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NATIONAL REGISTER

United States Department of the Interior
National Park Service

National Register of Historic Places Multiple Property Documentation Form

This form is for use in documenting multiple property groups relating to one or several historic contexts. See instructions in *Guidelines for Completing National Register Forms* (National Register Bulletin 16). Complete each item by marking "x" in the appropriate box or by entering the requested information. For additional space use continuation sheets (Form 10-900-a). Type all entries.

A. Name of Multiple Property Listing

Reinforced-Concrete Highway Bridges in Minnesota

B. Associated Historic Contexts

Reinforced-Concrete Highway Bridges in Minnesota, 1900-1945

C. Geographical Data

State of Minnesota

☐ See continuation sheet

D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards for Planning and Evaluation.

Nina Archabal (signature) — 9/22/89

Signature of certifying official Nina Archabal — Date

State Historic Preservation Officer

State or Federal agency and bureau Minnesota Historical Society

I, hereby, certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

Beth Boland (signature) — 11/6/89

Signature of the Keeper of the National Register — Date

E. STATEMENT OF HISTORIC CONTEXTS

HISTORIC CONTEXT: Reinforced-Concrete Highway Bridges in Minnesota, 1900-1945

I. 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 (MNDOT #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 speciality all its own.[3]

II. 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]

<u>The Reinforced-Concrete Arch Bridge</u>

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 (MNDOT #L-9329, #L-5853, #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 (MNDOT #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 (MNDOT #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 reenforced [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 (MNDOT #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 <u>single</u> (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 (MNDOT #2441, 1919-23) and the Mendota-Fort Snelling Bridge (MNDOT #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 non-continuous 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 (MNDOT #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 (MNDOT #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]

III. 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 (MNDOT #L-9329) in Minneapolis, and two Como Park bridges in St. Paul (MNDOT #92247 and #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" for "parks and approaches to towns and cities, where cost is not the first consideration."[57]

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 panelled 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 (MNDOT #2440, 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 (MNDOT #2441, 1919-23), the Inter-City (Ford Parkway) Bridge (MNDOT #3575, 1925-27), the Robert Street Bridge (MNDOT #9036 monumental rainbow arch, 1924-26), and the Tenth Avenue (Cedar Avenue) Bridge (MNDOT #2796, 1929). In addition, Hennepin County built the Fort Snelling-Mendota Bridge (MNDOT #4190, Minnesota River, 1925-26) 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]

IV. 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 #2366, 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. 108-113.

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): 620-21.

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. 268-69.

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 M.I.T. 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, subsitituting 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."

F. ASSOCIATED PROPERTY TYPES

I. Name of Property Type: Reinforced-Concrete Highway Bridge

II. Description

The single Associated Property Type, "Reinforced-Concrete Highway Bridge," includes several related span sub-types: (a) arch spans; (b) slab, beam, and girder spans; and (c) rigid frame spans. In some cases, more than one span sub-types may be found within a single bridge structure. For example, a bridge may have main spans in an arch design and approach spans in a girder design.

All span sub-types in this property type share the common characteristic of employing reinforced concrete to construct a bridge of one or more spans. This property type does not include "plain" or unreinforced concrete bridges; the distinction is academic in Minnesota, however, since no example of an unreinforced-concrete bridge has been located in the state. This property type includes only spans generally designed to be highway bridges, a category that, in a few cases, includes bridges that carry only pedestrian (i.e., lighter load) traffic. Most importantly, it does not include spans specially designed to carry only railroad traffic. Although such railroad bridges may have some or all of the characteristics of bridges included here, the field survey was not designed to provide an adequate sampling of railroad bridges, which usually are engineered to carry different and heavier loadings than highway or pedestrian bridges.

Reinforcing materials and systems may vary, but usually this situation is found only in arch bridges designed and built before World War I. After about 1921 reinforcing materials and techniques were more or less standardized and did not vary in major ways. Early varieties include the Melan steel-rib design, and related designs by the Standard Reinforced Concrete Company and the Marsh Company.

