Minnesota Department of Transportation (Mn/DOT)
Historic Bridge Management Plan

Bridge Number: 9036

Executive Summary

Bridge 9036 (Robert Street Bridge) was built in 1926 to carry vehicular traffic on U.S. Highway 52 (Robert Street) over the Mississippi River in downtown St. Paul, Ramsey County. It has an overall structure length of 1,428.9 feet and an out-out width of 80.4 feet, with eight reinforced-concrete-arch main spans and nine prestressed-concrete-beam approach spans. The main spans include three open-spandrel barrel arches, four open-spandrel rib arches, and a 264-foot, rib through-arch (rainbow arch) over the navigation channel. The massive ribs of the rainbow arch give the bridge its identifiable profile and provide a gateway for motorists entering downtown St. Paul. Because of its prominent urban location it received architectural detailing in the Moderne style. A 1989 reconstruction included replacement of the deck and approach spans, restoration of the arch spans, and reconstruction of the ornamental railing.

Bridge 9036 is generally in fair condition. It has adequate deck width and load capacity. The primary concerns for Bridge 9036 are conveyance of deck and sidewalk drainage and deterioration of several concrete components.

The recommended future use of the bridge is rehabilitation for continued vehicular use on-site. The bridge should be rehabilitated based on the Secretary of the Interior's Standards for Rehabilitation (Standards) [36 CFR Part 67] and Guidelines for Bridge Maintenance and Rehabilitation Based on the Secretary of the Interior's Standards (Guidelines).

Until the Federal Highway Administration (FHWA), State Historic Preservation Office (SHPO) and Minnesota Department of Transportation (Mn/DOT) have signed a historic bridge Programmatic Agreement, all proposed work on this bridge (including maintenance, preservation and stabilization activities) needs to be sent to the Mn/DOT Cultural Resources Unit (CRU) for formal review.

MEAD & HUNT HNTB JUNE 2006

Minnesota Department of Transportation (Mn/DOT)
Historic Bridge Management Plan

Bridge Number: 9036

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I - Project Introduction

Bridge Number: 9036

The Minnesota Department of Transportation (Mn/DOT), in cooperation with the Minnesota State Historic Preservation Office (SHPO) and Federal Highway Administration (FHWA), has committed to preserve selected historic bridges in Minnesota that are owned by the state and managed by Mn/DOT. In consultation with SHPO and FHWA, Mn/DOT selected 24 bridges as candidates for long-term preservation. Mn/DOT's objective was to preserve the structural and historic integrity and serviceability of these bridges following the Secretary of the Interior's Standards for the Treatment of Historic Properties (Standards) [36 CFR Part 68], and their adaptation for historic bridges by the Virginia Transportation Research Council as Guidelines for Bridge Maintenance and Rehabilitation Based on the Secretary of the Interior's Standards (Guidelines). The character-defining features of each bridge received special attention. Mn/DOT also hopes to encourage other owners of historic bridges to follow its model for preservation.

The Glossary in the Appendix explains historic preservation terms used in this plan, such as historic integrity and character-defining features, and engineering terms, such as serviceability and deficiency.

Mn/DOT's ongoing efforts to manage historic bridges are intended to comply with Section 106 of the National Historic Preservation Act of 1966, as amended, and Section 4(f) of the U.S. Department of Transportation Act of 1966. This effort began with Robert M. Frame's 1985 study and list of significant and endangered bridges in Minnesota and incorporates Jeffrey A. Hess's 1995 survey and inventory of historic bridges in Minnesota that were built before 1956. That inventory identified the subject bridge as eligible for listing in the National Register of Historic Places. Using the results of the 1995 study, Mn/DOT selected individual historic bridges for long-term preservation.

To achieve its preservation objectives, Mn/DOT retained the consultant team of Mead & Hunt and HNTB to develop management plans for 22 of the 24 selected bridges. The remaining two bridges have been addressed through separate projects.

Mn/DOT requested that the team consider a full range of options for each bridge and present the option that the team judged to be best for long-term preservation with due consideration given to transportation needs and reasonable costs. For example, if two options are explored that both result in an equivalent level of preservation for the bridge (e.g., retention of historically significant features and projected life span), but one option costs significantly more than the other, the less costly option will be recommended. In cases where one option results in a significantly better level of preservation than any other reasonable options but costs more, it will be the recommended action.

Preservation objectives call for conservation of as much of the existing historic fabric of the bridge as possible. However, safety, performance and practical considerations may have dictated replacement of historic fabric, especially of a minor feature, if such action improved the overall life expectancy of a bridge.

Options that were considered for the 22 historic bridges, listed from most to least preferred, are:
1. Rehabilitation for continued vehicular use on-site
2. Rehabilitation for less-demanding use on-site, such as one-way vehicular or pedestrian/bicycle traffic
3. Relocation and rehabilitation for less-demanding use
4. Closure and stabilization following construction of bypass structure
5. Partial reconstruction while preserving substantial historic fabric

A recommended option was selected for each bridge through consultation among the consultant team, Mn/DOT and SHPO. Within the recommended option, the plan identifies stabilization, preservation and maintenance activities. Stabilization activities address immediate needs in order to maintain a bridge's structural and historic integrity and serviceability. Preservation activities are near-term or long-term steps that need to be taken to maintain a bridge's structural and historic integrity and serviceability for the foreseeable future. Preservation activities may include rehabilitation and replacement of components, as

needed, and remedial activities to address a deficiency. Maintenance activities, along with regular structural inspections and anticipated bridge component replacement activities, are routine practices directed toward continued serviceability. Mn/DOT is responsible for final decisions concerning activities recommended in the plan.

Recommendations are intended to be consistent with the Standards. The Standards are ten basic principles created to help preserve the distinctive character of a historic property and its site, while allowing for reasonable change to meet new needs. They recommend repairing, rather than replacing, deteriorated features when possible. The Standards were developed to apply to historic properties of all periods, styles, types, materials, and sizes. They also encompass the property's site and environment as well as attached, adjacent, or related new construction.

Because the Standards cannot be easily applied to historic bridges, the Virginia Transportation Research Council prepared Guidelines, which adapted the Standards to address the special requirements of historic bridges. The Guidelines, published in the Council's 2001 Final Report: A Management Plan for Historic Bridges in Virginia, provide useful direction for undertaking historic bridge preservation and are included in the Appendix to this plan.

The individual bridge management plan draws from several existing data sources including: PONTIS, a bridge management system used by the Mn/DOT Bridge Office to manage its inventory of bridges statewide; the current Mn/DOT Structure Inventory Report and Mn/DOT Bridge Inspection Report for each bridge (the complete reports are included in the Appendix); database and inventory forms resulting from the 1995 statewide historic bridge inventory; past maintenance reports (if available, copy included in the Appendix); and other information provided by Mn/DOT. Because PONTIS uses System International (metric) units, data extracted from PONTIS are displayed in metric units.

The plan is based on information obtained from Mn/DOT in 2005, limited field examinations completed in 2005 for the purpose of making a qualitative assessment of the condition of the bridge, and current bridge design standards. Design exceptions are recommended where appropriate based on safety and traffic volume. The condition of a bridge and applicable design standards may change prior to plan implementation.

This plan includes a maintenance implementation summary at the end. This summary can be provided as a separate, stand-alone document for use by maintenance staff responsible for the bridge.

The plan for this individual bridge is part of a comprehensive effort led by Mn/DOT to manage the statewide population of historic bridges. The products of this management effort include:

1. Minnesota Historic Bridge Management Plan
2. Individual management plans for 22 bridges
3. National Register of Historic Places (NRHP) nomination forms for 2 bridges
4. Minnesota Historical Property Record (MHPR) documentation for 46 bridges

The first product, the Minnesota Historic Bridge Management Plan, is a general statewide management plan for historic bridges in Minnesota that are owned by the state, local governments or private parties. It is intended to be a single-source planning tool that will help bridge owners make management and preservation decisions relating to historic bridges. Approximately 240 historic bridges owned by parties other than Mn/DOT survive in the state as of 2005. Mn/DOT is developing this product to encourage owners of historic bridges to commit to their long-term preservation and offer guidance.

This individual plan represents the second product. The third and fourth products will be prepared as stand-alone documents.

Date of Construction	1926		
SHPO Inventory Number	RA-SPC-3177		
Common Name (if any)	Robert Street Bridge		

Location

Feature Carried:	Robert Street (TH 952A)		
Feature Crossed:	Mississippi River, RR, Second and Shepard Streets		
Descriptive Location:	0.7 Miles Southeast of TH 35E and 94		
UTM Zone: 15	NAD:	1927	
Easting: 493060	Northing:	4976600	
USGS Quad Name:	St. Paul East		
Town or City:	St. Paul		
County:	Ramsey		

Structure Data

Main Span Type:	111	Concrete Arch - Deck	Total Length: 1429

Descriptive Information (or narrative as available)

Superstructure:

Substructure:

Floor/Deck:

Other Features:

Narrative:

The Robert Street Bridge is located in downtown St. Paul, Ramsey County, where it carries Robert Street (U.S. Trunk Highway 52) over the Mississippi River, Second Street, Shepherd Road, and the railroad tracks. It links the downtown St. Paul business and commercial district at Kellogg Avenue with the city's west side neighborhood and the city of South St. Paul, together a mixed industrial-commercial-residential area. On the north the bridge reaches the top of the river bluff; on the south it opens to the river's flood plain. The bridge is involved with a wide variety of transportation networks: it crosses river, rail, and vehicular traffic; it carries vehicular traffic, in part to Holman Field, the downtown St. Paul airport. Adjacent, and so close that its north approach spans are literally beneath the Robert Street Bridge, is the Chicago Great Western Railroad Lift Bridge (1912, 1925). The location of the existing lift bridge determined the location of the river navigation channel, which is beneath the main spans of each bridge. The Robert Street Bridge parallels the Wabasha Street Bridge (1889; MNDOT No. 6524), which is located about three blocks west, and the Lafayette Freeway Bridge (1968), which is located about seven blocks east.

Aligned on a northwest-southeast axis, the Robert Street Bridge is a reinforced-concrete, multiple-arch bridge, with an overall structure length of 1,428.9 feet. Starting at the north end, the bridge includes: a reinforced-concrete trestle with three spans of varying length, totaling 89 feet; a skew steel deck-girder span of about 53 feet across Second Street; three flat, open-spandrel, barrel arches of 95.5, 71, and 98 feet, with a combined length of about 291 feet; a two-rib, through arch (also known as a rainbow arch)

of 264 feet, center to center piers, with a 244-foot clear span; four five-rib, open spandrel arch spans of 112 feet each; and a prestressed-concrete beam approach. The out-out deck width is 80.4 feet, carrying a 56-foot roadway and 9.5-foot sidewalks on each side. The main span meets the federal navigation requirements of 62-foot headroom above low water.

Of particular engineering interest in the Robert Street Bridge is the main span. The two main ribs are each 6 feet wide and 8 feet deep at the crown, and spaced 64 feet, 8 inches, center to center. Each rib is fundamentally a structural steel frame, designed to carry the weight of the steel structure, including the steel floor system, and the dead load of the concrete arch proper. The dead load of the concrete roadway and the live loads are carried by the composite concrete and structural steel arch. The arch ribs have heavy steel cross-bracing below the roadway (W.E. King and Roy Childs Jones, "Engineering and Architectural Design of a Long Concrete Bridge," in Engineering News-Record 97 (November 4, 1926): 732-37).

Aesthetically, the most important element of the structure is the monumental rainbow arch that dominates the bridge. The overall detailing of the surfaces has been described by Roy Childs Jones, the architectural designer, in general terms, as involving "the breaking up of all surfaces with lines of light and shade," with modeling "accomplished by vertical breaks and grooves, by bevels, and by wedge-shaped indentations." According to Childs, "the idea was to make, out of natural patches of lighter and darker toned material, patterns definitely bounded by strong lines of shadow; and to effect an emphasized interest in light shade in place of the unattainable color interest (which is inherent in concrete)." The railing, a focus of the architect, is comprised of precast perforated panels anchored between poured, heavily reinforced members at top and bottom, and between posts from side to side. Although the south railing is erected on grade, the panels are set vertically. Twelve large medallions, modeled by the Brioschi-Minuti Co. of St. Paul, mounted on the piers, are the only applied ornament (See King & Jones; see also John F. Greene, "Some Lessons Learned in Building Long Concrete Bridge," in Engineering News-Record 97 (November 11, 1926): 785-88). The original light standards have been replaced with modern light poles. Moderne characterizes the basic style of the bridge.

The bridge was rehabilitated in 1989, including the replacement of approach spans.

Roadway Function:	Mainline
Ownership:	State
Custodian/Maint. Agency:	State

Contractor

Designer/Engineer Engineer: Toltz, King & Day, St. Paul, Minnesota
Architect: Roy Childs Jones

Significance Statement

The Robert Street Bridge is historically significant as an outstanding example of an unaltered, monumental, multi-span, reinforced concrete arch bridge. It is the product of a very complex engineering design process to enable this bridge to be built in this location with its established vehicular, railroad, streetcar and river-navigation demands. The resulting bridge includes a monumental reinforced concrete rainbow arch, by far the largest in Minnesota, which is outstanding not only for its engineering, but for its aesthetic effect in the overall design of the bridge. In addition, the bridge received special architectural treatment by the architect assigned to the design team.

Work on the bridge was begun on June 19, 1924. The bridge was completed and dedicated on August 6, 1926. It was a joint undertaking of Ramsey County and St. Paul. Plans and specifications were prepared by Toltz, King & Day, Inc. The Toltz, King & Day, Inc. design team included Max Toltz, mechanical engineer; W.E. King, structural engineer; B.W. Day, architect; Roy Childs Jones, architectural designer; P.E. Stevens, office engineer; W.A. Thomas, electrical engineer; and John F. Greene, in charge of arch design and resident engineer. The contractor was Fegles Construction Company, Ltd.

The Robert Street Bridge was built to replace an 1884-1885 wrought-iron span that, by the 1920s, had proved inadequate for drastically increased traffic and streetcar demands. The original structure was designed for horse-drawn vehicles with no provision for streetcars. Streetcar tracks were added in 1893. By 1920, the bridge was carrying 2,730 vehicles and 400 streetcars every 12 hours. Two years later the vehicular traffic had increased 55 percent. This traffic increase had been caused by widening Robert Street in 1912-1914 and by connecting Robert Street with University Avenue, a major artery linking St. Paul with Minneapolis. This brought traffic to and from Minneapolis and downtown St. Paul on the north, and St. Paul's west side neighborhood and South St. Paul on the south. In fact, cities as far south as Winona, Minnesota, viewed the new bridge as a needed "capitol highway" to give them greater access to the state capitol.

The engineering firm commissioned to design the new bridge, not only had to provide a span with adequate vehicular and streetcar capacity, but had to accommodate the congested local conditions, with the location of nearly every pier being determined by the clearances required by existing structures and railroad property. The engineers had to reckon with Second Street, the freight shed and tracks of the C.St.P.M.&O. Railway, the tracks of the St. Paul Union Depot, which handles the entire passenger traffic of the city, the main line of the Chicago Great Western Railroad, the river channel of the Mississippi as defined by the War Department and the south end of the bridge then terminating in a busy manufacturing district. These factors and their various requisite clearances dictated the exact location of the roadway. They came together with foundation conditions and the existing Chicago Great Western railroad lift bridge which strictly defined the navigation channel, to dictate the location, size and design of the piers. The net result is the combination of barrel-arch and rib-arch flanking spans and especially the rainbow arch main span over the navigation channel.

Because of the many factors dictating elements of the main span, a rainbow arch was the only solution if an arch was to be used. The solution was an unusual rainbow arch. Instead of the usual compound curves resembling a basket handle, with the long radius at the crown and the shorter radii at the haunches, the radius is 122.16 feet at the crown and 191.60 feet at the haunch. The structural-steel-arch

inside each concrete rib also is a significant feature. The steel arch is designed to carry the dead load of the steel arch, floor and concrete rib.

According to the bridge architect Roy Childs Jones in the Engineering News-Record of November 4, 1926, "The Robert Street Bridge is unique in that its designers included in their own permanent organization both architects and engineers." This design team, Jones wrote, allowed the bridge to avoid "applied ornament" on a predetermined structure. Instead, the team could "select and control the structural features so as to secure for the bridge an inherent beauty of form and proportion." The design team faced "the complicated requirements of street grades and of railroad and channel clearances," which precluded "any simple and regular composition of arches and piers." For the most part, then, architectural treatment in this bridge involved working with "shapes and proportions and relations of the structural members" and employing shadow and line. There also was a conscious effort to deal aesthetically with concrete as a material and Jones felt that unbroken surfaces and lines did not work well in concrete. Instead, a choice was made to create a totality out of a series of "definitely bounded segments," produced by "the breaking up of all surfaces with lines of light and shade." This was accomplished by using "vertical breaks and grooves, by bevels, and by wedge-shaped indentations." The result of this practice is readily seen in the surface treatment of the massive rainbow-arch ribs.

Historic Context Reinforced-Concrete Highway Bridges in Minnesota

National Register Criteria C

References

Robert M. Frame, "Robert Street Bridge," National Register of Historic Places Nomination Form, August 15, 1988, available in State Historic Preservation Office, Minnesota Historical Society, St. Paul. Green, John F. "Some Lessons Learned in Building Long Concrete Bridge." Engineering News-Record 97 (November 11, 1926): 785-88; King, W.E. and Roy Childs Jones. "Engineering and Architectural Design of a Long Concrete Bridge." Engineering News-Record 97 (November 4, 1926): 732-37.

Character-Defining Features

Character-defining features are prominent or distinctive aspects, qualities, or characteristics of a historic property that contribute significantly to its physical character. Features may include materials, engineering design, and structural and decorative details.

Feature 1. Reinforced-concrete arches. The bridge is significant for its series of reinforced-concrete arches and, in particular, its massive rainbow arch ribs that rise 30 feet above the roadway.

Feature 2. Architectural detailing. Minnesota architect Roy Childs Jones used architectural detail to add highlighting and shadows to the surfaces "in place of the unattainable color interest," he noted, inherent in concrete. The overall stylistic effect is Moderne. This feature includes the twelve, large, concrete medallions mounted on the piers, floor-beam ends, reconstructed ornamental railing, and bronze dedication plaques.

