The Main Street Replacement Bridge
Columbus, Ohio

Elevation View of Proposed Main Street Bridge

Paper Length: 7386 words [2886 words + (18 x 250) = 7386]

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ABSTRACT:

Faced with the challenge of replacing an existing art-deco arch bridge, the City of Columbus, Ohio decided against replication in favor of constructing a new "aesthetic symbol" for the City. The proposed Main Street Replacement Bridge, a bridge consisting of a single-ribbed arch inclined at a 10-degree angle will gracefully span the Scioto River and will provide the City with its new "aesthetic symbol" as well as provide the final link between new parkway developments on both banks of the river.

The original design concept was scrapped due to increasing construction complexities compounded by a decreasing budget allowance. With a client committed to aesthetic design, a requirement for a less complicated erection process and a shortened construction timeline, the engineers were challenged to redesign the bridge within the revised budget while maintaining the intriguing geometry of the previous bridge design.

This paper will discuss how the design team overcame the new design challenges and will focus specifically on the redesign of the arch geometry, the reshaping and redesign of the pedestrian and vehicular decks, the redesign of the lateral bracing of the inclined arch and the complete overhaul of the bridge piers.

Keywords: Inclined Arch, Bridge Aesthetics, Pedestrian Comfort, Pedestrian Enhancements

INTRODUCTION:

Over the last 10 years, the City of Columbus, Ohio has subscribed to a proactive approach towards the redevelopment of the downtown civic area. Recent projects include the unique conversion of a historic high school facility into a modern new science center, the transformation of an old prison site into a new downtown arena district, renovated City and State office buildings as well as the addition of an outdoor amphitheater along the riverfront.

Crossing the Scioto River and centered amongst the City's redevelopment were three deteriorating, below-deck concrete arch bridges. Two of the bridges were very similar in character while the third, the "Main Street Bridge", set itself apart with unique art-deco architecture (see Figure 1).

Faced with the challenge of replacing the three arch bridges, the City decided to maintain the below-deck arch architectural relationship between two of the bridges. However, for the "Main Street Bridge", the City favored constructing a new modern "aesthetic symbol" rather than replicating the art-deco features of the existing bridge.

The City planners and project architect set their expectations high as they truly desired a one-of-a-kind design that would become an aesthetic symbol for Columbus. The bridge was to be designed to accommodate current and future traffic patterns (including a possible switch from the current two lane one-way configuration to a new two-way configuration with a middle turning lane). The bridge was also to be designed, "Pedestrian Friendly", with pedestrian comfort and enjoyment as prime considerations.

Designing a bridge to meet these criteria challenged the project engineers as the City's expectations exceeded the capacity of the limited project budget. Initially, a very low-profile concrete-filled arch with a post-tensioned concrete deck and very slender "V" shaped piers was proposed (see Figure 2). The proposed bridge met all of the City's aesthetic, functional and pedestrian requirements however the estimated cost to construct the bridge exceeded the City's budget.

A conditional redesign of the bridge was authorized. The redesigned structure was to make use of more economical construction materials and erection methods, was to be developed with a more efficient arch geometry and was to use more economical detailing practices, yet was to maintain the character of the original inclined arch bridge concept.

The project engineers met the challenges. The proposed redesign of the "Main Street Replacement Bridge", maintains the concept of a single-ribbed steel arch (see Figure 3). In addition, the integrity of the previous decks was maintained. The pedestrian deck consists of a unique precast, post-tensioned concrete section. The vehicular deck consists of a continuous steel box with transverse floor beams cantilevered to support the pedestrian deck on one side and to support the wide roadway on the other side (see Figure 4).

ARCH SHAPE:

The arch of the previous design was proportioned with a shallow 10:1 span-to-rise ratio (see Figure 5). The complex profile was achieved by linking three compound (non-parabolic) curves established by the project architect. The arch spanned 480 feet from spring point to spring point.

The asymmetric, trapezoidal cross-section of the arch was intentionally undersized to reduce the scale to a more pedestrian friendly size. Unfortunately, to accommodate the high axial and bending forces, the steel arch was made composite with a high-strength self-compacting concrete core and was designed using 70 ksi steel plate ranging from 2.25” to 3.25”. When the complexities were totaled, the low, inefficient arch profile and small cross-section along with the challenge of ensuring the integrity of the concrete core proved too costly for the project and were critical areas where the engineers focused revisions.

The redesigned arch maintains many of the same aesthetic features of the previous design however critical improvements were made to the efficiencies of the arch profile and cross-section.

- The redesigned arch was proportioned as a taller arch with a shortened span of 400 feet. The new profile consists of a 6.6:1 span-to-rise ratio (see Figure 5).
- The redesigned arch cross-section was enlarged to eliminate the need for a composite concrete core and reduce the need for steel plates over 2.5” thick. The over-all dimensions increased from 84” x 62” to 94” x 68”.
- Over-all, a net savings of 60,000 lbs of Grade 70 steel and 360 cubic yards of an expensive 8000 psi self-consolidating concrete were achieved

The engineers recognized that the previous arch was proportioned with a shallower span-to-rise ratio and a smaller cross-section to minimize the apparent over-powering nature the arch could have on pedestrians. To accommodate the larger cross-section and taller profile of the redesigned bridge, the separations between the pedestrian deck and arch and between the arch and vehicular deck were increased providing sufficient distances for pedestrians to view the arch and appreciate its critical function as part of the bridge structure without being over-whelmed by its size.

PEDESTRIAN AND VEHICULAR DECKS:

The pedestrian and vehicular decks of the previous design were two complex post-tensioned, cast-in-place concrete box sections. The undersides of the decks were sculpted with gentle complex curves to soften all exposed edges (see Figure 6). At each abutment the two concrete decks were merged into one “unified” deck. As the pedestrian walkway approached the spring points of the arch, the steeper vertical curve of the walkway elevated pedestrian traffic above the roadway profile. In addition, the pedestrian walkway contained a gentle, yet complex, horizontal curve that pulled the pedestrian deck 22 feet away from the roadway deck at the midspan of the bridge.