The reinforced-concrete arch bridge is the most complex span sub-type, in engineering terms, and is the most interesting visually. It was designed and built in all lengths, from the shortest span that is officially termed a "bridge" instead of a "culvert" (10 feet), to the largest reinforced-concrete spans (100 feet and over) in the state. It was built throughout the entire period covered in the context, 1900 through 1945.

Arch bridges may be designed as single-arch spans, multiple single-arch spans, or continuous-arch spans. The fundamental difference is that single spans in any arrangement are independent and can stand alone; continuous spans are dependent upon each other and cannot stand alone.

Since virtually all arches are "deck arches," meaning that the arch is below the floor, the deck arch is conventionally referred to simply as an "arch bridge." (This convention does not apply to other span sub-types of concrete bridge designs, however.) The only other version of concrete arch bridge in Minnesota is the "through arch," more commonly known as the "rainbow arch" because of its distinctive appearance. It also is sometimes known as the "Marsh rainbow arch," after its original designer and patent-holder, J.B. Marsh and the Marsh Engineering Company.

The arch element itself may be either a barrel arch or a rib arch. Occasionally a bridge was designed as a double-barrel arch, in which the two barrels may be either adjacent or separate. While reinforced-concrete arches may be either fixed or hinged designs, fixed arches are overwhelmingly the most common in the United States, and the only kind found in Minnesota.

The space between the arch and the floor is the spandrel area. An arch bridge may have either a filled or an open spandrel design. While most barrel arches have filled spandrel areas, and most rib arches have open spandrel areas, any combination is possible and may be found in Minnesota.

Reinforced-concrete slab, beam, and girder bridges are variations on the same basic design, with the different variations employed to meet demands of clearance, length, and/or economics. These bridges were built almost as early as reinforced-concrete arch bridges, but were used more extensively after the beginning of the state highway commission, which specified them in standard designs as alternatives to wood and metal. After World War I, slabs, beams, and girders were specified almost exclusively for concrete bridges of small to medium spans, with arches recommended only for large spans.

The slab span is a square or rectangular panel of reinforced concrete and was recommended for short spans of 10 to 12 feet, with a maximum of 20 feet, prior to World War I. Later the length was extended to 20 to 30 feet. Beyond that length a slab of sufficient strength was not considered to be economical.

A significant variation of slab design is that employing the mushroom-column support designed and patented by Minnesota engineer Claude A.P. Turner. Another variation is the cellular slab designed by the Minnesota Highway Commission in 1916, although an extant example has not yet been found and it is not clear whether any examples beyond experimental models ever were built.

For spans at the longer end of the slab range (20 to 35 feet), where the slab would have to be uneconomically thick, the T-beam design was sometimes recommended. The T-beam is a slab constructed with integral concrete floor beams.

For spans beyond the range of the slab and T-beam, the reinforced-concrete girder was used. The girder can be either a deck girder or a through girder. It also can be either a single, continuous, or cantilever design.

The last major span sub-type is the reinforced-concrete rigid-frame span, in which the three sides (floor and two end supports) are rigidly connected at the two "knees," creating a single structure with all elements working together to carry a load. The rigid-frame design was developed in the United States in the early 1920s, although examples that early have not been found in Minnesota. Though usually found in a deck version, it could be constructed in a through version.

For several of these span sub-types, such as the rigid frame and arches with unusual reinforcing, it may be necessary to consult original plans to determine the exact nature of the design, since the external appearance may be misleading or may not give any clue to the internal construction.

Any of these span sub-types may exhibit a variety of additional functional elements, such as railings, abutments, piers. In addition, these elements, along with the overall structure, may receive architectural or ornamental treatment. By far the most common architectural style given to bridges is Classical Revival. This is found from the earliest to the latest examples. Next would be the rustic, stone-veneered treatment, found in park bridges and in bridges from the New Deal era. Occasionally a bridge may exhibit elements of Art Deco or Streamline Deco styling, usually in a mild form and mixed with classical elements.

In many small bridges, particularly slab and girder designs, architectural treatment is found only in the railings. This is especially true in standardized state designs, where the railing usually is a filled-panel slab in the Classical Revival mode. Larger and more urban bridges, including urban park bridges, may have an open-balustrade railing with turned balusters. Large bridges also may incorporate Classical Revival elements into the design of piers, abutments, and spandrel walls and columns.

