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Rehabilitation of Bridge Street Bridge Preserving a Nineteenth Century Historic Bascule Lift Span

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Introduction

The Bridge Street Bridge was constructed in 1880 by the King Iron Bridge Company of Cleveland, Ohio. It survives as a unique example of a nineteenth century hand operated mechanical drawbridge. The lifting system is based on a French design from the early 19th Century.

The Bridge Street Bridge has long since been replaced as a vehicular crossing across the Sparkill Creek. The Ferdon Avenue Fixed Bridge crossing is located just down stream of Bridge Street. The Bridge Street Bridge has deteriorated significantly over the years and has been closed to vehicular traffic since the construction of the Ferdon Avenue Bridge. Understanding the importance of this link to Piermont's past the County of Rockland Department of Highways was committed to reconstructing this Historic Bridge. In spring 2004 the County hired Bergmann Associates to prepare a rehabilitation design for the for this landmark structure.

What makes the Bridge Street Bridge unique and why is it important to spend taxpayers' money to preserve this important link to our past? This paper will discuss some of the unique characteristic of the basic bridge design. The paper will also discuss the efforts that were made during the rehabilitation of the Bridge Street Bridge to maintain an important link to Rockland County's historic heritage as well as our nation's history of creative bridge engineering.

Piermont, NY – A brief history (1)

The Village of Piermont part of Orangetown in Rockland County, NY is a small isolated community below the Palisades on the West bank of the Hudson River. Piermont is in the shadows of the Tappan Zee Bridge. The Village is located adjacent the Sparkill Creek which flows into the Hudson River through a break in the Palisades. Sparkill creek was a gateway to the interior portions west of the Hudson. It is no wonder this location became a trade center. The local Tappan Indians traded with Dutch settlers. The area known as the Slote (meaning ditch in Dutch) or the Landing, was teeming with wild life including: salt and freshwater fish, oysters, geese, swans and other shore birds, deer, bear, mountain lions and elk. Settlers moved west through the creek and their goods were transported back along the creek to market. A dam was built upstream of the Bridge Street Bridge location to power mills. The dam is still standing today and the mill has been converted to residential property.

During the American Revolution the Slote was at the center of the conflict with numerous raids and canon fire from British ships in the Hudson River. In 1783 George Washington was headquartered in Tappan and met with Sir Guy Carleton, Commander – in – Chief of His Majesty's forces to develop the evacuation of British troops from New York.

The Slote boomed in the 1830's when it became the eastern terminus for the Erie Railroad which ran from Lake Erie to the Hudson River. The construction of the Erie Railroad would be the beginning of the end for the Erie Canal's dominance as an inland trade route. At the time of construction of the eastern terminus it was illegal for the Erie Railroad to cross the border into New Jersey. As part of the construction a long pier was constructed that extended a mile into the Hudson River. The pier was constructed from rock and fill from the adjoining hillside. It is from this pier that Piermont gets its name since Piermont is located between the pier on one side and the mountain on the other. In 1853 Erie Railroad would locate its eastern terminus in New Jersey at Jersey City, now known as the Erie Lackawanna Terminal on the Hoboken Jersey City border. The Erie terminal at Piermont would become superfluous and a rail link was constructed between Piermont and Jersey City.

Bridge Street Design

The Bridge Street Drawbridge was constructed in 1880 by the King Iron Bridge Company. "The King Iron Bridge Co. played an important role in the development and construction of metal truss bridges, a product of American engineering and construction technology, nationwide during the later part of the Nineteenth Century. The King Iron Bridge & Manufacturing Co. was organized under that name in Cleveland in 1871 by Zenas King, who had started his career in building bridges in 1858…. During the 1880's the Company was the largest highway bridge works in the country…. (2) Included in the list of movable bridges that were built by the King Iron Bridge Company is the University Heights Bridge over the Harlem River in New York and the Bridge Street Bridge in Piermont. Bridge Street may be the only bridge of its type still in existence today.