The combination of the heavy concrete deck, a shallow arch profile and a dead load imbalance that created large bending and torsional moments required the engineers to utilize a large number of longitudinal and transverse PT tendons. In addition, the longer arch span resulted in short end spans which produced unfavorable uplift reactions at the abutment. Mass concrete pours in the voids of the concrete box sections provided the counterweight required to overcome the uplift. When the complexities were totaled, the inefficiency and over-all difficult constructability of the concrete decks proved too costly for the project and were critical areas where the engineers focused revisions.

The redesigned pedestrian and vehicular decks maintain many of the same aesthetic features of the previous design however critical improvements were made to material selection, connection detailing and erection methods:

- The pedestrian deck was redesigned as a series of precast panels post-tensioned longitudinally to develop continuity. This redesign facilitated a simplified erection as the number of PT tendons was reduced to 25% of the original design. In addition, falsework to support the concrete forms over the river were eliminated.
- The vehicular deck was redesigned as an 84" deep x 288" wide multi-cell trapezoidal steel box. This redesign also facilitated a much simplified erection as a majority of the PT tendons were eliminated.
- Almost 10,000 kips of structural dead load were eliminated from the deck system
- Erection of the deck system was simplified by eliminating the need for continuous heavy falsework in the river.
- In the previous design, the concrete post-tensioning doubled as the tension tie for the arch thrust. The redesigned arch also required an active tension tie. Rather than burying the tension ties eccentrically in the steel box, the designers efficiently centered the PT on and about the arch spring line (see Figure 7). The new tension tie would be enclosed in four (4) exposed tubes paralleling the steel box of the vehicular deck.

The engineers recognized the change from concrete to steel would create a significant change to the underside of the decks. Therefore to minimize the industrial nature of the steel structure, the redesigned decks were painted grey to match the "earthy" feel of the previous concrete soffit. The character of the previous design was maintained by providing a curved separation of the decks between the arch spring lines and was improved by providing a continuous separation of the decks from abutment to abutment. As with the original design, transverse floorbeams cantilevered from the vehicular deck to support the pedestrian deck and wide roadway. This rhythm of floorbeams through the open space between the decks creates spectacular views looking down at the river as well as looking up from the shore lines (see Figure 8).

L-STRUTS:

The arch of the previous design was braced with thirteen (13) vertical elements rigidly connected to the arch as well as to horizontal elements embedded between the pedestrian and vehicular decks. The vertical/horizontal elements, called “L-Struts”, were an interesting aesthetic detail as well as an integral structural component for bracing the arch (see Figure 9).

The “L-Struts” were steel boxes simultaneously tapering in both directions (differing slopes for each direction). The tapering geometry continued through the intersection of the vertical and horizontal portion for of the struts and extended back towards the vehicular deck. Thus the size of the cross-section at the bottom of the vertical strut varied and was dependent on the over-all height of that particular “L-Strut”. In addition, with varying distances between the two decks, each horizontal leg was unique with a different height and width.

Although very interesting to visualize, the complex details (see figure 10) coupled with the non-uniformity of thirteen (13) unique “L-Struts” and the installation of the both vertical and horizontal post-tensioning proved too costly for the project and were critical areas where the engineers focused revisions.

The redesigned “L-Struts” maintain many of the same aesthetic features the previous design provided however critical improvements were made to the cross-sections of both the vertical and horizontal members as well as to the connections of the vertical strut to the arch and horizontal floorbeam (see Figure 11).

- The redesigned “L-Struts” were detailed as true pin connections at both the top and bottom of the vertical member (see Figure 12). This pin connection simplified erection and eliminated large full-penetration field welds.
- The redesigned vertical members consist of two flanges of continuous width as well as two closely spaced webs. The over-all appearance of the vertical member would resemble an I-Section rather that of a closed box. Each vertical leg had a similar taper in one direction and a constant dimension in the other direction.
- The redesigned horizontal members are now extensions of the I-shaped floorbeams that cantilever out from the steel vehicular box. The flanges are a constant width while the webs taper top and bottom at a slope driven by the distance between the opening between the two decks.
- Over 400,000 lbs of steel were eliminated from the “L-Struts”.

The designers recognized the “L-Struts” of the previous design provided both visual interest and structural stability for the bridge. The “L-Struts” were also recognized by the City planners as key elements to maintain with the redesigned bridge. Therefore to minimize the impact of the changes in the redesign, the pins were covered with shrouds and the “L-Strut” concept was maintained (see Figure 13).

PIERS AND ABUTMENTS:

The previous bridge design included a pair of unique “V-Piers” that provided an intriguing, yet extremely complicated opening below the deck. The “V-Pier” cross-section was multi-faceted and did not have one face parallel with another (see Figure 14). The “V-Pier” was rigidly connected to the underside of the deck in two places thus allowing a small opening to be formed below the deck within the “V” (see Figure 15). The “V-Pier” was to be a concrete extension of the steel arch down to the waterline and was to “bounce” back up to and connect with the deck. With the “V-Pier” rigidly connected to the vehicular deck, the only possible location for structural bearings was at the base of the “V”, near the normal water elevation of the river.

The combination of a complex and slender cross-section of the V-Pier” and high maintenance structural bearings located where they would be exposed to high fluctuations in the river levels proved too costly for the project and were critical areas where the engineers focused revisions.

The redesigned “Crescent Piers” are one area of the bridge that truly changed in character from the previous bridge design (see Figure 16 and Figure 17). The change was a result of necessary cost savings which dictated a simpler pier design. There was simply no efficient way to achieve a properly proportioned V-shaped pier without eliminating the opening below the deck. Rather than fight the “V” shape, the City relinquished their desire for a below deck opening and directed the design team to develop the most cost-effective pier.

- The redesigned “Crescent Pier” is shaped to reflect the curvature of the arch.
- The wider redesigned pier is skewed with the flow of the river to minimize the hydraulic impacts of the new pier.
- The bearings were moved from the river level to up under the deck. This allowed a more traditional separation of superstructure and substructure.
- As a result of the change, unit costs for the concrete placement of the piers reduced from over $900 per cubic yard to under $450 per cubic yard.

