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Ash Avenue Bridge (Tempe Bridge, Old Tempe Bridge,
Salt River Bridge)
Spanning Salt River at the foot of Ash Avenue
Tempe
Maricopa County
Arizona

HAER No. AZ-29

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
Western Regional Office
National Park Service
U.S. Department of the Interior
San Francisco, California 94102

HISTORIC AMERICAN ENGINEERING RECORD

Ash Avenue Bridge
(Tempe Bridge, Old Tempe Bridge, Salt River Bridge)

HAER No. AZ-29

Location:	Spanning Salt River at the foot of Ash Avenue Tempe, Maricopa County, Arizona UTM: South End - Zone 12, Easting 412460, Northing 3699280 North End - Zone 12, Easting 412420, Northing 3699720 Quad: Tempe, Arizona
Date of Construction:	1911-1913
Engineers:	J. B. Girand, Territorial Engineer Carl E. Hasse, Design Engineer Arizona Territory Highway Department
Present Owner:	City of Tempe/State of Arizona, acting through the Arizona Department of Transportation
Present Use:	Abandoned highway bridge (demolished in 1991)
Significance:	Constructed over the Salt River on the Phoenix-Tempe Highway, the Ash Avenue Bridge is the first concrete multi-arch bridge erected in Arizona. The structure is comprised of eleven spans of two-rib, open-spandrel, hinged arches. After the bridge was opened in 1913, it contributed immensely to the development of the Salt River Valley.
Historians:	Gerald A. Doyle & Associates, P. C. Historical Architects 4331 North 12th Street Phoenix, Arizona 85014-4580
Date:	January 1991

HISTORICAL CONTEXT

The site of the Ash Avenue Bridge coincides with a historic ford across the Salt River (HAER photograph AZ-29-1). The ford undoubtedly was used by prehistoric Hohokam Indians, whose irrigated fields lay along the banks of the river. One of the first recorded crossings of the stream at this locale was made by Charles Trumbull Hayden in 1866, when that Tucson merchant made a journey from Tucson to Whipple Barracks, near Prescott, so he could submit a bid to the army for freighting and providing supplies. While waiting two days for a flood to subside, Hayden climbed to the top of what is now called Tempe Butte and viewed the wide Valley of the Salt River, then generally called Rio Salado.[1]

Sometime later, a settlement was established nearby, and farms began producing a variety of crops. In 1870, Hayden claimed two sections of land on the south side of the Salt, taking in two buttes on the main road from Phoenix to the Gila River. He also claimed "ten thousand inches of the water of the Salt River" (for irrigation purposes).[2] Hayden immediately began a number of business enterprises, including a mill to grind wheat; a store; and a ferry from which the settlement took its first name, Hayden's Ferry (HAER photograph AZ-29-2). The 1870 census counted only 9,655 non-Indians in Arizona, when the national population was approaching 40 million.

In 1876, Hayden married Sallie Davis, and she transformed his crude adobe house at the foot of the large butte into a comfortable hacienda, now Monte's La Casa Vieja restaurant. Sallie Davis Hayden soon became one of the Salt River Valley's most prominent women. In 1877, she gave birth to Carl, the first Anglo-American child born in Hayden's Ferry. Later on, daughters Sallie and Mapes were born.[3] Carl T. Hayden served in the United States Congress longer than any other person, first as a congressman from 1912 to 1927 and then as a senator from 1927 to 1969.

On the suggestion of "Lord" Darrell Duppa, who had already given Phoenix its name, the local irrigation company was christened "Tempe Canal Company," because of the similarity of the nearby countryside to the Vale of Tempe near Mount Olympus in Greece. As time went on, the name "Tempe" was more frequently used, and on May 5, 1879, Hayden's Ferry's name was officially changed to Tempe.

The 1880s brought the town a large number of settlers, many of them members of the Church of Latter-day Saints. In 1882, Hayden sold a large tract of land to Mormon pioneer Benjamin Franklin Johnson. By 1883, the Arizona Gazette reported:

> At Tempe, all is life and activity. The Mormon Colonists have started a cooperative store which is doing well. They have built several neat houses and several more are going up. There are twenty families in the colony and they expect ten more by fall.[4]

Four years later, many of the Mormons moved to a nearby area which later would be named "Mesa."

By this time, farmers were settling the Valley in large numbers, growing crops and taking their grain to the Hayden mill. In 1882, the Phoenix Herald praised Hayden's work:

> From a small country store has grown a business that occupies an extensive building and furnishes everything that is likely to be needed by farmers, mechanics or merchants, from a nail to the most delicate silks. Wagons, machinery, dry goods, stationary, provisions, canned goods, all find a place on the many tiers of shelving.[5]

In the following year, the Arizona Gazette reported that Tempe was destined to be number one in the industry of fruit raising, because of the unusually fertile soil.[6]

The first railroad into Arizona, the Southern Pacific, arrived in Tucson from Yuma in 1880 and connected with the Texas and Pacific at Sierra Blanca, Texas, in 1882. In the national scope, the Southern Pacific was one of the main contenders for the transportation development of the West and was instrumental in building the first line to Phoenix. Called the Maricopa and Phoenix Railroad, the line was a branch of the main Southern Pacific line to the south, running near the stage station at Maricopa on the old Butterfield Trail through Tempe and on to Phoenix. (Although the Southern Pacific supported the development of the Maricopa and Phoenix, the latter was an independent line.) The line arrived in Tempe in 1887 and crossed the Salt River on a timber structure, the first bridge in the area, near Hayden's river ferry.[7]

The second railroad to arrive in Tempe was the Phoenix and Eastern, an affiliate of the northerly Santa Fe transcontinental line. With the completion of this road in 1904, the communities of the Salt River Valley were connected to other Arizona Territory towns as well as to interstate rail lines (HAER photograph AZ-29-3).

The railroad in the Salt River Valley greatly increased the economic potential of this fast-developing agricultural region. When the rail system was completed, it enabled trading to grow between the cities of Salt River Valley and between the Valley and the rest of the nation. The growth and prosperity of the Valley radiated outward, attracting new settlers and investors. This development culminated in the move of the territorial capitol from Prescott to Phoenix in 1889.

Another factor of vital significance to the economy and development of Tempe was the creation of the Tempe Normal School in 1885. Today, the institution is Arizona State University, the largest university in the state with an enrollment of more than 40,000 students.

The growth of Tempe from its founding in the 1860s was rapid and echoed the expansion all over the Salt River Valley. On October 25, 1907, the Tempe News reported:

> The Arizona Republican has joined the Tempe News in its crusade for a wagon road across the Salt river. This morning's Republican contains the following:
>
> "The need of a good wagon bridge across Salt river at some convenient point is a proposition that few, if any, people will take issue with. Many suggestions have been made for the building of the bridge and some people have objected to each one of them, while most of them have seemed so expensive that almost everybody objected to them as being impracticable even if not undesirable.
>
> "But all this time the need of a bridge grows more and more apparent. As the country fills up with settlers on the south side there is a greater number of farmers who are inconvenienced in their communication with the county seat. And by this is not meant alone the farmers adjacent to Tempe and Mesa, but those south of Phoenix, those for whom Phoenix is the natural business center. Then there is the communication between Phoenix and the southside towns. If there were a half dozen railroads there would still be the need of a bridge for carriages, automobiles, etc. . . ."[6]

In 1909, the territorial legislature appropriated funds for the construction of a highway bridge at Tempe. Initially it was called a "wagon" bridge. Utilizing convict workers from the territorial prison at Florence, construction on the bridge began in the spring of 1911 on an alignment approximately 500 feet east of the 1905 Maricopa and Phoenix Railroad Bridge, which today, in an altered form, is the Southern Pacific Railroad Bridge. Upon completion in 1913, a year after the Territory of Arizona was admitted to the Union, the bridge provided the long-needed, all-weather link between Phoenix and the other Salt River Valley communities to the east, and between northern and southern Arizona (HAER photographs AZ-29-4 and AZ-29-5). It immediately began to receive extremely heavy use. The continuing rapid development of the area and the ever-increasing size of automobiles and trucks created more and heavier traffic than initially contemplated by the structure's designers. Weakened by overloading and periodic flooding of the river, the bridge began to deteriorate. In 1920, extensive repairs were made on the superstructure after one of the piers settled during a flood.

