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COMPARISON OF MOVABLE BRIDGE DESIGN IN DOMESTIC AND FOREIGN MARKETS

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Abstract

Arguably, the most apparent distinction between movable bridges in the U.S. and those in foreign markets is appearance. Although the importance placed on architecture and aesthetics by owners plays a role in this phenomenon, other factors prevalent throughout the design process have significant influence on the final product. Through the use of multiple case studies, this paper examines the differences between movable bridges in the U.S. in comparison to those in international markets by analyzing several contributing facets of the design process including: the bridge conception process, design methodologies and codes, and project delivery methods. Case studies include recent movable bridge projects in France, Turkey, China, and the U.S., and include bascule, swing, and vertical lift bridges.

Introduction

Movable brides exist and continue to be constructed throughout the world. Even though the basic types and configurations of these kinetic structures are fairly uniform regardless of location, a comparison of movable bridges in the United States to those overseas reveals striking differences. The most apparent distinction is aesthetics. Seemingly and certainly with some exception, in developed nations outside of the U.S., great importance is placed on bridge architecture and appearance, whereas here in the U.S. functionality often dictates the look of a movable bridge. Examining this issue more closely, factors other than merely a greater emphasis on aesthetics contribute to this result. These factors include: bridge conception processes; design methods and governing codes; and project delivery methods.

Although the basic movable bridge types in the U.S. and overseas are the same (bascule, vertical lift, and swing bridges), the styles are usually easily discernable. Examples are shown in Figures 1, 2, and 3, each one consisting of a movable bridge of the same type in the U.S. and in a foreign country.

FIGURE 1a: Tomlinson Vertical Lift Bridge – Connecticut, U.S.

FIGURE 1b: Garrone River Bridge, - Bordeaux, France

FIGURE 2a: Third Avenue Swing Bridge – New York City, U.S.

FIGURE 2b: El Ferdan Swing Bridge – Egypt (Suez Canal)

FIGURE 3a: Christa McAuliffe Bascule Bridge - Florida

FIGURE 3b: Port River Bascule Bridge – South Australia

Certainly, not all movable bridges in the U.S. look the same, and plenty of unique, signature movable bridges exist in the U.S. (for example, see Figure 4), however the basic styles shown in Figures 1 through 3 are common.

FIGURE 4a: 17th Street Causeway - FL

FIGURE 4b: SW 7th Ave. Bridge - FL

Bridge Conception

Bridge conception refers to the design of a bridge in the "grandest sense". Typically, the bridge conception process begins with defining the "objective" of the bridge. For example, considerations such as civic architecture (i.e. will the bridge making a statement?), utility (i.e. what job will the bridge doing?), and context sensitivity (i.e. what will be the bridge's relationship to its surroundings?) drive the initial design conception of a bridge by the project team. Ultimately, at the end of the bridge conception process, the big picture concepts of the bridge, in terms of appearance, type, function, significance, and basic layout.

Critical to the bridge conception process are the composition of the project team and the definition of roles within the group. A typical project team consists of the owner (commonly the public), the design engineer, and the contractor (for design/build deliveries). An additional and perhaps the most critical member to the team in terms of developing the initial bridge concept is the "design conceptor", who is generally an architect or a design engineer. Commonly, the conceptor has expertise in both architectural and engineering concepts. It is the design conceptor who, relying on input from the owner, engineer, and contractor, develops the bridge concept. The roles and prominence of each of the team members varies by owner and project, and ultimately dictates selected concept.

For movable bridge projects in the U.S., owners (and thus designers), often driven by construction and maintenance cost considerations, generally employ a utilitarian approach, whereby the primary driver of the concept development is functionality. In this case, bridge conceptors are generally not involved. The exception is where an owner is committed to building a signature structure. By contrast, skilled bridge conceptors commonly lead major movable bridge projects in European forums. This distinction plays a prominent role in the differences in the final bridge product appearance. An example of a bridge concept developed under the lead of a bridge conceptor is shown in Figure 5.