III. Significance

The governing historic context for this property type examines Minnesota reinforced-concrete highway bridges for the period 1900 to 1945. Since the context applies to some structures that are not yet 50 years old, it is necessary to consider the issue of "exceptional significance." The topic is discussed more for the sake of completeness than relevance. According to the research and field-survey findings of this study, there is no indication that any bridge falls into this unusual category. It is recommended, therefore, that all bridges be evaluated under the normal National Register Criteria A, B, and C. Since research and field survey were conducted on a statewide level, there is a sound basis for making judgments of statewide significance as well as local significance.

Because virtually every bridge in Minnesota is associated with the "broad pattern" of transportation, one could use Criterion A liberally to find every bridge in the state eligible to the National Register. This, however, would make the process meaningless. Rather, to be eligible under Criterion A, a bridge must have been involved in a meaningful way with the settlement or development of a geographically definable area, facilitated major passage to or through a region, or been significantly integral to the development of an effective transportation system. Consequently, large bridges over major rivers are most likely to have significance for their historical associations with regional development or settlement. Smaller bridges may be historically significant for association with the development of an effective transportation system. Examples of the latter would include bridges which were built as a result of an important railroad grade separation program.

In evaluating a bridge's significance under Criterion A, it is helpful to consult other historic contexts dealing with the general geographical area, especially those prepared for municipal and county surveys. Generally speaking, a bridge is significant for its historical associations with a region only if it dates from the period of significance established for that region. For example, the second bridge over a major waterway may not be significant for its historical associations if the period of significance determined for that region is previous to the date of the bridge's construction.

Bridges are rarely eligible under Criterion B. When a bridge is associated with a significant individual, it is almost always in relation to an engineer, architect, contractor, or fabricator. According to National Register guidelines, such cases are to be considered under Criterion C. It is conceivable, however, that a bridge might have played a significant role in the career of an important politician or civic leader, for example, who advocated its construction or preservation. In such a case, the bridge might be eligible under Criterion B.

Criterion C is most frequently invoked for finding historic bridges eligible for the National Register. As in the case of Criterion A, an overly liberal application might lead to the determination that all bridges are eligible, particularly as "representatives of a type." Rather, Criterion C should be employed to winnow a group of similar resources to a meaningful list. Instead of looking simply to typicality as an indicator of significance, evaluation under this criterion should identify additional important qualities, such as being the sole surviving example, the oldest example, the longest span, the most intact example, the work of a major engineer or contractor, or exhibiting notable engineering or architectural details. By selecting the superlative examples from the major structural categories, a list of truly important bridges can be gleaned from a large number of similar resources.

The reinforced-concrete highway bridge type includes the following related span sub-types: (a) arch spans; (b) slab, beam, and girder spans; and (c) rigid frame spans. Each span sub-type has one or more variations. Each span sub-type can be found in a design that exhibits one of several architectural styles. Each span sub-type can be found in one of several locational situations that probably influenced both its engineering and its architectural treatments.

There are several eras in the development of the reinforced-concrete bridge: (a) early experimental, non-standardized-design, 1890s-1911; (b) early highway-commission, standardized design, 1912-1921; (c) established highway department, trunk highway, and major urban bridge period, 1921-1945.

The reinforced-concrete arch bridge, in one or another variation, is significant in each era. During the period 1890s-1911, before the advent of state highway commission standardization, the arch bridge was almost the only design to be found. Usually the arch was built in one of its smaller variations and almost certainly it would be in a more-or-less experimental form, since the use of reinforced concrete in Minnesota at that time was in a universally experimental stage. Of particular note for this time would be vernacular builders and street-railway companies, since this is largely the pre-automobile era. Located during the survey were examples of the early vernacular work of Rock County contractor Perley N. Gillham and examples of the work of Minneapolis bridge-builder William S. Hewett for the Twin City Rapid Transit company.