In 1928, a delegation of Tempe businessmen requested the Arizona Highway Commission to replace the Ash Avenue Bridge. The only bridge over the Salt River in the area, the eighteen-foot-wide structure carried traffic for U. S. highways 60, 80, and 89, as well as local Salt River Valley traffic. Its narrow width was the cause of many accidents. Later that year, Arizona Highway Department engineer Ralph Hoffman designed a multi-span, open-spandrel, concrete arch-rib bridge reminiscent of the Ash Avenue Bridge, to be located a short distance east of Ash Avenue. Completed and dedicated in July 1931, the Mill Avenue Bridge was individually listed on the National Register of Historic Places in 1981 as one of Arizona's significant vehicular structures (HAER photograph AZ-29-6).

HISTORY OF THE ASH AVENUE BRIDGE

Transportation in Tempe was an integral factor in the community's development. Passenger service by train in the Salt River Valley began in the late 1880s and reached a peak in the decade after the turn of the century. At that time, horse-drawn vehicles were the main mode of family transportation; buggies, buckboards, and surreys were privately owned or could be hired from local liveries. With the advent of the automobile at the end of the first decade of the twentieth century, "auto liveries" opened, and an "auto stage" operated throughout the Valley. The increasing popularity of the auto caused a sharp decline in the use of passenger trains in the Tempe area, as well as in other Valley communities.

When the first railroad bridge over the Salt River at Tempe was constructed by the Maricopa and Phoenix Railroad in 1887, Charles T. Hayden proposed that a wagon bridge be constructed with it to enable non-rail traffic to cross the Salt.[9] The Maricopa County Board of Supervisors opposed the measure, and travelers had to continue using Hayden's ferry to cross the river for another quarter of a century.

Then, on April 3, 1908, the Tempe News reported:

> The Tempe board of trade. . . . has addressed the following petition to the [Maricopa County] board of supervisors:
>
> Gentlemen - The board of trade of Tempe believing that the time has arrived when the best interests of Maricopa county demand that a wagon road be built across the Salt river; and recognizing that Tempe offers the most practical point of crossing for many miles up and down the river, the board of Trade respectfully petitions your honorable body to at once take such steps as your best judgement dictates, toward securing the building of a wagon bridge across the Salt river at Tempe.
>
> In connection with the above. . . ., the Maricopa Commercial Club reports that organization enthusiatically [sic] in favor of the Tempe wagon bridge movement and will aid in every possible way. The chambers of commerce of Phoenix and Mesa will join the crusade. . . . With such potent factors at work the prospects look very encouraging.[10]

On October 8, 1909, the Tempe News reported under the heading "NO BRIDGE FOR TEMPE":

> The News has it from the highest authority that nothing will be done toward building a bridge across the Salt river at Tempe this year. The reason is assigned to the lack of sufficient money in the territorial road fund from which the cost of constructing the bridge is to come. The shortage of funds is accounted for by the fact that certain counties did not make the full levy for territorial road purposes.[11]

However, at that time sufficient money was available for the construction of a bridge across the Salt in Phoenix at Center Street (now Central Avenue). As the largest community in the county and the county seat of government, Phoenix apparently had greater influence on the territorial legislature than Tempe, and Phoenix received the first bridge over the Salt. It was a short-lived structure, being washed away by one of the Salt River's frequent and heavy floods.

Finally, later in the year, the territorial legislature authorized the construction of a wagon bridge at Tempe, and on May 31, 1911, the superintendent of the territorial prison at Florence was instructed to send twenty-five convicts to work on the bridge. The prisoners were accompanied by six guards.

The original plans for the bridge were prepared under the supervision of James B. Girand, Territorial Engineer. They provided for a nine-span, concrete, solid-spandrel, arch-ring bridge some 1,225 feet in length and sixteen feet in width. However, soon after construction on the approaches began, the structure was totally redesigned by Carl E. Hasse, again under Girand's direction, to delineate an eleven-span, concrete, open-spandrel, arch-rib structure some 1,507 feet long and eighteen feet wide.[12] Documentation of the reasons for this change have not come to light. A detailed article on the project in the March 28, 1912, issue of Engineering News described the bridge as "somewhat out of the ordinary in design."[13]

Although the use of convict labor on public works was not unusual in the United States at the time, convicts generally worked in "chain gangs," where they were chained together or restrained with a heavy iron ball shackled to one leg. However, recently elected Governor George W. P. Hunt, who began serving his first of seven non-consecutive terms in January 1912, was a staunch prison reformer. At a Chamber of Commerce banquet in Prescott, he proclaimed his intention of employing convicts without guards. The governor was quoted as being so confident in his men that he offered to resign if one of them should escape.[14]

In July 1912, the Arizona honor system was launched, and Hunt confided to a close friend:

> Next week I am going to put a force of convicts to road building. THIS IS OUR FIRST EXPERIMENT, it is a picked body of men from the prison and what will be remarkable is that they are going to work on the roads WITHOUT GUARDS, and another thing is that two or three will be lifers.[15]

Convicts working on the bridge, however, were confined in a stockade at night, but during the day were not closely guarded and caused no concern to the townspeople, who often took an active interest in the affairs of the men (HAER photograph AZ-29-7). The prisoners organized a baseball team and played local and visiting teams.[16] The games were popular events with Tempe citizens, and they began the practice of "passing the hat" at Sunday games, so the convict team could purchase baseball equipment. On one occasion, the "bridge squad" even traveled to Phoenix. There it played one of that city's best teams and received a percentage of the gate. This unprecedented move was supported by Governor Hunt. Following the game, the governor took the entire team out to dinner.

Even though Hunt did not originate the convict honor system, he was the first governor to inaugurate it, and the honor system became closely associated with him, according to Thomas Mott Osborne, one of the nation's foremost experts on prison reform and one-time warden of Sing Sing. "As for the Honor System," he wrote to Hunt in 1925, "I have always believed that you deserve the credit of being the first Governor to insist on prisoners being treated with humane consideration."[17]

During the construction of the bridge, an average of fifty-seven prisoners was at the site. Forty-eight were employed on the bridge proper and nine on camp work (HAER photograph AZ-29-8). The paid force consisted of one engineer, one assistant engineer, five foremen, two carpenters, seven guards, and one bookkeeper.[18] For every day of faithful and conscientious labor performed on the bridge, a prisoner was allowed two days of credit to be deducted from his sentence in addition to the regular good-time allowance. The district engineer in charge of the project reported:

Paid labor force required to do the same amount of work per day as 48 prisoners:

1 Blacksmith	$ 4.00	
3 Derrick Engineers @ $3.50	10.50	
14 White laborers on foundation work, etc. @ $2.50	35.00	
8 Laborers on concrete work @ $2.00	16.00	
4 White teamsters @ $2.50	10.00	
6 Laborers on rock crusher @ $2.00	12.00	
1 Cook for Engineer's Mess	2.50	
		$ 90.00
48 Prisoners @ $1.11		53.28
Difference in favor of Prison Labor per day		$ 36.72[19]

Other persons, however, disagreed that the use of convict labor was cost effective, claiming the expense of guards, stockades, and better food than was served at the prison made the use of prisoners more costly than skilled contract workers.

