# Bridges of Arizona

(Extracted from National Register of Historic Places - Vehicular Bridges in Arizona)

Bridges, as integral elements of a developing transportation network, have played a pivotal part in the spanning of America. Generally the most sophisticated components of any overland transportation system, from the early primitive territorial roads to transcontinental highways, they are also the most prominent. Bridges serve not only as gauges of technological advancement in design and construction, but as singular indicators of the tenets, values and ambitions of the people who erected them. This is particularly true for Arizona, a state in which overland transportation forms a central historical theme. From the earliest wooden spans on the territorial toll roads to the later steel trusses and concrete arches, bridges have facilitated - and in some instances, created - settlement across the state.

Whether spanning rivers, creeks, draws, arroyos or canyons, bridges have functioned similarly since the first log was thrown across a stream, with dif-ferences only in dimensions and capacity. Beyond this, however, the idea soon unravels, as a variety of forms to achieve that function has sprung up through centuries of empirical usage. Bridge types are generally classified by material as stone, timber, concrete, iron/steel. The inherent strengths and weaknesses of each tends to dictate its form and usage, as does availability of materials.

By the time the country was undergoing initial settlement, most of the principal bridge types and materials had been used or at least experimented with. What remained over the last two centuries has been a process of refinement - a vast refinement to be sure - revolving principally around the introduction and proliferation of structural metals and concrete as building materials.

As recent as America is in terms of bridge development, Arizona is younger still. In the 1840s, when most of the major trusses were invented, Arizona was not even under United States control. When the rest of the country was experiencing what was probably the greatest period of roadway bridge construction in the 1880s and 1890s, Arizona was not a member of the union. When Daniel Luten patented his arch in 1900, Arizona Territory had built only a handful of permanent crossings. And by the time Arizona was admitted as a state in 1912, frankly little was left to develop in bridge technology. Despite this, a number of outstanding bridges have been constructed on Arizona's roads and highways. Fortunately, most of the best of them have survived.

Between 1848, when the Arizona territory was acquired from Mexico by the treaty of Guadalupe, to the Federal Organic Act of February 24,1863, which designated the Territory after its separation from New Mexico, Arizona was crossed by only two main overland routes. Both traversed the state east-west. Known as the Gila Trail because it largely paralleled the Gila River, the southern route was popular for those rushing to California for gold. The northern route, known as Beale's Road, was used almost entirely by hunters and trappers and the military traveling to California. Other secondary routes - no more than trails, really - developed intermittently by usage, with maintenance, such as it was, performed by users as needed.

After formation in 1863, the Arizona Territorial Assembly immediately recognized the need for transportation routes to connect the widely scattered settlements and foster economic growth. Money for road construction was scarce, however. In 1864, the First Territorial Assembly did what government bodies have traditionally done when short of funds themselves: it authorized others to build roads. Privately held toll companies were given the authority and exclusive right to build and administer toll roads and collect fees based upon predetermined schedules. To raise capital for construction, they were allowed to issue stock, and to protect their sometimes considerable investments, the companies were granted franchises for definite periods of time. In return for these exclusive rights, the territorial auditor collected part of the gross proceeds from each road.

The acts of incorporation for the toll companies were similarly structured and contained the same general provisions: the roads were to be completed and a specified amount spent on their improvement within a designated period. Water wells were to be dug and maintained at intervals along the roads and facilities provided for use by both men and animals. The roads were to be kept safe and passable. And finally, exclusive rights to maintain the roads and collect tolls would be granted as long as they did not encroach on other existing toll roads. Toll rates were generally set on a per-mile basis, depending on the mode of transportation. As a free-market function, they varied from road to road, but usually reflected the road's use, location and difficulty of construction.

The law did little to encourage excellence in construction, and the toll road operators tried to avoid bridge construction as unnecessarily expensive. The few bridges that were built rarely lasted beyond the statutory limits of the franchise. Often poorly constructed and unevenly maintained, these crude structures typically washed out in floods or collapsed under load. Only two such toll road structures from the territorial period are known to exist still in Arizona. Both were built in 1907 in Graham (now Greenlee) County on the Clifton-Solomonville Road. They are unusual in that they were built as grade separations over railroads (the earliest datable overpasses in Arizona), they were constructed using substantial concrete arch construction, and they were built relatively late in the toll road milieu.

In a region in which government revenues were minimal, toll roads were regarded as a necessary evil: an expedient way to develop a much-needed roadway system. At the same time the First Territorial Assembly recognized the need for free highways to promote transportation and settlement. The assembly tried to legislate a balance between roads built by private capital and supported by tolls and those over which no tolls could be extracted. To prevent toll operators from monopolizing transportation by incorporating every road, the lawmakers designated several existing roads, developed solely by previous use, as free routes. This formed the basis for a free-highway network in Arizona, upon which subsequent legislatures would expand. Succeeding sessions of the territorial legislature incorporated toll road companies, while simultaneously declaring other existing roads as toll-free.