FIGURE 1: Bridge Street Bridge prior to rehabilitation

The Bridge Street Bridge is a hand cranked drawbridge. The bridge design is a through truss drawbridge construction similar in design to a medieval drawbridge. The ends of the span are lifted by chains (see Figure 1). The drawspan rotates about pinned bearings at the north abutment. Although the bridge rotates about a fixed point, the design is not a true bascule design. The word bascule is derived from a French word bascule meaning seesaw or balance. The seesaw approach was an early solution to bridge balancing. A traditional bascule bridge utilizes a counterweight behind the pivot point of the seesaw so the net unbalanced moment is close to zero (see Figure 2). As the bridge opens and the center of gravity of the span moves closer to the pivot, the center of gravity of the counterweight also moves closer to the pivot. As the span arm shortens the counterweight arm shortens proportionately. Therefore, the bridge remains in a balanced state throughout the opening and closing operation. This balanced condition is true if you assume the bridge is a plane and there is no vertical variation in the centers of gravity of the span or the counterweight.

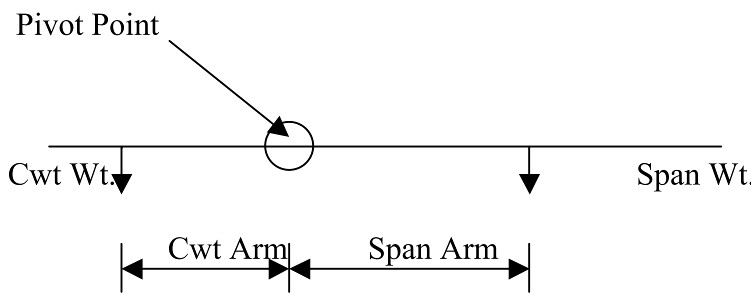

FIGURE 2: Schematic view of bascule

When opening a drawbridge similar to Bridge Street the movable span pivots about a fixed center of rotation or pivot point. As the bridge opens the center of gravity moves closer to the pivot point and the moment required to overcome the imbalance decreases (see Figure 3). The problem with hand operation is the significant force required to open the bridge when the span is down. At opening the initial load in each of the lifting chains would be greater than half the weight of the drawspan.

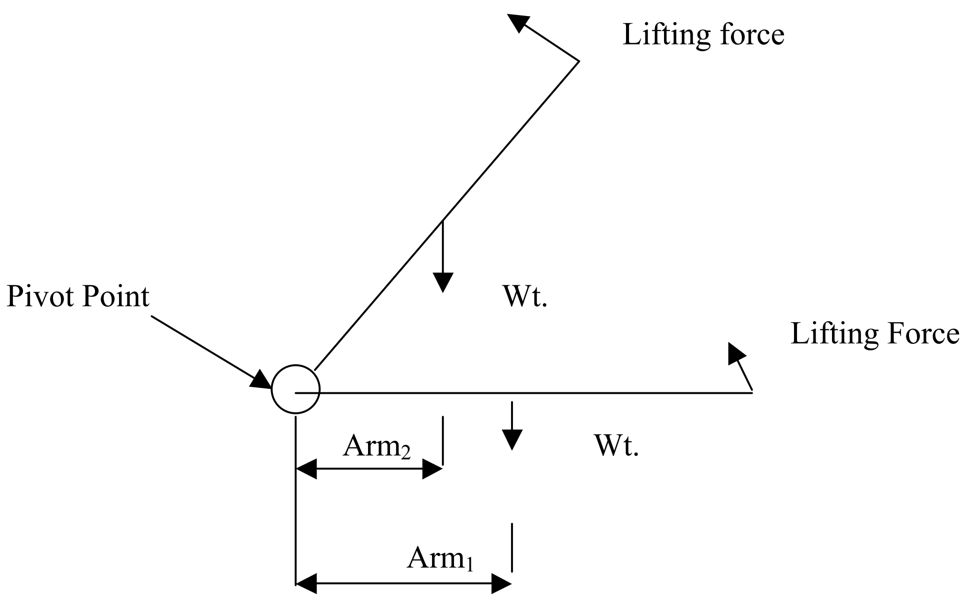

FIGURE 3: Schematic view of drawspan

Early attempts to balance a drawspan were made by connecting the other end of the lifting chains to a counterweight. The lifting chain passed over a sheave located above and behind the drawspan. The sheave was free to rotate as the drawspan opened. The basic problem with the design is: if the counterweight is sized to balance the span when the bridge is in the down position the counterweight will be significantly heavier than required to balance the span as the bridge opens. The result is excessive force is required to restrain the hand crank. The crank will rip out of the operators hand and slap them in the head at which point the counterweight will free fall until the span runs into the tower. Conversely if the counterweight is sized to balance the span in the open position excessive force would be required to control the span when closing.