On February 14, 1912, Arizona was admitted to the Union as the "Baby State," and work on the bridge was rapidly progressing. In an effort to hasten the bridge's completion, electric lights had been installed at the site and a three-shift program initiated.

Materials for the construction were acquired from various sources. Rock, gravel, and sand were obtained from the Salt River channel, and a rock crusher operated by convicts produced suitably sized aggregates for the concrete. Cement came from El Paso and steel reinforcing from Colorado (HAER photographs AZ-29-9 and AZ-29-10).[20] The steel caissons used in the pier foundations were delivered from Leavenworth, Kansas.[21] Castings for the crown hinges were manufactured by the American Iron Works in Phoenix.[22]

On April 14, 1912, the Arizona Republican commented on the project:

> The bridge is of special interest here, in that it is entirely a product of the west, and largely local. . . . It should be gratifying to local engineers to know that Arizona can claim the design, engineering and construction of the bridge, . . . Too often outside talent is called in to supervise work when local engineers familiar with local conditions, and equally able, are the logical men to solve Arizona's engineering problems.

When the bridge was completed in September 1913, approximately two hundred and fifty different convicts had worked on the project. Governor Hunt, however, did not keep his promise to resign if one should escape--during the twenty-seven months of construction, fifteen convicts did escape and only about nine were apprehended.

Initially estimated to cost $78,397,[23] the final cost of the bridge was about $120,000. Much of the cost increase probably can be attributed to the increase in length and width of the completed bridge over that provided in the original design, and to the difficulties caused by river floods during construction (HAER photograph AZ-29-11).

Although the designers of the bridge were well aware of the hazards of building in the channel of the Salt River, even after the construction of Roosevelt Dam in 1911 reduced the ferocity of periodic floods, and had taken particular care in the design of the supporting piers, the structure was endangered by settlement in the latter part of 1919 and the early part of 1920 (HAER photographs AZ-29-12). In the April 21, 1921, issue of the Engineering News - Record, Merrill Butler, bridge engineer with the Arizona Highway Department, explained what had happened:

> Shortly after the floods of Thanksgiving, 1919, the second pier from the north end of the bridge (Pier 9) settled about 4¾ in. Traffic was maintained, except during high water, until Feb. 13, 1920, when a further settlement occurred, about ¾ in. A two-ton limit was then placed on the loads permitted to cross the bridge. On March 2 an additional settlement of 1 1/8 in. occurred, and the bridge was closed to traffic. The following day there was a sudden drop of nearly 5 in. At this time also it was noticed that the pier had shifted out of line about 0.1 ft., downstream.[24]

Flooding of the Salt River had threatened the railroad bridges at Tempe almost from the time of their construction. In fact, frequent bridge washouts were more commonplace than unusual, and Tempe residents were accustomed to the problems caused by the temperamental river.[25] The original Maricopa and Phoenix crossing washed out just four years after it was built. Other wood bridges were built in place of the one destroyed, but these too fell victim to seasonal floods. In October 1902, a train wreck caused by bridge failure resulted in great excitement locally (HAER photograph AZ-29-14).[26]

Because of the failure in 1905 of two piers of the Phoenix and Eastern Bridge located about 500 feet upstream from Ash Avenue, the piers of the Ash Avenue Bridge were intended to be founded on solid rock. Some of the piers were carried to the rock in open excavations, but others were supported by concrete-filled cylindrical steel caissons. It was one of the latter that settled.

Before the 1919 flood, Pier 9 was entirely surrounded by sand and gravel, which served to carry a considerable portion of the load by way of the base of the pier block. When the flood swept away this material, the pier was supported solely by the two concrete cylinders, which failed under the load. Engineer Butler speculated what had happened:

> . . . In the light of the difficulties subsequently experienced in sinking the new cylinders it is very probable that the concrete in the bottom of the original cylinders was of inferior grade, or that a foot or so of sand had filtered in after the rock had been cleaned off. The natural consequence would be a crumpling of the steel shells of the cylinders, and this is what actually happened, it is believed. Unbalanced live-load thrust would tend to accelerate such failure.[27]

Butler also reported other defective conditions had developed in the bridge:

> . . . A great number of the spandrel columns were found broken in horizontal shear near the extrados and several spandrel walls near the crown had pulled loose from the arch rings. In the vicinity of Piers 2, 3 and 4 the roadway slab and spandrel arches had cracked completely through; in the spans adjacent to these piers none of the spandrel columns were cracked.
>
> There was also trouble at the floor expansion joint. The type of joint used had proved unsatisfactory and large chuck holes had formed alongside each joint, causing serious impact whenever a heavy vehicle passed over the bridge; in some cases the concrete supporting the wooden strips which bridged the joints was found to be cracked and broken from traffic action.[28]

The state highway department began repair work in the spring of 1920. In order to safeguard the traffic while reconstruction was in progress, falsework was erected under the arches of two of the spans. One of the principal repair measures was the underpinning of Pier 9. It was decided to place six new cylinders around the original pier, which would allow the underpinning to be accomplished without disturbing the existing structure. Immediately after the completion of the falsework, a wood cofferdam was constructed around Pier 9, and the sinking of the steel cylinders began early in July. Buried debris, in the form of cottonwood logs, made the procedure difficult. Finally, the cylinders were in place, and reinforcing steel was installed. The cylinders were then filled to a level just below the cap concrete. Then the concrete caps were poured, up to the top of the original pier block. After the concrete caps had set, the original shaft was cut out in sections, and a reinforced beam that transferred the pier load to the new cylinders was poured. No effort was made to raise the pier or the bridge deck back to their original elevations (HAER photograph AZ-29-15). However, the balustrades were rebuilt to eliminate the appearance of sag. The repair work is detailed an Arizona Highway Department drawing (HAER photographs AZ-29-49 and AZ-29-59).

The bridge's problems did not end there. In its May 1925 issue, <u>Arizona Highways</u> published an article evidencing continuing concern about the bridge's structural integrity:

> A question of great importance to many persons of the Salt River valley is the ultimate life of the Tempe bridge. We are quite certain that its days are numbered. The life of the structure has been variously estimated and almost from the time of its inception the design has been of sufficient importance to call forth articles by some of the most noted consulting bridge engineers. . . .
>
> The settlement of the pier mentioned [Pier 9] subjected the superstructure to considerable strain and the deck took remarkable deflections without showing fractures, but these have been gradually developing under the impact vibrations set up by the passage of heavy traffic. New developments could be seen at each inspection and these were made at frequent intervals. It was thought that the immediate danger lay in a gradual destruction from vibrations, resulting from the impact at the faulty expansion joints and the recent repairs to these have sustained that belief.
>
> These vibrations were transmitted the full length of the bridge so that the effect of one truck passing over each of the thirteen joints was a succession of violent shocks. The traffic count for this highway was in the neighborhood of 3500 to 4000 per day, and hence some idea may be had of the destructive action of such forces.
>
> Plans were prepared for the replacement of the joints . . . . A joint composed of two heavy angles and a plate one-half inch in thickness and eight inches wide was selected. The plate was securely riveted to one angle and the angles provided with anchor bolts at four foot centers on both legs.
>
> The problem of backing these angles up with a thin section of concrete that would stay, was still with us until it was determined that the State had many uses for a cement gun other

