upon considerations such as:

- The ability to construct the bridge without entering into the Rideau River
- No adverse effects on the environment
- Potential for net positive environmental effect
- Sensitivity to heritage issues
- Aesthetics
- Cost and maintenance issues
- Environmental responsibility
- Compatibility with a 100 year design life
- Life-cycle costing determinations
- Sustainability
- Speed of construction
- Compatibility with seismic requirements
- Combined architectural and engineering considerations and compatibility with the existing site.
- Gateway features and potential
- The ability to astonish and inspire
- Compatibility with the family of the bridges on the waterways

These elements were considered in conjunction with an appreciation of the family of bridges on the Rideau waterways, which included some linear structures, but also several attractive arch bridges. The interim result of this work was the identification of two schemes which were deemed to be preferred. These were

- An **underdeck arched frame** scheme
- An **overhead multiple arch** scheme.

These schemes were tested against all of the design criteria, and the overhead arch was found to satisfy virtually every one. It was therefore ultimately accepted as the preferred scheme.

One can see that the climate in which this design evolved and was selected is quite different from the climate of the 1970s. The result accordingly is a bridge totally different from St. Patrick Street Bridge. While St. Patrick Street bridge has served admirably in many ways, we hope that the new Strandherd Armstrong Bridge will far exceed it in its positive effects, not only on transportation, but also on the environment in which we live.

We hope, too, that this bridge will, like the 2000 year old Alcántara Bridge, be the most interesting and noteworthy element of its environment far into the future.

Figure 9 Strandherd Armstrong Bridge

Figure 10 Strandherd Armstrong Bridge

Figure 11 Strandherd Armstrong Bridge

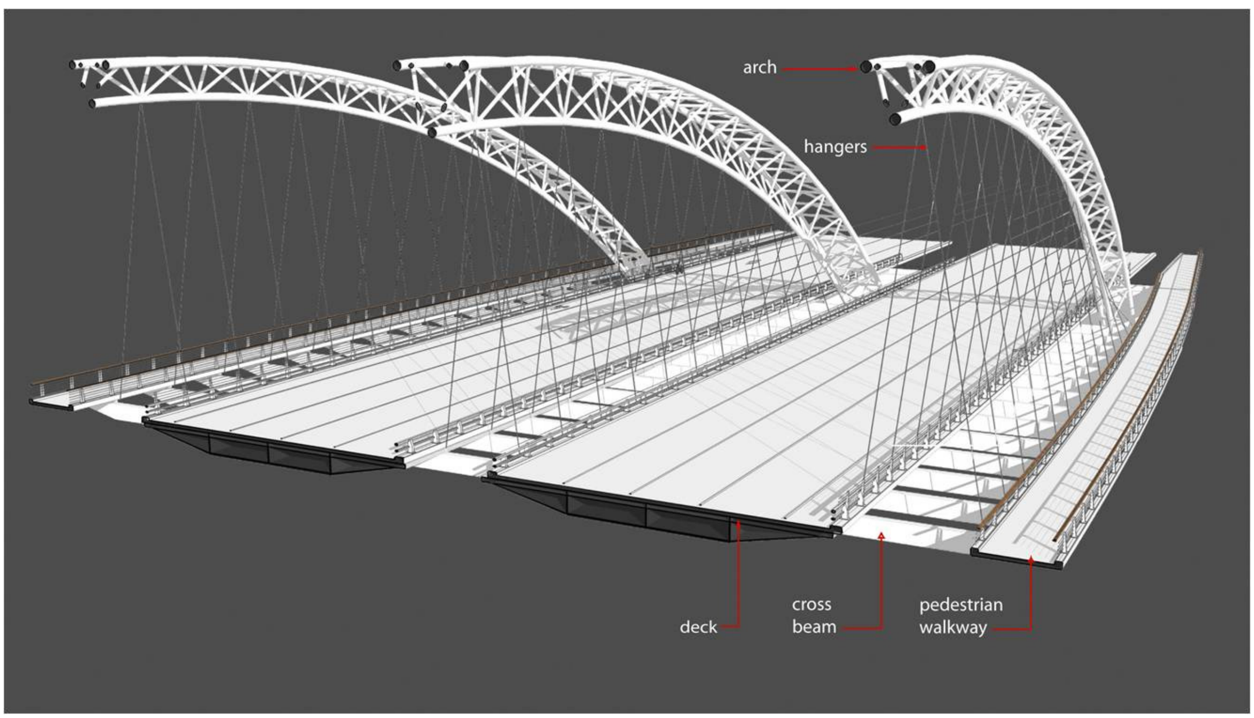

Figure 12 Strandherd Armstrong Bridge Structural Elements

Figure 13 Strandherd Armstrong Bridge at night

Figure 14 Strandherd Armstrong Bridge at night