IV - Engineering Data

Bridge Number: 9036

Inspection Date	9/23/2003	*(Inspection and inventory data in this section was provided for this project by Mn/DOT in May 2005)*
Sufficiency Rating [1]	74.3	
Operating Rating [1,2]	29.48	
Inventory Rating [1,2]	18.87	
Posted Load [1]	0	
Design Load [1]	9	
Deficiency Rating Status [1]	F	
Condition Codes		
Deck:	7	
Superstructure:	7	
Substructure:	6	
Channel and Prot.:	8	
Culvert:	N	
Appraisal Ratings		
Struct. Eval.:	6	
Deck Geometery:	2	
Underclearances:	2	
Waterway Adequacy:	8	
Appr. Alignment:	8	
Smart Flag Data [1]	☐	*(A check indicates data items are listed on the Bridge Inspection Report)*
Fracture Critical [1]	N	
Last Inspection Date		
Waterway Data		
Scour Code [1]:	A scour evaluation has been completed for Bridge 9036 and countermeasures have been installed to correct a prior problem with scour. The bridge is no longer scour critical. Scour countermeasures should be inspected at least once every 4 years and after major flows, or as recommended in the Bridge Scour Evaluation Report. Report any changes that have occurred to countermeasures.	
Roadway Data		
ADT Total:	17000	
Truck ADT Percentage:	2	
Bypass Detour Length [2]:	1.6093	
Roadway Clearances		
Roadway Width [2]:	17.0688	
Vert. Clearance Over Rdwy [2]:	99.99	
Vert. Clearance Under Rdwy [2]:	7.3152	
Lat. Under Clearance Right [2]:	0.4572	
Lat. Under Clearance Left [2]:	0.36576	
Geometry Characteristics		
Skew:	0	
Structure Flared:	0	

[1] These items are defined in the glossary in Appendix A. [2] These items are provided in metric units.

Roadway Characteristics

Floodplain Data

Available data indicates that Bridge 9036 will not inundate during a Q100 flood event.

Accident Data

The Mn/DOT Accident Database reports 68 accidents associated with this bridge for the 15-year period of 1990-2004.
45 – Property Damage – No Apparent Injury accidents
15 – Injury – Possible Injury accidents
8 – Injury – Non-incapacitating Injury accidents

Location of Plans

Bridge Office

Existing Conditions

Available information was reviewed prior to assessing the various options for preservation of Bridge 9036 and visiting the bridge site. This information is cited in the Project Introduction section of this plan. A site visit was conducted to qualitatively establish the following:

1. General condition of structural members
2. Conformation to available extant plans
3. Roadway geometry and alignment
4. Bridge geometry and clearances

Serviceability Observations:

Bridge 9036 has an ADT of 19,000 (2004) and a roadway width of 56 feet, which satisfies the desired width for low-speed bridges carrying four lanes of traffic.

There are no independent vehicular railings to separate traffic and pedestrians.

The load capacity of Bridge 9036 is adequate. It has an inventory load rating of HS 20.8 and an operating rating of HS 32.5. The controlling elements for the load ratings are the concrete deck girders in the arch spans. The inventory report lists the rating date as 3-1-76.

Structural Condition Observations:

General Observations

The prestressed beam spans on the south end of the bridge appear in good condition.

In several locations where new concrete caps and pedestals have been added to old concrete elements, the old concrete is scaling and spalling.

Approach Roadway Elements

The crib retaining-wall on the east side of the south approach has several vertical cracks. The fascia of the crib wall cap is scaling and spalling at the same location.

The bituminous/concrete pavement joint at the south end of the south approach is deteriorated. Several interior joints on the south approach have cracks and delaminations, producing many openings that are wider than 1” allowing water to reach the subgrade.

The pavement joint between the south approach and the bridge approach panel is open a couple inches with vegetation growing in the joint.

The brick paver sidewalk adjacent to the concrete sidewalk on the northwest corner of the bridge shows distress adjacent to the expansion joint.

The west edge of the south approach panel has been repaired with bituminous material and currently has several potholes. The west sidewalk adjacent to the approach panel contains a manhole. Settlement or undermining associated with the utility may be causing the deterioration.

Railing

The metal railing on the south approach is in good condition.

Grout popouts on the reconstructed portions of the ornamental concrete railing are common. The ornamental concrete railing components over the piers appear to be original concrete and have much more deterioration than the reconstructed railing between piers. The original concrete railing over the piers on the west sidewalk is in poorer condition than that on the east sidewalk.

A variety of joint filler material, including Styrofoam and neoprene, has been installed in the ornamental railing to replace material missing from the 1989 reconstruction.

Observations of concrete components

The arch ribs for the main span that rise above the deck are located very close to the curb line of both sidewalks. Nonetheless, minimal impact damage was noted during the site visit. The main arch ribs show some deterioration both above and below the deck. The heaviest deterioration appears near sidewalk level. The verticals for the main arch span contain small cracks.

The barrel arches contain longitudinal cracks.

The north face of the pier on the north bank of the river has vertical cracking.

Transverse cracks are present in both sidewalks.

Drainage Observations

There is a significant amount of drainage leaking onto the south pier adjacent to the parking lot below the bridge on its north end. The drainage has stained and discolored the pier wall in multiple locations.

Staining on several of the piers indicates that drainage details are not functioning properly.

Non-Structural Observations:

Many pigeons find their home on this bridge.

The bridge carries a lot of conduit, much of which was added during the 1989 rehabilitation project. A cable is supported with metal bands and unattractive hardware off of the ornamental railing on the northeast portion of the bridge. If it is a permanent utility, it should be carried below the deck.

The chain link fence preventing access to the stairs at the northwest corner of the bridge is an eyesore.

Decorative light fixtures attached to the east face of the piers over the river are broken.

Four tree grates on the east sidewalk of the south approach have no trees.

Date of Site Visit

October 18, 2005

Figure 1. Looking north at the bridge from the east sidewalk. There is a horizontal break in the roadway alignment at the south end of the bridge.

Figure 2. Looking north at the main span arch ribs above the deck from the east sidewalk. There is minimal setback from the curb to the arch ribs.

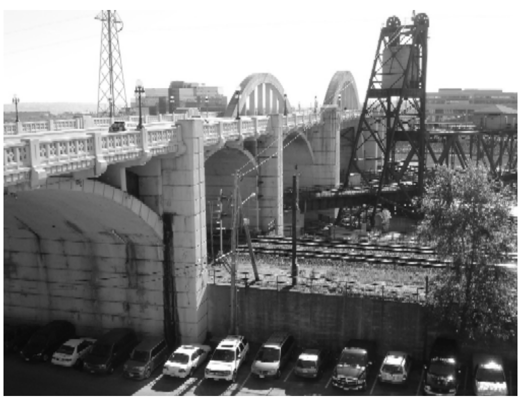

Figure 3. Looking south along the west face of the bridge. Below the barrel arch spans on the north side of the river is a parking lot, several train tracks, and Shepard Road.

Figure 4. Looking north at debris lodged in the fender on the west side of the bridge. Water drainage is evident on the pier wall between the arch ribs on both the main span and the adjacent south approach span.

Figure 5. Looking at the west side of the barrel arch span over the parking lot. Extensive staining is evident on the pier. The ornamental concrete railing has been rebuilt between the primary monuments over the piers.

Figure 6. In several areas the boundary between new concrete placed during the rehab and the original concrete is readily apparent because of the deterioration of the original concrete.

Figure 7. Longitudinal cracking is evident in the barrels of north approach spans

Figure 8. Deterioration is evident in the large railing elements (believed to be 1926 construction) that are located above several piers. The reconstructed concrete railing panels, located between piers, also exhibit deterioration. Grout popouts are prevalent on the lower rail.

Overall Recommendations

With adequate geometrics and load capacity for current standards, rehabilitation for continued use on-site is recommended. Less desirable options of relocation, construction of a bypass or less-demanding use on-site are not possible due to the bridge's large size and role as a major transportation link.

To retain the bridge's character-defining features and historic fabric, it is critical that the drainage deficiencies be addressed promptly to minimize the deterioration of primary superstructure and substructure components.

An extensive concrete testing program is recommended to delineate the areas of chloride contamination and unsound concrete. Without material testing information in hand, concrete repairs would likely need to be performed repeatedly as new regions show visible deterioration.

Recommended Future Use:

Rehabilitation for continued vehicular use on-site.

Recommended Stabilization Activities:

1. Clean and inspect all expansion joints. Confirm that all glands are intact and properly sealing the deck. Replace any damaged or missing glands with new glands compatible with the joint hardware.

2. Confirm that all pavement joints are properly sealed. Repair or replace damaged pavement joints utilizing standard Mn/DOT procedures.

3. Inspect and test all drainage features on the bridge to confirm that they are not plugged or leaking. Observe the performance of each feature, utilizing personnel above the deck to flush water into individual drainage features and additional personnel below the deck. Repair or replace leaking or non-performing features.

4. The other possible source of water leaking onto the below deck components of the bridge is the water main carried by the bridge. Pressure test the line on the bridge to confirm it is not leaking.

Recommended Preservation Activities:

1. Update the load-rating analysis or update the date recorded in the inventory if a more recent load-rating analysis has been performed.

2. Seal cracks in the bridge deck and on the sidewalks utilizing standard Mn/DOT procedures.

3. Replace the south approach panel to the bridge utilizing standard Mn/DOT procedures.

4. Repair the pavement joints on the south approach utilizing standard Mn/DOT procedures.

5. After the drainage system has been inspected and repaired, flush the entire bridge with water. Remove debris from the deck, sidewalks, and railings. Remove pigeon guano and drainage debris on the superstructure and substructure components.

6. Conduct extensive concrete coring, sounding, and chloride testing to evaluate the condition of the different bridge components. Perform testing on the bridge deck, sidewalks, railings (original and reconstructed elements), arch ribs and barrels, piers, abutments, and encasement concrete. The goal is to identify components that are sound and components that are contaminated with chlorides and

require treatment and repair. Implement required repairs as identified through testing. Following the repairs, develop and implement a program to ensure the integrity of these concrete elements. The program may include aggressive flushing with water or sealing of components.

7. Repair the vertical cracks in the piers and the longitudinal cracking in the arch barrels. Repair the railings, arch ribs and vertical hangers. Repair the fascia on the cap of the cribwall on the south approach.

8. Concrete repairs should generally be accomplished with standard Mn/DOT repair methods and should be consistent with the National Park Service's Preservation Bulletin 15 – Preservation of Historic Concrete. Consult with Mn/DOT's Office of Bridges and Structures before making final determination of the means and methods of concrete repairs.

9. Repair the broken decorative flood lights on the bridge.

10. Place type/size of trees in the tree grates on the south approach sidewalk.

11. Remove or relocate the cable attached to the east face of the railing on the north end of the east sidewalk.

12. If the stairs at the northwest corner of the bridge are to remain closed, replace the chain link fence with a closure unit that utilizes details similar to those utilized on the adjacent metal railing to the west.

Projected Inspections to Monitor Bridge Condition

Routine:

1. Routine annual inspections are recommended. Perform recommended maintenance activities identified as part of the inspection within a 12-month period.

2. Conduct in-depth, arm's length inspections on an interval not to exceed 4 years. Conduct maintenance and repair activities identified as part of the in-depth inspection within 24 months.

Special:

Conduct underwater inspections at 5-year intervals. Implement resulting recommended maintenance or repair efforts within a 24-month period.

Recommended Maintenance Activities

1. Flush the railings, sidewalks, deck, and main span arch ribs with water annually.

2. Seal cracks in the deck and sidewalks on a 5-year cycle utilizing standard Mn/DOT practices.

Qualifier Statement

The opinions of probable costs provided below are in 2006 dollars. The costs were developed without benefit of preliminary plans and are based on the above identified tasks using engineering judgment and/or gross estimates of quantities and historic unit prices and are intended to provide a programming level of estimated costs. Refinement of the probable costs is recommended once preliminary plans have been developed. The estimated preservation costs include a 20% contingency and 5% mobilization allowance of the preservation activities, excluding soft costs (see Appendix D, Cost Detail, Item 5: Other). Actual costs may vary significantly from those opinions of cost provided herein.

For itemized activity listing and costs, see Appendix D.

Summarized Costs

Maintenance costs: $22,700 annualized

Stabilization activities
Superstructure: $0
Substructure: $0
Railing: $0
Deck: $60,000
Other: $32,000
Total: $92,000

Preservation activities
Superstructure: $260,000
Substructure: $1,020,000
Railing: $205,000
Deck: $80,000
Other: $845,000
Contingency: $391,000
Total: $2,801,000

Applicable Funding

The majority of funding for the rehabilitation and reuse of historic bridges in the state of Minnesota is available through federal funding programs. The legislation authorizing the various federal funding programs is the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU).

SAFETEA-LU programs include the Transportation Enhancement (TE) Fund, the Surface Transportation Program (STP), the Highway Bridge Replacement and Rehabilitation Program (HBRRP), National Highway System Funds, and the National Historic Covered-Bridge Preservation Program. A program not covered by SAFETEA-LU, the Save America's Treasures Program, is also available for rehabilitation and reuse of historic bridges that have national significance.

Other than the Save America's Treasures Program, the federal funds listed above are passed through Mn/DOT for purposes of funding eligible activities. While the criteria for determining eligible activities are determined largely by federal guidelines, Mn/DOT has more discretion in determining eligible activities under the TE fund.

The federal funding programs typically provide 80-percent federal funding and require a 20-percent state/local match. Typical eligible activities associated with these funds include replacement or rehabilitation of structurally deficient or functionally obsolete bridges for vehicular and, non-vehicular uses, painting, seismic retrofit, and preventive maintenance. If a historic bridge is relocated, the

estimated cost of demolition can be applied to its rehabilitation at a new site. It should be noted that the federal funds available for non-vehicular uses are limited to this estimated cost of demolition. However, TE funds can be applied to bridge rehabilitation for non-vehicular use.

State or federal bridge bond funds are available for eligible rehabilitation or reconstruction work on any publicly owned bridge or culvert longer than 20 feet. State bridge bond funds are available for up to 100 percent of the “abutment to abutment” cost for bridges or culverts longer than 10 feet that meet eligibility criteria.

A more in-depth discussion regarding funding can be found in the Minnesota Historic Bridge Management Plan.

Special Funding Note

N/A

Appendix A. Glossary of Preservation and Engineering Terms

Glossary

Appraisal ratings – Five National Bridge Inventory (NBI) inspection ratings (structural evaluation, deck geometry, under-clearances, waterway adequacy, and approach alignment, as defined below), collectively called appraisal ratings, are used to evaluate a bridge's overall structural condition and load-carrying capacity. The evaluated bridge is compared with a new bridge built to current design standards. Ratings range from a low of 0 (closed bridge) to a high of 9 (superior). Any appraisal item not applicable to a specific bridge it is coded N.

Approach alignment – One of five NBI inspection ratings. This rating appraises a bridge's functionality based on the alignment of its approaches. It incorporates a typical motorist's speed reduction because of the horizontal or vertical alignment of the approach.

Character-defining features – Prominent or distinctive aspects, qualities, or characteristics of a historic property that contribute significantly to its physical character. Features may include structural or decorative details and materials.

Condition rating – Level of deterioration of bridge components and elements expressed on a numerical scale according to the NBI system. Components include the substructure, superstructure, deck, channel, and culvert. Elements are subsets of components, e.g., piers and abutments are elements of the component substructure. The evaluated bridge is compared with a new bridge built to current design standards. Component ratings range from 0 (failure) to 9 (new); element ratings range from 1 (poor) to 3 (good). In rating a bridge's condition, Mn/DOT pairs the NBI system with the newer and more sophisticated Pontis element inspection information, which quantifies bridge elements in different condition states and is the basis for subsequent economic analysis.

Deck geometry – One of five NBI inspection ratings. This rating appraises the functionality of a bridge's roadway width and vertical clearance, taking into account the type of roadway, number of lanes, and Average Daily Traffic (ADT).

Deficiency – The inadequacy of a bridge in terms of structure, serviceability, and/or function. Structural deficiency is determined through periodic inspections and is reflected in the ratings that are assigned to a bridge. Service deficiency is determined by comparing the facilities a bridge provides for vehicular, bicycle, and pedestrian traffic with those that are desired. Functional deficiency is another term for functionally obsolete (see below). Remedial activities may be needed to address any or all of these deficiencies.

Deficiency rating – A nonnumeric code indicating a bridge's status as structurally deficient (SD) or functionally obsolete (FO). See below for the definitions of SD and FO. The deficiency rating status may be used as a basis for establishing a bridge's eligibility and priority for replacement or rehabilitation.

Design exception – A deviation from standard bridge design practices that takes into account environmental, scenic, aesthetic, historic, and community factors that may have bearing upon a transportation project. A design exception is used for federally funded projects where federal standards are not met. Approval requires appropriate justification and documentation that concerns for safety, durability, and economy of maintenance have been met.

Design load – The usable live-load capacity that a bridge was designed to carry, expressed in metric tons according to the allowable stress, load factor, or load resistance factor rating methods. An additional code was recently added to assess design load by a rating factor instead of tons. This code is used to determine if a bridge has sufficient strength to accommodate traffic demands. A bridge that is posted for load restrictions may not be adequate to accommodate present or expected truck traffic.

Fracture critical – Classification of a bridge having primary superstructure or substructure components subject to tension stresses and which are non-redundant. A failure of one of these components could lead to collapse of a span or the bridge. Tension members of truss bridges are often fracture critical. The associated inspection date is a numerical code that includes frequency of inspection in months, followed by year, and month of last inspection.

Functionally obsolete (FO) – The FHWA classification of a bridge that cannot meet current or projected traffic needs because of inadequate horizontal or vertical clearance, inadequate load-carrying capacity, and/or insufficient opening to accommodate water flow under the bridge.

Historic fabric – The material in a bridge that was part of original construction or a subsequent alteration within the historic period (e.g., more than 50 years old) that has significance in and of itself. Historic fabric includes both character-defining and minor features. Minor features have less importance and may be replaced more readily.

Historic bridge – A bridge that is listed in, or eligible for listing in, the National Register of Historic Places.