Road construction and administration were largely county-level functions in America at this time, and Arizona's territory-level management soon proved burdensome. The legislators began to transfer this responsibility to the counties in 1866 by authorizing the boards of supervisors to divide their counties into road districts and appoint overseers to supervise roads in each district.

To fund road construction and maintenance, the counties were empowered to issue bonds and levy road taxes. In 1871 the Assembly further transferred road administration to the counties by giving them the right to incorporate toll road proprietors. The requirements for incorporation were generally the same as those for the territory, and the counties retained the option to purchase the privately built roads after five years, based upon the value established by five independent appraisers. With this, the county administrators possessed all the tools needed to pursue active road and bridge programs.

They rarely used them well. Seldom following a premeditated plan, county supervisors would authorize the surveying and clearing of roads and construction of bridges as needed, usually in response to urgent local petitions. In the sparsely populated areas outside of the major cities, however, with minimal government revenues, relatively few vehicular bridges were erected before the turn of the century, and none is known to remain today.

Many of the earliest county bridges, like those on the toll roads, tended more to the flimsy than the substantial. Some consisted of little more than two parallel boards laid across a stream bed to carry vehicles' tires. Often made up of timber stringer spans on timber or crude concrete abutments and piers, these questionable structures failed with distressing regularity. Only a handful proved more substantial. In 1885 Pinal County built what was perhaps the first vehicular truss in Arizona and probably the longest county bridge - over the Gila River at Florence. Completed in November, the bridge consisted of two 180' Pratt spans, with 719' of timber trestle over an island and slough. The bridge consumed 30 tons of iron, 174,375 board feet of lumber and cost $14,280.

Navajo County built a single-span Pratt through truss to carry the Winslow-Holbrook Highway over Chevelon Creek and another bridge to carry the road over Clear Creek. The county also built a truss over the Little Colorado River at Holbrook. Greenlee County built a four-span Pratt through truss over the Gila River at Duncan. One of these earliest county trusses is still known to remain: the Solomonville Bridge over the San Simon River in Graham County. Built in 1909 by the El Paso Bridge and Iron Company, it consisted of a single Pratt pony truss supported by steel cylinder piers.

The Territorial Legislature during this period made only minimal impact on vehicular transportation in Arizona other than to authorize toll road companies and enact laws passing the responsibility to the counties. The legislature issued road bonds totaling $70,000 between 1871 and 1881, and $15,000 in 1885. In 1905, the legislature appropriated funds for the repair of the Florence Bridge. But other than these tentative steps, the territory contributed little to road and bridge construction. Indeed, no territorial organization or staff had even been established to administer roads.

After the turn of the century it had become apparent that many major road and bridge projects were beyond the capacity of the counties. Further, the county supervisors were building roads on an individual basis, without regard to the roads in adjacent counties. This tended to create an uneven patchwork of dissimilar routes, making travel difficult for all but a few destinations.

To take a more active role in the development of intrastate highways, the Territorial Assembly on March 18, 1909, established a road tax and created the office of the Territorial Engineer. A political appointment made by the governor, the position carried a two year term and functioned under the supervision of the Board of Control.

J.B. Girand was the first and only Territorial Engineer. His entire staff consisted of a clerk and a draftsman.

Immediately after his appointment, Girand began to plan and build several territorial highways in Arizona. The strategy was to link the county seats and more populous towns through a network of graded, but unpaved, roads that varied in width from 16' to 24' according to terrain and projected traffic loads. In connection with this highway work, Girand supervised the construction of a handful of important bridges over key crossings on the territorial network. Curiously, none of these bridges resembled each other even remotely.

One of the first bridges that Girand undertook was a replacement structure for the truss at Florence. In September 1909 Girand designed a 700' multiple- span concrete girder structure. He submitted the plans and specifications to the Board of Control in November, and advertised for competitive bids. Five contractors responded, but Girand rejected all bids and recommended to the board that the Florence Bridge be built using prison labor. With a territorial prison nearby in Florence, the idea had merit. The board agreed. In March 1910 a prison force of 14 men began the preliminary excavation for the foundations. The crew averaged 55 men as full-scale construction proceeded through the year; the Florence Bridge was completed in December.

What was perhaps the most unusual territorial bridge was not located on a territorial highway at all, but was built on a remote military road to Fort Apache. Since its construction by the army in 1899, the Rice-Fort Apache road forded the Black River southwest of the fort. In 1911, however, the Arizona Territorial Legislature funded the construction of a wagon bridge over the Black. Designed by Girand in December, the 214' Black River Bridge featured two timber/iron Howe deck trusses, carried high above the river by tapered concrete piers. (The trusses were replaced in 1929, but the original piers carry the new superstructure.)

Girand built three other major structures - a three-span, pin-connected truss over the Verde River at Camp Verde, and 60' concrete arch between Bisbee and Douglas and a 100' timber trestle over Forest Wash - and numerous 10' to 16'-span concrete slabs built from standard plans.