While the varieties of design and construction of the earlier era continued after 1905, the period 1906-21 is particularly defined by the advent and early work of the state highway commission before the introduction of the trunk highway system. This period involves initial state advocacy of reinforced-concrete construction (c1908-1911), the beginning of state standardization in bridge design (c1912-21), and some state experimentation with reinforced-concrete designs (c1916).

All reinforced-concrete-bridge span sub-types were constructed in Minnesota during the pre-1921 period, with the exception of the rigid frame, which was not yet introduced into the United States. There was an increasing emphasis on slab, T-beam, and girder designs, with a slowly decreasing emphasis on arch designs for ordinary roads where economy was a strong factor. Arch designs still were preferred for locations where aesthetics and ornament were important, such as parks and prominent urban settings.

The first structural indication of a state standard design for a reinforced concrete bridge during this period usually is the railing, which was designed as a flat slab with filled panels in a Classical Revival mode. Even a through-girder, with the girders serving as railings, was given the panelled, Classical Revival treatment. Park bridges, often not state-designed, sometimes received a stone veneer and sometimes were given a more articulated Classical Revival surface.

Significant during this period are patented reinforcing systems, patented structural designs, the early works of engineers specializing in concrete, the early works of Minnesota consulting engineers, and the early works of state highway commission engineers. During survey work, examples were found incorporating the designs or patents of the Melan system, the Marsh rainbow arch, and the Standard Reinforced Concrete Company. This also is the period in which the early reinforced-concrete bridge work of Claude A.P. Turner will be found, although all of the known early examples have already been demolished. Research indicates that the early reinforced-concrete work of the following significant Minnesota engineers and builders will be found from this period: Milo A. Adams, William Pierce Cowles, the Hewett family, Charles F. Loweth, Louis P. Wolff, and the Minneapolis Bridge Company. Also among those whose work should be considered as significant are the state bridge engineers and the Minneapolis and St. Paul city bridge engineers of this and the subsequent period (whose early work may appear during this period). Railroad engineers J.H. Prior and H.C. Lothholz, of the Chicago, St. Paul, & Pacific Railroad, built a significant series of highway bridges over urban Twin Cities' rail lines.

The period 1921-45 encompasses three overlapping eras: (a) the period of design and construction of nationally significant concrete-arch bridges in the Twin Cities, largely in the 1920s-30s; (b) the introduction, development, and expansion of the state trunk highway system, from 1921 onward; and (c) bridge construction during the New Deal era, 1930s-40s.

Large, often monumental, reinforced-concrete arch bridges stand out as the most significant Minnesota bridges for the period 1921-45. The most notable of these were constructed in the Twin Cities area to bridge the Mississippi and Minnesota river valleys during the era of dramatically expanded automobile traffic. These particular bridges were the work of city engineers and Minnesota's nationally significant consulting engineers, such as C.A.P. Turner and Walter Hall Wheeler. Among the city engineers is an especially noteworthy group of four, major, innovative and influential Norwegian-American engineers that were involved in the design of the great bridges of the Twin Cities: Martin Sigvart Grytbak, Kristoffer Olsen Oustad, Andreas W. Munster, and Frederick William Cappelen.

During the same period similar bridges on a smaller scale were being built by municipalities statewide as well as by the state highway commission on its trunk highway system.

The general theme of reinforced-concrete construction for these decades is the refinement and expansion of existing technologies and designs, leading to larger and/or longer spans. This suggests the continued use of slab and girder designs, but mainly those variations that allowed longer spans and could accommodate future widening. This meant the diminished use of through-girder bridges.

One important new factor was the introduction of the rigid-frame bridge, a design first used in the United States in the 1920s in New York state for park-like expressways. Survey and research suggests that the rigid frame reached Minnesota in the 1930s and was employed for new beltways being constructed around the Twin cities, generally involving the engineers of the state highway department.

The federal government influenced Minnesota bridge design and construction through its New Deal programs, which were intended to provide work for the unemployed and to stimulate private business. These programs did not necessarily create new bridge engineering, but often funded new construction that would not otherwise have occurred, and often influenced the architectural treatment of the bridges that were funded. These public works projects included park bridges in rustic, stone-faced styles, designed to be compatible with park settings. Other New Deal bridges might exhibit Classical Revival or Art Deco and Streamline Moderne stylistic elements.