Historic integrity – The authenticity of a bridge's historic identity, evidenced by the survival and/or restoration of physical characteristics that existed during the bridge's historic period. A bridge may have integrity of location, design, setting, materials, workmanship, feeling, and association.

Inspections – Periodic field assessments and subsequent consideration of the fitness of a structure and the associated approaches and amenities to continue to function safely.

Inventory rating – The load level a bridge can safely carry for an indefinite amount of time expressed in metric tons or by the rating factor described in design load (see above). Inventory rating values typically correspond to the original design load for a bridge without deterioration.

Maintenance – Work of a routine nature to prevent or control the process of deterioration of a bridge.

Minnesota Historical Property Record (MHPR) – A documentary record of an important architectural, engineering, or industrial site, maintained by the MHS as part of the state's commitment to historic preservation. MHPR typically includes large-format photographs and written history, and may also include historic photographs, drawings, and/or plans. This state-level documentation program is modeled after a federal program known as the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER).

National Bridge Inventory – Bridge inventory and appraisal data collected by the FHWA to fulfill the requirements of the National Bridge Inspection Standards (NBIS). Each state maintains an inventory of its bridges subject to NBIS and sends an annual update to the FHWA.

National Bridge Inspection Standards – Federal requirements for procedures and frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of state bridge inventories. NBIS applies to bridges located on public roads.

National Register of Historic Places – The official inventory of districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, and culture, which is maintained by the Secretary of the Interior under the authority of the National Historic Preservation Act of 1966 (as amended).

Non-vehicular traffic – Pedestrians, non-motorized recreational vehicles, and small motorized recreational vehicles moving along a transportation route that does not serve automobiles and trucks. Includes bicycles and snowmobiles.

Operating rating – Maximum permissible load level to which a bridge may be subjected based on a specific vehicle type, expressed in metric tons or by the rating factor described in design load (see above).

Posted load – Legal live-load capacity for a bridge usually associated with the operating or inventory ratings as determined by a state transportation agency. A bridge posted for load restrictions may be inadequate for truck traffic.

Pontis – Computer-based bridge management system to store inventory and inspection data and assist in other bridge data management tasks.

Preservation – Preservation, as used in this report, refers to historic preservation that is consistent with the Secretary of the Interior's *Standards for the Treatment of Historic Properties*. Historic preservation means saving from destruction or deterioration old and historic buildings, sites, structures, and objects, and providing for their continued use by means of restoration, rehabilitation, or adaptive reuse. It is the act or process of applying measures to sustain the existing form, integrity, and material of a historic building or structure, and its site and setting. Mn/DOT's *Bridge Preservation, Improvement and Replacement Guidelines* (BPIRG) describe preservation differently, focusing on repairing or delaying the deterioration of a bridge without significantly improving its function and without considerations for its historic integrity.

Preventive maintenance – The planned strategy of cost-effective treatments that preserve a bridge, retard future deterioration, and maintain or improve its functional condition without increasing structural capacity.

Reconstruction – The act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location. Activities should be consistent with the Secretary of the Interior's *Standards for the Treatment of Historic Properties.*

Rehabilitation – The act or process of returning a historic property to a state of utility through repair or alteration which makes possible an efficient contemporary use, while preserving those portions or features of the property that are significant to its historical, architectural, and cultural values. Historic rehabilitation, as used in this report, refers to implementing activities that are consistent with the Secretary of the Interior's *Standards for the Treatment of Historic Properties*. As such, rehabilitation retains historic fabric and is different from replacement. However, Mn/DOT's *Bridge Preservation, Improvement and Replacement Guidelines* (BPIRG) describe rehabilitation and replacement in similar terms.

Restoration – The act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time. Activities should be consistent with the Secretary of the Interior's *Standards for the Treatment of Historic Properties.*

Scour – Removal of material from a river's bed or bank by flowing water, compromising the strength, stability, and serviceability of a bridge.

Scour critical rating – A measure of bridge's vulnerability to scour (see above), ranging from 0 (scour critical, failed, and closed to traffic) to 9 (foundations are on dry land well above flood water elevations). This code can also be expressed as U (unknown), N (bridge is not over a waterway), or T (bridge is over tidal waters and considered low risk).

Serviceability – Level of facilities a bridge provides for vehicular, bicycle, and pedestrian traffic, compared with current design standards.

Smart flag – Special Pontis inspection element used to report the condition assessment of a deficiency that cannot be modeled, such as cracks, section loss, and steel fatigue.

Stabilization – The act or process of sustaining a bridge by means of making minor repairs until a more permanent repair or rehabilitation can be completed.

Structurally deficient – Classification indicating NBI condition rating of 4 or less for any of the following: deck condition, superstructure condition, substructure condition, or culvert condition. A structurally deficient bridge is restricted to lightweight vehicles; requires immediate rehabilitation to remain open to traffic; or requires maintenance, rehabilitation, or replacement.

Structural evaluation – Condition of a bridge designed to carry vehicular loads, expressed as a numeric value and based on the condition of the superstructure and substructure, the inventory load rating, and the ADT.

Sufficiency rating – Rating of a bridge's structural adequacy and safety for public use, and its serviceability and function, expressed on a numeric scale ranging from a low of 0 to a high of 100. It is a relative measure of a bridge's deterioration, load capacity deficiency, or functional obsolescence. Mn/DOT may use the rating as a basis for establishing eligibility and priority for replacement or rehabilitation. Typically, bridges rated between 50 and 80 are eligible for rehabilitation and those rated 50 and below are eligible for replacement.

Under-clearances – One of five NBI inspection ratings. This rating appraises the suitability of the horizontal and vertical clearances of a grade-separation structure, taking into account whether traffic beneath the structure is one- or two-way.

Variance **-** A deviation from standard bridge design practices that takes into account environmental, scenic, aesthetic, historic, and community factors that may have bearing upon a transportation project. A design variance is used for projects using state aid funds. Approval requires appropriate justification and documentation that concerns for safety, durability and economy of maintenance have been met.

Vehicular traffic – The passage of automobiles and trucks along a transportation route.

Waterway adequacy – One of five NBI inspection ratings. This rating appraises a bridge's waterway opening and passage of flow through the bridge, frequency of roadway overtopping, and typical duration of an overtopping event.

Appendix B. Guidelines for Bridge Maintenance and Rehabilitation Based on the Secretary of the Interior's Standards

Guidelines for Bridge Maintenance and Rehabilitation Based on the Secretary of the Interior's Standards

1. The original character-defining qualities or elements of a bridge, its site, and its environment should be respected. The removal, concealment, or alteration of any historic material or distinctive engineering or architectural feature should be avoided.
2. All bridges shall be recognized as products of their own time. Alterations that have no historical basis and that seek to create a false historical appearance shall not be undertaken.
3. Most properties change over time; those changes that have acquired historic significance in their own right shall be retained and preserved.
4. Distinctive engineering and stylistic features, finishes, and construction techniques or examples of craftsmanship that characterize an historic property shall be preserved.
5. Deteriorated structural members and architectural features shall be retained and repaired, rather than replaced. Where the severity of deterioration requires replacement of a distinctive element, the new element should match the old in design, texture, and other visual qualities and where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.
6. Chemical and physical treatments that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the most environmentally sensitive means possible.
7. Significant archaeological and cultural resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.
8. New additions, exterior alterations, structural reinforcements, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.
9. New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

Source: Ann Miller, et al. *A Management Plan for Historic Bridges in Virginia*. Charlottesville, Va.: Virginia Transportation Research Council, 2001.

Appendix C. Current Mn/DOT Structure Inventory Report

Current Mn/DOT Bridge Inspection Report

Past Maintenance Reports (if available)

Other Reports (if available)

Mn/DOT STRUCTURE INVENTORY REPORT

Bridge ID: 9036 **ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD** Date: 01/04/2006

* IDENTIFICATION *

Agency Br. No. (RS 1) - 1
District 05 **Maint. Area** 5A
County 62 RAMSEY (123)
City 3425 ST PAUL
Township
Placecode 58000
Desc. Loc. 0.7 MI SE OF TH 35E & 94
Sect. 6 **Tnsp.** 028N **Range** 22W
Lat. 44d 56m 40s **UTM-Y** 4976794.50
Long. 93d 05m 17s **UTM-X** 493042.91
Toll Bridge (Road) NO
Custodian STATE
Owner STATE
Inspector METRO DISTRICT
BMU Agreement No
Year Built 1926 **Yr Fed Rehab** 1989
Year Remod. 1989
Temp.
Skew 0 **Plan Avail.** CENTRAL

* STRUCTURE DATA *

Service On HWY;PED
Service Under HWY;RR;STREAM
MN Main Span 112 CONCR/ARCH
MN MSpn Det Def RAINBOW ARCH
MN Appr. Span 501 PRESTR/BM SPAN
MN ASpn Det Def
Culvert Type
Barrel Length
No. Main Spans 8 **No. Appr.Span** 9
Total Spans 17 **NBI Len. (?)** YES
Main Span Length 264.0 ft
Structure Length 1,428.9 ft
Abut. Mat'l. CONCRETE
Abut. Fnd. Type FTNG/PILE
Pier Mat'l. CONCRETE
Pier Fnd. Type FTNG/PILE
Deck Width 80.4 ft
Deck Material CIP CONC
Wear Surf. Type MONO CONC
Wear Surf. Inst. Yr. 1989
Wr. Crs/Fill Depth
Deck Membrane NONE
Deck Rebars EPOXY REBAR
Deck Rebars Inst. Yr. 1989
Structure Area 114,884 sq ft
Roadway Area 80,019 sq ft
Swk Width L/R 9.5 ft 9.5 ft
Curb Ht. L/R 0.8 ft 0.8 ft
Rail L/R/FHWA 01 01 YES
Ped. Fencing
Hist. Significance NATL REGISTER
Bird Nests (?) NO

* ROADWAY DATA *

Route System (Fed) USTH
Mn. Route System USTH
Route Number 952A
Roadway Name ROBERT ST (TH 952A)
Roadway Function MAINLINE
Roadway Type 2 WAY TRAF
Control Section 6217
BDG. Reference Point 131+00.035
Date Opened to Traffic 07-01-1990
Detour Length 1 mi
Lanes 5 ON BRIDGE (1)
ADT 19,000 **HCADT** 380
ADT Year 2004
Functional Class URB/MINOR ART
Nat'l. Hwy. System NOT NHS
STRAHNET NOT STRAHNET
Truck Net NOT TRUCKNET
Fed. Lands Hwy. N/A
OnBaseNet NOT BASENET

* ROADWAY CLEARANCES *

	If Divided	NB-EB	SB-WB
Rdwy. Wid. Rd 1/Rd 2		56.0 ft	
Vrt. Clr. Ovr. Rd 1/Rd 2			
Max Vert Clr Rd 1/ Rd 2			
Horz U/Clr - Rd 1/Rd 2			
Lat UndClr Left/Right			
RR UndClr Vert/Lat		24.0 ft	18.0 ft
Appr. Surface Width		56.0 ft	
Median Width			

* ROADWAY TIS DATA *

	TIS 1st KEY	TIS 2nd KEY
Route System	02	
Route Number	0000952A	
High End	767	
Low End	767	
Direction	N	
Reference Pt.	131+00.035	
Interchg. Elem.		

* MISC. BRIDGE DATA *

Struct. Flared
Parallel Struct. NONE
Field Conn. ID
Cantilever ID
Permit Code A 1
Permit Code B 1
Permit Code C 1
Permit Code Fut.

* BRIDGE SIGNS *

Posted Load NO SIGNS
Traffic NO SIGNS
Horizontal NO SIGNS
Vertical NOT APPL

Def. Status F.O. **Suff. Rating** 74.3

* WATERWAY DATA *

Drng. Area
Wtrwy. Opening 99,999 sq ft
Navigation Control PERM REQD
Nav. Vert./Hrz Clr. 62.0 ft 200.0 ft
Nav. Vert. Lift Clr.
MN Scour Code P-STBL;PROT INPL
Scour Eval. Year 1996

* INSPECTION DATA *

Inspection Date 09-23-2003 (YTUV)
Inspection Frequency 24
Inspector METRO

Condition Codes		Appraisal Ratings	
Deck	7	Struct. Eval.	6
Superstruct.	7	Deck Geometry	2
Substruct.	6	Underclearances	2
Chan. & Prot.	8	Waterway Adeq'cy	8
Culvert	N	Appr. Alignment	8

Other Inspection Codes

Open, Posted, Clsd.	A	Rail Rating	1
Pier Protection	1	Appr. Guardrail	0
Scour Critical	7	Appr. Trans.	0
Deck Pct. Unsnd.	1 %	Appr. Term.	N

In Depth Inspections

	Y/N	Freq.	Last Insp.
Frac. Critical			
Pinned Asbly.			
Underwater	Y	60	12/2004
Spec. Feat.			

* PAINT DATA *

Year Painted 1989 **Pct.Unsound**
Total Painted Area 32,502 sq ft
Primer Type INORGAINIC ZINC RICH
Finish Type

* CAPACITY RATINGS *

Design Load HS25
MN
Operating Rating HS 32.5
Inventory Rating HS 20.8
Posting Veh: Semi: Dbl:
Rtg Date 03-01-1976

* IMPROVEMENT DATA *

Prop. Work REPLACE COND.
Work By CONTRACT
Prop. Structure BRIDGE
Length 1,430.4 ft **Width** 49.2 ft
Appr. Rdwy. Work
Bridge Cost 6,173,000
Approach Cost 959,000
Project Cost 14,394,000
Data - Year/Method 2003 COMPUTER

Mn/DOT STRUCTURE INVENTORY REPORT

Bridge ID: 9036 **ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD** Date: 01/04/2006

* IDENTIFICATION *

Agency Br. No. (RS 2) - A
District 05 **Maint. Area** 5A
County 62 RAMSEY (123)
City 3425 ST PAUL
Township
Placecode 58000
Desc. Loc. 0.7 MI SE OF TH 35E & 94
Sect. 6 **Tnsp.** 028N **Range** 22W
Lat. 44d 56m 40s **UTM-Y** 4976794.50
Long. 93d 05m 17s **UTM-X** 493042.91
Toll Bridge (Road) NO
Custodian STATE
Owner STATE
Inspector METRO DISTRICT
BMU Agreement No
Year Built 1926 **Yr Fed Rehab** 1989
Year Remod. 1989
Temp.
Skew 0 **Plan Avail.** CENTRAL

* STRUCTURE DATA *

Service On HWY;PED
Service Under HWY;RR;STREAM

MN Main Span 112 CONCR/ARCH
MN MSpn Det Def RAINBOW ARCH

MN Appr. Span 501 PRESTR/BM SPAN
MN ASpn Det Def
Culvert Type
Barrel Length
No. Main Spans 8 **No. Appr.Span** 9
Total Spans 17 **NBI Len. (?)** YES
Main Span Length 264.0 ft
Structure Length 1,428.9 ft
Abut. Mat'l. CONCRETE
Abut. Fnd. Type FTNG/PILE
Pier Mat'l. CONCRETE
Pier Fnd. Type FTNG/PILE
Deck Width 80.4 ft
Deck Material CIP CONC
Wear Surf. Type MONO CONC
Wear Surf. Inst. Yr. 1989
Wr. Crs/Fill Depth
Deck Membrane NONE
Deck Rebars EPOXY REBAR
Deck Rebars Inst. Yr. 1989
Structure Area 114,884 sq ft
Roadway Area 80,019 sq ft
Swk Width L/R 9.5 ft 9.5 ft
Curb Ht. L/R 0.8 ft 0.8 ft
Rail L/R/FHWA 01 01 YES
Ped. Fencing
Hist. Significance NATL REGISTER
Bird Nests (?) NO

* ROADWAY DATA *

Route System (Fed) CNTY
Mn. Route System CSAH
Route Number 37
Roadway Name SHEPARD ROAD (CSAH 37)
Roadway Function MAINLINE
Roadway Type 2 WAY TRAF
Control Section
BDG. Reference Point
Date Opened to Traffic 01-01-1926
Detour Length 1 mi
Lanes 4 UNDER BRIDGE (A)
ADT 19,000 **HCADT**
ADT Year 2003
Functional Class URB/OTH PR ART
Nat'l. Hwy. System NHS
STRAHNET NOT STRAHNET
Truck Net NOT TRUCKNET
Fed. Lands Hwy. N/A
OnBaseNet ON BASENET

* ROADWAY CLEARANCES *

If Divided	NB-EB	SB-WB
Rdwy. Wid. Rd 1/Rd 2	22.4 ft	22.3 ft
Vrt. Clr. Ovr. Rd 1/Rd 2	24.0 ft	24.0 ft
Max Vert Clr Rd 1/ Rd 2	24.0 ft	24.0 ft
Horz U/Clr - Rd 1/Rd 2	27.7 ft	27.8 ft
Lat UndClr Left/Right	1.2 ft	1.5 ft
RR UndClr Vert/Lat		18.0 ft
Appr. Surface Width	51.0 ft	
Median Width	6.0 ft	

* ROADWAY TIS DATA *

	TIS 1st KEY	TIS 2nd KEY
Route System	04	
Route Number	62000037	
High End	767	
Low End	767	
Direction		
Reference Pt.	001+00.985	
Interchg. Elem.		

* MISC. BRIDGE DATA *

Struct. Flared
Parallel Struct. NONE
Field Conn. ID
Cantilever ID
Permit Code A 1
Permit Code B 1
Permit Code C 1
Permit Code Fut.

* BRIDGE SIGNS *

Posted Load NO SIGNS
Traffic NO SIGNS
Horizontal NO SIGNS
Vertical NOT APPL

Def. Status F.O. **Suff. Rating** 74.3

* WATERWAY DATA *

Drng. Area
Wtrwy. Opening 99,999 sq ft
Navigation Control PERM REQD
Nav. Vert./Hrz Clr. 62.0 ft 200.0 ft
Nav. Vert. Lift Clr.
MN Scour Code P-STBL;PROT INPL
Scour Eval. Year 1996

* INSPECTION DATA *

Inspection Date 09-23-2003 (YTUV)
Inspection Frequency 24
Inspector METRO

Condition Codes		Appraisal Ratings	
Deck	7	Struct. Eval.	6
Superstruct.	7	Deck Geometry	2
Substruct.	6	Underclearances	2
Chan. & Prot.	8	Waterway Adeq'cy	8
Culvert	N	Appr. Alignment	8

Other Inspection Codes

Open, Posted, Clsd.	A	Rail Rating	1
Pier Protection	1	Appr. Guardrail	0
Scour Critical	7	Appr. Trans.	0
Deck Pct. Unsnd.	1 %	Appr. Term.	N

In Depth Inspections

	Y/N	Freq.	Last Insp.
Frac. Critical			
Pinned Asbly.			
Underwater	Y	60	12/2004
Spec. Feat.			