> than making repairs to the columns and beams of the Tempe bridge, and that valuable piece of equipment was purchased.
>
> The cement gun was used for placing the joints as well as for the column repairs. . . .
>
> One outstanding feature was the use of Lumnite Cement for a majority of the concrete work. This was probably the first practical use of this quick-setting cement in the state. It was estimated that the use of the bridge was worth approximately $1,000 a day to the public and the use of the Lumnite Cement, giving twenty-eight day strength in twenty-four hours was a considerable advantage, shortening the period of closing by at least two weeks. . . .
>
> All of the thirteen crown joints were replaced with the new type. Several spandrel columns were entirely rebuilt with wire mesh and gunite and slight repairs made on others. Seven new steel cross-beams were placed at the crown sections of the two spans adjacent to Pier No. 9. These were also encased with gunite. The work was . . . completed on March 1, 1925, with only about two weeks interruption to traffic.[29]

With automobiles and trucks becoming larger and heavier and as traffic continued to increase in the Salt River Valley, motorists began to demand a new and larger bridge. In 1928, the Arizona Highway Commission recommended the construction of a new bridge, and plans for one were prepared. Construction of the new bridge, which became known as the Mill Avenue Bridge, began in March 1930, and it was opened to traffic in July 1931. With the completion of the New Tempe Bridge, the Commission closed the Ash Avenue Bridge to all but pedestrians, and in 1933 officially abandoned the structure. A few years later, the commission's attorney delivered an opinion that the Arizona Highway Department could not expend money to demolish the structure. In 1943, the Works Progress Administration decided not to demolish the bridge to salvage reinforcing steel. And so the old bridge, now in an advanced state of deterioration, still stands as a remarkable example of early twentieth century bridge technology. It is listed on the National Register of Historic Places under the Tempe Multiple Resource Area.

In May 1990, Donohue & Associates, Inc., Engineers, Phoenix, completed an evaluation of the historic bridge for the City of Tempe.[30] The study was designed to determine the structure's capability of accommodating pedestrian loading, and hydraulic loading under the present non-channelized condition and the proposed channelized configuration of the river.

The study concluded that the Ash Avenue Bridge had "failed," even though this failure has not yet resulted in collapse. Therefore, the engineers recommended that removal or extensive rehabilitation of the structure be undertaken, both being feasible alternative actions. The Arizona Department of Transportation concurred that removal or extensive rehabilitation of the Ash Avenue Bridge were the only measures that would provide assurance of a safe condition in the channel.[31] After considering the cost of rehabilitating even the south abutment and two adjacent spans of the bridge as a pedestrian overlook on a planned Salt River reservoir, the Tempe city council reluctantly authorized the structure's demolition.

Under a memorandum of agreement among the City of Tempe, the U. S. Army Corps of Engineers, and the Arizona State Historic Preservation Office, this HAER documentation was prepared to mitigate the impact of the Ash Avenue Bridge's removal by recording the historical and technological significance of its purpose, design, construction, and use. The study increased the understanding of the development of the Salt River Valley and of the utilization of prison labor on public works projects in Arizona. Additionally, it makes a contribution of knowledge to the history of bridge engineering.

Epilogue

On January 11, 1991, demolition of the old bridge was commenced by J.W.J. Contracting Corporation, Inc., of Phoenix. Utilizing a hoe-ram, the structure was collapsed into the dry channel of the Salt River, broken into manageable pieces, and hauled away. Only the south abutment, located near the edge of Tempe Beach Park, was retained for anticipated use as a viewing station on the planned reservoir and as a part of the tangible record of the nation's history.

SIGNIFICANCE OF THE BRIDGE

The Ash Avenue Bridge is one of the most historically and technologically significant bridges in Arizona--one of a handful of vehicular spans from the territorial period.

The bridge was one of the first major highway bridges constructed in the Territory of Arizona, and the first successful vehicle bridge over the Salt River.[32] Initially designated a "wagon" bridge, it served primarily as an automobile bridge from the time of its completion in 1913 until its abandonment in 1933. During those years, it was the only highway bridge across the Salt River in central Arizona and provided an essential link between northern and southern Arizona, and between Phoenix and other Salt River Valley communities, especially Tempe and Mesa. As an important element of Arizona's highway system, the bridge played a vital role in the state's economic development.

Additionally, the bridge is one of the few structures remaining in the state that was constructed largely by convict labor. In 1911, convicts were commonly used on public works throughout the country, frequently under conditions that were harsh and oppressive. However, a noteworthy program of prison reform had been introduced in the Territory of Arizona. This program was not based entirely upon the economic advantage of using convict labor, but also upon sociological enlightenment. After his inauguration in 1912, Governor George W. P. Hunt, somewhat naively, stated, "Arizona's statehood will bring a new day for her prisoners as well as her citizens, since many are in there [prison] primarily because of an adverse environment over which they had little control." He urged that a special effort be made to rescue first offenders by separating them from hardened criminals, and giving them useful activity both for mind and hands.[33]

Because the construction of complex engineering projects with convict labor is now uncommon, the Ash Avenue Bridge has become a noteworthy example of such an undertaking and provides an exceptional illustration of twentieth-century prison reform.

The bridge, however, derives its greatest measure of significance from its engineering technology. One of the first large arch-rib structures built in the United States, it is a remarkable example of early reinforced concrete construction.

The invention of portland cement in England in 1824, and the subsequent development of concrete in France and Germany during the 1850s, provided a new material for bridge construction. In the early uses of concrete for bridges, only its great compressive strength was exploited. Therefore, for a while, the semicircular, solid arch was the only feasible shape for the superstructures of concrete bridges, because an arch works only through compression. Several such bridges were built in Europe through the 1870s. In the United States, a little 31-foot concrete arch bridge was built in Brooklyn's Prospect Park in 1871. It was designed to look as much as possible like a conventional masonry arch bridge, such as those constructed since Roman times.

Equally important to the development of modern bridge technology, were the experiments of the American, W. E. Ward, who in 1871 and 1872 established the need to reinforce the lower, "stretched" portion of concrete beams. These experiments led to the use of iron reinforcement in concrete arches, which first occurred in the United States in 1889 in a thirty-five-foot span at Golden Gate Park in San Francisco.[34] Even with the development of the idea of reinforcing concrete with iron bars, it took a number of years for bridge builders to free themselves of the desire to make concrete bridges appear as if they were built of masonry. As time passed, bridge engineers and architects began to realize that, in order to achieve the most pleasing result, concrete must be treated differently than natural stone, and that the obvious forms of cut-stone masonry should not be imitated in concrete, which, because of its plasticity, could take virtually any shape.

Before the turn of the century, serious work on reinforced concrete construction was going on in Europe. From the office of François Hennebique (1842-1921) in France, came a number of textbooks on working with reinforced concrete. The most notable of his actual bridges was built for the International Exposition in Liège, Belgium, in 1905, just six years before construction began on the bridge over the Salt River in Tempe.

Associated with Hennebique in the first years of the century was a young Swiss structural engineer, Robert Maillart (1872-1940). Maillart has since become one of the most celebrated designers of reinforced concrete bridges. He gained a great deal of experience in using reinforced concrete from his association with Hennebique, but soon overtook the older man in the field of bridge design.

Maillart's work is noted for the use of the minimum amount of material required to carry the loads and the use of shapes upon which shrinkage, creep, temperature change, and foundation settlement would have the least effect. Among his innovations was the use of the three-hinged arch. Although such arches were not uncommon in steel, they had not been considered practical in concrete. In 1905, Maillart built the Tavanasa Bridge, the proto-type three-hinged concrete arch, over the Rhine River in Switzerland. The forces of that structure were concentrated on the three hinges, at the crown and at the abutments, much as the forces in the Ash Avenue Bridge would be concentrated a few years later. Although the hinges were concrete, and strongly reinforced, their flexibility allowed movements of the bridge without harming its members. Also, as in all of Maillart's work, enormous care went into the design of the steel reinforcement to obtain maximum effect. Since Maillart was committed to the idea of minimum materials, the placement and quantity of the reinforcing steel was critically important. Much like Maillart's structures in the use of minimal materials, the Ash Avenue Bridge is remarkable for the slenderness of its members.