The designers recognized the original “V-Pier” provided a unique and visually interesting structural support for the bridge. The “V-Pier” however simply was not an efficient support for a structure of this magnitude. Recognizing that costs were to be prioritized, the City authorized the designers to change the aesthetics and utilize a solid crescent shape for the piers.

CONCLUSION:

Striving to keep pace with other significant redevelopments in the nearby downtown area, the City of Columbus, Ohio designated the Main Street Replacement Bridge as an opportunity to create a new symbol for the City.

As with many unique large scale projects, the initial aesthetic design criteria of providing a unique symbol for the City while providing flexibility for both current and future traffic configurations proved to be challenging to achieve within the budget limits for the project.

A slender, shallow single-ribbed arch design was proposed for the bridge. The proposal also included two individual decks (one for pedestrian use and one for vehicular use) joined at the bridge ends and separated at midspan. The first attempt at satisfying these aesthetic requirements set by the City planners and the project architect proved to be a challenge that could not be met within the tight budget. Rather than completing the bridge plans and risking high bid prices, the City challenged the design team to reduce the cost of the bridge by 25% (almost $10,000,000) and effectively redesign the bridge to fit within the budget limits of the project. However the conditional redesign could not stray significantly from critical aesthetic elements of the previous design.

The City required the design team to maintain the sloping single-ribbed arch concept, the use of “L-Strut” type braces for the arch and separate pedestrian and vehicular zones. The redesigned Main Street Replacement Bridge satisfies these criteria and will provide the City of Columbus with a new symbol for the City while meeting the City’s revised budget criteria. (see Figure 18).

LIST OF TABLES AND FIGURES:

TABLES AND FIGURES:

Figure 1 - Art-Deco features of the existing Main Street Bridge

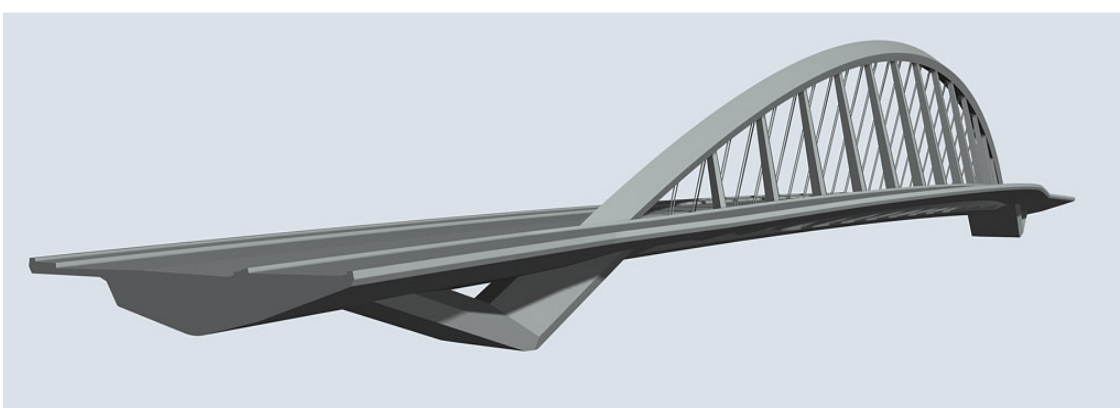


Figure 2 – Previously proposed Main Street Replacement Bridge

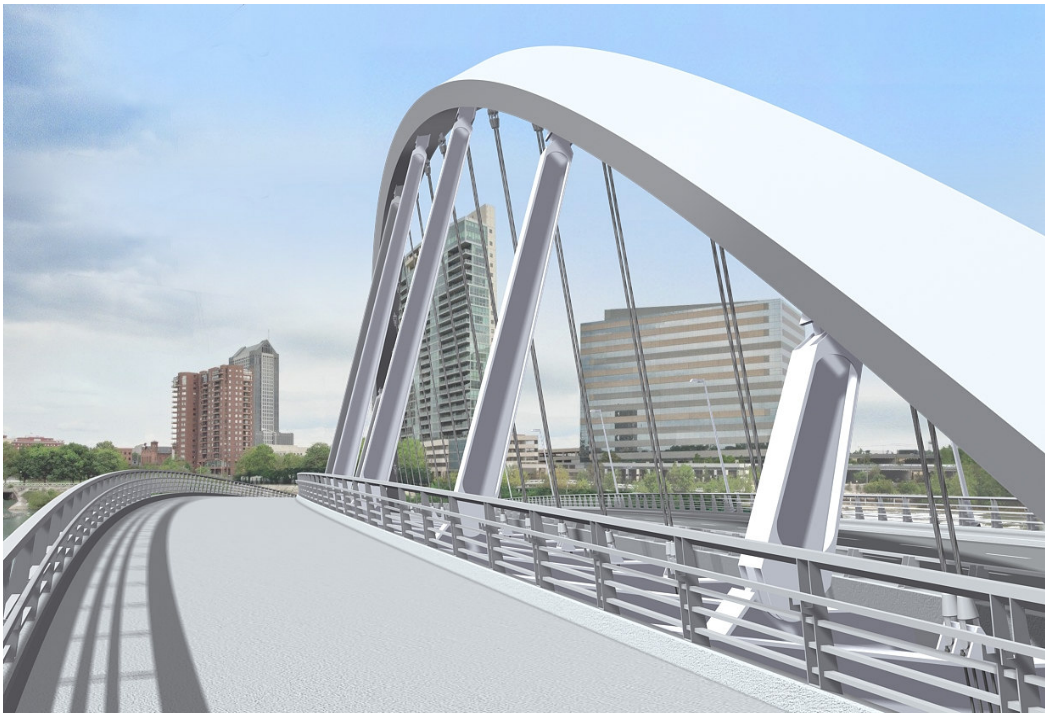


Figure 3 - Redesigned bridge with an inclined single ribbed arch

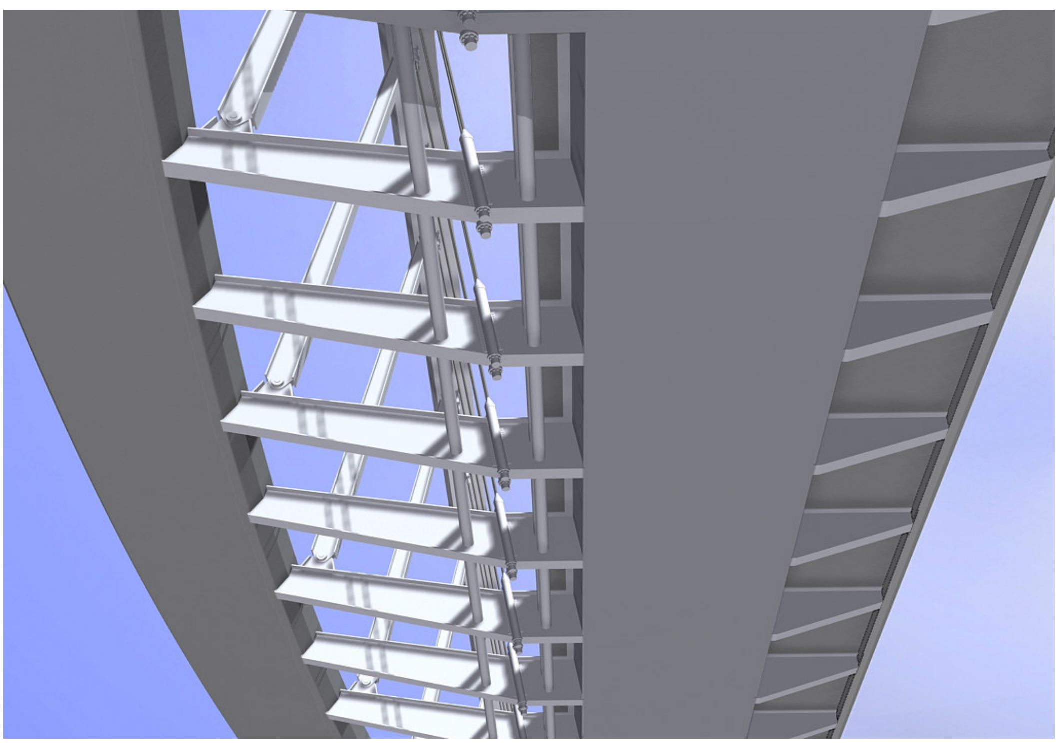
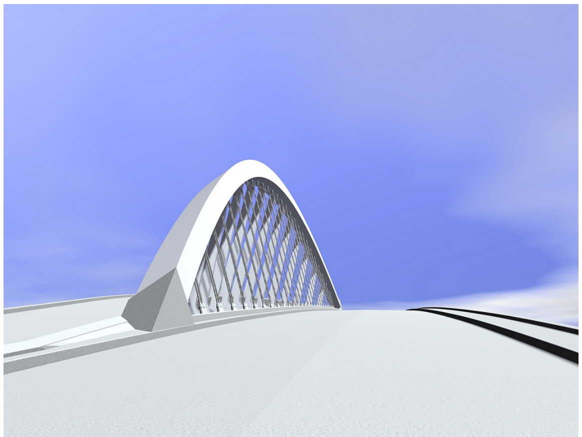


Figure 4 – Steel box and transverse floorbeams of the redesigned bridge



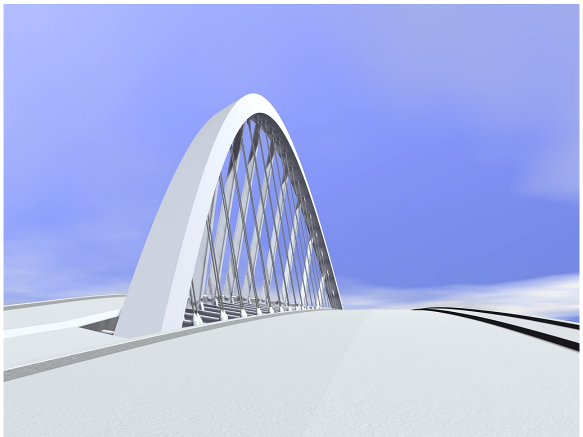


Figure 5 – Previous arch profile (left) with a 10:1 span-to-rise ratio and redesigned arch profile (right) with a 6:6 to 1 span-to-rise ratio