Subsidiary bridge elements may enhance the overall significance of a bridge. These include abutments, piers, approaches and approach spans, railings, and light standards.

It also is possible that the significance for some bridges may relate to innovative developments in bridge construction, such as a an improved concrete mixture or a new design for bridge "centering," an element that is vital in the construction of arch bridges.

IV. Registration Requirements:

Reinforced-concrete highway bridges in Minnesota may be eligible for the National Register under Criterion A for their association with events that have made a significant contribution to the broad patterns of American history, Minnesota history, or local history, especially in relation to transportation or regional settlement or development. This includes bridges associated with the designation of "named" or "signed" roads or "trails" (i.e., like the Lincoln Highway in Nebraska), such as the Red Ball highway, Yellowstone Trail, and others; and associated with the design and construction of the earliest designated trunk highways following the 1921 creation of the state trunk highway system.

A bridge in this property type may be eligible for the National Register under Criterion B for its association with an significant person, if that person was not the designer or builder of the bridge.

For a bridge in this property type to be eligible for the National Register, the significant reinforced-concrete element in the superstructure span (i.e., the actual arch, slab, girder, mushroom-capped column, or rigid frame) must be in substantially original condition. Because this engineering element is the most important feature of bridges in this property type, neither an original substructure nor an original deck and railing system are necessary for the bridge to be eligible (although these components, when original, may enhance the significance of the bridge).

Bridges eligible under Criterion A must have integrity of location. Bridges eligible under Criteria B or C may have been relocated, although the likelihood of any reinforced-concrete bridge having been moved is very small.

Most eligible bridges in this property type will fall under Criterion C. They may be eligible for their association with significant engineers or engineering firms, architects or architectural firms, builders, contractors, or other individuals or firms who made significant contributions to the design and construction of bridges or transportation systems. Bridges in this property type also may be eligible because they embody distinctive characteristics of bridge engineering and construction or significant phases in the evolution of bridge engineering and construction.

Under Criterion C, a reinforced-concrete highway bridge may be eligible if it was or is:

1. Built prior to 1912. Such bridges represent the earliest, pre-standardization, experimental era in reinforced-concrete bridge construction, and are rare. They usually are the product of a pioneering builder or pioneering engineer, or were

part of the pioneering efforts of the new (1905-1911) State Highway Commission to improve the quality of bridge design in Minnesota. There is a high probability that they involve a patented or otherwise unusual reinforcing system. They may represent an overall vernacular construction, both in engineering and architectural design. In terms of age-related significance, such a pre-1912 bridge is the concrete equivalent of a nineteenth-century metal truss bridge.

2. Designed or constructed with patented or otherwise specially designed elements, such as Josef Melan reinforcing system, Fritz von Emperger reinforcing system, W.C. Marmly reinforcing system, Daniel Luten patent, 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, Thacher reinforcing bar, C.A.P. Turner mushroom-cap column, or other patented elements documented on original plans, specifications, or in an engineering or other article on the bridge. The patented element must be present in the bridge (though not necessarily visible), so it can be recorded and possibly preserved if the bridge is removed.

3. Designed with a span length of monumental proportions (i.e., 100 feet and over). Such bridges are rare and represent a major engineering effort to solve an unusual site problem.

4. Designed at the outer recommended limits for its span type. Such bridges represent extraordinary engineering efforts to push a particular span sub-type to its limits to solve an unusual site problem, and are rare. Generally, the significant span lengths are:

--slab span: 30 feet and over
--through girder: 50 feet and over
--deck girder: 50 feet and over, before 1921; 60 feet and over after 1921
--arch span: 100 feet and over
--rigid frame: 50 feet and over

5. Designed with outstanding architectural style or ornamentation. These bridges represent extraordinary aesthetic efforts to enhance a crossing at an important location. They usually are found in significant and prominent urban settings, such as city approaches and entrances, and in park settings, either urban or rural. These bridges may demonstrate formal styles (Classical Revival is common; Art Deco or Streamline Moderne is rare), or rustic styles (usually stone veneer). A stone veneer may be formal (i.e., coursed, ashlar, with Classical Revival overtones) or informal (rubble, cobblestone, or other "rustic" mode). Usually these are arch bridges, but a rare type is a girder bridge designed to resemble an arch bridge. An eligible bridge will retain considerable architectural integrity. Original light standards often have been removed; this does not make the bridge ineligible, but original light standards do enhance significance.