Without question, the most spectacular, expensive and important of the territorial bridges was the multi-span concrete structure over the Salt River in Tempe. For this, Girand originally delineated a nine-span, filled spandrel concrete arch structure with a total length of 1225', estimating its cost at $80,000. He later changed the design to eleven spans of two-rib open-spandrel arches, and in February 1911 the plans were submitted to the Board of Control for approval. To build the immense structure, Girand recruited laborers from the territorial prison at Florence - 25 men when construction began in June and up to 57 men during the course of the project. A total of 250 prisoners worked on the bridge between 1911 and 1913. In September 1913, the Tempe Bridge was opened and immediately carried the heaviest traffic of Arizona's highway spans. Total cost: $118,919.

By the time Arizona was admitted to the Union on February 14, 1912, the territory had constructed over 243 miles of highway at an average cost of $2500 per mile. Additionally, 1812 linear feet of bridges over 100' in length had been built, totaling $144,000 in value. Girand estimated that an additional 740 miles of trails and county roads would soon be improved to form highways, "completing the great east and west and the north and south roads." Thus, preliminary surveys and construction had been undertaken on over 1000 miles of highways, broken down as follows (asterisks indicate completed projects):

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| *Prescott - Phoenix | 131.0 miles | *Bisbee - Tombstone | 24.0 miles |
| *Globe - Roosevelt | 90.0 miles | *Glendale - Mesa | 24.0 miles |
| Phoenix - Yuma | 201.6 miles | *Flagstaff - Campe Verde | 75.0 miles |
| *Globe - San Carlos | 32.0 miles | Dewey - Camp Verde | 45.0 miles |
| San Carlos - Clifton | 114.3 miles | *Florence -Tucson | 66.0 miles |
| San Carlos - Douglas | 170.8 miles | Bisbee -Tucson | 106.2 miles |
| *Bisbee - Douglas | 23.3 miles | | |

On June 20, 1912, the new state legislature passed enabling legislation for the state engineer's office. Like the territorial law, the state act authorized property taxes, sufficient to raise $250,000 annually, to fund the road and bridge programs. To augment these revenues, the legislature passed the first of a series of acts providing for the licensing and governing of motor vehicles the following year. Road and bridge construction continued as before using the same administrative process. In fact, several road and bridge projects begun under Girand's administration - including the Tempe Bridge - were taken over by State Engineer Lamar Cobb without interruption. The major difference lay in the level of activity. Less than $200,000 were spent on road and bridge construction through the territory in the year that Girand took office.

Six years later in 1915 over $500,000 were spent by the counties alone. Under direction of Cobb and his successors, B.M. Atwood, Thomas Maddock and W.C. Lefebvre, the state engineer's office pursued an aggressive policy of road and bridge construction during the 1910s and 1920s. This corresponded with the dramatic increase of in state vehicular traffic, and was especially spurred by the rapid influx of overland tourist trade. The 1910s marked the initiation of a number of transcontinental highways across the country and several regional highways in the West, spawned by the nationwide Good Roads movement. Arizona was traversed east-west by two such routes, as Beale's Road in the northern part of the state, which evolved into the Old Trails Highway and the Gila Trail through the southern part became the Ocean-to-Ocean Highway.

As the workload and bureaucracy grew, the state engineers themselves became less often involved directly with bridge design and construction. Instead, they depended on bridge engineers and the growing staff of the bridge department. Arizona's first bridge engineer, R.V. Leeson, was retained on a consulting basis in 1917.

In addition to his design responsibilities in Arizona, Leeson functioned as the Assistant Chief Engineer for the Topeka Bridge and Iron Company and even consulted independently on at least two county bridges in the state. Leeson's most noteworthy commission as consulting engineer for Arizona was the Gila River Bridge in Greenlee County.

By 1920, the state had hired Merrill Butler as the first permanent staff bridge engineer. Butler was later succeeded by Ralph Hoffman, who served with distinction for several years. When the design responsibilities proved too much for a single engineer in the mid-1920s, Hoffman in turn hired ex-bridge contractor L C. Lashmet as his designing engineer.

Several of Arizona's most important vehicular bridges date from this early state period. The Chevelon Creek Bridge and the Jack's Canyon Bridge were two of the earliest state-built structures, built in Navajo County on the Santa Fe Highway. The Santa Cruz Bridge was an outstanding multiple-span concrete girder completed in 1917 on the Nogales-Patagonia Highway. Built in 1923, the Allentown and Sanders bridges formed important crossings of the Rio Puerco on the Santa Fe Highway, and the Hell Canyon and Little Hell Canyon bridges carried the Prescott-Ash Fork Highway. The Antelope Hill Bridge, completed in 1915 using prison labor, carried the Ocean-to-Ocean Highway over the Gila River in Yuma County.