Prior to the development of reinforced concrete, timber bridges were common in the United States, having been used since colonial times. They were vulnerable to excessive loads, fire, and inclement weather, and deteriorated rapidly, especially under Arizona's relentless sun. Arizona Territory's first railroad bridges, including those erected across the Salt River at Tempe, were built of wood. The second generation of Arizona's railroad bridges, including spans at Tempe, was largely constructed of steel, a material favored by American engineers at the time. The territory developed a strong tradition of steel bridges, especially of the Pratt-truss-type, which was popularized by the railroads. Steel truss bridges were economical in the industrialized regions of the county where iron was readily available, easy to erect, and resistive to the elements. However, steel bridges of the common type were unattractive and uninspired. A new generation of imaginative American bridge designers began to seek new solutions to the age-old problems of creating attractive, economical, and permanent spans at river crossings.

With most of the major rail lines completed by the end of the first decade of the twentieth century, American engineers turned their attentions to highway and bridge design and construction. Many looked toward Europe and the work of Hennebique and Maillart for inspiration and a new technology--the technology of reinforced concrete.

Until the end of the century, road and bridge construction in Arizona were largely county government functions. However, in the sparsely populated territory, county revenues were minimal, and few bridges were constructed for public use. None of these nineteenth-century structures is known to remain today.

During the first decade of the twentieth century, it became evident that many road and bridge projects were beyond the capability of the counties. To take a more active role in the development of highways, the territorial legislature, on March 18, 1909, established a road tax and created the office of Territorial Engineer. James B. Girand was appointed to the position by the governor of the territory.

Girand was born May 20, 1873, at Austin, Texas. He studied civil engineering at the Agricultural and Mechanical College of Texas from 1888 to 1891, but did not receive a degree. On the organization of Moore County, Texas, in 1891, Girand was elected county surveyor, apparently at the age of eighteen. During the next several years he held a variety of surveying positions, many of them with railroads. During 1901-02, he was engaged in general engineering practice in northern Arizona, having an office in Prescott. In 1903, he accepted a position as engineer in charge of the United Gold and Platinum Mines Co. After several other positions with mining and railroad companies, he served as Territorial Engineer from 1909 until 1912, when he was appointed chief engineer of the Gila Water Company. By 1914, he had established a private engineering firm, Girand, Hasse & Lewis, in Phoenix. The firm Johannessen Girand is still in practice in Phoenix.[35]

Before being appointed Territorial Engineer in 1909, Girand does not appear to have had any noteworthy experience in the design of concrete arch-rib bridges, although at Texas A & M he undoubtedly became familiar with the basic concepts of masonry arch structures. Therefore, it is hypothesized that he administered the activities of his office and, perhaps, designed highways, while his assistants performed the actual design work on the bridges.

Immediately after his appointment, Girand began to plan and build a territorial highway system. His strategy was to link the county seats and more populous towns with a network of roads. In connection with this highway construction, he supervised the construction of a handful of important bridges at key river crossings, the most noteworthy of which was across the Salt River at Tempe. Curiously, none of these bridges resembled each other even remotely, suggesting each had a different designer. Girand's first bridges consisted of a concrete girder structure across the Gila at Florence, a single-span concrete arch over Mule Gulch near Bisbee, the solid-spandrel Lowell Arch Bridge in Cochise County, a timber-iron Howe truss span over the Black River southwest of Fort Apache, a three-span, pin-connected truss over the Verde River at Camp Verde, and a timber trestle over Forest Wash.

Without question, Girand's most spectacular, expensive, and important undertaking was the multi-span concrete bridge at Tempe. Initially, plans were prepared for a nine-span, solid-spandrel, arch-ring structure with a total length of 1,225 feet. However, soon after site work began, Girand directed his assistant, bridge engineer Carl E. Hasse, to redesign the bridge.[36] The new design delineated eleven spans of two-rib, open-spandrel, three-hinged arches. The reason for this abrupt change has never been determined, but may have resulted from anticipated economies in an open-spandrel, arch-rib design over a solid-spandrel, arch-ring design, or from a desire by Girand to utilize a unique opportunity to produce a memorable structure with an innovative technology.[37]

At that time, few reinforced concrete, arch-rib bridges had been constructed either in Europe, where Robert Maillart had first used the technique only six years earlier, or the United States. Maillart's designs often were elegant but mistrusted by his clients. However, they were so economical that engineering authorities simply could not ignore them.[38]

Regardless of the reasons for Girand and Hasse deciding to build a reinforced concrete, arch-rib bridge, it was a bold action. Such a complex and innovative engineering endeavor had never before been undertaken in Arizona, which at the time of the project's conception was a sparsely populated, seldom-visited, frontier territory.

Elsewhere in the country, reinforced concrete, open-spandrel, arch-rib designs were still in their infancy, and few, if any, undertakings equaling the Ash Avenue Bridge in size and inventiveness had yet been completed in 1911, the year Girand and Hasse finished their construction documents.

It is difficult to say with certainty when or where the first three-hinged, arch-rib bridge was constructed in the United States. However, some of the earliest were built in California. One of the first was probably the Main Street Bridge in Los Angeles. Constructed in 1910, it remains today. The bridge has three spans of 87.5 feet and a total length of about 363 feet. Eight rows of ribs were utilized to achieve a width of seventy feet.[39] In an article published in 1910, it was reported that the Main Street Bridge "is of a type, known as three hinged ribbed arch, never before used in the Southwest and rare in the United States. . . ."[40]

Among the first large multi-span, open-spandrel, arch-rib bridge built in California is the North Broadway Bridge, also in Los Angeles. Under construction in 1910, the seven-span structure still stands and has a total length of 968 feet; the largest of its arches has a span of 119 feet. As with the Main Street Bridge, six rows of ribs are utilized to achieve a width of seventy feet.[41]

Girand and his associates appear to have been in the vanguard of the reinforced concrete, open-spandrel, arch-rib bridge designers. And certainly, their Ash Avenue Bridge was a forerunner in the new concrete technology, exceeding other similar undertakings in length, difficulty, and artistic qualities. At the same time, J. A. L. Waddell, noted American bridge engineer and author of several well-known textbooks on bridge design and construction, was working on a similar project.[42] His Colorado Street Bridge in

Pasadena, California, was completed in 1913, the same year as the Ash Avenue Bridge.

The Colorado Street and Ash Avenue bridges are remarkably similar. Both are eleven-span, open-spandrel, arch-rib structures. The Pasadena bridge has a total length of 1427.75 feet, a maximum arch span of 222.5 feet, and a typical arch span of about 94 feet.[43] The Tempe bridge has a total length of 1507.75 feet and a typical arch span of 131 feet.

These two bridges, and undoubtedly others not identified, gave impetus to reinforced concrete, arch-rib construction, which became increasingly popular throughout the United States in subsequent years. By 1916, spectacular arch-rib structures were being erected. One of the most noteworthy of these is the Tunkhannock Viaduct on the Delaware, Lackawanna & Western Railroad at Nicholson, Pennsylvania. This descendant of the Ash Avenue Bridge has a total length of 2,375 feet and a typical arch span of 180 feet.

Unlike Girand's design that expresses the inherent plastic quality of concrete in an inventive way, the Tunkhannock arches are divided into imitation voussoirs in the traditional manner. Another detail used in the design of the viaduct and in many other early concrete bridges, which is obviously superfluous to concrete construction, is the use of the projecting cornice at the top of the spandrel posts. The Ash Avenue Bridge, in contrast, derives its remarkable aesthetic quality from its simplicity, articulated quality, absence of ornamentation, and slenderness.

