US 20 Arch over the Mississippi River

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Summary

Very few long span tied arch bridges have been built recently in the U.S. due to concerns regarding redundancy of the structural system and the fact that cable-stayed systems are typically more economical. However, tied arch systems can be developed that ensure sufficient redundancy and improve cost competitiveness. One such example is the new US 20 bridge. The new bridge is over 1700 meters long with a 258 meter main span. It will carry eastbound US 20 over the Mississippi River between Dubuque, Iowa and East Dubuque, Illinois. The existing two lane bridge will remain in place to carry westbound traffic. This paper will focus on the new materials and technologies that were implemented to meet the redundancy, durability and constructability requirements of the project.

Keywords: tied-arch; redundancy; high performance steel; durability; Mississippi River; bridge type selection

1. Introduction

The new bridge will carry eastbound US 20 over the Mississippi River between Dubuque, Iowa and East Dubuque, Illinois. There are 13 west approach spans and 23 east approach spans for a total bridge length of 1700 meters. The estimated construction cost for the project is US$200 million which includes the main river crossing, approach roadway and other miscellaneous local roadway and bridge improvements.

The existing two lane bridge is a three span, 106-258-106 meters, continuous tied arch bridge built in 1943. The Julien Dubuque Bridge is listed in the National Register of Historic Places. When it was built, it was the second-longest span over the Mississippi River and the longest continuous tied arch in the world. Its historic status requires that the new bridge meet the Secretary of the Interior's standards for rehabilitation. The new bridge must not destroy historic materials, features, and spatial relationships that characterize the existing bridge. The new bridge must be differentiated from the existing and be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the existing bridge and its environment.

A total of 13 bridge alternates were developed; however, the Iowa State Historic Preservation Officer determined that only 4 meet the Secretary of Interior's Standards for compatibility:

- Tied arch with parallel ribs and x-bracing
- Tied arch with parallel ribs and k-bracing
- Replicate of the existing bridge
- Variable depth truss

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The bridge type selection and public involvement process included the organization of a Project Coordinating Committee (PCC) comprised of representatives from state agencies, municipal agencies, local businesses and community organizations. An evaluation matrix was used that consisted of both aesthetic and engineering criteria. The engineering criteria were ranked by the design team and the aesthetic criteria were ranked by the PCC team. The two scores for each alternate were then added together to determine the composite score. The tied arch with lateral x-bracing received the highest composite score and was selected as the final bridge type.

Fig. 1: Rendering of new and existing bridge

2. Design Development

The tied arch structure has a main span of 258 meters to match the main span of the existing bridge. The arch rib follows the line of the lower chord of the existing arch, resulting in a rise of 32 meters and a rise-to-span ratio of 1:8. While this is lower than the optimal ratio of 1:4 to 1:5, it poses no unmanageable design conditions. It does however increase the thrust in the ribs and tension in the tie girder. The bridge consists of 22 equally spaced hangers at 11.7 meters to match the existing bridge.

The arch ribs are spaced at 17 meters center-to-center. The rib element is 1.2 meters wide and 2.1 meters deep. The rib is braced with a lateral system with an “X” configuration to match the bracing system on the existing bridge.

One of the most significant constraints imposed on the floor system was the necessity to minimize the overall depth to maintain the required navigational clearance and keep the two profile grade lines relatively close. The existing bridge has a total floor system depth of only 1.7 meters. This is due to the fact that the spacing of the trusses is only 10.7 meters and the tie is shallow since the stiff arch trusses resist global flexure in the bridge.

A conventional floating stringer and deck system with the stringers running over the top of the floor beams requires a higher profile grade line that compromised the aesthetics and compatibility relative to the existing bridge. Our solution was to develop and evaluate composite floor systems utilizing a relatively shallow tie girder.

The main span incorporates three major innovations that address challenging constraints and advance the state-of-the-art in tied arch bridge technology: 1) composite floor/tie system 2) continuous deck 3) bolted, high performance steel tie girders. The end result is an efficient and durable floor system with a tie that has a high degree of both internal and load path redundancy.