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Year Painted 1989 **Pct.Unsound**
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Primer Type INORGAINIC ZINC RICH
Finish Type

* CAPACITY RATINGS *

Design Load HS25
MN
Operating Rating HS 32.5
Inventory Rating HS 20.8
Posting Veh: Semi: Dbl:
Rtg Date 03-01-1976

* IMPROVEMENT DATA *

Prop. Work REPLACE COND.
Work By CONTRACT
Prop. Structure BRIDGE
Length 1,430.4 ft **Width** 49.2 ft
Appr. Rdwy. Work
Bridge Cost 6,173,000
Approach Cost 959,000
Project Cost 14,394,000
Data - Year/Method 2003 COMPUTER

Mn/DOT STRUCTURE INVENTORY REPORT

Bridge ID: 9036 **ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD** Date: 01/04/2006

* IDENTIFICATION *

Agency Br. No. (RS 3) - B
District 05 **Maint. Area** 5A
County 62 RAMSEY (123)
City 3425 ST PAUL
Township
Placecode 58000
Desc. Loc. 0.7 MI SE OF TH 35E & 94
Sect. 6 **Tnsp.** 028N **Range** 22W
Lat. 44d 56m 40s **UTM-Y** 4976794.50
Long. 93d 05m 17s **UTM-X** 493042.91
Toll Bridge (Road) NO
Custodian STATE
Owner STATE
Inspector METRO DISTRICT
BMU Agreement No
Year Built 1926 **Yr Fed Rehab** 1989
Year Remod. 1989
Temp.
Skew 0 **Plan Avail.** CENTRAL

* STRUCTURE DATA *

Service On HWY;PED
Service Under HWY;RR;STREAM
MN Main Span 112 CONCR/ARCH
MN MSpn Det Def RAINBOW ARCH
MN Appr. Span 501 PRESTR/BM SPAN
MN ASpn Det Def
Culvert Type
Barrel Length
No. Main Spans 8 **No. Appr.Span** 9
Total Spans 17 **NBI Len. (?)** YES
Main Span Length 264.0 ft
Structure Length 1,428.9 ft
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Abut. Fnd. Type FTNG/PILE
Pier Mat'l. CONCRETE
Pier Fnd. Type FTNG/PILE
Deck Width 80.4 ft
Deck Material CIP CONC
Wear Surf. Type MONO CONC
Wear Surf. Inst. Yr. 1989
Wr. Crs/Fill Depth
Deck Membrane NONE
Deck Rebars EPOXY REBAR
Deck Rebars Inst. Yr. 1989
Structure Area 114,884 sq ft
Roadway Area 80,019 sq ft
Swk Width L/R 9.5 ft 9.5 ft
Curb Ht. L/R 0.8 ft 0.8 ft
Rail L/R/FHWA 01 01 YES
Ped. Fencing
Hist. Significance NATL REGISTER
Bird Nests (?) NO

* ROADWAY DATA *

Route System (Fed) CITY
Mn. Route System MUN
Route Number 1596
Roadway Name 2ND STREET
Roadway Function MAINLINE
Roadway Type 1 WAY TRAF
Control Section
BDG. Reference Point
Date Opened to Traffic 01-01-1926
Detour Length 1 mi
Lanes 2 UNDER BRIDGE (B)
ADT 500 **HCADT**
ADT Year 1974
Functional Class URBAN LOCAL
Nat'l. Hwy. System NOT NHS
STRAHNET NOT STRAHNET
Truck Net NOT TRUCKNET
Fed. Lands Hwy. N/A
OnBaseNet NOT BASENET

* ROADWAY CLEARANCES *

	If Divided NB-EB	SB-WB
Rdwy. Wid. Rd 1/Rd 2	28.0 ft	
Vrt. Clr. Ovr. Rd 1/Rd 2	12.2 ft	
Max Vert Clr Rd 1/ Rd 2	12.2 ft	
Horz U/Clr - Rd 1/Rd 2	29.0 ft	
Lat UndClr Left/Right		0.5 ft
RR UndClr Vert/Lat		18.0 ft
Appr. Surface Width	28.0 ft	
Median Width		

* ROADWAY TIS DATA *

	TIS 1st KEY	TIS 2nd KEY
Route System	10	
Route Number	34251596	
High End	714	
Low End	714	
Direction		
Reference Pt.	000+00.195	
Interchg. Elem.		

* MISC. BRIDGE DATA *

Struct. Flared
Parallel Struct. NONE
Field Conn. ID
Cantilever ID
Permit Code A 1
Permit Code B 1
Permit Code C 1
Permit Code Fut.

* BRIDGE SIGNS *

Posted Load NO SIGNS
Traffic NO SIGNS
Horizontal NO SIGNS
Vertical NOT APPL

Def. Status F.O. **Suff. Rating** 74.3

* WATERWAY DATA *

Drng. Area
Wtrwy. Opening 99,999 sq ft
Navigation Control PERM REQD
Nav. Vert./Hrz Clr. 62.0 ft 200.0 ft
Nav. Vert. Lift Clr.
MN Scour Code P-STBL;PROT INPL
Scour Eval. Year 1996

* INSPECTION DATA *

Inspection Date 09-23-2003 (YTUV)
Inspection Frequency 24
Inspector METRO

Condition Codes		Appraisal Ratings	
Deck	7	Struct. Eval.	6
Superstruct.	7	Deck Geometry	2
Substruct.	6	Underclearances	2
Chan. & Prot.	8	Waterway Adeq'cy	8
Culvert	N	Appr. Alignment	8

Other Inspection Codes

Open, Posted, Clsd.	A	Rail Rating	1
Pier Protection	1	Appr. Guardrail	0
Scour Critical	7	Appr. Trans.	0
Deck Pct. Unsnd.	1 %	Appr. Term.	N

In Depth Inspections

	Y/N	Freq.	Last Insp.
Frac. Critical			
Pinned Asbly.			
Underwater	Y	60	12/2004
Spec. Feat.			

* PAINT DATA *

Year Painted 1989 **Pct.Unsound**
Total Painted Area 32,502 sq ft
Primer Type INORGAINIC ZINC RICH
Finish Type

* CAPACITY RATINGS *

Design Load HS25
MN
Operating Rating HS 32.5
Inventory Rating HS 20.8
Posting Veh: Semi: Dbl:
Rtg Date 03-01-1976

* IMPROVEMENT DATA *

Prop. Work REPLACE COND.
Work By CONTRACT
Prop. Structure BRIDGE
Length 1,430.4 ft **Width** 49.2 ft
Appr. Rdwy. Work
Bridge Cost 6,173,000
Approach Cost 959,000
Project Cost 14,394,000
Data - Year/Method 2003 COMPUTER

Crew Number: 7647
Inspector: METRO

Mn/DOT BRIDGE INSPECTION REPORT

BRIDGE 9036 ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD INSP. DATE: 09-23-2003

County: RAMSEY
City: ST PAUL
Township:
Section: 06 Township: 028N Range: 22W
Span Type: CONCR / ARCH
NBI Deck: 7 Super: 7 Sub: 6 Chan: 8 Culv: N

Location: 0.7 MI SE OF TH 35E & 94
Route: USTH 952A Ref. Pt.: 131+00.035
Control Section: 6217 Maint. Area: 5A
Local Agency Bridge Nbr:

Length: 1,428.9 ft
Deck Width: 80.4 ft
Rdwy. Area / Pct. Unsnd: 80,019 sq ft 1 %
Paint Area / Pct. Unsnd: 32,502 sq ft

Open, Posted, Closed: OPEN

Appraisal Ratings - Approach: 8 Waterway: 8 MN Scour Code: P-STBL;PROT INPL Def. Stat: F.O. Suff. Rate: 74.3

Load Posting: NO SIGNS Traffic Signs: NO SIGNS Horiz. Cntl. Signs: NO SIGNS Vert. Cntl. Signs: NOT APPL

STRUCTURE UNIT: 0

ELEM NBR	ELEMENT NAME	STR UNIT	ENV	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
377	CONC DECK-EPOXY&LSCO	0	2	09-23-2003	114,884 SF	114,884	0	0	0	0
				02-08-2002	1 SF	1	0	0	0	0
	Notes: 4 lanes. [1989] Deck & low slump overlay replaced.									
300	STRIP SEAL JOINT	0	2	09-23-2003	1,576 LF	1,576	0	0	N/A	N/A
				02-08-2002	1,576 LF	1,576	0	0	N/A	N/A
	Notes:									
301	POURED DECK JOINT	0	2	09-23-2003	1,351 LF	1,341	0	10	N/A	N/A
				02-08-2002	1,351 LF	1,341	0	10	N/A	N/A
	Notes:									
321	CONC APPROACH SLAB	0	2	09-23-2003	2 EA	0	2	0	0	N/A
				02-08-2002	2 EA	0	2	0	0	N/A
	Notes: [1993] 20 LF of random cracking in SW gutter line. 2 SF of spall. [1996] South panel: 15 LF transverse & 40 LF longitudinal cracks. SW corner: 20LF X 1LF of deep & wide random cracks with pavement uplifting.									
333	RAILING - OTHER	0	2	09-23-2003	2,856 LF	2,506	250	100	N/A	N/A
				02-08-2002	2,856 LF	2,506	250	100	N/A	N/A
	Notes: [1989] Rail code 36.									
109	P/S CONCRETE GIRDER	0	2	09-23-2003	3,106 LF	3,106	0	0	0	N/A
				02-08-2002	3,106 LF	3,106	0	0	0	N/A
	Notes: [1989] Beams replaced in north & south approach spans.									
113	PAINT STEEL STRINGER	0	2	09-23-2003	2,640 LF	2,640	0	0	0	0
				02-08-2002	2,640 LF	2,640	0	0	0	0
	Notes:									
144	CONCRETE ARCH	0	2	09-23-2003	2,980 LF	0	2,780	200	0	N/A
				02-08-2002	2,980 LF	0	2,780	200	0	N/A
	Notes: Arch ribs & barrels are original. [1989] Arch spans 1 - 3, the barrels were saw cut to allow for watermain. [1995/7] Span 3 (over Shepard Road), arch has 3 severe longitudinal cracks through barrel, (spalling with exposed rebar on bottom).									
152	PAINT STL FLOORBEAM	0	2	09-23-2003	846 LF	746	50	50	0	0
				02-08-2002	846 LF	746	50	50	0	0
	Notes:									
385	CONC SPANDREL COLUMN	0	2	09-23-2003	62 EA	0	52	10	0	N/A
				02-08-2002	62 EA	0	52	10	0	N/A
	Notes:									
380	SECONDARY ELEMENTS	0	2	09-23-2003	1 EA	0	1	0	0	N/A
				02-08-2002	1 EA	0	1	0	0	N/A
	Notes:									

Mn/DOT BRIDGE INSPECTION REPORT

BRIDGE 9036 ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD INSP. DATE: 09-23-2003

STRUCTURE UNIT: 0

ELEM NBR	ELEMENT NAME	STR UNIT	ENV	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
205	CONCRETE COLUMN	0	2	09-23-2003	46 EA	0	46	0	0	N/A
				02-08-2002	46 EA	0	46	0	0	N/A
	Notes: Approach pier columns are original (cracking & scaling).									
210	CONCRETE PIER WALL	0	2	09-23-2003	675 LF	0	625	50	0	N/A
				02-08-2002	675 LF	0	625	50	0	N/A
	Notes: Main span piers are hollow "pierwalls". [1989] Bearing caps rebuilt. [1992] 4 SF delamination, north side of pier 8. [1995] 2 SF delamination west side pier 16.									
215	CONCRETE ABUTMENT	0	2	09-23-2003	161 LF	161	0	0	0	N/A
				02-08-2002	161 LF	161	0	0	0	N/A
	Notes:									
234	CONCRETE CAP	0	2	09-23-2003	2,580 LF	2,550	30	0	0	N/A
				02-08-2002	2,580 LF	2,550	30	0	0	N/A
	Notes: [1989] Spandrel caps & south approach pier caps rebuilt.									
387	CONCRETE WINGWALL	0	2	09-23-2003	1 EA	0	1	0	0	N/A
				02-08-2002	1 EA	0	1	0	0	N/A
	Notes:									
358	CONC DECK CRACKING	0	2	09-23-2003	1 EA	0	1	0	0	N/A
				02-08-2002	1 EA	0	1	0	0	N/A
	Notes: [93/1995] 3000 LF transverse cracks in arch spans. Random longitudinal cracks.									
359	CONC DECK UNDERSIDE	0	2	09-23-2003	1 EA	0	1	0	0	0
				02-08-2002	1 EA	0	1	0	0	0
	Notes: [1995] 800 LF of transverse leaching cracks.									
361	SCOUR	0	2	09-23-2003	1 EA	1	0	0	N/A	N/A
	Notes: P - Stable due to protection. Inspect countermeasures. [1991] Underwater inspection performed by contract divers. [2004] Underwater Inspections by "Ayres Associates" found vertical cracks at piers #4 & #5. No evidence of scour.									
363	SECTION LOSS	0	2	09-23-2003	1 EA	1	0	0	0	N/A
				02-08-2002	1 EA	1	0	0	0	N/A
	Notes:									
964	CRITICAL FINDING	0	2	09-23-2003	1 EA	1	0	N/A	N/A	N/A
				02-08-2002	1 EA	1	0	N/A	N/A	N/A
	Notes:									
981	SIGNING	0	2	09-23-2003	1 EA	1	0	0	N/A	N/A
				02-08-2002	1 EA	1	0	0	N/A	N/A
	Notes:									
984	DRAINAGE	0	2	09-23-2003	1 EA	0	0	1	N/A	N/A
				02-08-2002	1 EA	0	0	1	N/A	N/A
	Notes: [1996] Deck scuppers in main arch span filled with debris, not functioning.									
986	CURB & SIDEWALK	0	2	09-23-2003	1 EA	1	0	0	N/A	N/A
				02-08-2002	1 EA	1	0	0	N/A	N/A
	Notes:									

Mn/DOT BRIDGE INSPECTION REPORT

BRIDGE 9036 ROBERT SR(US952A) OVER MISS R, RR, 2ND &SHEPARD INSP. DATE: 09-23-2003

STRUCTURE UNIT: 0

ELEM NBR	ELEMENT NAME	STR UNIT	ENV	INSP. DATE	QUANTITY	QTY CS 1	QTY CS 2	QTY CS 3	QTY CS 4	QTY CS 5
988	MISCELLANEOUS	0	2	09-23-2003	1 EA	0	0	1	N/A	N/A
				02-08-2002	1 EA	0	0	1	N/A	N/A

Notes: [1993] Abandoned phone line hanging down in south approach spans should be removed. [1997] Flood lights at base of main piers are broken. Underdeck & rail mounted ornamental lighting.

General Notes: *Bridge #9036, Year 2003 Bridge constructed in 1926, re-decked in 1989. [1997] Photos. Note: refer to plans for pier & span numbering. [97, 2003] Snooper inspection. Inspectors: K Fuhrman, V Desens.

Inspector's Signature

Reviewer's Signature / Date

Appendix D. Cost Detail

Mn/DOT Historic Bridge Management Plan

BRIDGE No. 9036 MAINTENANCE/STABILIZATION/PRESERVATION (M/S/P) Activity Listing and Costs

Notes:
1 *Costs are presented in 2006 dollars.*
2 *Unit costs are presented to the dollar or cent depending on the precision of the specific value.*

STABILIZATION COST SUMMARY

	ITEM	COSTS
1.00	SUPERSTRUCTURE	$ -
2.00	SUBSTRUCTURE	$ -
3.00	RAILINGS	$ -
4.00	DECK	$ 60,000
5.00	OTHER	$ 32,000
		$ 92,000

1.00 SUPERSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
1.05					$ -	$ -
1.10					$ -	$ -
1.15					$ -	$ -
1.20					$ -	$ -
1.25					$ -	$ -
1.30					$ -	$ -
1.35					$ -	$ -
1.40					$ -	$ -
1.45					$ -	$ -
1.50					$ -	$ -
						$ -

2.00 SUBSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
2.05					$ -	$ -
2.10					$ -	$ -
2.15					$ -	$ -
2.20					$ -	$ -
2.25					$ -	$ -
2.30					$ -	$ -
2.35					$ -	$ -
2.40					$ -	$ -
2.45					$ -	$ -
2.50					$ -	$ -
						$ -

3.00 RAILINGS

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
3.05					$ -	$ -
3.10					$ -	$ -
3.15					$ -	$ -
3.20					$ -	$ -
3.25					$ -	$ -
3.30					$ -	$ -
3.35					$ -	$ -
3.40					$ -	$ -
3.45					$ -	$ -
3.50					$ -	$ -
						$ -

4.00 DECK

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
4.05	Clean, inspect, repair expansion joints	20	1	LS	$ 40,000.00	$ 40,000
4.10	Repair pavement joints	20	1	LS	$ 20,000	$ 20,000
4.15					$ -	$ -
4.20					$ -	$ -
4.25					$ -	$ -
4.30					$ -	$ -
4.35					$ -	$ -
4.40					$ -	$ -
4.45					$ -	$ -
4.50					$ -	$ -
						$ 60,000

5.00 OTHER

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
5.05	Inspect, test, repair drainage features	N.A.	1	LS	$ 30,000.00	$ 30,000
5.10	Confirm utilities are not leaking	N.A.	1	LS	$ 2,000.00	$ 2,000
5.15					$ -	$ -
5.20					$ -	$ -
5.25					$ -	$ -
5.30					$ -	$ -
5.35					$ -	$ -
						$ 32,000

Mn/DOT Historic Bridge Management Plan

BRIDGE No. 9036 MAINTENANCE/STABILIZATION/PRESERVATION (M/S/P) Activity Listing and Costs