However, in their efforts to achieve this slenderness in the bridge's members, probably for both economic and aesthetic reasons, the designers of the Ash Avenue Bridge failed to provide adequate concrete coverage over the steel reinforcement and sufficient distance between bars (especially at their laps), thereby weakening the structure. These deficiencies, resulting perhaps from the engineers' inexperience in reinforced concrete design, were prominent among the causes for the bridge's demise and ultimate removal in 1991.

By the 1920s, the use of arch-rib bridges was becoming commonplace. Some of the most noteworthy examples are located in Minnesota's Twin Cities, where the Mississippi and Minnesota rivers offered engineers numerous challenges. According to David Plowden, prominent American bridge authority, the Fort Snelling-Mendota Bridge across the Minnesota River is usually considered to be the most sophisticated design for a concrete arch built in the 1920s, apart from the West Coast bridges."[44] Although much larger than the Ash Avenue Bridge and constructed with continuous arches rather than hinged arches, the Fort Snelling-Mendota Bridge is obviously in direct lineage from the Ash Avenue Bridge.[45]

Labor intensive, and consequently expensive to construct in the United States, arch-rib bridges are no longer used for public highways. They have largely been supplanted by standardized concrete girder and steel girder structures, which have added a measure of monotony to the American streetscape, especially along the interstate highways.

Unfortunately, the high cost of rehabilitating the early arch-rib bridges has limited such actions, and these interesting examples of engineering inventiveness are disappearing from the American scene. Only the south abutment of the Ash Avenue Bridge remains to commemorate this remarkable example of innovative American engineering accomplishment in the early years of the twentieth century.

PHYSICAL DESCRIPTION OF BRIDGE PRIOR TO DEMOLITION

The Ash Avenue Bridge is an open-spandrel, reinforced concrete, three-hinge-arch-rib structure with an overall length of 1,507.75 feet and an overall width of twenty feet. The clear roadway width is eighteen feet. The bridge consists of eleven main spans and two abutment spans. Individual main-span lengths are approximately 131 feet between the centerlines of the pier units, and the north and south abutment span lengths are 32.42 feet and 40.33 feet, respectively. The arch ribs have a rise of approximately 19.4 feet (HAER photograph AZ-29-16). The bridge is fully delineated in the original construction plans (HAER photographs AZ-29-29 through AZ-29-48). The various components of the bridge, as described below, are identified in Figure 1.

The superstructure of the main arch spans consists of a reinforced concrete deck slab supported by transverse deck beams spaced at 10.83 feet on centers and by longitudinal deck beams located on the longitudinal center line of the bridge between the transverse deck beams. The transverse deck beams are supported by vertical spandrel posts rising from the main arch ribs and by vertical spandrel columns rising from the pier units. The spandrel posts and spandrel columns are interconnected at their tops longitudinally with semicircular spandrel arches and transversely with the deck beams. The main arch ribs and spandrel arches are the principal character-defining architectural features of the bridge (HAER photograph AZ-29-17).

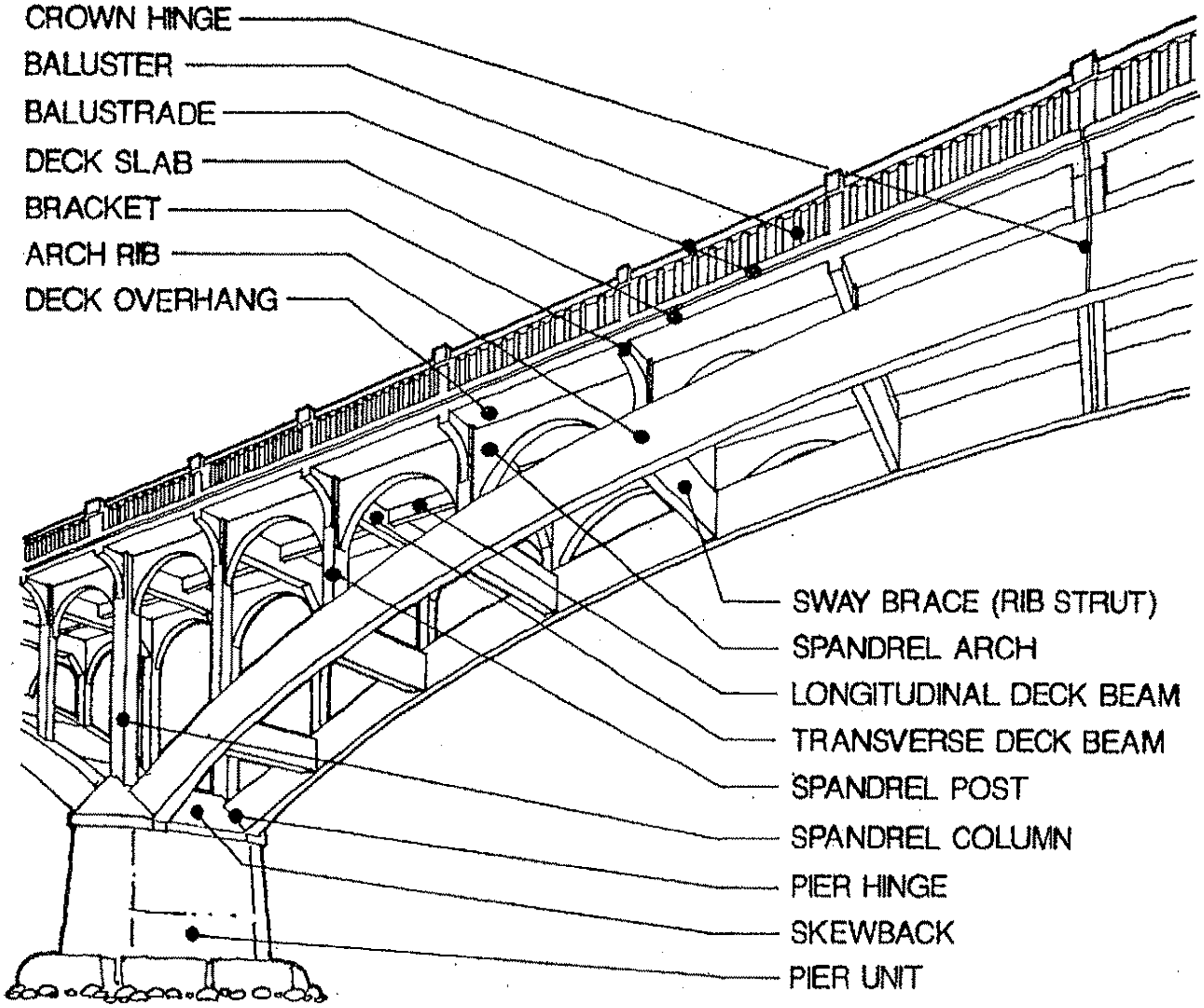


Figure 1. Identification of bridge components.

The main arch ribs consist of two variable-depth, cast-in-place concrete segments. The pier hinges are simple sheet-metal-lined pockets cast into the skewbacks on top of the piers that retain the rounded ends of the rib segments. The crown hinges, located at the centers of the arches, consist of a cast-iron (or cast-steel) spider-web plate cast into the upper ends of each of the arch segments and connected with an iron (or steel) pin (HAER photographs AZ-29-18 and AZ-29-40). At the main river channel, the roadway is approximately 48 feet above the dry stream bed.