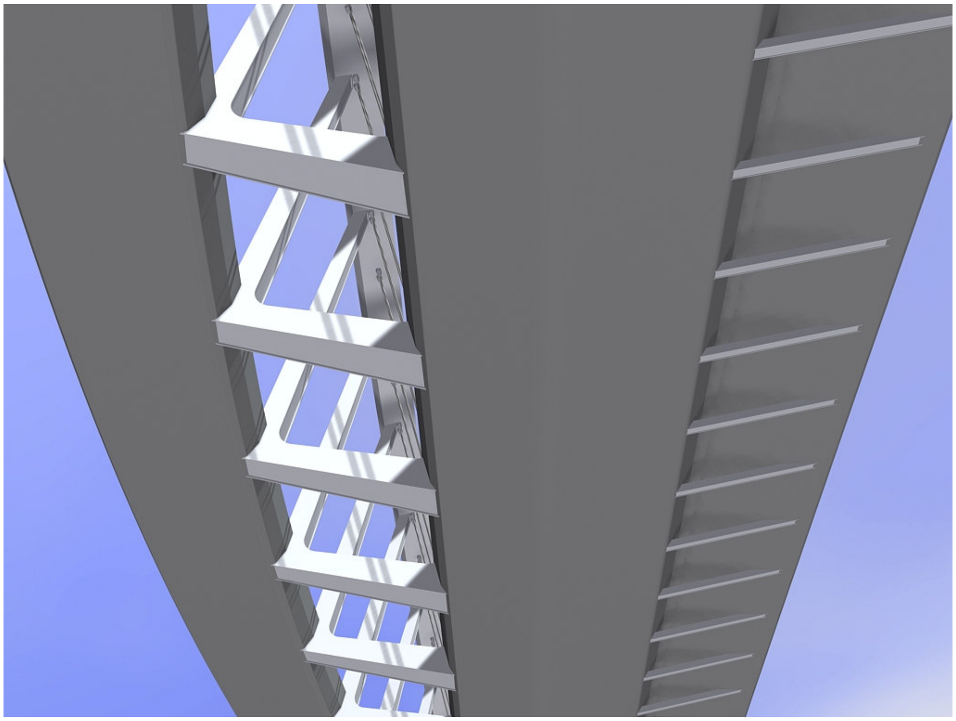


Figure 6 - Cast-In-Place decks of previous bridge design

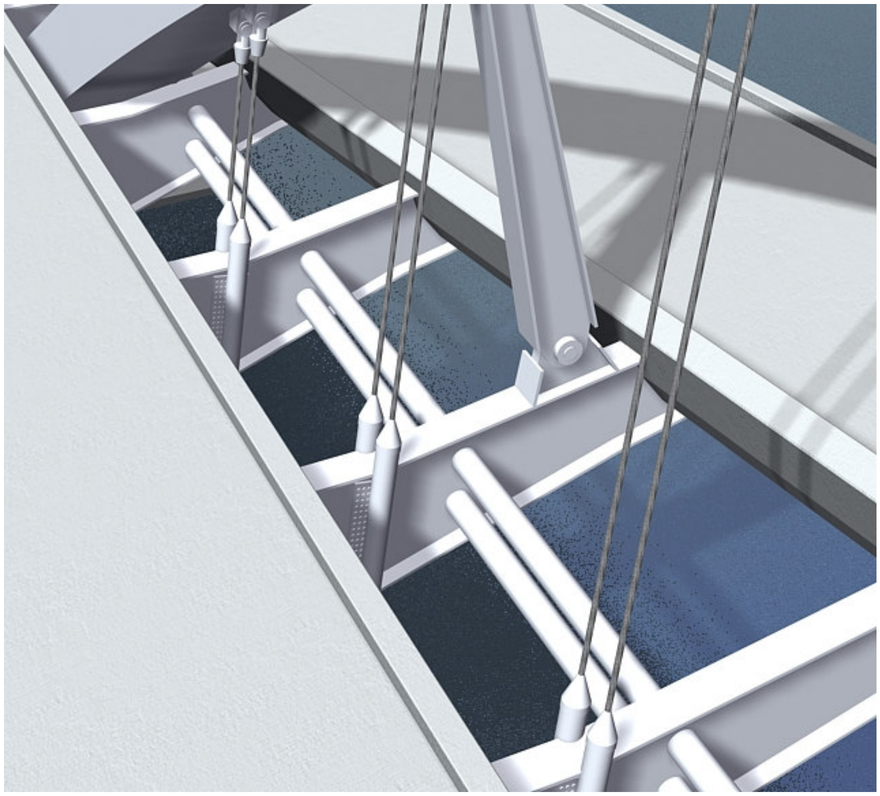


Figure 7 - Tension ties of redesigned bridge encased in exposed steel pipes

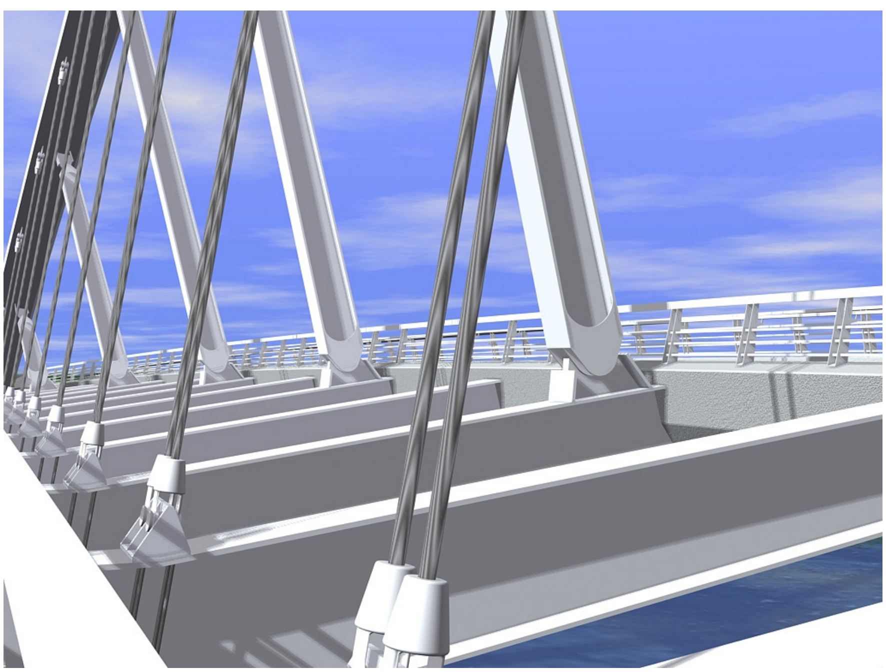


Figure 8 - Spectacular views of the exposed floorbeam structure