The State of Arizona during the 1910s and 1920s had taken a far more active role in road and bridge construction than the territory had ever done. But the amount of work still needed to complete Arizona's highway network was staggering. Using their 75% of the State Road Fund and adding considerable amounts from county road funds, the counties were still doing the lion's share of road work. Many of the bridges in use today on secondary roads in Arizona were funded and contracted for by the individual counties as part of their bridge construction programs. Unlike the state engineer, the counties rarely had the in-house facilities to design major bridges and could not tap the sizable labor pool in the state's prisons. Counties, therefore, had to hire bridge contractors for all but the smallest of roadway spans.

For a county contemplating construction of a major vehicular bridge, the decision was a serious one. Strapped for funds, as most perennially were, counties could usually afford no more than a handful - and often only one -major span per fiscal year. Costing several thousand dollars each, the bridges soon depleted road and bridge budgets. Counties frequently issued bonds of indebtedness when they lacked the cash. Or they simply delayed bridge projects because all of the available funds for the year had been expended

The decision to build a bridge usually would be made in the late spring or summer, after flooded rivers and creeks washed away existing spans, or in late fall, when riverbeds were dry and foundations and false work could be constructed economically. Usually, for all but the shortest spans, the supervisors would direct the county clerk or surveyor to advertise for competitive bids, A typical solicitation for bids in the local newspapers and engineering journals would be answered by a few local or regional bridge contractors.

Steel for trusses and girders was produced typically in the major foundries -Carnegie, Lackawanna, Cambria, Inland - of the Pennsylvania and Illinois mill towns. The foundries supplied rolled steel parts to bridge fabricators such as Hansell-Elcock or the American Bridge Company of Chicago, the Omaha Structural Steel Works of Nebraska, Minneapolis Steel and Machinery Company of Minnesota, the Midwest Steel and Iron Works of Denver or the Phoenix-based Allison Steel Company. These companies in turn marketed complete, prefabricated trusses to bridge firms that would build the superstructures and assemble them on-site.

Because the government entities of Arizona contracted for so few steel bridges, no indigenous steel bridge company of note ever developed. Those few local firms such as S.T. Clark of Bisbee that occasionally built steel trusses were far more dependent on other forms of contracting. The counties relied heavily upon out-of-state contractors for both design and construction, and virtually all of the major contracted steel bridges in the state were erected by out-of-state firms. Among the out-of-state bridge companies active in Arizona were; the El Paso Bridge and Iron Company (Walnut Grove Bridge , Solomonville Bridge); Midland Bridge Company (Allentown Bridge, Desert Wash Bridge, Hereford Bridge, Cameron Bridge); Monarch Engineering Company of Denver (Sanders Bridge, Little Hell Canyon Bridge); Missouri Valley Bridge and Iron Company (Chevelon Creek Bridge, Fish Creek Bridge, Lewis and Pranty Creek Bridge); James J. Burke of Salt Lake City (Sand Hollow Wash Bridge); Levy Construction Company of Denver (Holbrook Bridge, Dome Bridge); Kansas City Structural Steel Company (Navaio Bridge], Topock Bridge); and the Omaha Structural Steel Works of Nebraska (Saint Joseph Bridge, Yuma Bridge).

Given Arizona's proximity to southern California, it is surprising that almost all of the contract work went to companies from the South and Midwest. Although California firms occasionally submitted proposals, only one major bridge - the Winslow Bridge, built in 1915-16 by Los Angeles-based Mesmer and Rice - was built by a California company. And it was composed of trusses manufactured by the American Bridge Company.

But what Arizona lacked in steel bridges, it more than compensated for in concrete structures. Concrete technology was generally more rudimentary than steel. Material distribution was more decentralized, and the designs were almost all supplied by the counties. As a result, the state supported a large number of small-scale concrete bridge contractors.

On March 8, 1917, the Arizona State Legislature assented to the provisions of the Bankhead Act. The State Engineer, with the approval of the State Board of Control, was empowered to enter into agreements with the BPR. Arizona's share of the federal aid fund amounted to $3.7 million - or about 1.4% of the $75 million total - distributed over a five-year period. Despite promises by the state legislature and state engineer, the highway department soon encountered difficulties in matching the increasing federal allotments. The infusion of such large amounts of capital funds was welcome, but federal aid created a number of logistical problems. Immediately before passage of the Act, the agency had been organized to handle $1 million of construction and maintenance work annually, under the direction of the State Engineer. Federal Aid quadrupled this capacity and added several new layers of bureaucracy to the process.

The paperwork increased accordingly. The Bureau of Public Roads established more stringent bridge and highway guidelines and required more detailed planning, surveying and engineering for federal aid projects. State Engineer Thomas Maddock was further stymied by the $10,000 per mile limitation on highway funding. Arizona's rugged terrain, especially in the mountains east of Superior where a major highway had been planned, would require far more expensive construction for road building. To help alleviate the problem, he sought considerable cooperation of the county supervisors in planning and funding projects. He even urged them to issue bonds of indebtedness to commit money for future projects. Subsequently, twelve of Arizona's fourteen counties voted bond issues, totaling $15 million (Maricopa issued $8.5 million; Graham and Gila counties were the holdouts).