The main arch ribs have a center-to-center transverse spacing of 12.66 feet and are tied to each other with sway braces, or rib struts, located at the spandrel posts. These braces were precast on the site, placed between the arch ribs, tightened with iron turnbuckles, and then sheathed in concrete to create solid members that connect the main arches on opposite sides of the bridge (HAER photograph AZ-29-19).

The deck slab overhangs the main arch ribs on both sides of the bridge. Each overhang terminates in a curb at the outer edge of the deck slab. The curbs, overhangs, and parapet balustrades are carried by brackets that are continuations of the transverse deck beams, which, as previously noted, are supported by the spandrel posts and spandrel columns (HAER photograph AZ-29-20).

The superstructure of the abutment spans is similar to that of the main spans except for the vertical spandrel columns. These columns are supported on a large footing with caissons to bedrock at the south abutment, and directly on bedrock at the north abutment (HAER photograph AZ-29-21).

All the pier units are massive, reinforced concrete shafts supported by various types of foundation combinations: Piers 1, 3, 5, 6, and 8 are supported on two six-foot-diameter excavated caissons spaced at thirteen feet on centers; Pier 2 is supported on two seven-foot by twenty-six-foot rectangular caissons spaced at thirteen feet on centers; Pier 4 is supported on six excavated caissons with a transverse spacing of thirteen feet and a longitudinal spacing of twenty feet; Pier 7 is supported on two four-foot by twenty-four-foot rectangular caissons spaced at thirteen feet on centers; Pier 9 is founded on six five-foot-diameter excavated caissons with thirteen-foot transverse and longitudinal spacings; and Pier 10 is supported directly on bedrock (HAER photograph AZ-29-22). Pier 9 was rebuilt in 1920, at which time the six caissons were installed (HAER photographs AZ-29-49 and AZ-29-50).

The parapet balustrades are three-feet high and run continuously for the length of the bridge on each side. The top rail is supported on four-inch-diameter precast balusters spaced at nine inches on centers, and on eight-inch by twelve-inch posts, one of which is located at each spandrel post and spandrel column (HAER photograph AZ-29-23).

Concrete lighting standards originally were located at intervals on top of both parapet railings. The standards at the extreme north and south ends of the bridge remain, although the electric lamp holders have disappeared. Remnants of the attachments of other posts are still apparent along the railing (HAER photograph AZ-29-24).

The north approach to the bridge has been largely obliterated; no pavement remains (HAER photograph AZ-29-25). The south approach remains in place, although the concrete pavement immediately adjacent to the bridge has been removed, and Ash Avenue has been relocated a short distance to the west. The approach is approximately the same width as the bridge, and the pavement terminates on each side in a concrete curb (HAER photograph AZ-29-26). A guardrail, as evidenced by remnants of concrete posts, was located on top of each curb. This feature was undoubtedly identical to the one seen in HAER photograph AZ-29-5.

PHYSICAL CONDITION OF BRIDGE PRIOR TO DEMOLITION

The Ash Avenue Bridge has undergone considerable distress, as evidenced by the numerous areas of cracking, spalling, and general deterioration of load-carrying members. Much of this distress appears to have occurred during the early life of the structure and before its abandonment in 1933. In general, the deterioration has been caused by settlement of the piers, vibration and impact loading from trucks, excessive traffic, and thermal forces.

Deck Surface

The asphalt wearing surface is in poor condition. It is severely cracked, weathered, and spalled in numerous locations.

Concrete Deck

Since the concrete deck is covered with an original asphalt wearing surface, only the bottom side of the deck is visible. In this surface there are numerous transverse cracks throughout the deck exhibiting water penetration and efflorescence. In several locations the cracks extend into the spandrel arches. Additionally, in several locations the underside of the deck slab is severely spalled and delaminated, exposing the reinforcing steel.

Expansion Joints

The joints in the deck, located over the piers and the crown hinges, have failed and the surrounding concrete is spalled and delaminated.

Parapet Balustrades

The balustrades are in poor condition, and many balusters and segments of the top railing are missing. The curbs under the balusters are severely spalled and the longitudinal reinforcing steel in the curbs is exposed in many locations. Although several concrete lighting fixture standards remain atop the balustrades, most are missing (HAER photograph AZ-29-27).

Spandrel Posts

The posts are in poor to failed condition; many are severely spalled, delaminated, and cracked vertically and horizontally. At some of the post locations only the exposed reinforcing steel remains in place, the concrete encasement having completely disappeared. Many of the posts were expeditiously repaired with gunite, which is now cracked, spalled, and delaminated (HAER photograph AZ-29-28).

Spandrel Columns

The spandrel columns exhibit minor spalling, many have horizontal cracks at their pier connections, and several have one or more vertical cracks. Additionally, some of the columns located at deck expansion joints have cracks near their tops.

Main Arch Ribs

The main arch ribs are in poor condition. Most exhibit severe cracking and some spalling at their crown hinges. Many of the ribs have longitudinal cracks parallel to the main reinforcing steel near the tops or the bottoms of the members. These cracks may be full width of the ribs, since some appear in the same position on both interior and exterior faces of the same rib.

Other ribs exhibit horizonal cracks, exposed and buckled reinforcing steel, and cracks perpendicular to the rib curvature that are continuous around the rib.

Field Sampling and Testing

Concrete core samples were taken from various locations in the structure and were tested in accordance with the American Society of Testing Materials (ASTM) Specification C-42. Typical results were:[46]

Location	Core Size	Compressive Strength
Deck slab, Span 6	2-inch	5,230 psi
Deck slab, Span 8	2-inch	3,657 psi
Spandrel arch, Span 5	2-inch	3,590 psi
Spandrel arch, Span 7	2-inch	3,020 psi
Main arch rib, Span 6	2-inch	3,540 psi
Main arch rib, Span 2	6-inch	2,115 psi
Pier shaft, Pier 6	2-inch	3,060 psi
Footing, Pier 9	2-inch	6,960 psi

Reinforcing steel specimens were taken from various deck locations and tested in accordance with ASTM procedures to determine strength characteristics. Typical results were:

Location	Yield Strength	Ultimate Strength
Span 2	50,000 psi	68,000 psi
Span 3	58,500 psi	79,000 psi
Span 4	72,500 psi	97,500 psi

Summary of Physical Condition

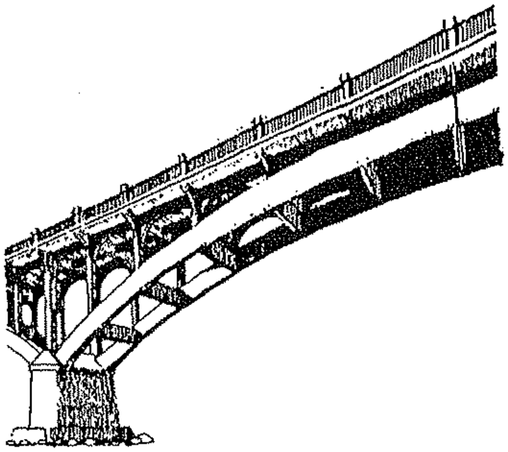
The bridge is in poor condition and numerous members have failed. No maintenance has been performed on the structure since 1933.

Field evaluation of the structure by Donohue & Associates, Inc., identified several design and construction deficiencies that are negatively affecting the structural capacity, serviceability, and functional aspects of the bridge. These deficiencies have resulted in an overstressed or failed condition in numerous principal members.

Bar development and lap lengths are inadequate to transfer the imposed loads at the connections between the spandrel posts and main arch ribs, thereby causing many of these joints to fail. Also, in the early years of the structure's life, excessive live-load deflections were documented. Considering the slenderness (depth, width, and length ratios) of principal load-carrying members, it can be suspected that deflections were always of a magnitude to cause concern.