Notes:
1 *Costs are presented in 2006 dollars.*
2 *Unit costs are presented to the dollar or cent depending on the precision of the specific value.*

PRESERVATION COST SUMMARY

	ITEM	COSTS
1.00	SUPERSTRUCTURE	$ 260,000
2.00	SUBSTRUCTURE	$ 1,020,000
3.00	RAILINGS	$ 205,000
4.00	DECK	$ 80,000
5.00	OTHER	$ 845,000
		$ 2,410,000
	Mobilization @ 5% and 20% Contingency:	$ 391,000
		$ 2,801,000

1.00 SUPERSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
1.05	Flush the arch ribs and barrels with water	1	1	LS	$ 10,000	$ 10,000
1.10	Concrete repairs to arches	50	1	LS	$ 250,000	$ 250,000
1.15					$ -	$ -
1.20					$ -	$ -
1.25					$ -	$ -
1.30					$ -	$ -
1.35					$ -	$ -
1.40					$ -	$ -
1.45					$ -	$ -
1.50					$ -	$ -
1.55					$ -	$ -
1.60					$ -	$ -
1.65					$ -	$ -
						$ 260,000

2.00 SUBSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
2.05	Flush the piers and abutments with water	N.A.	1	LS	$ 20,000	$ 20,000
2.10	Concrete repairs to piers	50	1	LS	$ 1,000,000	$ 1,000,000
2.15					$ -	$ -
2.20					$ -	$ -
2.25					$ -	$ -
2.30					$ -	$ -
2.35					$ -	$ -
2.40					$ -	$ -
2.45					$ -	$ -
2.50					$ -	$ -
						$ 1,020,000

3.00 RAILINGS

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
3.05	Flush the railings with water	1	1	LS	$ 5,000	$ 5,000
3.10	Concrete repairs to the railings	50	1	LS	$ 200,000	$ 200,000
3.15					$ -	$ -
3.20					$ -	$ -
3.25					$ -	$ -
3.30					$ -	$ -
3.35					$ -	$ -
3.40					$ -	$ -
3.45					$ -	$ -
3.50					$ -	$ -
3.55					$ -	$ -
3.60					$ -	$ -
3.65					$ -	$ -
3.70					$ -	$ -
						$ 205,000

4.00 DECK

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
4.05	Seal cracks in the deck and sidewalks	5	1	LS	$ 35,000	$ 35,000
4.10	Replace the south approach panel	50	1	LS	$ 25,000	$ 25,000
4.15	Repair pavement joints on south approach	20	1	LS	$ 15,000	$ 15,000
4.20	Flush the deck and sidewalks with water	1	1	LS	$ 5,000	$ 5,000
4.25					$ -	$ -
4.30					$ -	$ -
4.35					$ -	$ -
4.40					$ -	$ -
4.45					$ -	$ -
4.50					$ -	$ -
						$ 80,000

5.00 OTHER

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL
5.05	Update the load rating analysis	N.A.	1	LS	$ 25,000	$ 25,000
5.10	Extensive concrete testing	N.A.	1	LS	$ 450,000	$ 450,000
5.15	Field work for concrete repair project	N.A.	1	LS	$ 150,000	$ 150,000
5.20	Assemble contract document for repairs	N.A.	1	LS	$ 200,000	$ 200,000
5.25	Repair broken flood lights	20	1	LS	$ 5,000	$ 5,000
5.30	Relocate cable / replace chain link fence	N.A.	1	LS	$ 3,000	$ 3,000
5.35	Install trees on south approach sidewalk	N.A.	1	LS	$ 12,000	$ 12,000
						$ 845,000

Mn/DOT Historic Bridge Management Plan

BRIDGE No. 9036 MAINTENANCE/STABILIZATION/PRESERVATION (M/S/P) Activity Listing and Costs

Notes:

1. *Costs are presented in 2006 dollars.*
2. *Unit costs are presented to the dollar or cent depending on the precision of the specific value.*

MAINTENANCE COST SUMMARY

	ITEM	ANNUAL COSTS
1.00	SUPERSTRUCTURE	$ 2,000
2.00	SUBSTRUCTURE	$ -
3.00	RAILINGS	$ 4,000
4.00	DECK	$ 9,000
5.00	OTHER	$ 7,700
		$ 22,700

1.00 SUPERSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL	ANNUAL COST
1.05	Flush the arch ribs above the deck w water	1	1	LS	$ 2,000	$ 2,000	$ 2,000
1.10					$ -	$ -	$ -
1.15					$ -	$ -	$ -
1.20					$ -	$ -	$ -
1.25					$ -	$ -	$ -
1.30					$ -	$ -	$ -
1.35					$ -	$ -	$ -
1.40					$ -	$ -	$ -
1.45					$ -	$ -	$ -
1.50					$ -	$ -	$ -
						$ 2,000	**$ 2,000**

2.00 SUBSTRUCTURE

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL	ANNUAL COST
2.05					$ -	$ -	$ -
2.10					$ -	$ -	$ -
2.15					$ -	$ -	$ -
2.20					$ -	$ -	$ -
2.25					$ -	$ -	$ -
2.30					$ -	$ -	$ -
2.35					$ -	$ -	$ -
2.40					$ -	$ -	$ -
2.45					$ -	$ -	$ -
2.50					$ -	$ -	$ -
						$ -	**$ -**

3.00 RAILINGS

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL	ANNUAL COST
3.05	Flush the railings with water	1	1	LS	$ 4,000	$ 4,000	$ 4,000
3.10					$ -	$ -	$ -
3.15					$ -	$ -	$ -
3.20					$ -	$ -	$ -
3.25					$ -	$ -	$ -
3.30					$ -	$ -	$ -
3.35					$ -	$ -	$ -
3.40					$ -	$ -	$ -
3.45					$ -	$ -	$ -
3.50					$ -	$ -	$ -
						$ 4,000	**$ 4,000**

4.00 DECK

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL	ANNUAL COST
4.05	Flush the deck and sidewalks with water	1	1	LS	$ 5,000	$ 5,000	$ 5,000
4.10	Seal cracks in the deck and sidewalks	5	1	LS	$ 20,000	$ 20,000	$ 4,000
4.15					$ -	$ -	$ -
4.20					$ -	$ -	$ -
4.25					$ -	$ -	$ -
4.30					$ -	$ -	$ -
4.35					$ -	$ -	$ -
4.40					$ -	$ -	$ -
4.45					$ -	$ -	$ -
4.50					$ -	$ -	$ -
						$ 25,000	**$ 9,000**

5.00 OTHER

REF. No.	ITEM / DESCRIPTION OF WORK	EXPECTED LIFE CYCLE - YEARS	ITEM QTY	QTY UNIT	UNIT COST	ITEM TOTAL	ANNUAL COST
5.05	Routine annual inspection	1	1	LS	$ 2,500	$ 2,500	$ 2,500
5.10	Arm's length inspection	4	1	LS	$ 16,000	$ 16,000	$ 4,000
5.15	Underwater inspection	5	1	LS	$ 6,000	$ 6,000	$ 1,200
5.20					$ -	$ -	$ -
5.25					$ -	$ -	$ -
5.30					$ -	$ -	$ -
5.35					$ -	$ -	$ -
						$ 24,500	**$ 7,700**

MINNESOTA HISTORIC PROPERTY RECORD

PART I. PROPERTY IDENTIFICATION AND GENERAL INFORMATION

Common Name: Robert Street Bridge

Bridge Number: 9036

Identification Number: RA-SPC-3177

Location:

Feature Carried:	Robert Street (TH 952A)
Feature Crossed:	Mississippi River, RR, Second and Shepard Streets
Descriptive Location:	0.7 Miles Southeast of TH 35E and 94
Town, Range, Section:	28N-22W-6
Town or City:	St. Paul
County:	Ramsey

UTM:

Zone:	15
Easting:	493060
Northing:	4976600

Quad:

St. Paul East
7.5 Minute Series
1927

Present Owner:

State

Present Use:

Mainline

Significance Statement:

The Robert Street Bridge is historically significant as an outstanding example of an unaltered, monumental, multi-span, reinforced concrete arch bridge. It is the product of a very complex engineering design process to enable this bridge to be built in this location with its established vehicular, railroad, streetcar and river-navigation demands. The resulting bridge includes a monumental reinforced concrete rainbow arch, by far the largest in Minnesota, which is outstanding not only for its engineering, but for its aesthetic effect in the overall design of the bridge. In addition, the bridge received special architectural treatment by the architect assigned to the design team.

Work on the bridge was begun on June 19, 1924. The bridge was completed and dedicated on August 6, 1926. It was a joint undertaking of Ramsey County and St. Paul. Plans and specifications were prepared by Toltz, King & Day, Inc. The Toltz, King & Day, Inc. design team included Max Toltz, mechanical engineer; W.E. King, structural engineer; B.W. Day, architect; Roy Childs Jones, architectural designer; P.E. Stevens, office engineer; W.A. Thomas, electrical

engineer; and John F. Greene, in charge of arch design and resident engineer. The contractor was Fegles Construction Company, Ltd.

The Robert Street Bridge was built to replace an 1884-1885 wrought-iron span that, by the 1920s, had proved inadequate for drastically increased traffic and streetcar demands. The original structure was designed for horse-drawn vehicles with no provision for streetcars. Streetcar tracks were added in 1893. By 1920, the bridge was carrying 2,730 vehicles and 400 streetcars every 12 hours. Two years later the vehicular traffic had increased 55 percent. This traffic increase had been caused by widening Robert Street in 1912-1914 and by connecting Robert Street with University Avenue, a major artery linking St. Paul with Minneapolis. This brought traffic to and from Minneapolis and downtown St. Paul on the north, and St. Paul's west side neighborhood and South St. Paul on the south. In fact, cities as far south as Winona, Minnesota, viewed the new bridge as a needed "capitol highway" to give them greater access to the state capitol.
The engineering firm commissioned to design the new bridge, not only had to provide a span with adequate vehicular and streetcar capacity, but had to accommodate the congested local conditions, with the location of nearly every pier being determined by the clearances required by existing structures and railroad property. The engineers had to reckon with Second Street, the freight shed and tracks of the C.St.P.M.&O. Railway, the tracks of the St. Paul Union Depot, which handles the entire passenger traffic of the city, the main line of the Chicago Great Western Railroad, the river channel of the Mississippi as defined by the War Department and the south end of the bridge then terminating in a busy manufacturing district. These factors and their various requisite clearances dictated the exact location of the roadway. They came together with foundation conditions and the existing Chicago Great Western railroad lift bridge which strictly defined the navigation channel, to dictate the location, size and design of the piers. The net result is the combination of barrel-arch and rib-arch flanking spans and especially the rainbow arch main span over the navigation channel.

Because of the many factors dictating elements of the main span, a rainbow arch was the only solution if an arch was to be used. The solution was an unusual rainbow arch. Instead of the usual compound curves resembling a basket handle, with the long radius at the crown and the shorter radii at the haunches, the radius is 122.16 feet at the crown and 191.60 feet at the haunch. The structural-steel-arch inside each concrete rib also is a significant feature. The steel arch is designed to carry the dead load of the steel arch, floor and concrete rib.

According to the bridge architect Roy Childs Jones in the Engineering News-Record of November 4, 1926, "The Robert Street Bridge is unique in that its designers included in their own permanent organization both architects and engineers." This design team, Jones wrote, allowed the bridge to avoid "applied ornament" on a predetermined structure. Instead, the team could "select and control the structural features so as to secure for the bridge an inherent beauty of form and proportion." The design team faced "the complicated requirements of street grades and of railroad and channel clearances," which precluded "any simple and regular composition of arches and piers." For the most part, then, architectural treatment in this bridge involved working with "shapes and proportions and relations of the structural members" and employing shadow and line. There also was a conscious effort to deal aesthetically with concrete as a material and Jones felt that unbroken surfaces and lines did not work well in concrete. Instead, a choice was made to create a totality out of a series of "definitely bounded segments," produced by "the breaking up of all surfaces with lines of light and shade." This was accomplished by using "vertical breaks and grooves, by bevels, and by wedge-shaped indentations." The result of this practice is readily seen in the surface treatment of the massive rainbow-arch ribs.

PART II. HISTORICAL INFORMATION

Date of Construction:

1926

Contractor and/or Designer (if known):

Contractor:

Designer: Engineer: Toltz, King & Day, St. Paul, Minnesota
Architect: Roy Childs Jones

Historic Context:

Reinforced-Concrete Highway Bridges in Minnesota

National Register Criterion:

C

PART III. DESCRIPTIVE INFORMATION

Descriptive Information:

The Robert Street Bridge is located in downtown St. Paul, Ramsey County, where it carries Robert Street (U.S. Trunk Highway 52) over the Mississippi River, Second Street, Shepherd Road, and the railroad tracks. It links the downtown St. Paul business and commercial district at Kellogg Avenue with the city's west side neighborhood and the city of South St. Paul, together a mixed industrial-commercial-residential area. On the north the bridge reaches the top of the river bluff; on the south it opens to the river's flood plain. The bridge is involved with a wide variety of transportation networks: it crosses river, rail, and vehicular traffic; it carries vehicular traffic, in part to Holman Field, the downtown St. Paul airport. Adjacent, and so close that its north approach spans are literally beneath the Robert Street Bridge, is the Chicago Great Western Railroad Lift Bridge (1912, 1925). The location of the existing lift bridge determined the location of the river navigation channel, which is beneath the main spans of each bridge. The Robert Street Bridge parallels the Wabasha Street Bridge (1889; MNDOT No. 6524), which is located about three blocks west, and the Lafayette Freeway Bridge (1968), which is located about seven blocks east.

Aligned on a northwest-southeast axis, the Robert Street Bridge is a reinforced-concrete, multiple-arch bridge, with an overall structure length of 1,428.9 feet. Starting at the north end, the bridge includes: a reinforced-concrete trestle with three spans of varying length, totaling 89 feet; a skew steel deck-girder span of about 53 feet across Second Street; three flat, open-spandrel, barrel arches of 95.5, 71, and 98 feet, with a combined length of about 291 feet; a two-rib, through arch (also known as a rainbow arch) of 264 feet, center to center piers, with a 244-foot clear span; four five-rib, open spandrel arch spans of 112 feet each; and a prestressed-concrete beam approach. The out-out deck width is 80.4 feet, carrying a 56-foot roadway and 9.5-foot sidewalks on each side. The main span meets the federal navigation requirements of 62-foot headroom above low water.

Of particular engineering interest in the Robert Street Bridge is the main span. The two main ribs are each 6 feet wide and 8 feet deep at the crown, and spaced 64 feet, 8 inches, center to center. Each rib is fundamentally a structural steel frame, designed to carry the weight of the steel structure, including the steel floor system, and the dead load of the concrete arch proper. The dead load of the concrete roadway and the live loads are carried by the composite concrete and structural steel arch. The arch ribs have heavy steel cross-bracing below the roadway (W.E. King and Roy Childs Jones, "Engineering and Architectural Design of a Long Concrete Bridge," in Engineering News-Record 97 (November 4, 1926): 732-37).

Aesthetically, the most important element of the structure is the monumental rainbow arch that dominates the bridge. The overall detailing of the surfaces has been described by Roy Childs Jones, the architectural designer, in general terms, as involving "the breaking up of all surfaces with lines of light and shade," with modeling "accomplished by vertical breaks and grooves, by bevels, and by wedge-shaped indentations." According to Childs, "the idea was to make, out of natural patches of lighter and darker toned material, patterns definitely bounded by strong lines of shadow; and to effect an emphasized interest in light shade in place of the unattainable color interest (which is inherent in concrete)." The railing, a focus of the architect, is comprised of precast perforated panels anchored between poured, heavily reinforced members at top and bottom, and between posts from side to side. Although the south railing is erected on grade, the panels are set vertically. Twelve large medallions, modeled by the Brioschi-Minuti Co. of St. Paul, mounted on the piers, are the only applied ornament (See King & Jones; see also John F. Greene, "Some Lessons Learned in Building Long Concrete Bridge," in Engineering News-Record 97 (November 11, 1926): 785-88). The original light standards have been replaced with

modern light poles. Moderne characterizes the basic style of the bridge.

The bridge was rehabilitated in 1989, including the replacement of approach spans.

PART IV. SOURCES OF INFORMATION

References:

Robert M. Frame, "Robert Street Bridge," National Register of Historic Places Nomination Form, August 15, 1988, available in State Historic Preservation Office, Minnesota Historical Society, St. Paul. Green, John F. "Some Lessons Learned in Building Long Concrete Bridge." Engineering News-Record 97 (November 11, 1926): 785-88; King, W.E. and Roy Childs Jones. "Engineering and Architectural Design of a Long Concrete Bridge." Engineering News-Record 97 (November 4, 1926): 732-37.

PART V. PROJECT INFORMATION

Historians:

Robert M. Frame

Form Preparer:

Mead & Hunt, 2006

MHPR NO. RA-SPC-3177

D. Historic context: Reinforced-Concrete Highway Bridges in Minnesota, 1900-1945

NOTE: The original text of this context is included in "Reinforced-Concrete Highway Bridges in Minnesota," National Register of Historic Places, Multiple Property Documentation Form, prepared by Robert M. Frame III, Ph.D., 1988, available in the Minnesota State Historic Preservation Office.

Reinforced-Concrete Highway Bridges in Minnesota, 1900-1945

MATERIALS: An Introduction to the Elements of Concrete

Reinforced concrete universally consists of three elements: binder, filler, and reinforcement. The binder material in concrete is cement, and it is important to remember that concrete and cement are not synonymous. There is no such thing as a cement sidewalk, a cement block, or a cement bridge. There are concrete sidewalks, concrete blocks, and concrete bridges. Cement is a fine gray powder made of calcium, silica, and other minerals.

Cements (and the resulting concrete) are either hydraulic or non-hydraulic, meaning that they either do or do not harden under water and remain durable when wet. All modern cements and concretes are hydraulic.