6. Designed by an Important Engineer, Architect, or Firm. The following have been identified by this survey and/or the 1985 Historic Bridge Project Report as significant in Minnesota bridge-building (for dates, firm relationships, and alternate names see Appendix A, "Engineers, Fabricators, Builders and Contractors Active in Minnesota Bridge-Building," in 1985 Report) :

   Milo A. Adams, L.N. Butler, Frederick William Cappelen, Concrete-Steel Engineering Co., George Cooley, William Pierce Cowles, Donald B. Fegeles, Perley N. Gillham, Martin Sigvart Grytbak, William S. Hewett (and associated Hewett companies, including Security Bridge Co. and Great Northern Bridge Co.), Olaf Hoff, H.C. Lothholz, Illinois Steel Bridge Co. (whose name is sometimes used interchangeably with its Minnesota agents, John Zelch or Zelch & Walton), Charles F. Loweth, Marsh Engineering Co., Minneapolis Bridge Co. (sometimes used interchangeably with its officers and engineers, including C.P. Jones, A.Y. Bayne, and L.W. Johnson), Andreas W. Munster, Kristoffer Olsen Oustad, J.H. Prior, N.M. Stark & Co., Toltz, King & Day (particularly Max Toltz and Wesley Eugene Day), C.A.P. Turner, Walter Hall Wheeler, Louis P. Wolff. Additional names should be added as future work warrants.

7. A bridge visibly documented (has identification plaque) as being constructed through a New Deal agency (e.g., WPA) and having architectural merit and integrity as outlined in Requirement No. 5 above. New Deal agencies produced bridges of great architectural merit, sometimes by known designers and sometimes by obscure designers. Some of these bridges are outstanding representatives of contemporary architectural styles (e.g., Deco, Moderne); examples with great design integrity are eligible. Some of these bridges have great architectural compatibility and harmony with their sites (e.g., park bridges, rustic bridges, stone veneer bridges); examples with design and contextual integrity are eligible.

8. A rigid-frame bridge that:
   a. was built in 1938 or earlier and has a span length of 50 feet and over; or
   b. is one of the following unusual variations: false arch (designed to appear as an arch bridge); ribbed frame; or through-frame.

   Either type is an important engineering and/or architectural solution to an unusual site condition and is rare in Minnesota.

G. Summary of Identification and Evaluation Methods

Discuss the methods used in developing the multiple property listing.

[X] See continuation sheet

H. Major Bibliographical References

[X] See continuation sheet

Primary location of additional documentation:

- [X] State historic preservation office
- [ ] Other State agency
- [ ] Federal agency
- [ ] Local government
- [ ] University
- [ ] Other

Specify repository: __________

I. Form Prepared By

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G. SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

Jointly sponsored by the Minnesota Department of Transportation (MNDOT) and the State Historic Preservation Office (SHPO) of the Minnesota Historical Society (MHS), this study of historic reinforced-concrete bridges in Minnesota was initiated by means of a contract between MHS and the firm of Jeffrey A. Hess, Historical Consultant, which subcontracted a substantial portion of the work to Dr. Robert M. Frame III. Dennis A. Gimmestad and Susan Roth of SHPO served, respectively, as overall project supervisor and project manager. Technical assistance was provided by Clement P. Kachelmyer and Richard D. McAtee of MNDOT, and by James W. McCutcheon and Stanley Graczyk of the Federal Highway Administration. Research, field survey, and report preparation were completed by Dr. Frame, with the supervisory assistance of Jeffrey A. Hess.