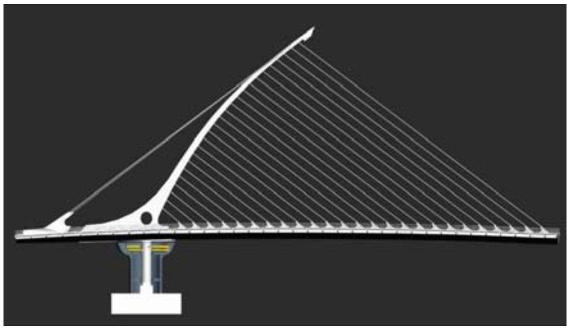

FIGURE 5: Calatrava Swing Span, Ireland

Methods and Codes

In the U.S., movable bridge design is governed by well-established, practical codes such as AASHTO and AREMA. Existence of movable bridge design codes in forums outside of the U.S. is limited. The Dutch and the Germans have adapted, limited codes, but not much else in the way of movable bridge design codes exists. Although design codes such as the Eurocode are widely followed, this code addresses only structural loading and design, and does not specifically address movable bridges or the design of mechanical or electrical systems. Thus, the impact of codes on movable bridge designs outside of the U.S. depends largely on the technical capabilities and experience of the bridge owner. More technically competent and experienced owners are more familiar with existing design codes and commonly prescribe the code and design methods to be followed. This is similar to owners in the U.S., who typically own multiple movable bridges and are knowledgeable in the areas of movable bridge design, construction, and maintenance. In contrast, less experienced owners generally rely on the engineer's expertise rather than specifying codes or other guidelines. As a result, movable bridge designers outside of the U.S. often look to codes and practices in adjacent industries such as paper mills, food processing, and crane systems for guidance. A good example of the result of this is a lift bridge in Rouen, France shown in Figure 6. The similarities of the lifting concept and mechanisms to crane technology are readily apparent.

FIGURE 6: Vertical Lift Bridge in Rouen, France

Project Delivery

While many, if not most U.S. movable bridge projects are still delivered through a conventional design-bid-build (DBB) approach, design-build (DB) delivery is the most common approach in many international markets. This situation plays a large role in the final bridge product. For example, under a typical DBB approach, the owner generally stays more involved and maintains some level of control throughout the design process, often resulting in a final product consistent with familiar designs that fit well with established operation and maintenance programs. Conversely, under a DB approach, the owner generally "hands over" the design to the DB team early in the process and plays a lesser role in design development. As a result, the less-controlled Contractor-led team is more likely to develop solutions that deviate from conventional designs. Bridge conceptors or preliminary designers generally serve as verifiers for the owner to ensure that the Contractor-led DB team produces a design consistent with the selected bridge concept.

Case Study 1 – Garonne Vertical Lift Bridge in Bordeaux, France

The Garonne Vertical Lift Bridge in Bordeaux, France is currently under design. On this project, the owner specified the Eurocode for the structural design. At the recommendation of the designer of the movable span mechanical and electrical systems (Hardesty & Hanover), the AASHTO Movable Bridge Specification was adopted for the design of the mechanical and electrical systems. In typical European fashion, a bridge conception process was employed, lead by the well-known French bridge conceptor Michelle Virlogeux. The massive lift span is 385 foot long, 150 feet wide, and weighs 5 million pounds. The span itself is a trapezoidal, welded steel box with an orthotropic deck. The resulting design, in terms of the aesthetics and structure type, is quite different from what we generally see in the U.S. Looking at Figure 7, the bridge is decidedly "European" in both style and structure type.