Moreover, pier settlement in 1919 and 1920 significantly impacted the bridge, inducing numerous cracks in structural members. These cracks permitted rain and flood water to rust the reinforcing steel, causing the concrete to spall and delaminate during the following years.

Acting in concert, the bridge's design and construction deficiencies and weather-induced debilities were more than the audacious structure could sustain, leading to its untimely abandonment and ultimate removal. Nevertheless, the remaining south abutment of the old bridge gives recall to the era of experimentation in reinforced concrete construction at the turn of the century and memorializes the efforts and accomplishments of Arizona's pioneer engineers.



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2. Arizona Miner, Prescott, December 10, 1870.

3. "Sallie Davis Hayden--Thoroughbred Pioneer," unpublished manuscript, Hayden Papers, Hayden Library, Arizona State University, Tempe, Arizona.

4. Arizona Gazette, Phoenix, November 22, 1883.

5. Phoenix Herald, Phoenix, September 29, 1882.

6. Marsha L. Weisiger, This History of Tempe, Arizona 1871 - 1930, A Preliminary Report, unpublished manuscript, Arizona Collection, Arizona State University, Tempe, Arizona, 1977.

7. The Arizona Eastern was a successor to the Maricopa and Phoenix. It was a separately owned affiliate of the Southern Pacific until 1955, when the two lines merged under the Southern Pacific name. See David F. Myrick, Railroads of Arizona, Vol II: Phoenix and the Central Roads, San Diego: Howell-North Books (1980), for detailed information on early railroads in the area and the construction of the Maricopa and Phoenix.

8. Tempe News, October 25, 1907, located in clipping file at Tempe Historical Museum, Tempe, Arizona. A copy of the document is contained in the HAER field notes.

9. HAER No. AZ-18, Arizona Eastern Railroad Bridge, Written Historical and Descriptive Data, 12, Barbara Behan, 1990, Library of Congress, Washington, D. C.

10. Tempe News, April 3, 1908, located in clipping file at Tempe Historical Museum, Tempe, Arizona. A copy of the document is contained in the HAER field notes.

11. Tempe News, October 8, 1909, located in clipping file at Tempe Historical Museum, Tempe, Arizona. A copy of the document is contained in the HAER field notes.

12. The term "arch-rib" is used to designate a free-standing arch having a width much less than that of the bridge, usually in pairs, and supporting spandrel columns. The term "arch-ring" is

used to designate the arch proper without the spandrels, fill, or other elements, and is applied to arches that are the full width of the bridge. The term "spandrel" refers to the triangular space between the extrados curve of an arch and the enclosing right angle, or to the space between the extrados of two contiguous arches and the horizontal line (roadway) above them.

13. Engineer News, Vol. 67, no. 13 (March 28, 1912), 578. A copy of the document is contained in the HAER field notes.

14. Tucson Citizen, March 12, 1912.

15. Letter from Hunt to Dr. A. F. Maisch, dated June 30, 1912, Arizona Department of Library, Archives and Public Records, Phoenix, Arizona.

16. Arizona Republican, January 27, 1912, 2. A copy of the document is contained in the HAER field notes.

17. Marjorie Haines Wilson, The Gubernatorial Career of George W. P. Hunt of Arizona, 145, unpublished manuscript, Arizona Collection, Arizona State University, Tempe, Arizona, September 1973.

18. Report of the State Engineer of the State of Arizona July 1, 1909 to June 30, 1914, 155. A copy of the document is contained in the HAER field notes.

19. Ibib., 158.

20. Arizona Republican, April 14, 1912. A copy of the document is contained in the HAER field notes.

21. Arizona Republican, June 23, 1911. A copy of the document is contained in the HAER field notes.

22. Arizona Republican, April 14, 1912. A copy of the document is contained in the HAER field notes.

23. Tempe News, March 18, 1909, located in clipping file at the Tempe Historical Museum, Tempe, Arizona.

24. Engineering News-Record, (April 21, 1921), 675. A copy of the document is contained in the HAER field notes.

25. HAER No. AZ-18, Arizona Eastern Railroad Bridge, Written Historical and Descriptive Data, 12, Barbara Behan, 1990, Library of Congress, Washington, D. C.

26. "Doings of the Flood," clipping probably from the Arizona Republican, December 1, 1905; Salt River Southern Pacific Railroad Bridge Property File, Tempe Historical Museum.

27. Engineering News-Record, (April 21, 1921), 675. A copy of the document is contained in the HAER field notes.

28. Ibid., 675-76.

29. Arizona Highways, (May 1925), 16. A copy of the document is contained in the HAER field notes.

30. Bridge Evaluation Study: Ash Avenue Bridge (Salt River Crossing), City of Tempe Project 876191B, Donohue & Associates, Inc., Engineers, May 4, 1990. A copy of the document is contained in the HAER field notes.

31. Letter from W. R. Bruesch, Bridge Operations Engineer-Manager, Structures Section, Arizona Department of Transportation, Highways Division to Steve L. Nielsen, Rio Salado Project Manager, City of Tempe, July 5, 1990. A copy of the document is contained in the HAER field notes.

32. The first bridge across the Salt River was constructed at Center Street (now Central Avenue) in Phoenix in about 1911. However, it was soon destroyed by a river flood.

33. Marjorie Haines Wilson, The Gubernatorial Career of George W. P. Hunt of Arizona, 113, unpublished manuscript, Arizona Collection, Arizona State University, Tempe, Arizona, September 1973.

34. Engineering Record, (August 13, 1910), 169. A copy of the document is contained in the HAER field notes.

35. For additional information on J. B. Girand see Who's Who in Arizona, vol. I, 1913, 779-81, compiled and published by Jo Conners, copy available at Arizona Room, Main Branch, Phoenix Public Library, Phoenix, Arizona. A copy of the document is contained in the HAER field notes.

36. Both Girand's and Hasse's names appear on the plans for the completed bridge. These plan sheets have various dates from "9-11-11" to "12-2-11." Two additional plan sheets relate to minor superstructure modifications. One dated Feb. 6, 1913, is marked "Drawn by C.E.H. & S.M.C."; and the other dated March 6, 1913, is marked "Drawn by T.F.N. & S.M.C." "C.E.H." is Carl E. Hasse, "S.M.C." is unknown, and "T.F.N." is Thomas F. Nichols. For additional information on Nichols see Arizona Prehistoric--Aboriginal--Pioneer--Modern: The Nation's Youngest Commonwealth Within A Land Of Ancient Culture--Biographical, 131, Vol. III, Chicago: The S. J. Clarke Publishing Co., 1916. A copy of the document is contained in the HAER field notes.

37. J. A. L. Waddell, Bridge Engineering, 940, Vol. 1, London: John Wiley and Sons, 1916.

38. Martin Hayden, The Book of Bridges, The history technology and romance of bridges and their builders, 134, New York City: Galahad Books, 1976.

39. Stephen D. Mikesell, historian, California Department of Transportation, Sacramento, in a telephone conversation with Gerald A. Doyle on August 16, 1990.

40. Southwest Contractor and Manufacturer, May 7, 1910. A copy of the document is contained in the HAER field notes.

41. See Endnote 39.

42. For more information on Waddell see Endnote 37.

43. Conversation between Dale F. Schaub, P.E., project engineer for the evaluation of the Ash Avenue Bridge, and Alan Charmatz, P.E., bridge engineer for the City of Pasadena, California, on August 17, 1990.

44. David Plowden, Bridges: The Spans of North America, New York: Viking Press, 1974.

45. Walter H. Wheeler, "Long Concrete-Arch Road Bridge Over Minnesota River," unknown publication. A copy of the document is contained in the HAER field notes.

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