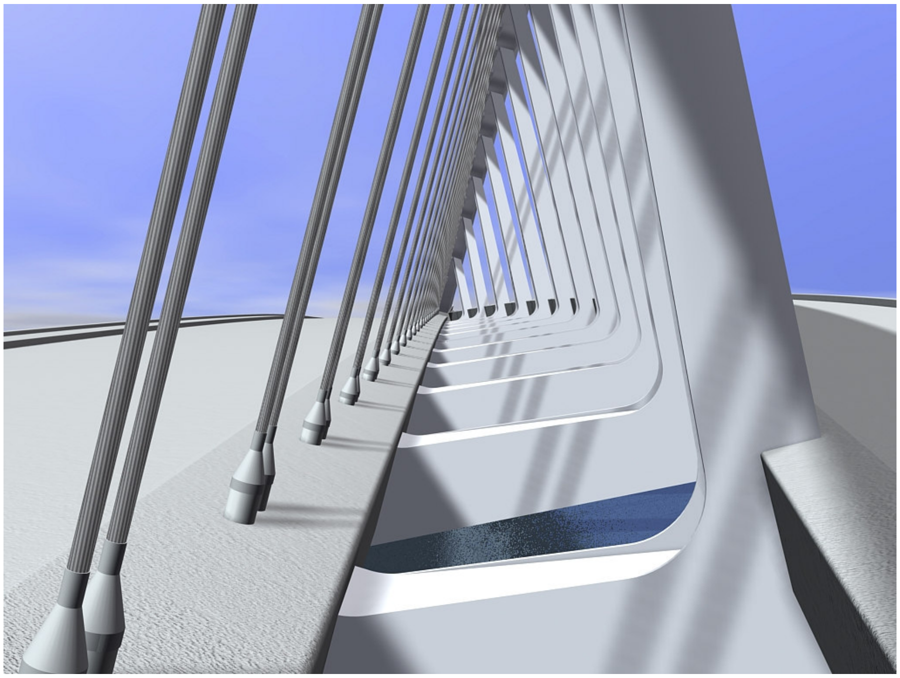


Figure 9 – L-Struts of the previous bridge design

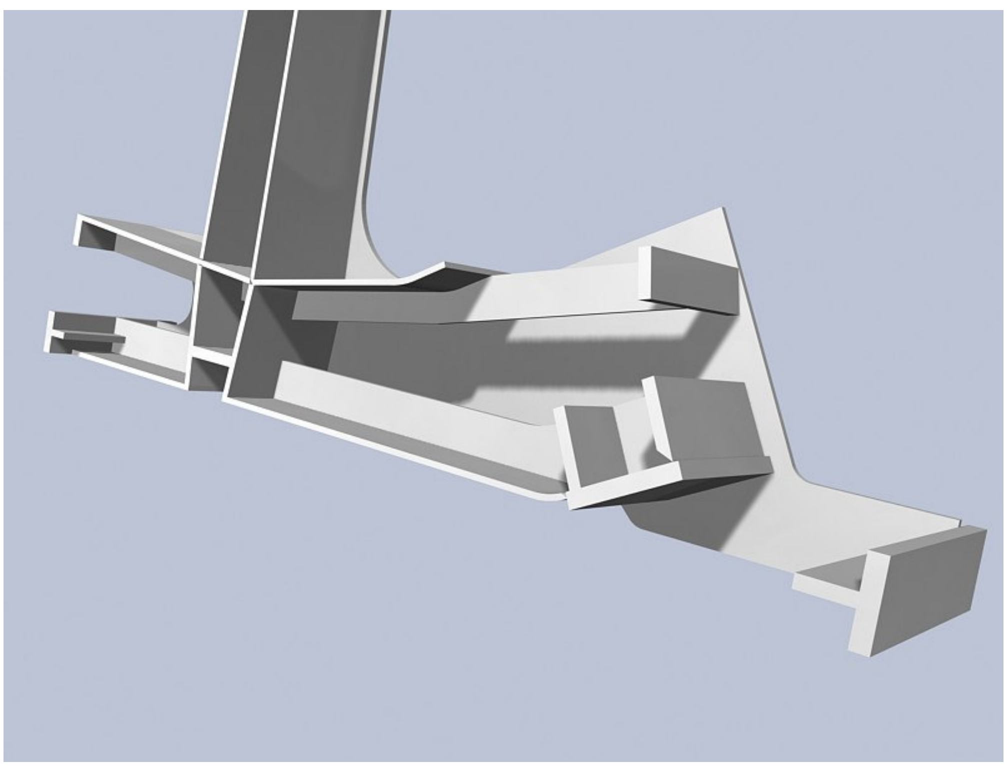


Figure 10 – Typical section cut thru an L-Strut of the previous bridge design

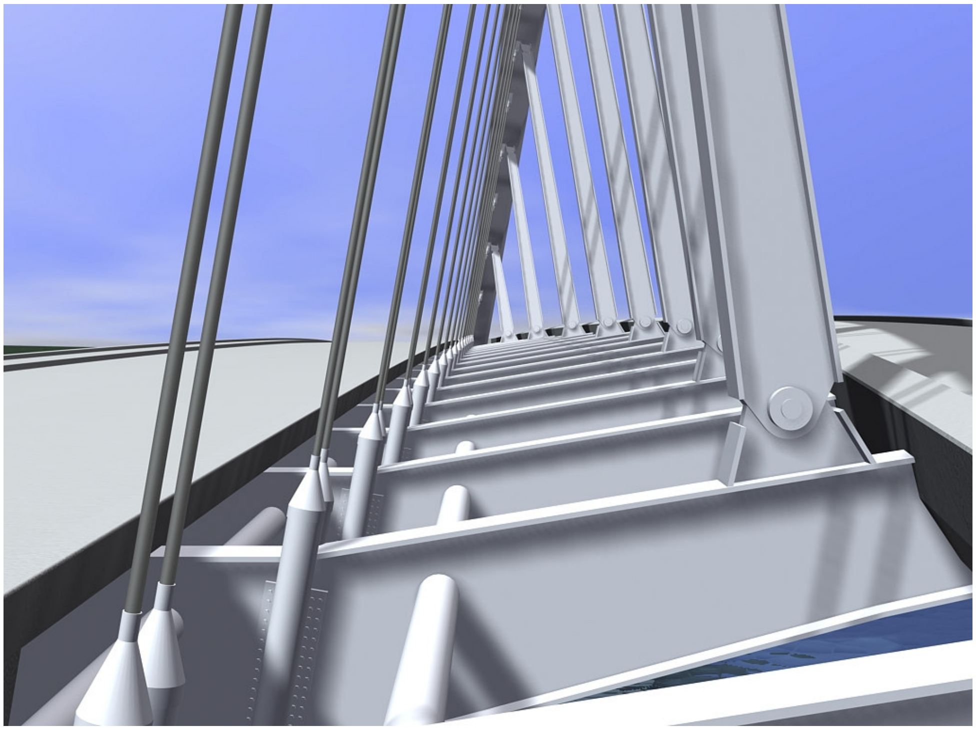
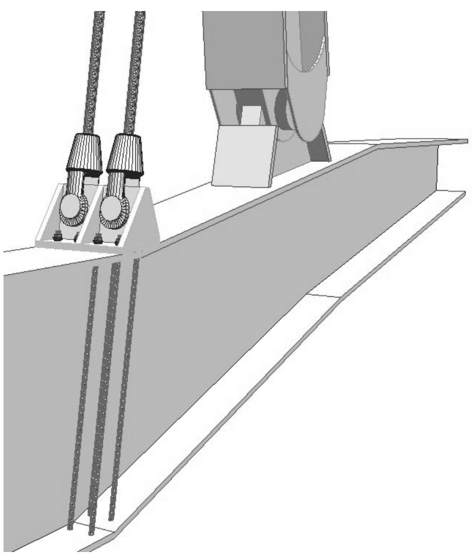