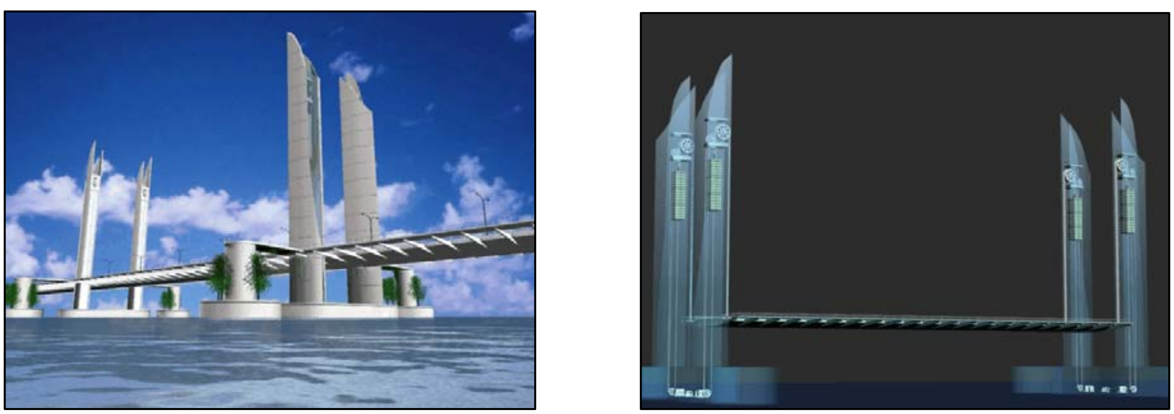

FIGURE 7: Garrone River Vertical Lift Bridge – Bordeaux, France

For this project, the owner (Urban Community of Bordeaux) hosted a design competition, which in itself is not unlike design competitions for landmark bridges in the U.S. However, this design competition in Bordeaux called for design-build teams to enter bridge concepts. Very much hands-off throughout the conception and design process, the owner provided only basic functional requirements and alignments to the competing teams and required the bridge to be a signature, context sensitive structure. The winning team consisted of a Contractor (GTM/Vinci), a bridge conceptor (Michelle Virlogeux), and a full design engineering team led by consultant JMI.

Case Study 2 – Halic Metro Crossing in Istanbul, Turkey

Another interesting international movable project currently under design is the Halic Metro Crossing over the Halic River at the historic Golden Horn in Istanbul, Turkey. For this project, the City of Istanbul needed a new bridge to link completed portions of their transit rail system, making it a project of the highest societal impact and importance. The owners realized they needed a movable bridge, but did not want to make it the centerpiece of the monumental crossing. Other than this requirement, they've remained essentially hands throughout the bridge conception and design process, relying instead on the recommendations and judgment of the architect / engineering design team. Unlike the Bordeaux project, this project is a design-bid-build delivery. However, much like was the case in Bordeaux, the design team was led by a bridge conceptor (again Michelle Virlogeux), who, along with the architectural firm of Hakan Kiran and structural engineers at Systra, developed the concept for the 1700-foot long river crossing, which consists of a 1200-foot long cable-stayed main span with a swing span located just off the south bank of the river.

The swing span consists of a 230 foot long forward span, and a 165 foot long rear span, weighs roughly 7million pounds, and carries two light rail tracks. Like the bridge in Bordeaux, the main structural element of the span is a trapezoidal steel box with an orthotropic deck. The basic mechanical concept is a tilt and turn system. Although the owner did specify the Eurocode for the structural design of the bridge, they left it up to the design engineer to recommend the governing code for the movable bridge systems. At the advice of the mechanical and electrical systems designer (Hardesty & Hanover), the owner agreed that applicable portions of the AASHTO and AREMA codes were appropriate.