The sample of reinforced-concrete bridges initially considered for this study was selected in the 1985 Historic Bridge Project Report. Beginning with Minnesota's 19,000 highway bridges on the MNDOT inventory, that project selected 887 bridges for research, including all concrete bridges on any type, built pre-1921, with a main span length of 20 or more feet (397 bridges); and all concrete bridges of any type, built 1921-45, with a main span length of 50 feet or more (60 bridges). The year 1921 was selected because it marked the beginning of the state trunk highway system, the most important single development in the state road system following the creation of the state highway commission and preceding the advent of the interstate highway system. The lengths were selected in order to limit the study sample yet include the major structures, especially for the post-World War I, post-experimental years when structure size and span length were more indicative of significance than structural type or novelty.

In this manner, the research and field survey of the reinforced-concrete highway bridge context was provided with a total sample of 457 bridges. Included were all concrete bridge (not culvert) types: arch, slab, beam, through girder, deck girder, and rigid frame. The current MNDOT inventory file for each was researched for the 1985 study, along with any existing historical files.

In preparation for the context statement, research in the professional literature was completed on all concrete types, in order to establish the history of their technological development and application. Further research was done to understand the history of the various types in Minnesota. Overall, this involved: technical texts and professional journals; historical studies of technology, engineering, and architecture; other reports on historic-bridge surveys; state highway commission reports and bulletins; and other professional and governmental publications. Where possible during the survey, research was done in local government records, local libraries, and local historical societies.

Given the time and resources available for the present project, it was impossible to field-survey all 457 bridges. To arrive at a more manageable sample, it was decided to establish priority levels for survey. The first priority was to survey as many as possible of the reinforced-concrete bridges that the 1985 Report had listed as "determined eligible" (designated "NR Status Group Two") and as "potentially eligible" (designated "NR Status Group Three"). This first priority included 43 bridges.

The second priority was to field-survey as many reinforced-concrete arch bridges as possible from the 457 total, while travelling to and from the bridges listed in the first priority. The third and last priority was to survey as many as possible of all the remaining bridges of the 457 total that had not been listed as "lacking National Register significance or integrity" ("NR Status Group Five"). (The bridges in group four had been designated as being of "indeterminate significance," and included all bridges not listed elsewhere.)

In order to survey the largest number of priority structures, geographical clusters of priority groups one and two were studied before isolated examples. Three of these clusters were identified: the Twin Cities metropolitan area, the Duluth area, and Rock County. The Twin Cities area includes significant examples of both early reinforced-concrete arch bridges and monumental reinforced-concrete arch bridges. The Duluth area includes a significant collection of early reinforced-concrete-arch park bridges that have notable architectural elements. Finally, Rock County has a unique collection of early, vernacular, reinforced-concrete arch bridges by a single builder.

Because the initial pool of Minnesota bridges was drawn from the MNDOT inventory of highway bridges, railroad-traffic bridges were included in the inventory only when they crossed highways. Bridges carrying railroad loadings, therefore, are under-represented compared with their total population in the state. Following discussions with the State Historic Preservation Office, it was determined that bridges specifically engineered to carry rail traffic would be dropped from the present study. It can be noted, however, that there is a group of highway-underpass bridges (rail over road) that exist only in road/rail situation and have features that would not exist in a water/rail--pedestrian sidewalk access, for example.

Working within the established limitations and priorities, it was possible to field-survey 97 reinforced-concrete bridges. The survey, of course, was biased toward arch bridges. This is not unreasonable, since of all the reinforced-concrete types, arch bridges have the most complex engineering. Also, arch bridges were used throughout the study period and were used for all span lengths, from the shortest to the longest. As a result, arch bridges are better understood than other types and this is reflected in the registration requirements. Further work is needed to establish more sophisticated and complete registration requirements for slab, beam, girder, and rigid frame bridges. Further research as well as survey is necessary for railroad bridges, particularly bridges carrying rail loadings.

Field survey involved the following: photography in both black-and-white and color slide formats; the completion of a field-survey form to document engineering, architectural, and ornamental design and details; notation of setting and surroundings; and research in local government and other sources when time and circumstances permitted.

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