The Bridge Street Bridge is based on a French design from the early 1800's which had a unique solution to dealing with the variation of bridge balance required while opening a drawspan3. There are two draw chains that lift the far end of the drawbridge. The draw chains wrap around sheaves as the bridge is opened. The sheaves are mounted to a shaft on top of a steel tower at the near abutment. The counterweights are hung from spiral cut sheaves mounted to the same shaft as the draw chains (see Figure 4). The spiral cut in the sheave means that the center of gravity of the counterweight moves inward toward the centerline of the shaft as the bridge is opened. Therefore the mechanical advantage from the counterweight changes as the as the center of gravity of the span moves closer to the pivot point. This system allowed the bridge to be opened and closed by hand with a relatively constant effort. A system of open gearing reduces the total torque required at the hand crank.

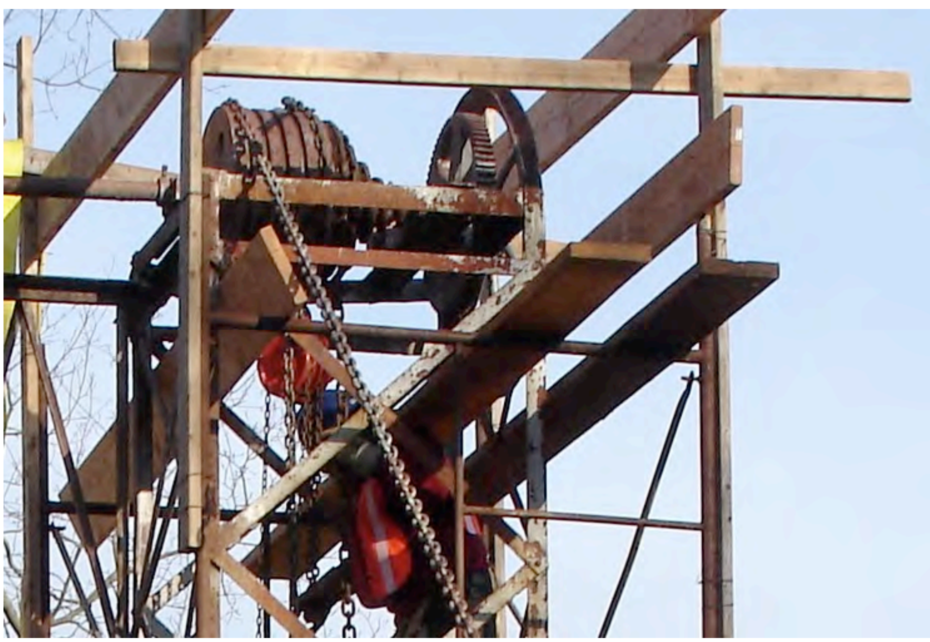

FIGURE 4: Constant diameter draw chain sheave and spiral cut counterweight sheave mounted on a common shaft

Rehabilitation of Bridge Street Bridge

Original Design

The original scope of work was to perform an in-depth inspection of the bridge, develop a bridge design report and to repair the bridge super structure so that it could adequately support pedestrian loading. The bridge was not to be opened to vehicular traffic. The lift span would be removed and repaired in the shop. The fixed portions of the bridge were to be cleaned and painted and rehabilitated in place. The existing concrete approach deck was to be resurfaced. Minor repairs were to be made to the substructure elements including repointing of stone abutments and resurfacing the concrete pier. Riprap scour protect would be placed around all substructure elements. The schedule was to get phase one: The Design Report approved and Phase Two: the final design completed in about 7 months so that Phase Three: Construction could start by summer of 2004.

The project was on a fast track with a tight budget. The Bridge Street Bridge is the only know bridge of its type, there were no available drawings, and there was no one alive today who was around in 1880 when the bridge was built.