For better or worse, the changes brought by federal aid transformed the state's road and bridge construction mechanism, as the state engineer's office grew into the Arizona Highway Department By the end of 1920, AHD employed more personnel than all other state agencies combined. The department's total allocation of funds that year exceeded the total expenditures of every state, county, city, school and road district in the state combined for 1914. AHD was the largest employer of engineers in the state. The department's maintenance and construction vehicles constituted Arizona's largest truck fleet. It purchased more supplies for its various construction camps than all other state institutions combined.

A few of the bridges, however, were of sufficient scale to warrant individual contracts.
The Arizona Highway Department and the individual counties and municipal-ities accounted for the overwhelming majority of bridges in the state, but a third entity (or group of entities, actually) was active in bridge work as well. The federal government, through its various agencies, has built several spans associated with highway programs. Coming from a variety of bureaucratic sources and circumstances, these bridges display a wide technological range, some of which were as esoteric as they were dramatic. The bridges themselves are remarkable enough, but what was perhaps even more remarkable was the fact that they were built at all. Virtually every major bridge built by the federal government in Arizona required individual Congressional approval.

Three of the state's oldest bridges were built by the government in connection with one of the Bureau of Reclamation's (BOR) first projects. In passing the Newlands Act in 1902, Congress authorized the construction of the Tonto Dam on the Salt River northeast of Phoenix. Before work could begin, though, an access road had to be graded from the railhead at Mesa to the dam site. BOR engineers routed the road alongside the ancient Apache Trail on its serpentine route through the rugged mountains. Grading began in 1903. The road, including the Alchesay Canyon Bridge, a small concrete arch, was completed in March, 1905. Construction on the dam began immediately, proceeding despite several setbacks between 1906 and 1910 under Hill's supervision. A 16' roadway crossed the dam crest, and over the giant spillways that flanked the dam on both sides, BOR engineers designed medium-span, segmental concrete arches. Arch centering for the North and South Spillway bridges was built as one of the last pieces of the work completed before the structure's dedication on March 18, 1911, as the Theodore Roosevelt Dam.

With much of Arizona set aside for Indian reservations, the Indian agencies were active in bridge construction in the state. Earliest of these structures was the Cameron Bridge over the Little Colorado River. Built in 1911 to provide access to Flagstaff from the Navajo and Hopi Reservations, the 680' suspension bridge is both historically and technologically significant. Two years after completion of the Cameron Bridge, Congress approved legislation for a wagon bridge across the Gila River on the San Carlos Reservation. Completed in 1913, the multi-span San Carlos Bridge carried traffic until the south approach washed away in a 1915 flood, rendering it impassable. Never known for an expeditious manner, the U.S. Indian Service waited until February 1921 to reopen the bridge by erecting four new through trusses.

The department was Arizona's largest consumer of explosives. And following a change in state law in January 1919 that allowed the highway department to contract for road construction, AHD constituted the largest contracting entity in the state.

Federal Aid Project No. 1, appropriately enough, involved construction on the Florence Bridge. One of the earliest county bridges and one of the fir^ bridges built by Arizona Territory, it needed extensive repairs in 1917. Unlike the Florence Bridge, most of the bridges built on the state highway system were small-scale concrete drainage structures, laid over dry washes or intermittent streams. For these, the bridge department of AHD used standard designs taken from BPR specifications. Most of the drainage structures were contracted for under the umbrella contracts of the adjacent road construction.

Two of Arizona's most significant spans were initiated by the Indian Office and funded in tripartite agreements with Arizona and California. Congress in 1913 approved a steel bridge over the Colorado River at Yuma. Ostensibly to provide a crossing for the Yuma Indian Reservation across the river, the bridge also carried the Ocean-to-Ocean Highway as the only bridged crossing of the Colorado for some 600 miles. The Yuma bridge was completed in March 1915. As the contractors were building the Yuma Bridge in 1914, the Indian Office solicited help from Arizona and California to erect another major span over the Colorado at Topock. This bridge would carry the Old Trails Highway, Arizona's other transcontinental route. An extraordinarily graceful span, the Topock Bridge was at the time of its completion in 1916, the lightest and longest three-hinged steel arch in America.

Another outstanding bridge built by the Indian Office was notable for its multiplicity of spans rather than its technological daring. Congress in May 1916 authorized the San Carlos Irrigation Project in Pinal County. A major component of the project involved construction of a diversion dam on the Gila River near the Indian village of Sacaton. A multi-span concrete bridge would carry vehicular traffic over the dam. Exceeded in total length by only Antelope Hill Bridge and the Tempe Bridge, the 25-span Sacaton Dam Bridge [3165] was completed using largely Indian labor in 1925.

These major bridges were all special projects, steered through Congress by Arizona Congressman Carl Hayden and Senator Marcus Smith and built under atypical circumstances. To build the hundreds of smaller scale drainage structures on federal roads, the Bureau of Public Roads was a more suitable agency. The Bureau was active directly in Arizona in building numerous roads and bridges through the Indian reservations, national forests and national parks and monuments. Functioning much like AHD in bridge design and contracting, BPR developed minor drainage structures from standard designs and contracted for them as parts of overall road grading and drainage projects.