Figure 11 - L-Struts of the redesigned bridge



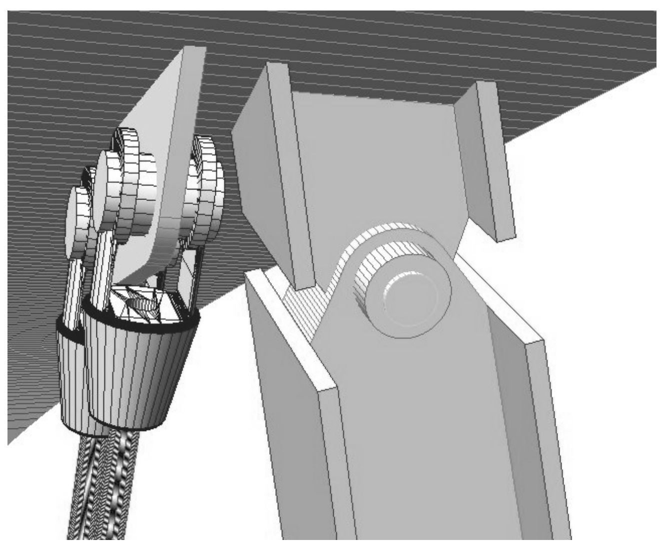


Figure 12 – Pinned "L-Strut" connections; at floorbeams (left); at arch (right)