Bergmann Associates performed a site survey, a bridge inspection and an underwater inspection was performed by Boswell Engineering during Phase One of the project in order to locate bridge and roadway elements and determine the extent of deterioration. Many bridge and roadway elements were inaccessible during the inspection. The approach span framing was encased in concrete with only the bottom of the stinger flanges exposed. The main span pivot bearings and the base of the counterweight towers were buried in asphalt. The end floorbeams were inaccessible, as were connections to the deck trusses. Timber decking was covered with plywood and steel plates. The limits of the substructure elements were unknown. Stone abutments were partially surfaced with concrete, and the condition of stone work below the concrete facing was unknown. Excavating to determine hidden details was beyond the scope of work. We determined that we would provide documentation of the bridge details as was feasible but certainly sufficient for design purposes. We would require the contractor to provide precise documentation during demolition such that the contractor will be ability to reassemble bridge components.

It was difficult if not impossible in many instances to determine the original configuration and original construction materials. Was the original 1880 approach deck constructed of concrete or timber? It would be very unlikely to find a reinforced concrete bridge decks from 1880, but some unreinforced concrete jack arch type construction from the period is still in existence. We guessed that the original approach deck might have been timber and later replaced with concrete. That would explain the out-of plane deformation of the through truss top chords (see Figure 5). However, there were no records that would indicate the original approach deck construction. Similarly, we were unsure if the original pier construction was unreinforced concrete or if the concrete was added as a modification to an older stone pier. From the historic preservation point of view, we came to an agreement with the County that we would repair the bridge to show the history of the bridge rather than the worry about the initial design. For example if a timber deck were replaced with concrete the concrete is part of the bridge history. Therefore we would restore the concrete deck by patching and resurfacing with a new overlay. We would resurface the concrete pier. At the abutments we would re-point the exposed stone masonry and repair the concrete facing on the portions that had been resurfaced previously. This was the basic design approach that we pursued for the design report.

Some improvements were planned for the rehabilitated bridge. The new timber deck would be durable and low maintenance. A hardwood "Ipe" was chosen for the timber deck construction due it strength, durability and resistance to decay. New concrete bridge seats would be provided at the abutments.

The existing bridge was to be converted into a park setting. Timber benches and planter boxes will be incorporated into the design. An historic bridge plaque will be added to highlight the significance of the bridge and some of the unique characteristics of the bridge.

FIGURE 5: View looking South across the deteriorated timber deck on the bascule span at the start of construction. Also note the asphalt overlaid concrete approach deck and lateral deformation of the approach truss.

Contract Modifications to the Design

In September 2005 after the contract had sat a while and a new Project Manager took over for the County, some modifications were made to the design approach. It was decided that the existing approach span and the counterweight tower would be removed and rehabilitated in the shop. This would eliminate the cleaning and painting operations in close proximity to the residential properties at the north side of the bridge. The existing concrete bridge would be replaced with a lightweight concrete reinforced deck to reduce the loading on the potentially overloaded approach span trusses and center pier foundations.

During flood conditions in the April 2006 the Sparkill Creek overtopped the bridge deck by as much as two feet. At this time it was decided to raise the bridge elevations to reduce the frequency with which the bridge. Along with the changes to the bridge elevation, the north roadway approach profile would be adjusted to remain ADA compliant and the pavement would be replaced with paving blocks as betterment to the community. In addition some planting areas were added so that the Village of Piermont can add flower beds along side the pavers at both approaches to the bridge.

Construction of Bridge Street Bridge

Schedule

The Contractor was given a Notice to Proceed on the construction in February of 2008. As per the contractor's schedule the estimated substantial completion would be in August 2008. Demolition of the existing structure would begin March 6, 2008.

FIGURE 6: Demolition of steel towers

Removal of the Existing Structure.

The first step was to remove the steel towers (see Figure 6), including all machinery and counterweights, all carefully stored for delivery to the Contractor's yard for restoration later. Pieces to be reused were all marked and photographed. On the second day the Contractor cut the counterweight chain at the Northwest Tower Leg (see Figure 7). Since the chain is a historic element that was to be reused in the reconstruction of the bridge, the Contractor was informed that he would have to restore the chain to its original condition.

FIGURE 7: Severed link at northeast counterweight chain

After the removal of the Counterweight Towers, the bascule span was removed. The timber deck was dismantled and discarded, and the steel floorbeams and trusses were carefully brought onto land. Existing ornate cast-iron movable bridge bearings were uncovered and it was decided that they would be reused. At this stage it was apparent that the condition of the existing steel was much worse than had been expected. All of the transverse W10 floorbeams were so badly corroded they had to be replaced (see Figure 8). The lower chord, end angles, many diagonal members and gusset plates on each truss would have to be replaced. All bracing members including lateral bracing and truss knees braces would require replacement.