Larger and more technologically ambitious bridges were designed individually (but still often using standard designs) by engineers in the BPR's San Francisco, Denver or Phoenix offices and contracted for on an individual basis. Several important BPR bridges can still be found in Arizona: the Salt River Bridge [0037], a long-span steel truss built in 1919-20 in the Tonto and Crook National Forest; the Rio Puerco Bridge [3010], a handsomely arched steel deck girder built in 1931-32 in the Petrified Forest National Monument; the Dead Indian Canyon Bridge [0032], a deck-truss trestle built in 1933-34 on the NavaHopi Highway to Grand Canyon National Park; the Pumphouse Wash [0079], Oak Creek [0128] and Midgley [0232] bridges on the Oak Creek Canyon Road through the Coconino National Forest; and the Walnut Canyon Bridge [9225] in the Prescott National Forest.

Each government entity had structural configurations that it relied upon principally. Counties tended to erect steel trusses because they could obtain the engineering free or at nominal cost as part of the bridge solicitation. The federal agencies built bridges of all types, reflective of their non-central administration and individual policies. And the state engineer depended heavily on reinforced concrete for a wide range of bridge applications. Concrete had a number of advantages in Arizona. First, a properly constructed concrete bridge was rightly considered more substantial than a steel or wood structure. Con-crete was more flood-resistant and more stable under load. Short concrete spans could be built using standard plans, allowing a minimal staff of engineers to design a disproportionately large number of structures. Unlike steel, which had a centralized system of manufacturing and marketing, concrete could be manufactured locally, using local materials. Finally, concrete technology was more rudimentary than steel, allowing the state to bid bridge projects to local contractors or build bridges using unskilled crews of convicts or day laborers.

The earliest concrete structures featured relatively modest spans - either simple slab or slab-and-girder - used singly or in multiples. These served well for minor dry wash crossings or for crossings of rivers with exceedingly wide flood plains. When the state engineer began planning bridges for intermediate watercourses and rugged canyons, however, it became immediately evident that long-span structures were needed. Long spans in concrete at that time meant arches. For these earliest structures. State Engineer Umar Cobb turned to the engineering of America's pre-eminent arch builder, Daniel Luten.

Arizona's first association with Luten occurred in 1913. That year, Cobb surveyed a bridge site over Canyon Padre, a rock-walled chasm on the Santa Fe Trail. Cobb's office in July advertised for competitive proposals and designs for a 136' span. The Topeka Bridge and Iron Company, western representative of Luten's National Bridge Company, was awarded the construction contract for $7900. For the crossing, Luten designed a 140' Luten, or horseshoe, arch with a cantilevered roadway. Construction began in September and was completed in April 1914.

A few months after the Canyon Padre Bridge was completed, Cobb contacted with Topeka for another long-span Luten arch on the Old Trails Highway. This bridge would span rugged Canyon Diablo just west of Two Guns, some eleven miles east of Canyon Padre. In 1914, Cobb selected and surveyed the site over the canyon and purchased plans and specifications from Topeka for $500. Although the drawings were submitted by Topeka, Luten himself engineered the 128' arch from his office in Indiana. Like the Canyon Padre Bridge, the Canyon Diablo arch featured a cantilevered roadway with reinforced concrete brackets and Darapet walls. Ute in 1914, Cobb's office let the construction contract to the lowest bidder, Thomas Maddock of Williams, Arizona, for $9000. Using concrete and reinforcing steel supplied by the state, Maddock built the Canyon Diablo Bridge that winter. It was opened to traffic in March 1915. This was soon followed by a third Luten arch over the Little Colorado River near Holbrook. followed by a third Luten arch: over the Little Colorado River near Holbrook. Completed in March 1916 for a cost of almost $19,000, the Holbrook Bridge was the state's longest concrete arch.

Thomas Maddock, contractor for the Canyon Diablo Bridge, succeeded Lamar Cobb as State Engineer in 1917. Like Cobb, Maddock soon enlisted the help of the Topeka Bridge and Iron Company for a major highway span: the Gila River Bridge [8152] near Clifton. First designed in 1917 as a single-span steel arch, then a concrete arch, the bridge was built by convict labor the next year as a two-span Luten arch. Succeeding state engineers contracted for a handful of other Luten arches around the state, but almost all have since been razed.

One Topeka-built arch that remains is the Queen Creek Bridge [8440], completed in May 1919 as part of the Mesa-Superior Highway in Pinal County.

Because Luten arches used proprietary designs, which were protected vigorously by Daniel Luten and his staff of attorneys, they were perceived as more expensive than other highway bridge types. For this reason, they were rarely built by Arizona's individual counties or municipalities. Two notable exceptions were the Kelvin [8441] and Winkelman [8442] bridges, constructed in 1916-17 under a single contract between Topeka Bridge and Iron Company and Pinal County.