Hydraulic cement either is produced from naturally occurring cement rock and is termed "natural cement," or it is manufactured from lime and other ingredients and is called "portland cement." Portland cement was first produced and patented in England in 1824. Although it was used in the United States, it was not manufactured here until a Pennsylvania plant was opened in 1871. Minnesota was one of a dozen or more states producing natural cement around 1902-04, but not portland cement.[1]

While the quality of natural cement is determined largely by the rock from which it is made, portland cement is a scientifically controlled product. This control would become increasingly important as the use of concrete escalated rapidly in the early twentieth century and engineers focused on the quality of the ingredients. Cement is the key ingredient in concrete. As demand increased, quantity output naturally became important. Introduced in the 1890s, the rotary cement-kiln provided continuous processing. The mass availability of carefully proportioned portland cement provided the basis for a construction industry utilizing concrete. The natural cement industry was finished. As an engineer remarked in 1894, "the use of Portland cement concrete has wrought a revolution in all branches of civil engineering, and it seems that we are only in the beginning of the radical changes, which in bridge work, sewers, water works, railroads, etc., are following its introduction."[2]

Since cement is only a bonding agent, it is mixed with filler to give it "monolithic bulk," or enough substance to be formed into a unified whole that can stand alone. The filler consists of "aggregate." Generally aggregates are naturally occurring sands (fine aggregate) and gravels (coarse aggregate). (When cement is mixed only with fine aggregate, the resulting compound is termed "mortar.") As with the cement, the origin, size, and nature of the aggregate became more important as engineers and scientists learned more about concrete construction. Simply mixing cement with gravel from a nearby pit was not necessarily desirable for quality concrete.

Finally, to create concrete, water must be added to the cement and the aggregate. The quantity and quality of the water, and the proportioning of all the ingredients, is extremely important and subject to

analysis. Specifications for bridge contractors working in concrete will indicate the required ingredients and their proportions.

The nature of the concrete used in concrete bridges affects the quality and economy of the structure. Other factors (outside of bridge design) involved in quality and economy include elements such as formwork, and mixing and placing the concrete. The larger the structure, the more these become critical. In particularly large projects, such as the Mendota-Fort Snelling continuous-arch bridge (Mn/DOT Bridge 4190), the design and engineering of the contractor's work is a gargantuan task that has a major impact on the project's cost. Formwork- "centering" in these large arch bridges- is an engineering specialty all its own.[3]

ENGINEERING AND DESIGN: Basic Elements and Bridge Types

Reinforcement

The first concrete bridge in the "modern" world (concrete construction was known in ancient Rome) was built in France in 1840; the first in the United States was built in 1871 in Prospect Park, Brooklyn.[4] These were arch bridges without reinforcement; concrete bridge design and construction does not demand reinforcement, since a massive enough concrete structure will absorb any tensile stresses.[5] A major unreinforced or "plain" concrete bridge, the Rocky River Bridge in Cleveland, Ohio was built as late as 1910. With its 280-foot span, this giant was the last of its type.[6] There are no extant concrete bridges in Minnesota that are known be of "plain concrete" (not reinforced).

The monolithic bulk comprised of cement and aggregate (binder and filler) is strong in compression but weak in its resistance to tensile stresses. To overcome the lack of tensile resistance, reinforcement is added in areas that will be subjected to tensile forces. The history of reinforced concrete should be understood in terms of the evolution of reinforcing, as well as in its own right as a building material.[7]

The materials of reinforcement, historically, have been related to systems of reinforcement: i.e., the Melan system used a curved I-beam, the Kahn system used the Kahn Bar, and so forth. Basically the materials have been steel rods or bars, while a variety of forms and shapes have been employed. Systems regarded as being early and significant include: Josef Melan reinforcing system, Fritz von Emperger reinforcing system, W. C. Marmly reinforcing system, Daniel Luten patents, James B. Marsh rainbow-arch patent, George M. Cheney patent (used by Standard Reinforced Concrete Co.), Kahn reinforcing bar (used by Trussed Concrete-steel Co.), Cummings reinforcing bar, and the Thacher reinforcing bar.[8] Even the term "reinforced concrete" was not standardized until the turn of the century.[9] The first national standards on reinforcing came in 1911 when the Committee on Steel, of the American Society for Testing Materials (ASTM) adopted specifications for reinforcing steel, covering plain, deformed, and cold twisted bars. Prior to this, any standards came from individual industry and municipal sources.[10]

The Reinforced-Concrete Arch Bridge

The masonry-arch bridge has been built since ancient times and its basic features have long been well known. The basic arch form was adapted to both plain- and reinforced-concrete construction. Since the mid-nineteenth century, builders had experimented with reinforcing in concrete and in 1889 the first reinforced-concrete bridge was built in the United States. It was the Alvord Lake Bridge in Golden Gate Park, San Francisco, and was the work of English-born Ernest L. Ransome, who had worked with concrete in California since the 1860s and with reinforcing systems since the 1880s. In 1884, he

patented a twisted reinforcing bar. During the same period, arch experimentation was continuing using the metal mesh system of Josef Monier.[11]

Most influential of all, however, was Viennese engineer Josef Melan, who in 1894 received an American patent on his reinforcing system. It consisted "of a number of steel I-beams bent approximately to the shape of the arch axis and laid in a parallel series near the undersurface of the arch. The resulting structure might be regarded as a combination of the steel-rib arch and the concrete barrel, the concrete serving a protective as much as a structural purpose." Interestingly, in terms of geography, the first American bridge to embody the Melan system reportedly was a small highway span designed by German-born engineer Fritz von Emperger and built by William S. Hewett at Rock Rapids, Iowa, the same year as the patent.[12] Several small but early Melan bridges were built and designed by Hewett in Minneapolis and Saint Paul for the Twin Cities Rapid Transit and survive today as park structures (Mn/DOT Bridge L-9329, Bridge L-5853, Bridge 92247).

--Open Spandrel and Filled Spandrel Designs

The space between the bridge arch and the bridge floor, known as the spandrel area, can be treated in a number of ways. In a smaller bridge, the floor is partly supported by longitudinal walls termed spandrel walls, which rise from the arch to the deck. The hollow interior space is filled with earth or other material, and the bridge is termed a "filled-spandrel" arch. This design involves a heavy dead load on the arch, which is too great in larger structures. To reduce the weight, the spandrel area is opened up. The walls and fill are replaced by columns or transverse walls that rise from the arch to carry the floor. This is an "open-spandrel" arch. These columns and walls are found in a variety of combinations and arrangements, depending on the size of the bridge. Barrel arch designs may be either filled- or open-spandrel; rib-arch designs are usually--but not always--open-spandrel. Minnesota has at least one example of a rib-arch-with a spandrel curtain-wall (Mn/DOT Bridge 5772), and this type has been built elsewhere.[13] The spandrel wall provides an opportunity for architectural treatment. Minnesota has many examples of both basic spandrel configurations, filled and open.

--Barrel Arch and Rib Arch Designs

In 1897 von Emperger, who built many Melan bridges, received two patents for additions to the Melan system. These incorporated additional steel which led, according to engineering historian Carl Condit, toward rib-arch design: "The division of the continuous arch barrel into separate ribs was achieved in the U.S. by F. W. Patterson, an engineer with the Department of Public Roads in Allegheny County, Pennsylvania. Patterson began in 1898 to design small highway spans in which the deck was supported by two parallel ribs each reinforced with a single curved I-beam."[14] In arch-bridge construction, the arch ring may be constructed either as a single arched structural element (a barrel) or in separate but parallel longitudinal elements (ribs). Ribs usually are interconnected by cross struts and braces. Historically there is a rough evolution from an early reliance on the barrel design to a widespread acceptance of the rib design. In terms of size, the larger the bridge the more likely that it is a rib design, since the rib configuration allows less material to be used, thus reducing cost, and lightens the weight of the bridge superstructure. On the other hand, a rib design involves more complicated formwork, thus adding an expense to an already expensive component. Minnesota has examples of each type.

In some cases it is difficult to say if a particular bridge is composed of ribs or double barrels, and it usually amounts to a distinction without a difference. A variation on this theme is found in the above-noted Rocky

River Bridge, which employs "Luxembourg construction," named after the Luxembourg Bridge (1903) over the Petrusse River in Germany, wherein "two comparatively narrow bridges are built side by side; the space between is then bridged over by a roadway."[15]

--Early Twentieth-Century Experimentation in Arch Design

Carl Condit views the turn-of-the-century period as one of experimentation and novelty in design, with the Melan system of reinforcing in the ascendant for concrete arches, although the more efficient methods of bar reinforcing, introduced by Ransome in 1889, were beginning to gain new attention. For a decade after 1900, the design of arch bridges tended to be conservative. The problem with Melan was that it required too much steel, making in actuality a steel bridge encased in concrete. A major Minnesota bridge of Melan construction, the Third Avenue Bridge (Mn/DOT Bridge 2440) in Minneapolis, was built at the end of the Melan era in 1914-16.

By 1910, according to Condit, the main line of evolution was moving away from massive construction, "with its echoes of the masonry tradition, toward the flattened parabolic curves of narrow ribs, the slender spandrel posts, and the minimal piers that scientific reinforcing was to make possible."[16] Among the systems that diverged from Melan was that patented in 1903 by Julius Kahn, which introduced the innovative Kahn Bar, actually a flat bar with the outside edges cut and bent upward to form shear reinforcement. In a 1903 article, Kahn argued that "concrete should be reinforced [sic] in a vertical plane, as well as a horizontal one," and further argued that his bar did this:

> "All of these results have been accomplished by taking a bar of cross section... and shearing the web upwards into an inclined position on both sides of the main body bar, thereby forming substantially the tension members of the ordinary Pratt truss."[17]

Another prominent early advocate for reinforced concrete was the Indiana engineer Daniel B. Luten,[18] who began to publish the first of many articles about this time and was responsible for another alternative to Melan:

> A more scientific solution [than the Melan system], closer to Ransome's method and pointing to later techniques of bar reinforcing, was the introduction from Germany about 1900 of the Luten system for reinforcing wide-span culverts. In this system several bars forming a complete loop were laid transversely through the vault and the bed, or invert, of the culvert, and a series of such loops were laid at regular intervals throughout the length of the structure. The bars were bent to conform to the semicircular section of the vault and the shallow curve of the trough-like invert and to lie near the surfaces of maximum tension under live load. In spite of such early uses of the concrete arch for railroad bridges of great size, the form has never been popular for rail service chiefly because of the problem of absorbing high impact loads.[19]

As with reinforcing bars and systems, not all of the arch forms proved to be prototypical, or even particularly influential. For example, the patented Marsh rainbow-arch design was built at several locations throughout Minnesota in the pre-World War I era, producing significant and visually striking structures, while never entering the design mainstream. Nevertheless, a monumental and significant example was built in 1926, St. Paul's Robert Street Bridge (Mn/DOT Bridge 9036)

In passing, it can be noted that arch bridges divide into two large categories, single arch or continuous arch. A continuous-arch bridge is so designed that, at any pier, the presence of one arch is necessary to provide the abutment-like countervailing force for the adjoining arch. If two single (non-continuous) arches are adjacent at one pier, the pier construction itself will provide the necessary abutment force even if one arch is removed. In practice, almost all multiple-span arches are continuous, and Minnesota has many examples.

--Standardization of Reinforced-Concrete Bridge Construction

In Carl Condit's analysis, the period from World War I to the Depression was largely one of refinement and standardization in reinforced-concrete-arch construction. It was marked by two important regional bridge-building programs: one in Minnesota's Twin Cities metropolitan area after 1915, and another in the California Department of Highways system after 1920. These groups epitomized fine design rather than the innovative and experimental work that characterized the earlier, prewar era. Each offered increasingly larger and longer--and longer-span--crossings, as well as more sophisticated versions of reinforced-concrete design. Prominent examples include Minneapolis's Cappelen Memorial Bridge (Mn/DOT Bridge 2441, 1919-23) and the Mendota-Fort Snelling Bridge (Mn/DOT Bridge 4190, 1925-26), both of which set world length records when built, and California's exquisitely proportioned Bixby Creek Bridge (1931-33). The Minnesota group is discussed in greater detail below.

The high point of standard fixed-arch design (i.e., an arch without hinges and therefore "fixed," stable, and rigid[20], a form used almost universally for concrete bridges with span lengths above 100 ft.) came in 1930-31 with the Westinghouse Memorial Bridge over Turtle Creek Valley in Pittsburgh. Its center span of 460 feet was the longest for a concrete arch in the United States.[21]

Much of what followed the Westinghouse Bridge, in reinforced-concrete bridge work, was a move away from increasingly costly arches toward precast and prestressed girders, deck slabs, and bents. The great demand for highway bridges "eventually became so great that they had to be erected by methods equivalent to mass production."[22] Thus, even though a major engineering research study of reinforced-concrete arches was conducted at the University of Illinois in the early years of the Depression, [23] the demands of economics eventually forced bridge design and construction in other directions. By World War II, the great era of reinforced-concrete arch construction had come to an end, superseded in the reinforced-concrete-bridge world by girders, rigid frames, and precast and prestressed construction.[24]

Reinforced-Concrete Slab, Beam, and Girder Bridges

The reinforced-concrete bridge may be best known in its arch form, since that has been the type employed for the largest, most spectacular, and ornate structures. Far more common, however, have been simple slab, beam, and girder bridges. Following their quick adoption and standardization by the state highway commissions that were created in the decade after 1900, these bridge forms were recommended everywhere for small to medium spans. By the 1920s arch bridges were recommended only for locations with very sound foundations for the abutments.[25] As late as 1906, however, arch-designer Daniel B. Luten wrote that a reinforced-concrete girder bridge ordinarily was not as economical as an arch, unless the abutments were already in place. Luten's example is a situation where a metal truss or beam span had been removed and, of course, an arch would be almost impossible to build, since the abutments had been designed for compression and not for arch thrust.[26]

For the highway department planner, slab, beam, and girder bridges would differ only in construction cost, according to the noted Oregon bridge engineer Conde B. McCullough, who published a study of the economics of highway bridge types in 1929.[27] Each may be used for a variety of span lengths, but only certain types are economical for certain lengths. For example, a slab bridge theoretically could be constructed to almost any span length desired. To achieve a long span with any load-carrying capacity, however, the slab would have to be unreasonably thick and be built with an uneconomically large amount of materials, compared to another design such as a girder. A secondary consideration is the amount of vertical clearance available with each type.

If the design of the concrete arch grew out of the masonry arch, slab and girder bridges were directly related to developments in concrete-building construction. The first concrete girder used in bridge work came in 1898 in Pittsburgh, Pennsylvania, and was similar to the Melan arch reinforcement. An I-beam was encased in concrete to form a reinforced-concrete girder and these were used as main girders and as stringers. As with the Melan work, the I-beam proved to be less desirable than bar reinforcing, and this method emerged around 1905 and was changed very little thereafter. In fact, according to Condit, "the number of concrete girder bridges is so great and the design and appearance so nearly uniform that it is difficult to select examples that are more noteworthy than many others."[28]

Reinforced-Concrete Slab Spans

In its most basic form, the slab-span bridge is nothing more than a square or rectangular panel of reinforced concrete with each end resting on an abutment or other vertical support, and with a railing mounted along each side of the slab. This simplicity has the asset of requiring uncomplicated and economical formwork and less labor in placing the reinforcing; it has the liability of requiring more concrete and steel than girder spans. Also, the simple slab can be used in locations requiring a minimum of vertical clearance or headroom. Overall, simple slab bridges are economical for only the shortest spans, since longer slabs require too much concrete and reinforcing material compared to a beam or girder of equivalent length, thus increasing the cost of the slab relative to the girder. In 1916 Taylor and Thompson recommended limiting slab length to only 10 to 12 feet for heavy loading (trolleys and trucks) and up to 20 feet for less severe loadings.[29] In 1920 Milo Ketchum stated that slabs could be employed for spans up to 25 feet, but were not economical for spans over 20 feet. Later engineering texts extended the maximum economical length to 30 feet.[30]

Like the girder and arch, slabs may be employed in a series of simple spans or the slab may be designed as a continuous span, where it is extended across a support of some kind. In 1921 Waddell found little difference, economically, between continuous and noncontinuous slabs, although he preferred the continuous from the point of view of paving and drainage. In 1939, however, Taylor, Thompson, and Smulski reported that the continuous design was cheaper, as well as being more rigid. Comparing the continuous slab with the continuous girder, the 1939 text reported advantages and disadvantages that are very similar for those in the simple-span comparison noted above. The continuous slab was simpler in terms of labor for formwork, arrangement of reinforcement, and placing of concrete; it had fewer critical sections in design; it had smaller areas of exposed concrete surface and thus lower surface-finish cost. Its disadvantages were greater cost of materials and larger dead loads. Except in cases where the lower headroom is needed, the added cost outweighed the advantages.[31]

Much of the discussion about continuous slabs involves the type of support, and one of the most significant innovations in slab design was C. A. P. Turner's adaptation of his flat-slab mushroom-column construction to bridge design. The first span to use this was his 1909 Lafayette Avenue Bridge over the Soo Line tracks in St. Paul. It was built only a few years after Turner had applied for his original patents (1905) and had built his first flat-slab building in Minneapolis (1906), and in the same year that he published his own engineering text, *Concrete Steel Construction*.[32] The bridge has been demolished, as has a second known early example, the Mississippi River Boulevard Bridge (Mn/DOT Bridge 92250), which was designed by Turner for the St. Paul Park Board and constructed in 1909. It was replaced in 1987.[33] A single, known surviving example of Turner's reinforced-concrete work is the approach to the Mississippi River bridge at Wabasha (Mn/DOT Bridge 4588), designed by Turner and constructed by the Minneapolis Bridge Company in 1931.