FIGURE 8: Demolition of timber deck

The approach span deck and steel framing was then removed, starting with the concrete slab spanning between the south abutment and the concrete center pier. The concrete deck was removed using saws and small jack hammers in an attempt to avoid damage to the existing steel trusses and steel beams embedded in the deck. During removal of the approach span concrete deck, the expected W12 steel beams embedded in the slab were not found. In fact the slab was supported by steel railroad rails cast into the bottom of the slab (see Figure 9). These rails apparently came from the dismantled Erie Rail Line into Piermont. It was immediately apparent that the concrete deck was not the original deck, but was rather from rehabilitation work in the first few decades of the twentieth century. It was also apparent at this time that a redesign of the approach span framing would be required.

FIGURE 9: Demolition of the concrete approach deck uncovered used rails in the deck

Several days after the removal of the approach concrete slab the center pier started to rotate about the bottom north edge of the pier (see Figure 10). The approach slab had provided lateral restraint to the pier, and once removed the pier was free to rotate and translate. Exacerbated by an undermined condition, the top of the pier translated sideways approximately twelve inches.

FIGURE 10: Concrete pier leaning toward the north

Reconstruction of the existing foundations.

The existing abutments consisted of dry stone walls seated just below the streambed. The contract called for pointing of the stone walls and construction of a new concrete bridge seat, including installation of stone riprap at the base of the wall. The contractor installed cofferdams and dewatered to gain access to the stone walls. During clearing of the riverbed with a backhoe for installation of the cofferdam, the wingwall adjacent to the abutment wall, which was constructed of loose stone with concrete stucco facing, was undermined and moved laterally several inches (see Figure 11). This wall had little foundation and eventually crumbled and collapsed into the river.

FIGURE 11: Movement of the Southwest Wingwall

Design changes during construction.

Steelwork:

Due to a significant amount of deteriorated steel, many structural steel elements were replaced that were not included in the original design (see Figure 12). After the exact configuration of the structural elements to be replaced was determined, existing deteriorated steel pieces were carefully measured and redetailed. Elements that were redetailed were as follows: Bascule and approach steel trusses, including transverse steel floorbeams, angle knee braces, outriggers that attach to steel bascule span to the counterweight chains, and all lateral bracing members. Several machinery support members at the tops of the towers were badly deteriorated and were replaced.

FIGURE 12: Severely corroded end floorbeam and truss gusset plate that were buried at the north abutment

Approach Span:

The concrete approach span was a recent addition to the bridge. It was determined that the concrete span was built c. 1930, and replaced what we believe was the original timber deck. It was suggested that for sake of consistency and bridge integrity that the approach span would be redesigned to provide a new timber deck and timber stringer system supported by transverse steel floorbeams similar to the drawspan. Several remaining steel elements strongly suggest that the original structure had been framed this way. It was also apparent that the weight of the concrete deck had caused truss buckling.

Timber Decking and Beams:

The contract called for IPE hardwood decking and stringers. The contractor was not able to procure the member sizes specified in the desired species, and so the client agreed to modify the contract requirements to provide timber more readily available in the sizes required. The timber to be used was Alaskan Yellow Cedar, a relatively rare, but hard, durable timber, with excellent resistance to deterioration especially suitable to the marine environment (see Figure 13). The timber properties were not as specified for IPE and so the number and arrangement of the timbers beams was modified.

FIGURE 13: New timber deck and rehabilitated steel framing erected in shop

Stone Wingwalls and Abutments:

The collapse of the wingwall adjacent to the south abutment necessitated a design for the replacement of this wall. The wall was on the property of an adjacent landowner and so close coordination with the landowner and the local authorities was important. A gravity stone wall on a concrete foundation was designed to provide support the riverbanks and an adjacent local road.