FIGURE 8: Renderings of Halic Metro Crossing in Istanbul, Turkey (developed by architect Hakan Kiran)

Case Study 3 – Ningbo, People's Republic of China

One further foreign case study is a movable bridge concept development and preliminary design performed by Hardesty & Hanover for the Ningbo City Proceeding Office of Municipal Engineering Projects in Ningbo, China. This project example represents a case where the owner possessed little movable bridge experience and relied entirely on the design engineers to develop the movable bridge concept. Essentially, the only requirements the designers were given were to replace the existing fixed bridge with a movable bridge that would achieve the needed additional vertical clearance, provide a 300 foot horizontal channel, and that the proposed options be aesthetically pleasing. With essentially no boundaries in place, Hardesty & Hanover developed several innovative and unique solutions that were well-received by the owners. Some of these concepts are shown in Figure 9.

At the recommendation of the designers, the concepts were developed following AASHTO criteria, for the structural, mechanical, and electrical systems. At present, the owner is reviewing the movable bridge concepts and will be making a selection in the near future.

FIGURE 9: Renderings of Movable Bridge Concepts Developed for Ningbo, China Bridge Replacement

Case Study 4 – Woodrow Wilson Bridge in Alexandria, VA

The final case study presented is the new Woodrow Wilson Bridge over the Potomac River in Alexandria, Virginia – a U.S. movable bridge. This bridge project presents both similarities and differences from the international projects described above. Unlike the Bordeaux, Istanbul, and China projects, the owners of the Woodrow Wilson Bridge – Maryland State Highway Administration, Virginia Department of Transportation, Federal Highway Administration, and District of Columbia Department of Transportation - are highly knowledgeable and experienced with movable bridge design, construction, and maintenance. Also unlike the other projects described, this project had clearly defined design specifications (AASHTO, as well as appropriate local standards).

FIGURE 10: New Woodrow Wilson Bascule Bridge in Alexandria, Virginia

For this mile-long, 12 lane bridge replacement, a heavily-contested competition was conducted to select an engineering consultant to develop the design for this design-bid-build project. Also in contrast to the international projects described above, the owners provided definitive criteria beyond basic alignment and channel clearance parameters to the competing teams. For example, to fit in with the surrounding architecture of the Capital region, the basic bridge style was to be arches, and the crossing was to include a bascule span across the navigation channel. However, much like the projects noted above, the owners sought and were committed to building a monumental, signature structure. The competition was won by the Parsons Transportation Group.

The owners and their representatives – a General Engineering Consultant team called the Potomac Crossing Consultants - stayed heavily involved throughout the design process to ensure the project criteria was being met by the designers. In order to meet the owner requirement for a operationally reliable, durable, and maintainable bascule span, bascule designers Hardesty & Hanover utilized innovative arrangements of conventional systems and components without impacting the signature aesthetics of the structure, as well as providing a fully-redundant electrical power and control systems. One example of this is the span lock concept, where designers adapted a conventional span lock arrangement to create theoretical continuity under live load across the double leaf bascule span. This solution proved essential not only to reduce anticipated live load deflections and thus reduce the main girder section, but also to provide a deflected shape that was more suitable for the transit rail that the bridge will carry in the future.

At the end of the design phase, the owners and their design team achieved their goal of a world-class, signature bridge with a reliable and maintainable movable span operational system. At present, the bridge is fully constructed and the bascule span is fully operational. The project is on schedule to increase the traffic carried on the bridge from 6 lanes to 12 lanes by the end of 2008.

Summary and Conclusion

It is apparent that there exist differences in general appearance, operational systems, and design details when comparing movable bridges in the U.S. to those overseas. Through experience gained on several international movable bridge design projects, it is evident that although this circumstance may be attributable to an increased focus on bridge aesthetics, at least in some cases, there exist other factors that ultimately impact the final bridge concept. Such factors include: the bridge conception process in general; applicable / specified design codes; owner experience with movable bridges and involvement during the concept development and design phases; and the project delivery method. Although it is clear that in all parts of the world, including in the U.S., highly-aesthetic, signature movable bridges have been achieved through different delivery methods and through different levels of owner involvement and prescription, the case studies presented in this paper suggest that the relationship between these factors significantly impacts the final bridge product.