By 1939 the column-supported, flat-slab design was being actively promoted by Taylor, Thompson, and Smulski, who commented that "in bridge construction... flat-slab floors have not been used to as great an extent as their merits would justify." They found this design to be very economical: "Often, by using a properly designed flat-slab construction, the cost of the bridge may be reduced by as much as 25 to 30 per cent of the concrete structure."[34]

In addition to Turner's and others' mushroom-column support (in which the slab is rigidly connected with the column), slabs can carried trestle-like, on concrete piles, concrete piers, or framed concrete bents. The trestle arrangement often is found in discussions of flat-slab designs for railroad bridges.[35]

A variation on slab design is the "T-beam," which is formed "where a concrete floor slab is constructed integrally with the supporting beams so that unity of action is insured."[36] A concrete deck-girder similarly integrated with a slab is much the same thing.[37] As discussed by Ketchum, a T-beam slab bridge can be seen as a transitional structure between a simple slab and a deck girder. Taylor and Thompson in 1916 stated that "when the combination of span and loading is such as to call for a slab thickness of more than 16 to 18 inches the simple slab will not prove as economical as the T-beam or girder type."[38] Generally, the T-Beam has been recommended for spans at the longer end of the slab range (20-35 feet). It uses less material than a simple slab, and it possesses some of the deck girder's disadvantages, i.e. it requires more headroom because of the beam.[39]

In 1916 the Minnesota Highway Commission reported developing a new reinforced-concrete slab design for 23-foot spans called the "cellular slab." Half-round sections of corrugated-pipe were used as forms on the underside of the slab, creating a pattern of hollowed-out "cells" in the finished concrete. The remaining concrete then functioned as longitudinal reinforced T-beams with cross beams. The intent was to reduce by one-third the amount of required concrete. Although construction of an experimental half-size model was reported, no further accounts of the use of this design have been found, nor has any example yet been located.[40]

Reinforced-Concrete Girder Bridges

As Taylor and Thompson stated in 1916, girder construction "becomes practical at the point where the simple slab ceases to be economical, while its maximum economical span is determined not only by the kind of loading provided for but also by the spacing and arrangement of the girders." The girder bridge,

they pointed out, "is in reality a modification of the slab bridge whereby a comparatively thin slab spans between a series of relatively deep beams which in turn span from abutment to abutment.[41]

--Single Span and Continuous-Girder Span

Girders are of two main types, single or continuous. The continuous girder bridge, with the girder extending over multiple spans, first appeared about 1910.[42] According to J. A. L. Waddell in 1921, there was not a great deal of economic difference between the two in highway bridges, and the continuous girder often was used, since it gave a solid, monolithic structure. In a multiple-span bridge with any danger of settling, however, a series of simple spans would be preferable. At the time, the balanced-cantilever type of girder was beginning to be used, involving for each unit a pier and two half-spans.[43] It is clear from discussions of girder bridges in Condit that the profile of girders can be misleading, since they are not always simply long rectangles, but may have various curves in their profiles. A girder can be given a slight concave curve along its lower edge for an aesthetically pleasing appearance. Hool and Kinne stated that "it is possible to construct a [cantilever girder] bridge resembling a concrete arch structure in appearance, in locations where the foundation conditions would not permit the construction of an arch...."[44] Without a more complete survey in Minnesota, it is difficult to be certain how many of each type survive, since single and continuous are not always properly designated in the Minnesota Department of Transportation inventory.

--Deck Girder and Through Girder

The fundamental difference between a deck-girder bridge and a through-girder bridge is straightforward: in a deck-girder, the bridge floor slab rests on top of the girders; in a through-girder, the bridge floor is a slab carried between the girders, which act as railings.

Each type has its advantages and its liabilities, and assessments of each remained consistent over two decades from 1920 to 1939.[45] The deck girder's liability is the depth required for its floor construction; the through girder carries the floor between the girders and therefore is preferred where headroom is limited. The situation is reversed when roadway width is a factor. Since the through girder is necessarily limited to the two girders containing the floor, its maximum roadway width is restricted to this outside-supported floor slab, or about 18 to 20 feet. On the other hand, a deck-girder configuration allows for multiple girders beneath the floor, thus extending the width potential. If necessary, the floor slab can be cantilevered beyond the outermost girders to provide additional width for sidewalks. By 1939, through girders were seldom used for highway bridges, although they continued in use for railroad bridges, which were not subjected to ever increasing width demands. Through girders were not being recommended for any road which might require future widening, a necessity by World War II that had not been anticipated twenty years earlier.[46]

Rigid Frame Spans

If a solid, horizontal slab is rigidly connected with vertical walls, a simple rigid-frame bridge has been created. The critical point is that the three sides are rigidly connected at the two "knees" or corners, and all work together in carrying a load. In sectional elevation, the rigid frame appears somewhat different from an abutment-supported slab. In the conventional slab arrangement, its abutments are heaviest at the bottom and lighter at the top where the bridge seat is located. In the rigid frame, the reverse tends to be true: the transverse vertical walls, which replace traditional abutments, are wedge-shaped, tapering downward to the footing. Overall, the rigid-frame bridge is considered much more economical than either

the T-beam slab or the fixed arch, particularly when unyielding foundations are easily obtainable. In addition, the rigid frame employs a smaller depth of construction, a decided advantage where headroom is limited and the required elevation of the top of the bridge is fixed. This is why rigid-frame bridges often have been used in grade separations, such as in freeway construction.[47]

Based on European precedents, the rigid frame was developed in the United States in the early 1920s by Arthur G. Hayden for parkway construction in Westchester County, New York. According to Condit, the rigid frame was the most important innovation in concrete bridge design after Turner's mushroom slab, and it "ranks second only to prestressing as a money-saving method."[48] In his 1931 text, Hayden stated that the concrete T-beam slab was probably more economical than the rigid frame for spans below 30 feet, but the concrete rigid-frame bridge was more economical from 35 to 80 feet. When built in steel, the rigid frame extended the economic advantage from 80 to 120 feet.

Hayden pointed out some variations of the rigid frame, which gave it a deceptive appearance. At times, the curve of the floor slab (it always has a slight arch in rigid-frame design) was great enough to make it appear to be a low-rise arch bridge. Also, the rigid frame sometimes has been constructed with large ribs instead of a solid barrel or slab, giving a visual suggestion of a low-rise ribbed arch. Some have an elliptical intrados.[49] In a narrow design, two rigid-frame ribs may have been used, one on each side of the bridge. The ribs may be extended above the road, creating a through version. As with other concrete spans, rigid frames could be used in a continuous design, sometimes termed "multi-span rigid frames."[50] It is possible that the true nature of a rigid-frame bridge may not be known until the bridge plans are reviewed and the bridge structure may be studied without its additional decorative pilasters and walls.

Within 15 years of its introduction, the rigid-frame bridge had gained wide popularity, replacing arches, slabs, and girders in many applications. In a 1938 address to the Concrete Reinforcing Steel Institute, "What the Future Holds for Reinforced Concrete," the president of the Portland Cement Association reported: "At the present time the rigid frame bridge is being actively promoted and practically every state in the Union has now accepted this type of construction as standard where it fits the location economically."[51]

REINFORCED-CONCRETE BRIDGES IN MINNESOTA

Before the Minnesota Highway Commission

There is very little documentation of reinforced-concrete bridge construction in Minnesota for the years prior to state involvement (i.e., basically before 1905). Almost all the evidence exists in the few surviving structures themselves. Fortunately, however, these extant bridges are excellent examples of significant early designs in both urban and rural areas.

In this pre-automobile era of "streetcar suburbs," where the former nineteenth-century "walking city" was being expanded dramatically by rails,[52] it is appropriate that the new reinforced-concrete bridge technology should be employed by the transit companies who were involved in other new technologies, such as electrification. Bridge builder, and concrete designer and promoter, William S. Hewett designed and built the bridges required by the Twin City Rapid Transit company around 1903-05. Surviving from this group are at least three small arch-bridges by Hewett that employ the Melan system of steel I-beam reinforcement to carry road over the rails: the Interlachen Bridge (Mn/DOT Bridge L-9329) in Minneapolis, and two Como Park bridges in St. Paul (MN/DOT Bridge 92247 and Bridge L-5853).[53]

While Hewett was busy erecting Melan-system streetcar bridges to link the twin metropolises of St. Paul and Minneapolis, an obscure mason and general contractor was designing and building small but elegant reinforced-concrete bridges in Rock County, an area so distant from the Twin Cities that it remains remote today. Perley N. Gillham, who built local roads and county buildings from the late nineteenth century to well into the twentieth, is an utterly unknown figure. He has left many small reinforced-concrete arch spans (some dated) on gravel roads, but virtually nothing is known of his background and where he learned his trade. Most of the bridges were built in the early and mid-teens and use a confusion of rod and twisted-bar reinforcement. One clue to the origins of Gillham's technique is the fact that just over the nearby state line in Iowa was the first Melan reinforced-arch in the United States, built by William S. Hewett for Fritz von Emperger at Rock Rapids in 1894. A photograph of the bridge shows a structure not unlike Gillham's in general size and scale. Ten years earlier, in 1883-84, Gillham and Hewett had worked at the same bridge project in Minnesota. Gillham repaired Rock County's Ash Creek Bridge in 1883 and Hewett built the replacement bridge in 1884. It is possible that the two established a relationship that later led to an exchange of information about reinforced-concrete construction techniques.[54]

Significance of the Minnesota Highway Commission

Through the creation of the Minnesota Highway Commission in 1905, the state government began a process of direct intervention in the bridge building process that continues today in enormous proportions that could hardly have been imagined at the outset. The initial era of the MHC was from 1905 to 1921, when the Babcock Trunk Highway Plan was adopted. During this first decade and a half, the state attempted to gain control over a road and bridge construction process whose antiquated, private-sector management was unable to deal adequately with, initially, the Good Roads Movement, directly followed by the introduction of the automobile. The new road systems demanded by vehicular transportation required two things that only the state could begin to provide: large amounts of money, and professional engineering and design.[55]

Bridges existing at the time of the commission's formation were not necessarily up to the loadings of modern vehicles, mainly heavy steam traction-engines. Early commission reports contain stories and photographs vividly demonstrating the bridge failures caused by these new machines. The problem was wooden and lightweight metal-truss bridges built on competitive design and bid by fabricators who sold cheap structures to nonprofessionals on township and county boards. In its first years, the MHC worked to stamp out these kinds of bridges by forbidding wooden bridges, and by appealing and (when possible) insisting that local designs by approved by state engineers. The movement toward concrete construction began in 1908 with state-prepared plans for concrete culverts and bridge floors. A few years later the MHC was recommending "lasting structures," meaning steel beam, Warren truss, and reinforced-concrete bridges. In 1912 specifications and standard plans were issued for steel and concrete bridges and included "reinforced concrete slab and girder bridges."[56] In his 1912 address on "Reinforced Concrete Highway Bridges," given before the Minnesota Society of Engineers and Surveyors, George Herrold of the St. Paul Department of Public Works recommended highway-bridge types and span lengths in accord with national consensus: the slab for spans 8 to 20 feet, the T-beam slab for spans 20 to 30 feet, and a girder design for spans 30 to 60 feet. In light of the new slab and girder designs, the arch was considered often uneconomical for a highway situation, but "a very desirable type"[57] for parks and approaches to towns and cities, where cost is not the first consideration.

Virtually all the major advances in basic reinforced-concrete bridge design were made in the first two decades of the twentieth century. By World War I, the fundamental designs of the "modern" reinforced-concrete arch, slab, and girder had been established. Only the rigid frame remained to be introduced in the 1920s. It was a time of creativity and experimentation for engineers and the new state highway commissions. The Minnesota Highway Commission participated by designing in 1916 a cellular-slab bridge (described above) in an attempt to refine existing slab design by reducing the amount of required concrete.[58] At the same time, the MHC decided to promote the construction of concrete-pile trestle bridges, after reviewing their use in railroad work.[59]

Other than the cellular slab, whose actual construction and use remains to be documented, there is nothing especially novel to report about the MHC and pre-World War I concrete-bridge construction. The essential concern of the state was that concrete (or steel) be used whenever possible, and that designs be professionally prepared and construction be professionally supervised, whenever possible. Exactly which concrete-bridge type was recommended would depend more on national professional standards than state-based opinions. The professional engineering literature clearly delineated the designs indicated for any particular situation. By 1930 the state was reporting that "our bridges are now being designed in substantial accordance with the approved specifications of the American Association of State Highway Officials (AASHO) which safely provides for the legal loadings specified in our own state laws. There appears to be a general tendency throughout the country to pass legislation safeguarding bridges built during recent years in accordance with recognized standard loadings."[60]

After World War I, the state's attention turned to the development of the trunk highway system initiated by the Babcock plan. Many bridges that the state "inherited" at that time were not up to new loadings, widths, or alignments and major efforts were made to upgrade or replace them. Particular concerns with concrete shifted to matters like aesthetics, or "what might be called the artistic features of bridge construction." This involved a reconsideration of railings, moving from the typical pre-war paneled slabs to a more open design. Other general areas of interest in concrete-bridge work were such things like clearances, floor construction, refining construction techniques, and developing better concrete ingredients. In a 1930 discussion of trunk highway bridges, the state's chief bridge engineer, M. J. Hoffmann, chose to emphasize major new structures over the Mississippi, the Minnesota, and the Red River of the North, rather the multitude of anonymous lesser bridges that routinely fulfilled AASHO standards in whatever form necessary.[61]

"King Concrete" and the Great Arch Bridges

If the first decades of reinforced-concrete bridge work had been a time of experimentation, the dramatic focus of years between the wars was on the spectacular monumental structures that extended the size and range of the earlier designs. Reinforced-concrete bridges of heroic proportions were designed and built, dominating the landscape. It was the era of "King Concrete," as characterized by Canadian bridge historian David Cuming.[62]

In its reports, the Minnesota Highway Commission showcased its large concrete arches at Brainerd, Redwood Falls, Fond du Lac, and two at Anoka.[63] The most exciting work, however, was in and around the Twin Cities, where urban expansion and the automobile encountered the great bluffs and gorges of the Mississippi and Minnesota rivers. "Nature has perhaps nowhere provided a more beautiful setting for an arch bridge than in the Mississippi River valley between Fort Snelling and St. Anthony," declared St.

Paul City Engineer George M. Shepard, in 1927.[64] To meet these challenges engineers designed world-record concrete-arch spans.

The Third Avenue Bridge (MN/DOT 112440, 1914-16) above St. Anthony Falls in Minneapolis constitutes a preamble to this work, being the last major use of Melan-rib reinforced-concrete construction in the Twin Cities. Following Third Avenue was a series of open-spandrel, reinforced-concrete bridges recognized by bridge historian David Plowden as "the first really sophisticated American program of concrete highway bridge construction" and considered highly significant by Carl Condit. Included are the Cappelen Memorial (Franklin Avenue) Bridge (Mn/DOT Bridge 2441, 1919-23), the Inter-City (Ford Parkway) Bridge (Mn/DOT Bridge 3575, 1925-27), the Robert Street Bridge (Mn/DOT Bridge 9036 monumental rainbow arch, 1924-26), and the Tenth Avenue (Cedar Avenue) Bridge (Mn/DOT Bridge 2796, 1929). In addition, Hennepin County built the Fort Snelling-Mendota Bridge (Mn/DOT Bridge 4190, Minnesota River, 1925-2b) over the Minnesota River at its confluence with the Mississippi. Most significant of the group were the Cappelen Memorial Bridge, whose 400-foot main span was the longest concrete arch in the world when built, and the Mendota Bridge, at 4,119 feet, the longest continuous-concrete-arch bridge in the world when built. These bridges constitute masterworks by nationally significant Minnesota engineers, including C. A. P. Turner, Walter Hall Wheeler, Frederick William Cappelen, Kristoffer Olsen Oustad, and the firm of Toltz King & Day. This group includes members of Minnesota assembly of Norwegian-American engineers of exceptional quality, whose reputation and fame was earned in Twin Cities reinforced-concrete bridge design: Frederick William Cappelen, Kristoffer Olsen Oustad, Andreas W. Munster, Martin Sigvart Grytbak, and Olaf Hoff.[65]

Reinforced-Concrete Park Bridges

Along with the chronological coincidence of urban expansion, the growth of city and state road systems, and the introduction of reinforced concrete, came the rise of the urban park. As social historian Alan Tractenberg has observed, noting particularly the ideas of park architect Frederick Law Olmsted, the park was meant to be a refuge from, and thus a contrast with, both the commercial and industrial center and the immigrant-crowded neighborhoods of worker housing. With its curvilinear streets, green open space, all carefully landscaped, the urban park was "all pastoral picture, composed views, nature artfully framed as spectacle."[66]

Within the park, the bridge was not merely an expected necessity, but it emerged as an opportunity. Here the city park commission and landscape architect could request special bridge designs, in harmony with the grand park scheme. Bridge engineer and aesthetic critic Henry Grattan Tyrrell declared in 1901: "In the matter of ornamental park-bridges the engineer has opportunity to display more or less artistic taste, and create not only useful works, but architectural ornaments as well." He indicated also that:

> It can not ...be expected to put up ornamental structures in any of the rural districts, or to any great extent for the use of railroads. The opportunity in the line of ornamental bridge-construction lies chiefly in and around our large cities and park systems and it is greatly to be hoped that, as old wooden bridges decay and are removed, our progressive American people will see their opportunity to replace these with suitable ones of iron and stone, made not simply to carry loads, but to be prominent architectural ornaments.[67]

For Tyrrell, particularly appropriate park styles would be based on the arch or suspension bridge, with rustic treatment desirable.[68] The park further provided an ideal opportunity to explore the possibilities of the new concrete and a great variety of forms emerged (with notable early examples illustrated in the works of Tyrrell and others[69]).
Today, since parks seldom have undergone the heavy usage and expansions of all other road systems, many of the original park bridges survive. Parks now provide us with significant extant examples of some of the earliest and most ornate reinforced-concrete bridges.[70] Particularly significant groups of park bridges are found in Minneapolis, St. Paul, and Duluth. Early stone-faced, reinforced-concrete, arch bridges survive as a unique, linear group on so-called "Seven Bridges Road" in Duluth. In Minneapolis, Minnehaha Parkway and the Lake District provide park-bridge examples, as do Como and Phalen parks in St. Paul.

"New Deal" Era Bridges
During the administration of President Franklin Delano Roosevelt, 1933-45, generally referred to as the "New Deal" era, a number of federal programs were created to provide Depression Era work for the unemployed and to stimulate private business. Among the many programs, for example, was the Works Progress Administration (changed in 1937 to Works Projects Administration and both known popularly as "WPA"), funded bridge construction, along with many other highway and transportation projects. The WPA was abolished in 1942, its work being absorbed by the Federal Works Agency. During that period it built some 78,000 bridges nationally, and built or improved 1,400 bridges in Minnesota.[71] For the period 1935-39, before World War II forced the nearly total cessation of bridge construction, the WPA in Minnesota reported building 176 new bridges and improving an additional 324 bridges.[72]

In part because of wartime steel shortages, WPA bridges usually were built of stone, wood, or concrete. At times, they incorporated traditional stone masonry as a way of providing employment. Instead of eliminating labor costs as in traditional bridge building economics, this was an explicit attempt to make the construction projects labor-intensive, thus creating more work. On occasion, this produced seeming anachronisms-stone-arch bridges. In other examples, a finely wrought stone-veneer was applied to a concrete structure.