FIGURE 14: View looking south from behind the north abutment. Note new timber piers and the reconstructed southwest wingwall

Center Pier:

The collapse of the center pier was the most significant change to the scope of the project. The concrete pier, a more recent replacement of the original pier, was removed while the plan for its replacement was considered. Once removed, it became clear that the concrete pier had no significant foundation. It was merely sitting on top of two timber piles which had been cut-off below the base of the newer pier foundation. The presence of the timber piles suggested that the original pier was a timber pile bent. It was decided to redesign the pier and replace it with a timber pile bent. In order to determine the type and depth of the piles required, a boring and a geotechnical design was performed. The final redesign consisted of five-12" diameter piles with a timber piles cap and cross bracing (see Figure 14 and 15).

FIGURE 15: View looking north at piles for new timber pier

Bridge Geometry:

The Bridge geometry was modified particularly at the top of the abutments and the new timber pier to accommodate changes in pier design and approach span framing. It was also discovered during construction that the counterweight trunnion shaft was slightly skewed in reference to the bridge. The centerline of shaft at the west tower leg was set back about an inch relative to the east tower leg. At first glance it appeared as though there may have been some change in bridge geometry since the original construction. It is also that possible that the skew may have helped the draw chain to reeve along the fixed diameter sheave as the bridge opens.

Rebuilding History

Steel Detailing:

A thorough field inspection was performed during demolition to measure existing pieces to be replaced, and to determine what had been there, in some cases using existing rivet hole locations to determine the configuration of replacement pieces that had long since disappeared. The extent of the repairs to the steel elements required careful detailing to be consistent with existing bridge elements. Truss members such as angles, structural tees and plates were measured and replaced exactly in kind (see Figure 16). Several angles to be replaced were of a size that is no longer rolled, and so were replaced with metric size angles that more closely matched the original pieces. For this effort, seven new sheets of steel details were produced.

FIGURE 16: View of rehabilitated truss after prime coat was applied in the shop. Note shafts and gearing in the background.

Bolts and Connections:

The existing trusses are slender elements connected mostly with rivets. During the demolition we found there were several locations where square head bolts were used instead of rivets. Rivets that were required to be replaced due to deterioration of the rivet or the connecting member were replaced with round head bolts and the existing square head bolts that could not be reused were replaced with new square head bolts.

Bridge Bearings:

The existing cast-iron bridge bearings uncovered during demolition were found to be ornate and an integral part of the bascule span (see Figure 17). They had been planned for replacement but these were retained. In order to do so the new concrete abutments were redesigned to accept older and larger bearings.

FIGURE 17: Existing movable bridge bearing uncovered during the removal of the existing draw span

Bridge Color:

The color of the bridge prior to construction was silver, but this was not the original paint color. Under the silver coat, and still very well intact in many areas, was found the original lead paint coatings. The client and others noted the importance of painting this structure in keeping with its natural surroundings and using a color that it had been in the past. Local agencies including the village government and the historic society were contacted to determine and agree upon the color the bridge would be painted. Eventually the bridge will be painted with a color to match as closely as possible to the color that was found on the existing steel members, namely Pantone 492U which is a brick red semi-gloss epoxy paint system (see Figure 18).

FIGURE 18: Paint sample for approved three coat system. Note rehabilitated sheave assembly in the background.

Conclusion

There are many potential unforeseen difficulties that are encountered during bridge rehabilitation projects. Rehabilitation of historic movable bridges adds several level of difficulty. Close coordination is required between the Engineer, Contractor, Owner, and the various stakeholders that have an interest in the project. During demolition it is necessary to accurately catalogue parts, sizes, fits and alignment since there are no available drawings. All parts should be piece marked to facilitate future erection of the rehabilitated components. Care must be taken at every step to guarantee the integrity of bridge components during the removal and rehabilitation. While the effort required may be painstaking the results are important. A snap shoot in time will be preserved for the community enjoyment. Bridge Street will be a place to sit and reflect on the past. Figure 19 and 20 show the North approach to the near complete construction of The Bridge Street Bridge.

FIGURE 19: Substantial completion of the Bridge Street Bridge. Note the paving blocks used for the north approach

FIGURE 20: Bridge Street Bridge looking northeast. Similar view to Figure 1

References

(1) Piermont Public Library Website: http://piermontlibrary.blogspot.com/
(2) King Bridge Company Website: http://www.kingbridgeco.com/
(3) Fraser D. J. & Deakin M. A. B. – Curved Track Bascule Bridges from Castle Drawbridge to Modern Application - 7th Historic Bridge Conference