Actually, given their scale and technology, the Winkelman and Kelvin structures proved to be bargains, compared with other similar spans. Costing almost $22,000, the 419' four-span Winkelman Bridge cost almost a third of the 288' two-span Gila River Luten arch [8152] and only slightly more than the 190' one-span Holbrook arch, completed earlier that same year.

These figures are even more remarkable given that the Winkelman Bridge was founded on driven timber piles, a more expensive construction technique than the spread footings of the Holbrook Bridge. The Winkelman and Kelvin bridges cost about as much as the four-span through truss built near Winslow by Navajo County in 1916-17 [8156] and almost half as much as the Santa Cruz Bridge #1 [8166], a 457' concrete girder built in 1916 near Nogales.

No government entities in Arizona pinched pennies more than the cities and towns, and the only municipality in the state to use Luten's design was the Town of Miami. In December 1919, Town Engineer Thomas ordered a set of plans and specifications from the Topeka Bridge and Iron Company for a shallow 50' arch to span Bloody Tanks Wash in the center of town. The following May, the town purchased 3500 barrels of cement and began construction of the Keystone Avenue Bridge [8588] with force-account labor, using Luten's design.

The project proceeded so successfully that Thomas soon began a bridge on Cordova Avenue [8586] using the same design. In 1921, identical bridges were completed over the channel on Reppy [8585], Inspiration [8587] and Miami [8589] Avenues. The Miami bridges marked the only short-span application of the Luten arch design in the state.

In an experimental move to provide an alternative to the Luten arch for long-span applications, the AHD bridge department in 1919-20 designed three almost identical open-spandrel concrete arches. The Cienega Bridge [8293] - a long-span arch with a concrete girder viaduct over a branch of the Southern Pacific Railroad - was to be built on the Borderland Highway in Pima County.

The other bridges were located over Queen Creek in Pinal County and Hell Canyon in Yavapai County. The design of the Hell Canyon Bridge was later changed to a multi-span concrete girder, but the other two structures were constructed as drawn in 1920-21. The bridges proved expensive and difficult to erect, however, and AHD shelved the design. The Mill Avenue Bridge in Tempe [0083] would be the only other open-spandrel arch designed by AHD.

The Arizona state engineer's office used Luten and open-spandrel arches for long spans, but for short- to medium-span concrete arches the bridge engineers developed another standard design. This arch featured a filled spandrel, with cantilevered roadway and reinforcing clustered in a manner noticeably similar to Luten's patent. The major difference between the Luten arch and what AHD termed as its "common arch" was the arch profile. Luten's bridges were distinguished by the hallmark horseshoe shape. AMD's common arches were more truly elliptical. The oldest AMD common arch remaining in the state is the Devil's Canyon Bridge, a 65' span located on the Miami-Superior Highway in Pinal County. Built in 1921-22, this handsomely proportioned bridge featured a moderate barrel rise, a roadway which cantilevered over the arches on both sides, a corbeled arch ring and paneled parapets with steel pipe guardrails.

The Devil's Canyon Bridge was followed soon by other AMD single-span common arches, including the Lynx Creek Bridge (built in 1922), the Verde River Bridge (built in 1922-23) and the Fossil Creek Bridge (built in 1924-25).

Although the concrete bridges built by the state engineer's office were demonstrably stronger and more durable and stable under load than their steel truss counterparts, many soon displayed a dangerous and expensive weakness. The superstructures could carry traffic well enough. The piers in the multi-span bridges, however, were often founded on spread footings poorly placed on alluvial sand or shallow bedrock. To exacerbate this, the engineers made little or no provision to prevent scouring at the piers' bases. For rivers which dwindled to a trickle in most seasons, this type of substructure served adequately. But during flash floods, the water quickly undermined the piers and approaches. As a result, the bridges collapsed in whole or part when the piers toppled over.

One of the most notorious of these early structures was the Antelope Hill Bridge over the Gila River. Ceremoniously opened to traffic on August 18, 1915, after several construction delays, this starcrossed structure began to fail almost immediately. In January 1916, floodwaters quickly washed away almost two miles of approach grading and widened the river's channel at the north end of the bridge by approximately 300'. To correct this, the Arizona State Legislature in March 1917 appropriated $50,000 to build an extension onto the north end. The new construction consisted of five additional 65' concrete girder spans and an extensive timber trestle approach. Completed in autumn 1918, the bridge carried traffic more-or-less as intended until a flood a week after Thanksgiving, 1919, destroyed some 500' of the north approach and shifted some of the concrete piers on the extension.