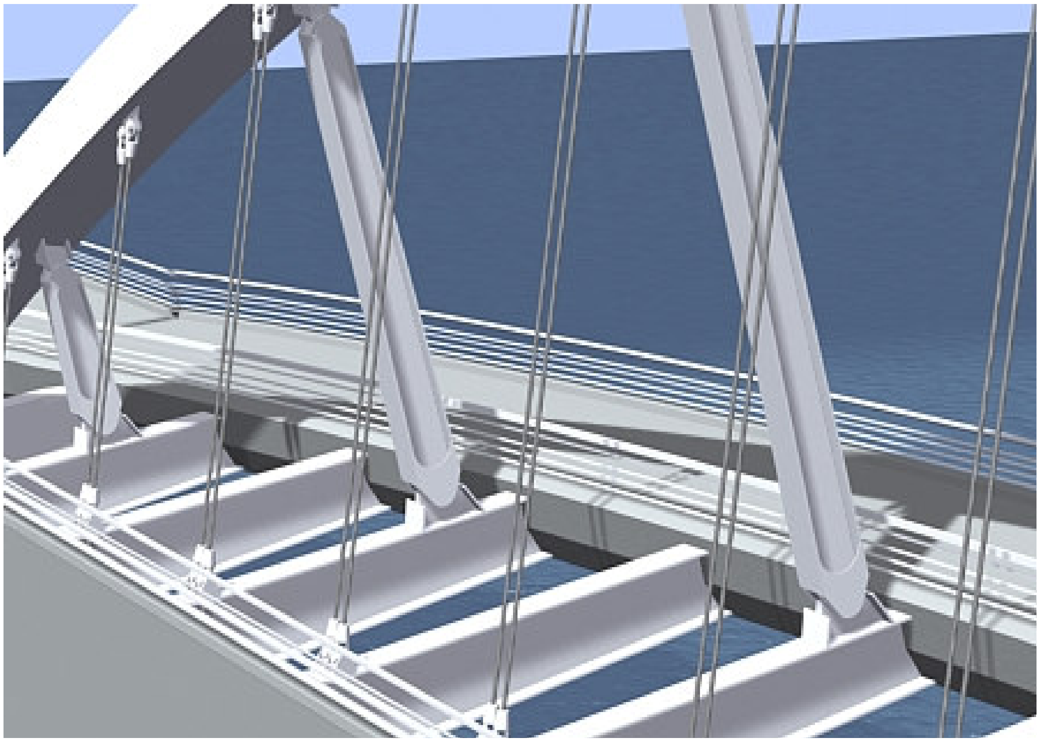


Figure 13 – Shroud covered pinned connections of the redesigned L-Struts

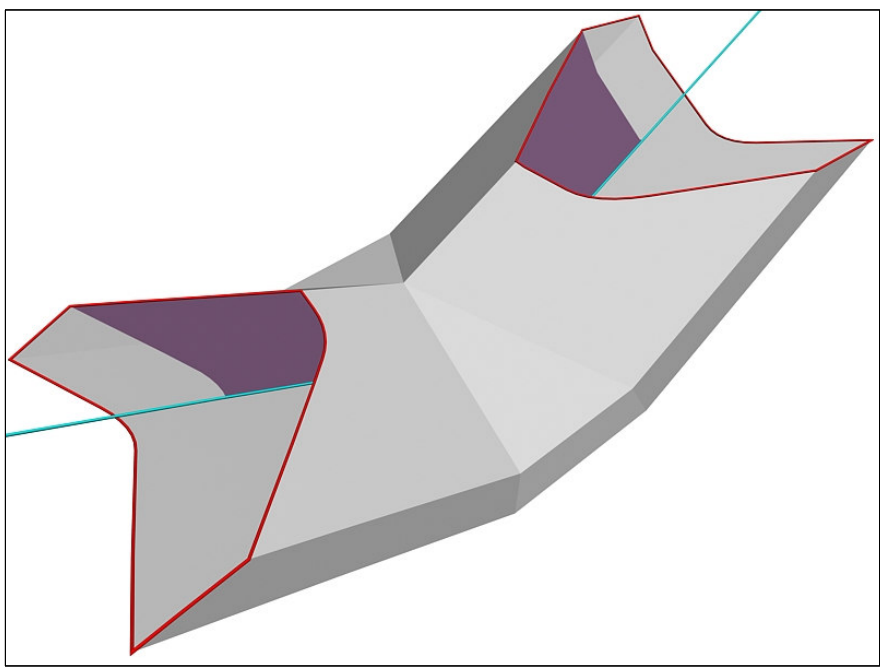


Figure 14 - Complex shape and cross-section of V-Pier of the previous bridge design

Figure 15 - “V-Pier” of previous bridge design

Figure 16 - “Crescent Pier” of redesigned bridge

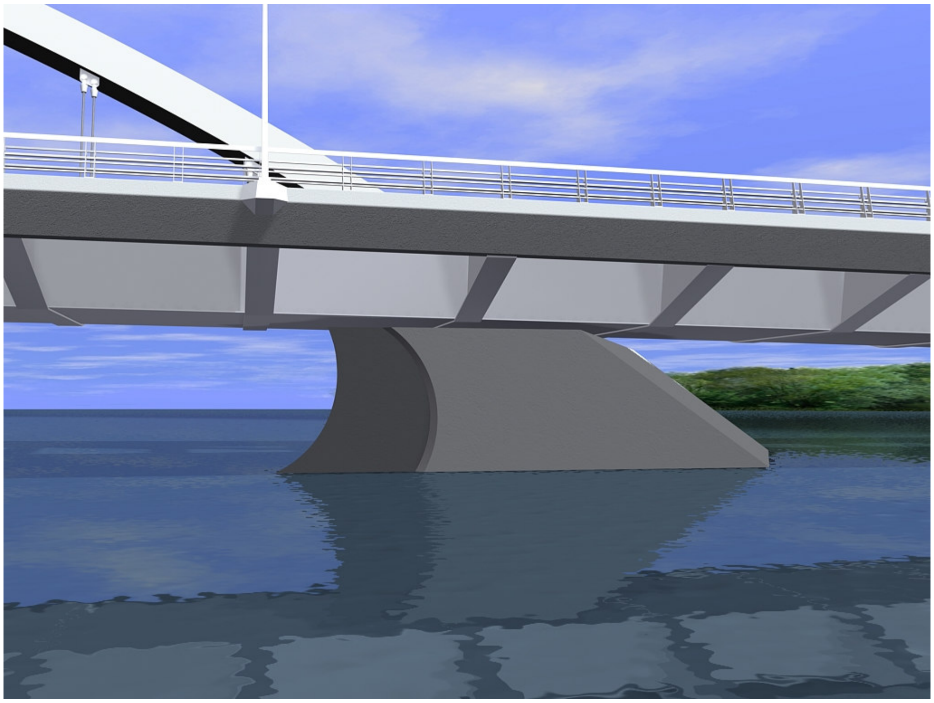


Figure 17 - “Crescent Pier” of redesigned bridge

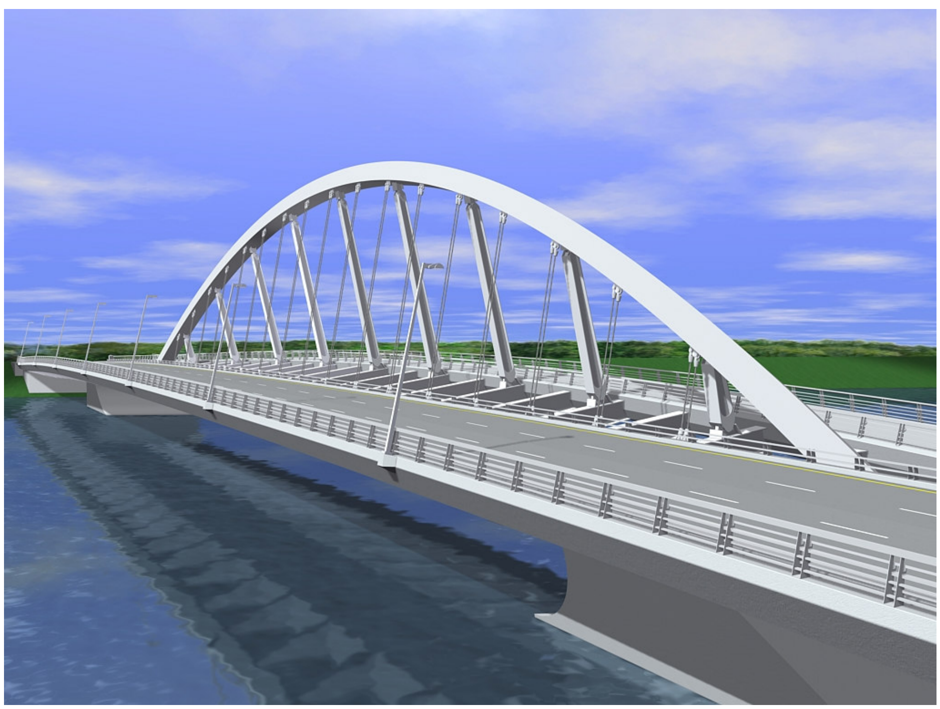


Figure 18 - The redesigned Main Street Bridge, anticipated construction in early spring of 2006