WPA bridges usually were designed in one or the other of two contemporary architectural style trends: a rustic, traditional style, or a WPA/government Deco Moderne style. The first style looked backward while the other looked ahead. New Deal era bridges might be large or small. Because the WPA funded park projects, many WPA bridges were built in park or park-like settings. These bridges would be built in a version of the rustic mode, either in stone or wood. Here, the WPA bridge category overlaps with the park-bridge category. Other WPA bridges followed the Moderne styles that had been developing prior to the advent of the federal relief programs. A 1939 pictorial summary of Minnesota WPA projects depicts bridges of both varieties. The Moderne examples have pipe railings with masonry posts, a railing design often found on earlier bridges that were remodeled during the 1930s (whether WPA or not).[73]

Notes

1. Edwin C. Eckel, "Cement Production and Manufacture in the United States," in Engineering Magazine 30 (February 1906): 717-18.

2. See remarks of Carl Gayler (p. 467) following paper of Fritz von Emperger, "The Development and Recent Improvement of Concrete-Iron Highway Bridges," with discussion, in American Society of Civil Engineers Transactions 31 (1894): 438-83.

3. Discussion on concrete adapted from Wisconsin, Department of Transportation, Historic Highway Bridges in Wisconsin, Vol. 1, Stone and Concrete-Arch Bridges, by Jeffrey A. Hess and Robert M. Frame III (1986), pp. 187-205.

4. Carl W. Condit, American Building Art: The Nineteenth Century (New York: Oxford University Press, 1960), pp. 246-47.

5. Carl W. Condit, American Building Art: The Twentieth Century (New York: Oxford University Press, 1961), pp. 196-98, and American Building Art: The Nineteenth Century, p. 340.

6. Carol Poh Miller, "The Rocky River Bridge: Triumph in Concrete," in IA: Journal of the Society for Industrial Archeology 2 (1976), pp. 47-58.

7. Howard Newlon, Jr., "Evolution of Concrete Structures," Structural Renovation and Rehabilitation of Buildings, Papers from a Lecture Sponsored by the Boston Society of Civil Engineers Section/ASCE in Cooperation with the Massachusetts Institute of Technology, Oct. 9-Nov. 13, 1979, p. 91.

8. The reinforcing types, including patents and illustrations, are listed and described in Newlon Evolution of Concrete Structures, pp. 100-05; "Reinforced Concrete," in Scientific American Supplement No. 1547 (August 26, 1905): 24784-85 (includes illustrations of a number of reinforcing systems); "Forms of Concrete Reinforcement," in Iron Age 77 (January 11, 1906): 193-97 (includes discussion and illustrations of many reinforcing forms and bars); A. E. Lindau, "The Development of Concrete Reinforcement," Parts I & II, in Concrete 29 (October 1926): 34-38, and (November 1926): 22-24 (includes discussion and illustrations of reinforcing forms and bars); and F. E. Turneaure and E. R. Maurer, Principles of Reinforced Concrete Construction, 4th ed.(New York: John Wiley & Sons, 1936; first published in 1907), pp. 24-25. For an overview of an example of manufacturing and fabricating an early reinforcing bar, the process used to manufacture the Kahn bar, see "Making Pressed-Steel Reinforcing," in Iron Trade Review 64 (April 24, 1919): 1073-80, which reviews the Youngstown, Ohio, plant of Truscon Steel Co., founded by Julius Kahn about 1902 as the Trussed Concrete Steel Co. with a plant in Detroit. It was originally designed to manufacture the Kahn reinforcing bar. In 1907 the Youngstown plant was opened and the name was changed in 1918. Eventually it produced a variety of pressed metal products, including shells for gas bombs during World War I. For a discussion of the bending and placing of reinforcing bars, see section 3 in George A. Hool and W. S. Kinne, eds., Reinforced Concrete and Masonry Structures (New York: McGraw-Hill Book Co., 1924). George M. Cheney, Indianapolis, Indiana, and received Letters Patent

No. 820,921 in 1906, and his patent was assigned to the Standard Reinforced Concrete Company, of Indianapolis, Indiana. His patent subsequently was used in Minnesota Bridge 112366, Beltrami County, and is documented in the Mn/DOT files for that bridge.

9. See Newlon "Evolution of Concrete Structures," pp. 99-104.

10. See Newlon "Evolution of Concrete Structures," pp. 99-104.

11. Carl Condit, American Building (Chicago: University of Chicago Press, 1968), pp. 171-74; Newlon, "Evolution of Concrete Structures," p. 100.

12. Condit, American Building: The Twentieth Century, p. 250; Condit's information is from Josef Melan, Plain and Reinforced Concrete Arches, authorized translation by D. B. Steinman (New York: John Wiley & Sons, Inc., 1917), opposite p. 7. For a more complete discussion see William Mueser, "The Development of Reinforced Concrete Bridge Construction," in The Cornell Civil Engineer, 33 May 1925): 162-63. It is now reported to be located in a Rock Rapids city park.

13. See discussion and example in C. B. McCullough, Economics of Highway Bridge Types (Chicago: Gillette Publishing Co., 1929), pp. 97, 112.

14. Condit, American Building, 1968, p. 175.

15. Miller, p. 49.

16. Condit, American Building, 1968, p. 251.

17. Newlon, "Evolution of Concrete Structures," p. 100; Condit, American Building, 1968, p. 252; and Julius Kahn, "Concrete Reenforcement," in Railroad Gazette 35 (October 16, 1903): 734-36. For a contemporary discussion of the manufacture of Kahn bars, see "Making Pressed-Steel Reinforcing," in Iron Trade Review 64 (April 24, 1919): 1073-80, on Kahn's Truscon factory in Youngstown, Ohio.

18. Paul B. Israel, "Spanning the Golden State: A History of the Highway Bridge in California," M.A. thesis, University of California--Santa Barbara, 1980, pp. 155-57.

19. See Condit, American Building Art: The Twentieth Century, p. 197, who doesn't give any explanation for the reference to Germany in his notes. Luten was based in Indianapolis.

20. Never popular in the United States, the concrete hinged-arch design is best known through the spectacular and elegant work of Swiss engineer Robert Maillart. See David P. Billington, Robert Maillart's Bridges: The Art of Engineering (Princeton: Princeton University Press, 1979). This design employs metal hinges at the spring lines and at the crown of the arch. Since the arch is thicker at the haunches, the points of stress between the hinges, the three-hinged arch presents a very different profile from the fixed arch, which tends to be heavier where it meets the abutments. In his landmark 1916 work, Bridge Engineering (New York: John Wiley and Sons), J. A. L. Waddell found the hinged

arch to be aesthetically awkward, but safe (p. 941). There are no known examples of concrete hinged-arch bridges in Minnesota.

21. Condit, American Building Art: The Twentieth Century, p. 204-05.

22. Condit, American Building, 1968, p. 251.

23. Jasper O. Draffin, "A Brief History of Lime, Cement, Concrete, and Reinforced Concrete," in University of Illinois Bulletin 40 (June 29, 1943): 36.

24 Condit, American Building, 1968, pp. 258-61.

25. Milo S. Ketchum, The Design of Highway Bridges of Steel, Timber and Concrete, 2nd ed., rewritten (New York: McGraw-Hill Book Co., Inc., 1920), p. 1; C. B. McCullough, Economics of Highway Bridge Types (Chicago: Gillette Publishing Co., 1929), pp. 108113.

26. Daniel B. Luten, "A Reinforced Concrete Girder Highway Bridge of 40 ft. Span," in Engineering News 55 (May 10, 1906): 517-18.

27. C. B. McCullough, Economics of Highway Bridge Types, p. 52.

28. Condit, American Building Art: The Twentieth Century, p. 207-08.

29. Frederick W. Taylor and Sanford E. Thompson, A Treatise on Concrete Plain and Reinforced (New York: John Wiley & Sons, Inc., 1917 [copyright 1916]), p. 694.

30. Ketchum, Design of Highway Bridges, pp. 273, 345; Hool and Kinne, Reinforced Concrete and Masonry Structures, p. 397; and Frederick W. Taylor, Sanford E. Thompson, and Edward Smulski, Reinforced Concrete Bridges (New York: John Wiley & Sons, Inc., 1939), p. 29. Falling in the middle is Clement C. Williams, The Design of Masonry Structures and Foundations (New York: McGraw-Hill Book Company, 1922), who states that "reinforced concrete slab bridges may be used advantageously for spans of about 12 to 24 ft. and are sometimes built up to 30 ft although the girder type will usually be found the more economical for spans above 24 ft." (pp. 331-32).

31. Waddell, Economics of Reinforced-Concrete Bridges (New York: John Wiley and Sons, Inc., 1921), pp. 220-21; Taylor, Thompson, Smulski, Reinforced-Concrete Bridges, pp. 35-36.

32. "Claude Allen Porter Turner," in A Selection of Historic American Papers on Concrete, 1876-1926, Howard Newlon, Jr., ed. (Detroit: American Concrete Institute, 1976), p. 243; C. A. P. Turner, Concrete Steel Construction (Minneapolis: Farnham Printing & Stationery Company, 1909); and C.A.P. Turner, "The Mushroom System as Applied to Bridges," in Cement Age (January 1910): 7-12.

33. Art Werthauser and Eriks V. Ludins, "Mississippi River Boulevard Bridge No. 92250: A Historical Report" (City of St. Paul, Dept. of Public Works, Bridge Bureau, June 1987). Copy in City Bridge Bureau office files. See also Turner, "The Mushroom System as Applied to Bridges."

34. Taylor, Thompson, Smulski, Reinforced Concrete Bridges, pp. 326-27.

35. See, for example, Hool and Kinne, Reinforced Concrete and Masonry Structures, pp. 397, 405-07, and Williams, Design of Masonry Structures and Foundations, pp. 332-40.

36. F. E. Turneaure and E. R. Maurer, Principles of Reinforced Concrete Construction, 4th ed. (New York: John Wiley and Sons, Inc., 1936), p. 54; an almost identical statement is found in Waddell, Bridge Engineering, p. 961.

37. "In deck girder designs, the cross section of the main girders in the center of each span is usually a T-beam, the floor slab forming the compression flanges." Taylor, Thompson, Smulski, Reinforced Concrete Bridges, p. 152.

38. Taylor and Thompson, A Treatise on Concrete, p. 694.

39. Ketchum, Design of Highway Bridges, pp. 273, 354.

40. Minnesota Highway Commission, Report, 1915-16 (St. Paul, 1917), pp. 19-23; "Test of New Type of Reinforced-Concrete Bridge," Engineering News 76 (Sept. 28, 1916): 62021.

41. Taylor and Thompson, A Treatise on Concrete, p. 694.

42. Condit, American Building Art: The Twentieth Century, p. 208.

43. J. A. L. Waddell, Economics of Bridgework, pp. 221-22.

44. George A. Hool and W. S. Kinne, eds., Reinforced Concrete and Masonry Structures, p. 428.

45. See Milo S. Ketchum, The Design of Highway Bridges of Steel, Timber and Concrete, 2nd ed., rewritten (New York: McGraw-Hill Book Co., Inc., 1920), pp. 275, 375; , George A. Hool and W. S. Kinne, eds., Reinforced Concrete and Masonry Structures, pp. 405-432; and Taylor, Thompson, and Smulski, Reinforced-Concrete Bridges, pp. 93-94.

46. Taylor, Thompson, and Smulski, p. 93.

47. See discussions in Arthur G. Hayden, The Rigid-Frame Bridge (New York: John Wiley and Sons, Inc., 1931), pp. 1-4; Condit, American Building: The Twentieth Century, pp. 213-14; and Taylor, Thompson, and Smulski, Reinforced Concrete Bridges, pp. 26869.

48. Condit, American Building Art: The Twentieth Century, p. 213.

49. Hayden, pp. 170-73.

50. Taylor, Thompson, Smulski, Reinforced Concrete Bridges, p. 321 (separate frame, ribs), 148-62 (multi-span).

51. Remarks of Frank T. Sheets, reported in "Trend Toward Continuity in Bridge Design," in Concrete 46 (Nov. 1938): 8.

52. See Sam Bass Warner, Jr., Streetcar Suburbs: The Process of Growth in Boston, 1870-1900 (Cambridge: Harvard University Press and The MIT Press, 1962).

53. "Reinforced Concrete Arch Bridges, Como Park, St. Paul," in Engineering Record 50 (Dec. 3, 1904): 648-49; Henry Grattan Tyrrell, Concrete Bridges and Culverts (Chicago: Myron C. Clark Publishing Co., 1909), pp. 163-66; A Guide to the Industrial Archeology of the Twin Cities, Nicholas Westbrook, ed. (St. Paul & Minneapolis: Society for Industrial Archeology, 1983), p. 18; the background and accomplishments of William S. Hewett and the Hewett firms are discussed in Fredric L. Quivik, "Montana's Minneapolis Bridge Builders," in IA: The Journal of the Society for Industrial Archeology 10 (1984): 35-54.

54. Condit, American Building: The Nineteenth Century, p. 250. Condit's information is from Josef Melan, Plain and Reinforced Concrete Arches, authorized translation by D. B. Steinman (New York: John Wiley & Sons, Inc., 1917), opposite p. 7. Von Emperger's major article on the subject, read and published in 1894, makes no mention of any bridges in Iowa or elsewhere in the Midwest (see von Emperger, "The Development and Recent Improvement of Concrete-Iron Highway Bridges," with discussion, in American Society of Civil Engineers Transactions 31 [1894]: 438-83). However, the Rock Rapids bridge project is recounted in William Mueser, "The Development of Reinforced Concrete Bridge Construction," in The Cornell Civil Engineer, 33 (May 1925): 162-63. On the possibility that Gillham and Hewett met in the 1880s, see statements on the Ash Creek bridge in the Rock County Commissioners Minutes' for March 29, 1883, and December 26, 1884.

55. See discussion in Robert M. Frame III, "Historic Bridge Project" A Report to the Minnesota State Historic Preservation Office (1985) pp. 22-29.

56. See discussion in Frame, Historic Bridge Project Report, pp. 24-26.

57. George H. Herrold, "Reinforced Concrete Highway Bridges," in Tenth Bulletin of the Minnesota Surveyors' and Engineers' Society (1912-13), pp. 84-86.

58. See Frame, Historic Bridge Project Report, p. 27.

59. Minnesota Highway Commission, Report for 1915-16 (St. Paul, 1917), pp. 23-24.

60. Minnesota Highway Commission, Report of the Commissioner of Highways for 1929-30 (St. Paul, 1931), p. 11.

61. M. J. Hoffmann, "Minnesota Trunk Highway Bridge Construction," in The Minnesota Federation of Architectural and Engineering Societies Bulletin 26 (April 1931): 13-18; Minnesota Highway Commission. Report of the Commissioner of Highways for 1920 (St. Paul, 1921), pp. 7-8, and Report of the Commissioner of Highways for 1922 (St. Paul, 1922), p. 17.

62. David Cuming, Discovering Heritage Bridges on Ontario's Roads (Erin, Ontario: Boston Mills Press, 1983), pp. 51-56.

63. Minnesota Highway Commission, Report of the Commissioner of Highways for 1929-30 (St. Paul, 1931), p. 6 (Anoka); Report of the Commissioner of Highways for 1931-32 (St. Paul, 1932), frontispiece (Brainerd); Biennial Report of the Commissioner of Highways for 1933-34 (St. Paul, 1934), frontispiece (Redwood Falls); and Biennial Report of the Commissioner of Highways for July 1, 1940 to June 31, 1942 (St. Paul, 1942), frontispiece (Fon du Lac) and p. 41 (Anoka).

64. George M. Shepard, "Twin City Bridge Construction," in Minnesota Techno-Log 7 (Feb. 1927): 137.

65. Discussed in Westbrook, "Bridges," pp. 14-29, who quotes Plowden; see also Condit, American Building: Twentieth Century, pp. 201-02, and Kenneth Bjork, Saga in Steel and Concrete: Norwegian Engineers in America (Northfield, Minn.: Norwegian-American Historical Association, 1947), pp. 138-55; for further details, consult Appendix A, "Engineers, Fabricators, Builders and Contractors Active in Minnesota Bridge Building," in Frame, Historic Bridge Project Report.

66. See park-bridge discussion in Wisconsin Department of Transportation, Hess and Frame, Stone and Concrete-Arch Bridges, pp. 233-35. Tractenberg, p. 111.

67. Henry Grattan Tyrrell, "American Park Bridges," in The American Architect, March 1901, pp. 100-01.

68. Tyrrell, "American Park Bridges," p. 99.

69. Along with Tyrrell's volume, see also Gilmore D. Clarke's essay on "The Architecture of Short-Span Bridges" in Hayden, The Rigid Frame Bridge, pp. 193-232. The rigid frame originally was introduced as a parkway bridge and it often has been used in this capacity, substituting for the concrete arch and receiving the same architectural treatment. See also the many ornamental bridges in the important volume by Wisconsin engineer Charles S. Whitney, Bridges: A Study in Their Art, Science and Evolution (New York: W. E. Rudge, 1929; reprinted New York: Greenwich House, 1983).

70. For a discussion of a significant and influential park system and its bridges, see Marilyn E. Weigold, Pioneering in Parks and Parkways: Westchester County, New York, 1895-1945, Essays in Public Works History No. 9 (Chicago: Public Works Historical Society, February 1980).

71. U.S. Federal Works Agency. Final Report on the WPA Program, 1935-43 (Washington, D.C.: U.S. Government Printing Office, [1947]), pp. 53, 135.

72. Works Progress Administration of Minnesota, WPA Accomplishments: Minnesota 1935-39 (St. Paul: Works Progress Administration, 1939), unpaginated, see second page of section "Physical Accomplishments."

73. Works Progress Administration of Minnesota, WPA Accomplishments: Minnesota 1935-39, unpaginated, see section on "Minnesota Highways."

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