Further flooding three months later dropped about 300' more of trestle, the north abutment and the northernmost girder. Worse, the flood caused several of the piers on the extension, already damaged by the previous flood, to sink further and shift downstream. Within two years, the highway department had rerouted the road to bypass the Antelope Hill crossing entirely; the bridge was replaced in 1929 with the Dome suspension bridge. Virtually all of the other multi-span concrete crossings built in the state in the 1910s proved problematical. The Florence Bridge over the Gila River required extensive repairs to its approaches after almost every major flood. Similarly, the San Carlos Bridge over the Gila, built by the U.S. Indian Service in 1913, was impassable for five of its first seven years until the erection of four through trusses on one end. AMD bridge engineers were forced to post a 2-ton restriction and undertake major repairs on the Tempe Bridge after it experienced pier settlement and superstructural cracking after flooding in 1919-20.

Significantly, most of these bridges spanned the Gila River. Outlet for several other rivers and subject to extremely violent fluctuations in stream flow at any time of the year, the Gila proved almost as difficult for bridge engineers in Arizona as did the larger Colorado. In fact, among the early multiple-span concrete bridges over the Gila, only the Sacaton Dam Bridge [3165] managed to survive without major damage. This was due in large part because the bridge was situated over a diversion dam, which blunted the force of the river at this point.

Ironically, when the Arizona Highway Department sought to bridge the Gila River for the Ocean-to-Ocean Highway in the early 1920s, the bridge engineers opted for a steel truss instead of a multi-span concrete bridge. But even this enlightenment came relatively late in the design process. AHD began planning for a bridge for the highway in western Maricopa County even before Oklahoman Frank Gillespie built his dam over the Gila in 1921. Despite the problems with other multi-span concrete bridges over the Gila, AHD bridge engineers initially planned a series of concrete girders for this crossing, too. After reconsideration in 1925, they hired a consulting engineer to help design and locate the structure. At the consultant's advice, AHD scrapped the girder design in favor of a series of steel through trusses with a concrete deck. The trusses were supported by solid concrete piers, set as deep as 45' below the riverbed on the compact caliche hardpan. The Gillespie Dam Bridge [8021], completed in July 1927, did not experience the pier and approach failures of its predecessors.

Upon its completion in July 1927, the Gillespie Dam Bridge was notable as the longest steel highway bridge in Arizona. A list of the five longest vehicular structures in the state in 1926 indicates the tremendous impact that the Gila River had on bridge construction. Four of the five spanned the Gila, and the fifth - the Tempe Bridge over the Salt River - spanned a tributary of the Gila near the two rivers' confluence. The bridges are:

Antelope Hill Bridge, 1765' (extant; abandoned and deteriorated)
Gillespie Dam Bridge, 1660' (extant; in off-system service)
Tempe Bridge, 1508' (extant; abandoned)
Sacaton Bridge, 1486' (extant; abandoned)
Florence Bridge, 1430' (demolished)

The Gila prompted long bridges, but it was the Colorado that historically has presented the most formidable barrier to bridge construction. The Yuma and Topock bridges, completed in 1915 and 1916, had proved exceedingly expensive and difficult to erect, even on relatively flat sites. This was due to the unpredictable nature of the Colorado River, and its propensity to flood at odd times. When the Arizona Highway Department sought to bridge the river a third time in the 1920s, the problem of flooding on the river was eclipsed by the bridge site's great height and remoteness.

In 1923, AMD began planning for a bridge over the Grand Canyon near Lee's Ferry. AHD engineers originally considered a suspension bridge like the Cameron Bridge, then a through arch like the Topock Bridge, but eventually AHD Bridge Engineer R.A. Hoffman designed a long-span steel deck arch. With funding provided by the State of Arizona and the Navajo Tribal Fund, AHD contracted with the Kansas City Structural Steel Company in June 1927 to fabricate and erect the arch. The contractors combated severe logistical problems to build the immense structure and by the following April had set the concrete foundations into the sheer canyon walls. The first steel was swung on April 16, 1928, the main span completed on June 14, 1929.

Completion of the Navajo Bridge [0051] marked a culmination of sorts for highway bridge engineering in Arizona. The Arizona Highway Department would design a few other exotic bridges - most notable of which was the Dome Bridge, a 798'-span suspension bridge over the Gila River in Yuma County - but by and large the experimentation with different structural types that had marked the 1910s and early 1920s had given way to design standardization. The only structural type of note with which AHD continued to experiment was the steel arch.

The Navajo Bridge was the only spandrel-braced arch undertaken by AHD.(The Bureau of Public Roads did erect one spandrel-braced arch; the Midgley Bridge in Coconino County). But the bridge department soon turned to another arch configuration: the girder-ribbed deck arch, made up of five or more riveted plate girders. Completed in 1934, the Salt River Canyon Bridge in Gila County was AHD's first girder-ribbed arch. It was soon followed by three other such arches: the Cedar Canyon, Corduroy Creek and Canyon Padre bridges.

The end of the 1930s generally meant the end of truss construction in Arizona. Although a few trusses and arches have been built since, more modern concrete and steel beam designs, well illustrated by the multi-span Winslow Bridge, have received greater use. As county roads have been widened and paved and state roads superseded by interstate highways, the make-up of Arizona's road systems have changed. But enough significant bridges have survived to form a tangible record of history.